ESSAYS ON REAL EXCHANGE RATE VOLATILITY AND OPENNESS IN INTERNATIONAL TRADE

ABELARDO SALAZAR NEAVES

Submitted to the University of Nottingham for the degree of Doctor of Philosophy,
December 2010.

Abstract

This work comprises five chapters that explore in detail issues related to real exchange rate volatility and trade openness. In the case of real exchange rate volatility, we start with the decomposition of this measure to determine the relative contribution of traded and non-traded goods to the variance of the real exchange rate. We obtain evidence in favour of a relevant role for non-traded goods.

Our estimation of the real exchange rate volatility is included in the second chapter. Our results, based on a cross-section regression, show that the existing link of openness to real exchange rate volatility is weaker when we control for imposed and natural trade barriers. At the same time we are able to obtain a relationship between inflation volatility and the variation of the real exchange rate.

Chapters three and four are related to our real exchange rate volatility model. We decide to obtain a specification for openness that could help us explore in detail the idea of country characteristics affecting trade flows. Our first approach considers a cross-section estimation to identify the factors that consistently affect trade openness. The second approach considers a more dynamic specification. We are able to establish a link between country characteristics and trade openness. At the same time our results capture interesting changes in the effects of the dependent variables on openness across time.

The final chapter takes us back to the analysis of real exchange rate volatility. In this case, we explore which measure is the most appropriate amongst those calculated from series in levels and the ones in first differences. We conclude that series that do not show less stationary behaviour require longer time series (more observations) in order to display results that close to the reference value.

Acknowledgements

First and foremost, I would like to thank my supervisors, Prof. Michael F. Bleaney and Dr. David Harvey for their enthusiasm and guidance in the course of my PhD study. I am deeply grateful to them for their consistent support and constructive criticisms which pointed me in the right direction towards completing this thesis.

I would also like to express my most sincere gratitude to the CONACyT (Consejo Nacional de Ciencia y Tecnología) - Mexican Government for the research studentship funding which made possible this thesis to be written.

This work is dedicated to my family; Their love, support and help over the years gave the strength to accomplish this. I am also very grateful to Olga and her family for also giving me advices to continue and finish this work, vielen Dank.

For my Mother and Father.

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Chapter 1

Introduction

1.1 Relevance of RER in an open Economy

The concept of the real exchange rate (we can also refer to this variable as "RER" from now on) is without question an important one in the macroeconomic literature. Its relevance is observed in the amount of empirical work and new theoretical models that are developed in order to have a better understanding of the variable. The real exchange rate is also the source of interesting debates in the international economics literature as the theory behind this variable encounters some difficulty in replicating its behaviour observed in real life. There is also a debate regarding its role in macroeconomic policy and long-run growth. Soto and Elbadawi (2008) mention that this variable has a strong influence on economic activity (medium- and long-run); at the same it also determines almost entirely the expected profitability of investment in the traded sector. Hence, it also affects a country's capital accumulation and trade flows.

Several of the above mentioned variables are by themselves research topics usually explored to determine which ones affect economic growth. The real exchange rate is linked to these and also to economic growth, so it is important to do an extensive and detailed analysis of this index. Its evolution in levels and its volatility have also been related to macroeconomic phenomena. If we consider the idea of an optimal level for this variable, an equilibrium,[1]

[1] In the following sections we discuss in detail the existence of an equilibrium real exchange rate and

we find that several works have shown a relationship between levels of overvaluation and low rates of growth, which represents a higher likelihood of experiencing a currency crises.

It might be useful before going any further to state more explicitly what we understand for real exchange rate and its differences with the nominal exchange rate. If we consider the textbook definition found in Edwards (1989), we have that the real exchange rate is equal to the price ratio of tradable goods and non-tradable goods. If we consider a more specific approach such as the purchasing power parity, we find in Dreger and Girardin (2007) a definition that links more directly the role of the nominal exchange rate in the real one: the nominal exchange rate is equal to the purchasing power of two currencies at home country and abroad. Then, the real exchange rate can be obtained by adjusting the value of these two with the help of the nominal exchange rate in order to express the ratio in a base currency. This means that the RER is a constant and shocks affect this variable only in the short run. Finally, we can mention that for nominal exchange rate we understand the national currency's quotation in respect to foreign ones.

During the past few decades, the number of studies devoted to the topic of real exchange rate volatility has grown enormously. The increase in this literature can be traced back to the moment at which several economies abandoned a fixed nominal exchange rate regime to let their currencies be determined by international markets. Since the end of the Bretton Woods regime several economies have suffered from an increase in the volatility of their exchanges rates, both nominal and real. The subsequent high degree of short-term volatility in nominal exchange rate was largely unexpected. In developing and least developed countries this problem has been combined with periods of high inflation, which have created several inconsistencies in the economy and disequilibria that affect nations' welfare. In a seminal paper from Mussa (1986), he notices a correlation of almost one between real and nominal exchange rates in high frequency data, and that the volatility of the former increases dramatically when a country moves from a fixed to a floating exchange rate regime.

The study of real exchange rates is an old topic in international economics, but there have been no significant developments in the area due to an apparent disconnection between the theory behind real exchange rate and economic data observed in real life. One of the most important problems we can mention first is that the purchasing power parity (PPP)

several theory models that explore this idea.

does not hold empirically; in other words, baskets with the exact same goods in different countries do not cost the same after adjusting for exchange rate. This has cast doubt on existing theoretical models of the real exchange rate. To quote Chinn (2008), *How should the real exchange rate be defined? How does it behave over time? and what determines it at various time horizons are all questions that have been posed over the years.*

The volatility reported by this variable has attracted the attention of several researchers in recent times. Explaining the sources of real exchange rate variations is an expanding research topic. Similarly, the existing differences in the registered real exchange volatility of different economies has served as motivation to enlarge recently the number of works devoted to explain such differences. It is easy to realize the repercussions of very volatile real exchange rates in the economy if we link this variable with the concept of equilibrium and economic growth. The more volatile this variable is, the more exposed an economy is to several kinds of shocks. It is relevant to find better and more systematic explanations of high levels of real exchange rate volatility experienced by economies around the world.

It is a well known fact that the volatility of some relevant variables of the economy is higher in developing countries than what developed nations experience. We can find several works that document well the case for capital flows (Broner and Rigobon 2005; Broner, Lorenzoni and Schmukler 2007, and Rhenals and Garcia 2007). The real exchange rate volatility is no exception and we find differences between the records of this variable for rich countries and the ones observed in developing nations.

In Dornbusch (1989) we can find that he also notices differences in RER volatility between industrialized countries and other economies. As a matter of fact, he is not the only author that has noticed these differences. We can mention the work of Hausmann *et al.* (2006) as another example. These authors find three times higher volatility in developing countries than what is observed in industrialized economies. However, they cannot explain completely why such differences arise between the volatility of the real exchange of developing and developed nations. We consider that it is necessary to identify the main sources of real exchange rate volatility by establishing and measuring the existing relationship between the RER volatility and a set of independent variables. This is one of our main research questions and objectives in the present work: to shed some extra light on a possible solution to this stylized fact by finding systematic links between the real exchange rate volatility and relevant exogenous factors. It is possible that our results might not be able to represent a complete solution to the puzzle of why we observe different levels of RER volatility according to the income level of the country. However, we consider that our work represents a step forward in the obtention of a definitive and conclusive explanation to the previous stylized fact. This is our first and main premise for our research.

Recent research has established that more open economies to trade register lower levels of volatility in the real exchange rate. In Bleaney's (2008) work, we find that part of this existent correlation between real exchange volatility and trade openness can be explained by the adjustment of domestic prices to exchange rate movements, but this does not represent a satisfactory answer for the whole phenomenon. The author also shows that real exchange rate series are less persistent under floating exchange rate regimes, and also that these series are more mean-reverting in more open economies. We want to exploit the differences observed between industrialized countries and other economies and their levels of openness to obtain more information about the volatility of the real exchange rate. The relationship between trade openness and real exchange rate volatility represents our main research topic. As a matter of fact, we make an extra effort to obtain a better explanation for the levels of trade openness that economies register. At the same time we can get a better understanding of our first research topic.

As Siregar and Rajan (2006) mention in their work, it is important to understand the structure of the economy and the relevance of its various components (sectors) in order to analyse comprehensively the fluctuations that the real exchange rate suffers. For this reason we consider the two most simple sectors in the economy that can allow us to explore further the sources of variation of real exchange rate volatility. These sectors are the one for non-traded goods and its counterpart the traded goods. If we stick to the determination of the real exchange rate based on PPP's framework, and assuming that this holds in the traded goods sector of the economy, then variations in the real exchange rate are generated by the non-traded sector.[2] However, Engel (1999) finds that this does not hold for the United States. He finds that most of the variations of the real exchange rate come from the traded goods sector. Morales-Zumaquero (2006) follows the work of Engel (1999) and concludes that the impact of nominal and real shocks is different according to the type of

[2]If we are more specific about the influence of non-traded goods, we must say that the variations are generated by differences in the relative price of non-traded to traded goods ratio observed between the economies considered in the real exchange rate.

economy. She also finds that the results can change if we consider different periods in time to do our analysis.

So far, we have mentioned the relevance of openness and our desire to explore further the issue. Additionally, we also investigate the impact of traded and non-traded goods in the volatility of the real exchange rate, which at the same time are related to the trade flows of the country. In theoretical models, the existence of non-traded goods is the result of having trade costs different from zero (or the existence of barriers to trade), which at the same time affect the levels of openness of the economy. Following the Balassa-Samuelson hypothesis, variations of the RER are generated by adjustments in the non-traded sectors of the economy. In other words, we can say that economies with more non-traded goods are more likely to suffer higher levels of real exchange rate volatility.

There is a final and central issue that is discussed in this work. The topic is related to how we can measure real exchange rate volatility better. As Morales-Zumaquero (2006) mentions, one of the approaches of the empirical literature on real exchange rate fluctuations is the computation of measures of the variance in the real exchange rate. Our work in this aspect tries to shed light on the decision whether to use volatility measures taken from RER series in levels or ones from series in first differences, analyse their differences, and determine under what conditions one could outperform the other. This is a very relevant topic that has not been explored in detail for the real exchange rate.

It is important to obtain a good measure of real exchange rate volatility because this becomes our reference value to evaluate new models that try to capture the dynamics of the variable. At the same time, an accurate measure is necessary to investigate more complex empirical models that help us obtain better explanations of stylized facts observed in the real exchange rate series. In our analysis, we try to identify differences (or similarities) between volatility measures calculated from series in levels and first differences, as we mention earlier. We explore which one is closer to their respective reference value, and if one could be a good proxy for the other; in other words, if by taking a measure in first differences we have a good proxy for the volatility of the series in levels. In our results we have that stationarity of the series plays an essential role.

This last part of our research takes us back to the disconnection between the PPP in theoretical models and empirical results. It is a well-known fact that real exchange rate series are very persistent (not very stationary) and this fact contradicts what PPP predicts.[3] This is also a relevant, complex and important debate in international macroeconomics: the stationarity of the real exchange rate. This variable is highly persistent which can be translated in the following: it could take several periods for the real exchange rate to absorb economic shocks completely. These issues are also crucial for the fluctuations of the real exchange rate.

From our discussions related to the real exchange rate volatility of countries, we and previous authors detect an existing link between this variable and openness. However, the literature devoted exclusively to study a trade openness specification is almost non-existent. This serves us as a motivation to explore this topic in detail. We find that the relevance of openness (on the real exchange rate) can vary if the econometric specifications consider factors such as country-specific characteristics. For this reason, we decide to analyse trade openness in detail (this may be considered a secondary line of research and also a small detour from our primary research goal). In this aspect, we are able to obtain important conclusions from cross-section and panel data regressions that can help us explain the link between openness and real exchange rate volatility.

1.1.1 A more detailed description of this work

This work includes five empirical chapters in which the topics of real exchange rate volatility and the determination of a trade openness equation are discussed. Three of the chapters develop actual and relevant issues related to the real exchange rate volatility topic. These three chapters try to focus on very important approaches: the analysis of real exchange rate volatility via estimation of a model for this variable. The second approach is the computation of more than one measure of dispersion for the real exchange rate to obtain more accurate and efficient measures of RER volatility. We explore the differences between volatility measures calculated from real exchange rate series in levels and the ones from the series in first differences. And finally, the third one involves a variance decomposition of the real exchange rate to identify quantitatively the contribution of variations of traded and

[3]For a very complete survey on the topic, please refer to Rogoff (1996), Taylor and Taylor (2004) and Taylor (2003, 2006).

non-traded goods prices.

The remaining two chapters are not directly related to RER volatility. In these two we estimate an openness equation using two different frameworks. One of these involves a cross-section OLS estimation framework; and in the next one we start with a fixed-effects panel data estimation and end up utilizing a new technique called Fixed-Effects Vector Decomposition in order to allow our specification to include (almost) time-invariant variables. The reason for having these two chapters on openness is to obtain a more profound analysis of the variable as in several empirical works there has been stated to be a strong and existing link between the real exchange rate volatility and trade openness. We consider that It is possible to use these findings in a more refined exploration of the sources of variation of the real exchange rate.

In a more detailed description of the contents, we start in order with chapter one. In this chapter we explore the variance decomposition of the real exchange rate, which involves the construction of real exchange rate measures for three different countries (Canada, Mexico and Norway). The real exchange rates constructed are bilateral ones between each of the previous economies' domestic currencies and the US dollar. The RER is constructed using different price indices as proxies for non-traded and traded goods prices, which are multiplied by the nominal exchange rate between the domestic currencies and the US dollar. We end up constructing two real exchange rates for each country. In one of the calculated measures we use subindices of the consumer price index (CPI). For the second measure we take the total CPI and the producer price index as proxies for our exercises. The series, after being constructed, are used in different statistical and time-series econometric exercises in order to establish what is the contribution of each type of goods in the real exchange rate volatility. A simple set of statistics and a more complex exercise that involves obtaining the forecast error variance decomposition show us that non-traded goods are a relevant component of the variations of the real exchange rate.

The next chapter develops a model of the real exchange rate volatility equation employing 10- and 20-year average variables to be estimated using cross-section and panel OLS regressions. The chapter is based on the works of Hau (2002) (in which he finds and shows empirically the existence of a link between then real exchange rate volatility and openness of a country) and Bravo and di Giovanni (2006) (exploring the link obtained in Hau's work and also considering other factors that affect the real exchange rate volatility). In this case we do as the previous authors and focus on the effective real exchange rate and not on the bilateral one. We are able to replicate the findings of Bravo and di Giovanni and also improve some of them as we refine the panel OLS estimation approach. At the same time, we include a relevant variable in our estimation that is not considered in the previous studies; this variable is inflation volatility. Our results show that this type of volatility affects real exchange rate variations. At the same time, this chapter allow us to identify changes in the impact of openness on real exchange rate volatility when we also control for trade restrictions (imposed and natural ones) in our estimations. The following chapters explore in more detail this finding.

Our third chapter reports a first attempt to obtain a parsimonious openness equation. We are able to explain this variable in a cross-section regression using 20-year averages (the time span is 1981-2000). We also identify an interesting problem in the estimation of the openness equation. This problem is the differentiated impact of some variables on openness according to the country's income level. Chapter four (the second one involving the estimation of an openness equation) explores further the development of a model for trade openness by increasing the sample analysed in the previous chapter and shifting the estimation framework to now allow for a more dynamic representation of the openness equation. In this chapter we include more variables to control for extra effects, but we also allow for the inclusion of variables used in the previous chapter. There is one problem that arises if we consider some of the variables used in the cross-section estimation of an openness equation. Some regressors are not time-varying variables and these cannot be estimated using a fixed-effects regression framework.

We are able to address that problem by the implementation of a new estimation technique named Fixed-Effects Vector Decomposition. Our results show that, with the help of this recent estimation technique and controlling for time-invariant variables, trade openness has been increasing in recent years. Not only that, we also report evidence of how the impact of some exogenous variables has changed over the years.

The final chapter take us back to the real exchange rate volatility discussion. In this chapter we explore the issue related to which measure of real exchange rate volatility must be considered to obtain accurate results in empirical research. In the chapter we discuss the problems of using measures taken from real exchange rate series in levels and also the disadvantages of considering measures of series in first differences. In order to carry out our analysis we estimate two types of autoregressive moving average models in order to obtain specific parameters. As our first case, we assume that the real exchange rate time-series of more than a hundred countries follow a mean reversion model that we estimate using a proxy process (an ARIMA(2,0,1) representation). The results are relevant but we consider that the whole process is too restrictive in order to consider all the countries that are part of our sample. For this reason we implement a second set of estimations using a simple AR(1) model. With the help of an AR(1) we do not need to use a proxy model to estimate the parameters we need to conclude our analysis. At the same time, the results from the AR(1) approach are used as a robustness check for the set of results obtained in the first part of the chapter. The estimation of both models helps us obtain parameters to calibrate a Monte Carlo experiment in order to generate artificial data. The artificial series are then used to calculate volatility measures of the data in levels and in first differences. These are compared with reference values calculated using the data generating process assumed for each exercise.

The findings of the chapter let us see the importance of calculating our volatility measures from stationary series; the more stationary the series, the more accurate our volatility measures are. It is also possible to observe the existing differences between measures taken from series in levels and the ones from series in first differences. It is clear from our results that it is not straightforward to replace one measure in first differences (levels) to analyse the volatility from a series in levels (first differences). Finally, sample size plays a determinant role in the calculation of accurate real exchange rate volatility measures (the more observations available, the better).

Chapter 2

Literature Review

2.1 Equilibrium Real Exchange Rate

It is important to note the relevance of the concept of the equilibrium real exchange rate before we start our empirical analysis of real exchange rate (RER) volatility. So far we have mainly focused our attention on fluctuations of this variable; however, this topic is very relevant because these variations are registered around a reference value, which is the equilibrium real exchange rate. One of the theories related to the concept of equilibrium is Purchasing power parity (PPP). But this approach has its limitations as empirical models do not support PPP. The Purchasing power parity states that identical basket of goods must cost the same in different economies after adjusting their prices by the relevant exchange rates. In real life it is hard to test whether PPP holds because of non-traded goods and transaction costs make it impossible to have the same products in all the economies.

This has been the main motivation for several researchers to construct alternative models of the equilibrium real exchange rate. We can mention in the first place the concept of the fundamental equilibrium exchange rate (FEER) developed by Williamson (1994). The FEER describes a real exchange rate that ensures both internal and external balance for the long-run at the same time.[1] The FEER allows for variations in the equilibrium real

[1]The internal balance is reached when the economy is at full employment and registering low inflation levels. The External balance is characterized as a sustainable balance of payment position over the medium-run, ensuring desired net flows of resources and external debt sustainability.

exchange rate through time. The problem with this approach is its normative nature. It is hard to define an objective sustainable level of the current account in order to reach the external balance.

As a response to these limitations, Clark and MacDonald (1998, 2000) develop a new concept named Behavioural Equilibrium Exchange Rate (BEER). The BEER is focused on the actual values of fundamental determinants of the economy; that is, proxy indicators of these internal and external balances of the real exchange rate. These authors mention that there are three very relevant variables for the determination of the equilibrium of the real exchange rate. These variables are the terms of trade; the relative price of non-traded goods; and net foreign assets. The determination of the equilibrium rate via a BEER approach involves the estimation of cointegrating (time series framework) relationships between the real exchange rate and short- and long-run economic fundamental variables.

The Natural Rate of Exchange (NATREX) is a fourth approach developed by Stein (2001) that is defined as the rate reached by the RER if speculative and cyclical factors are removed from it. In the case of the NATREX, the selection of fundamental variables can vary from one case to the other according to the size and development of the local economy.

The models based on the determination of an equilibrium real exchange rate have evolved to include not only price levels, but also to consider internal and external balances that take into account movements of several other economic variables (fundamental ones). All these variables affect in one way or the other fluctuations of the RER. At the same time, these can help explain the volatility of the real exchange rate and make us realize the difficulties and importance of the task. Despite the progress observed in the area, there is no consensus on a definitive model.

2.2 The problem of variance and persistence in the RER. Fundamentals versus Random Walk

There is a very relevant stylized fact that should be considered in the construction of an analytical model for real exchange rate in levels or for its variance. This fact is the following one: contrary to what PPP-based theories argue, real exchange rates fluctuate more than these models predict and departures from its trend are quite persistent. The idea of high persistence in real exchange rates is related to the stationarity of the series. There is a vast literature in which these series are tested for the existence of unit roots in them. There is, however, an important inconvenience when the stationarity of the series is analysed. This problem is related to the current unit root tests used on this type of series as these have little power for highly persistent real exchange rates.

Caporale et al. (2003) show the erratic behaviour of Dickey-Fuller unit root tests when these are applied to real exchange rate series. As a matter of fact, it is not only the lack of power in the tests used, there are other factors that should be remarked. Yoon (2009) considers that the real exchange rate behaves differently according to the exchange rate regime adopted by the economy. He finds evidence showing that real exchange rate series behave as stationary processes during fixed exchange rate regimes. In particular, the more stationary episodes are found in the gold standard and Bretton Woods periods.

These concepts (high persistence and stationarity) are relevant to the volatility of the real exchange rate because it is possible to relate directly the intensity of the latter measure with the previous concepts. Countries that have real exchange rate series with high persistence and also show a behaviour that some authors consider resembles more a random walk than a stationary process register higher fluctuations in the RER. Meese and Rogoff (1983a, b and 1988) find that a random walk model can often forecast exchange rates better than economic models. This is one of the reasons we find some attempts in the literature to model real exchange rate series implementing a random walk process (An example of this is found in Gandolfo, Padoan and Paladino (1990)).[2]

Mussa (1986), while studying the exchange rate between U.S. Dollar and Deutschemark, notices that this exchange rate approximates closely to a random walk process, and also that its changes are very persistent. One of the most well-known puzzles in international economics is the apparent disconnection between floating exchange rates and macroeconomic fundamentals. The missing link arises when several authors have tried to test theories in which exchange rates are determined by fundamental variables, and the results of empirical studies do not support the theoretical models. The common conclusion reached by the authors is that fundamental variables do not help much to predict future changes in exchange

[2]In terms of forecast models, we find that it is hard to outperform a random walk model.

rates.

However, Glen (1990) finds that several countries behave significantly differently to a random walk by calculating long-horizon autocorrelations and variance ratio statistics for the real exchange rates series measured on both monthly and annual basis. Some other authors have also considered the possibility that the real exchange rate can be explained as the sum of a random walk and a stationary mean-reverting processes. Choi (1999) also applies the variance ratio test to real exchange rates of the US dollars versus some major currencies and rejects the random walk hypothesis in several cases.[3]

Fama and French (1987) suggest that stock prices may include a slowly decaying stationary components. Rossi (2005) explores in more detail this idea for the RER and finds that economic models could be experiencing problems to forecast real exchange rates because the relationship between fundamentals and real exchange rates is changing across time. Instead of using fixed parameters to forecast real exchange rates, she allows for variations in these across time. This new feature in her model helps outperform the results of the random walk model in several cases.

Some other authors use more complex estimation techniques to approximate the behaviour of the real exchange rate. Kilian and Taylor (2003) use a non-linear, exponential smooth transition model (ESTAR) to find an explanation for the persistence and volatility puzzle of the real exchange rate.[4] They provide empirical evidence against the random walk model for horizons of 2 to 3 years, but they add that this model is hard to outperform using real time data (nominal exchange rate series only). In Rogoff (1992) we find that it is possible to develop an economic model to replicate some regularities of real exchange rates observed in real life. In this case, he models an economy in which we find a division of goods between traded and non-traded ones.

Engel and West (2004) analyse exchange rate time series taken from six developed countries. They obtain results that support the existence of a link between fundamentals and exchange rates with good forecasting capabilities for the latter. They focus on short-term variations that the nominal exchange rate suffers. They analyse the nominal exchange rate as a

[3]Choi (1999) also uses Durlauf's (1991) spectral domain tests and Andrews' and Ploberger's (1996) optimal tests to the real exchange rate series included in his study.

[4]See Dijk, Teräsvirta and Franses (2002) for more details on ESTAR models.

discounted sum of current and expected future values of the "fundamentals" using an asset-pricing model. In an empirical work with a sample of 48 industrialized and emerging economies, Lee, Milesi-Ferretti and Ricci (2008) obtain a long-run relation between real exchange rates and a set of fundamental variables. They pay particular attention to the inclusion of variables that proxy productivity of traded and non-traded sectors in order to capture some sort of Balassa-Samuelson effect. Another example of a good response of the real exchange rate to fundamentals variables is found in Alexius and Nilsson (2000). In their work they find systematic long-run relationships between relative productivity and terms of trade with the real exchange rate.

Since the debate about the use of fundamentals instead of a random walk model to study real exchange rate's dynamics is far from being solved, some authors have turned their attention to the second moment of the series; that is, to analyse RER's variance instead of trying to find a model to fit the expected value, the mean. Bleaney (2006) determines a better connection between fundamentals and RER by considering a different approach. His work shed light on the puzzle by showing that fundamental variables can help with establishing the range in which the RER moves. Outside this range the RER behaves as a mean reverting series to return to this interval. This finding makes appealing the idea of studying the variance of the real exchange rate and not only its levels registered.

2.3 Real Exchange Rate Volatility Analysis

It is difficult to model real exchange rates as we have explained in our previous sections. One is the fluctuations this variable experiences and the difficulty of representing these in a model. The repercussions of these variations on the economy are also important because these affect real variables. The variations of the real exchange rate can influence the economic growth; consumption levels; production; saving decisions and other relevant aspects of the economy. This is the research path we follow: we analyse and understand better these variations by detecting exogenous factors that have important repercussions on real exchange rate volatility. It is possible that by examining the movements of the real exchange rate we get a better understanding of the variable. Simultaneously, we could find more precise explanations of why current theoretical models cannot capture relevant features of real exchange rates.

There are several contributions in the real exchange rate literature, and some of these go further to other issues such as its volatility. For example, Hau (2002) uses theoretical and empirical arguments to support the idea of an inverse relationship between economic openness and real exchange rate volatility. He continues by saying that a high degree of trade integration tends to provide relatively stable real exchange rates, while intercontinental exchange rates with a low degree of underlying integration are extremely volatile. As we establish above, this is one of the main lines of research in this work.

2.3.1 Repercussions of Real Exchange Rate Volatility

It is possible to link episodes of real exchange rate volatility with currency crises experienced by several developing countries. Bleaney (1992) mentions that the concept of volatility, in some sense, measures the potential for misalignment of that variable. Higher levels of volatility could represent greater misalignments of the real exchange rate. In this sense we have that for some countries this phenomenon has represented serious economic problems in the past.

Gala (2008) refers to the problem by saying that an excessively overvalued currency can be the cause of saving displacement. The problem could grow and turn into something more serious like the Dutch disease phenomenon (Williamson 2003), which can cause balance of payments crises.[5] From the results of the previous works, we can infer the following: a misalignment can be translated into unbalances (internal and/or external ones) that could become unsustainable representing volatile periods, and ultimately degenerate into a more serious situation such as currency crises. Some authors explain the difficulties and even currency crises episodes experienced by Latin-American countries during the eighties using the overvaluation argument.

In the aftermath of a currency crises, these imbalances could still be present and affect real exchange volatility. Gonzaga and Terra (1997) explore this idea in detail. They find a positive relationship between real exchange rate volatility and price variations. They

[5] See Goldjan and Valdes (1996) and Palma (2003) for more details.

develop their work around the idea of price stabilization mechanisms and how these can affect the variability of the RER. Their work focuses more on countries that have experienced high inflation episodes. They develop a theoretical model in which it is possible to observe that one of the consequences of experiencing money supply shocks is an increase in the volatility of the price of imported and exported goods. This can be translated as the existence of a positive relation between the volatility of inflation and the one of real exchange rates. The empirical part of their work supports this idea: inflation volatility help explain variations in the RER. In their work they analyse only developing countries as these are the ones that have experienced this type of episode in recent years. To be more precise, they use data from Argentina, Brazil and Mexico to estimate their empirical model and test their hypothesis. Real exchange rate volatility can be linked with several crisis episodes that have occurred in developing countries, and in particular with currency crises experienced by Latin-American countries.

2.3.2 Variance Decomposition

As we have mentioned in previous paragraphs, our work is focused on the idea of real exchange rate volatility and how openness affects this. At the same time, we want to explore in more detail what can affect the level of openness of a country. If we obtain a detailed analysis of this variable we could get not only a better explanation of real exchange volatility but also of the existing differences reported by industrialized and developing countries. To a lesser extent, we also study the idea of what we should take as the measure of real exchange volatility, and also a not so extensive but very insightful analysis of a variance decomposition of the real exchange rate in mainly two very relevant components. This analysis could be regarded as a first step in our analysis to sketch what is the contribution of non-traded and traded goods on fluctuations of the real exchange rate.

According to the purchasing power parity approach, in a world with no transportation and transaction costs the PPP should always hold with a real exchange rate equal to one at all time. If we allow for the existence of transportation and transaction costs, non-traded goods appear and we have a source of variations in the real exchange rate. Several authors have explored the idea of what is the contribution of each component to the variations of the real exchange rate. Then the idea of decomposing the real exchange rate into a geometric average of traded and non-traded goods becomes appealing. With this decomposition we can still consider a PPP that holds for the traded goods and the variations on the real exchange rate are mainly generated by variations in the non-traded goods prices.

However, Engel (1999) in his seminal paper concludes that traded goods are more relevant to RER volatility. He decomposes the real exchange rate into two parts: one based on traded goods prices and the second one constructed with non-traded ones. He analyses RER's variance using the mean-squared error statistic of five different RER indices that measure the competitiveness of the US dollar with respect to other relevant currencies. He constructs the RER measures from different price indices (based on CPI, PPI, GDP deflators, output prices and a combination of CPI and PPI to model non-traded and traded goods prices respectively), he finds no evidence to support the idea that non-traded goods prices account for the fluctuations in the real exchange rate. He also shows that variations mostly originate in the traded goods sector component. This finding is the opposite one to what the PPP theory and models like the ones from Balassa (1964) and Samuelson (1964) predict.

Despite the findings of Engel (1999), Mendoza (2006) uses Mexican data to show that non-traded goods prices are relevant in real exchange rate fluctuations. He collects data on bilateral (Mexico - USA) real exchange rates that goes from 1969 until 2000 and obtains results that show the relevance of non-traded goods prices. These account for a significant fraction of real exchange rate volatility when the economy has a fixed exchange rate regime. He also constructs a model that predicts high volatility in the RER of economies with liability dollarization and credit constraints when these have a floating exchange rate regime. The volatility observed in the real exchange rate is driven by the relative price of non-traded goods.

Betts and Kehoe (2008) do a similar analysis for the US economy using bilateral RER between this country and other nations. They find that non-traded goods do contribute to RER volatility. At the same time, they are able to find some interesting regularities in bilateral real exchange rates. The first thing they notice is that the correlation between the overall RER volatility and its non-traded component is positive. As a second regularity, they are able to report that fluctuations of the non-traded part are not as high as the ones of the real exchange rate (measured by its relative standard deviation). Finally, they show that the contribution of non-traded goods on the RER volatility increases as trade intensity between the two countries that are part of the bilateral RER increases. This idea is explored in more detail in Betts and Kehoe (2006).

Naknoi (2008) begins her work by analysing the results from Engel (1999) and Mendoza (2000) and the relative importance of traded and non-traded goods prices on RER variance. She suggests that by doing a variance decomposition of the real exchange rate it is possible to show that nominal shocks raise the importance of the non-traded component when the economy has a fixed exchange rate regime. As a matter of fact, her research goes beyond this as she shows that if the conditions of the economy change (such as the exchange rate regimes or modifications to what kind of shocks hit the economy), the relative importance of the traded and non-traded components changes.

The data analysed in Naknoi (2008) are taken from the results of a DSGE modeled economy in which she incorporates several features of Ghironi and Melitz (2005) and specially of Melitz (2003) models.[6] With her model, she is able to generate endogenous tradability. This makes it possible to have three types of goods each economy: Domestic, foreign and non-traded ones as not all the firms are able to export their products. The existence of endogenous trade amplifies expenditure switching effects of exchange rates in response to nominal shocks. She is able to obtain an imperfect correlation between traded and non-traded RERs, which is the result of having endogenous tradability as part of the results of the model.

We can also mention an earlier work of Engel (1996) in which he analyses price indices to test two empirical regularities observed in consumer price data series. One of those is the fact that real exchange rate based on CPI indices of industrialized countries are highly volatile. The second regularity represents evidence that supports the claim that volatility of the relative price of the same good in different countries is bigger than the volatility of different goods in the same country.[7]

In the previous paragraphs we have considered works in which authors explore the idea of

[6] These works explore the topic of heterogenous firms related to their productivity and the self-selection to produce goods to be exported.

[7] Engel makes a distinction for this to hold: the relative price variance of a good in different countries will be greater than the relative price of two goods in the same country as long as we are talking about typical stable goods prices.

decomposing real exchange rate volatility into two components exclusively. However, it is possible to find in the literature a different approach to exploit further this decomposition of the real exchange rate volatility. These studies consider time-series Vector Autoregresive (VAR) models to investigate the impact of traded goods prices, non-traded goods prices, and also exogenous variables on the real exchange rate volatility. Alexius (1999) is one of these efforts. She tries to identify if RER volatility can be explained either by productivity shocks, monetary shocks, or even both. She claims that if this volatility is generated mainly by monetary shocks, then these movements should disappear in time (assuming money neutrality and taking as valid Dornbusch's (1976) "Overshooting" model in exchange rates). If RER fluctuations are explained with productivity shocks then we face more permanent changes.

Using real exchange rate volatility series taken from Nordic countries (Denmark, Finland, Norway and Sweden), she finds that a large share of the movements are caused by supply shocks in the permanent component of real exchange rate variance. Her empirical model is based on finding a GDP trend, then calculating deviations from this trend. These are accounted for as productivity shocks. The other kind of shocks, monetary ones, are taken into consideration via changes in price levels. She then constructs a VAR system to decompose and analyse the variance of real exchange rates. Her final results shows that the transitory variance's component is larger than the volatility of the permanent component.

Joyce and Kamas (2003) use cointegration techniques to disaggregate real exchange rate volatility from three Latin-American countries (Argentina, Colombia and Mexico). They use a cointegration approach to show that it is possible to obtain a long-run relation between real and nominal variables and the real exchange rate. This relationship can be regarded as the real exchange rate equilibrium, which is affected in different forms by nominal and real variables, as in Alexius work. They do a variance decomposition for a Vector Error Correction Model for these three countries. They find that for Argentina almost all its variance is generated by the own RER and also by terms of trade variations. For Colombia, things are different because productivity and terms of trade explain most of RER volatility. Finally, Mexico behaves similarly as Colombia because productivity and terms of trade are behind real exchange rate variations.

We can conclude from this section that it is difficult to observe a homogeneous result. Some empirical findings could seem contradictory if we contrast results of different economies, or even different periods in time for a single country. But, at the same time, we can obtain relevant information of the real exchange rate volatility by just analysing its components.

2.3.3 Real Exchange Rate Volatility and the Capital Account - After Breton Woods Regime

It is also important to take account of specific episodes in time and events that have affected the volatility of the real exchange rate. One of the most relevant, signaled by several researchers as a turning-point event, that brought changes in the magnitudes observed of real exchange rate volatility is the end of the Bretton Woods system. This episode also represented the departure from a fixed exchange rate regime to a more flexible system for several nations. A considerable amount of studies find higher real exchange rate volatility with the transition to a flexible exchange rate regime.

Stockman (1983) and Mussa (1986) show that countries switching from a fixed exchange rate regime to a flexible one experience a systematic and dramatic increase in the volatility of both nominal and real exchange rates. Most of the countries that are part of their samples adopted a floating exchange rate regime after the collapse of the Bretton Woods system.[8] These works and some others studies published afterwards represent important evidence to confirm that the exchange rate regime is also an important factor on the real exchange rate volatility.

Kenen and Rodrik (1986) also acknowledge the fact of observing lower levels of real exchange rate volatility during fixed exchange rate regimes. Their work is based on the analysis of effective real exchange rates. Using as reference values the volatility records registered during fixed exchange rate regimes, they analyse data taken from periods with flexible exchange rate regime. They find that the volatility of real exchange rates has not diminished despite the fact that markets have gained experience operating with floating exchange rates. They also find that the levels of volatility vary from one country to the other. The decision to switch from a fixed (flexible) exchange rate regime to a flexible (fixed) one carries consequences to the volatility of real exchange rates. There are other factors that also change

[8]These economies also have to deal with a period characterized by a major real disturbances like the oil price shocks of the 1970s.

with the adoption of a different exchange rate policy, such as financial openness and capital movements.

Devereux and Lane (2003) determine an empirical relationship between bilateral nominal exchange rate volatility and financial variables. They start their analysis by including Optimal Currency Area (OCA) variables (such as trade interdependence, differences in economic shocks and country size) plus financial variables such as financial depth within countries and external financial factors (bilateral portfolio debt liabilities between countries). Their hypothesis is the following one: a country experiences lower exchange rate volatility the more financial depth it has and/or the smaller its debt portfolio is. However, they find that financial variables affect developing and industrialized countries in different ways. While developing countries' exchange rate volatility depends more on financial variables, for industrial countries OCA variables seem to be more important. Another finding is that external debt is generally not significant in explaining bilateral rate volatility.

Several authors have recently focused their attention on trade costs and trade openness to explain variations on real exchange rate. However, there are previous works that have explored a different angle. These works try to find a link between capital flows and RER volatility. Dabos and Juan-Ramon (2000) is an example of the previous; on the topic of sudden stops and capital flows (reversals, to be more precise) we can mention Mendoza's (2006) work. Dabos and Juan-Ramon (2000) analyse the relationship between the real exchange rate for export goods and some other variables like capital flows, external terms of trade and productivity in the manufacturing sector. Using data from Mexico from 1970 to 1998, they find that net capital inflows is the most relevant variable to explain real exchange rate volatility. Another finding related to the Mexican economy in Dabos' and Juan-Ramon's work is the identification of a structural break in 1995, which is also the year when a floating exchange rate arrangement was adopted by the Mexican economy.

2.3.4 Real Exchange Rate Volatility and Openness

Hau (2002) in his seminal paper finds evidence to support the idea that openness (obtained as the sum of exports and imports divided by GDP, trade intensity[9]) is an important factor

[9] Leamer (1987) explores the issue of analysing different measures of openness in great detail.

behind RER volatility. He analyses the effective real exchange rates of several countries and calculates the volatility of these measures. The author tries afterwards to establish a link between these and trade openness. He develops a model in which real exchange rate volatility is affected directly by unexpected monetary and productivity shocks; however, the effects of these shocks are reduced as the economy increases its level of trade openness.

Bravo and di Giovanni (2006) obtain very similar results to Hau's (2002) work. But they not only control for measures of openness to trade; they also analyse the volatility in the real exchange rate from a different angle: considering also trade barriers, natural and imposed ones, and the way these affect volatility of the RER. They include import tariffs and export duties as measures for the imposed ones, although their results do not support their inclusion as explanatory variables in their regressions. In the part of natural trade barriers, they construct a remoteness index (weighted distance measures). This index measures how far a country is from a theoretical world trade centre. This artificial world trade centre is based on the distance from the country to all its trade partners weighted by trade intensity. The econometric analysis shows support for the inclusion of a remoteness variable. Their results are based on cross-section and panel data regressions using data taken from the IFS database. They are also able to obtain a negative relation between openness (trade volume) and RER volatility, as Hau does. But the impact of openness is not as great as that of remoteness in their regressions. We infer that studying trade costs can be as important as analysing trade openness of an economy in the determination of RER variability's sources.

In an earlier work of these two authors, Bravo and di Giovanni (2005) also study trade costs as a relevant source of real exchange rate volatility. Their approach is somehow different as they study bilateral real exchange rates and are mainly interested on bilateral trade relationships. They show that technological shocks have a greater impact on relative price indices of two countries the more heterogenous their foreign goods' suppliers are. In other words, (bilateral) real exchange rate volatility can be reduced if these two countries have a great number of suppliers in common. With this idea in mind, they construct an Index for Common Suppliers and their estimations show that there exits a negative relation between this index and their measure of RER volatility.

Haussman *et al.* (2006) show that industrialized and developing countries experience different levels of long-run real exchange rate volatility. Developing economies have in average a

2.5 times higher real exchange rate's standard deviation than the observed one in industrialized economies. The authors also show that these differences cannot be explained by only using the fact that developing economies experience larger economic shocks. Their results confirm that RER volatility for developing countries experiences more persistent swings.[10] A significant part of the RER volatility in developing countries is associated with a much larger persistence of shocks that impact the economy.

Another work related to trade openness and real exchange rate variations is the one from Li (2003). This author determines what changes are experienced by real exchange rates after a trade liberalization programme is put in place by a country. His study does not follow the line of work of Hau or Bravo and Di Giovanni because he does not try to model real exchange rate volatility. In his work he explains how the level of RER is affected after a country becomes more open to foreign markets. His research is inspired by the difficulties of predicting the exact consequences of reducing import taxes or tariffs on the real exchange rate. After analysing panel data that include 62 countries and using both bilateral and effective real exchange rates, based on two price indices (consumer price index and the wholesale price index), he establishes a relationship between trade liberalization and depreciation of the currency in real terms.

Calderon (2004) argues that monetary instability is only one of several factors driving real exchange rate volatility. He continues by saying that the New Open Economy Macroeconomics (NOEM) framework's literature is growing and supporting the idea that non-monetary factors can explain the recent high volatility phenomenon observed on exchange rates. In his work he finds that more volatile output, money and terms of trade shocks generate more real exchange rate volatility. He also finds a robust negative relationship between RER fluctuations and openness.[11]

The empirical literature shows that trade openness limits the impact of nominal and real shocks on the volatility of the real exchange rate. Calderon and Kubota (2009) is a very recent effort to show this. In order to achieve this, they construct a dynamic general equilibrium model to capture exchange rate movements as their theoretical framework. They

[10] They even extent their study to model not only a mean equation but also the variance. Unfortunately, using an ARCH approach to model the evolution of the variance does not help explaining completely the differences on the variance level between industrial and developing countries.

[11] We assume that Calderon considers not only trade openness but also financial openness in his work, since he does not specify which one he is referring to.

also implement the use of econometric techniques to test some of the model's implications.[12] They corroborate what others have found: countries with higher trade linkages display more stable exchange rates. Trade openness helps attenuate shocks to the RER, but the ability to smooth shocks is weaker in countries with higher levels of output concentration. Hence, the RER is more stable in economies with well-diversified output structures and greater share of equity in total foreign liabilities. Also, trade openness helps reducing the likelihood of severe drops in the real exchange rate (including possible episodes of currency crisis).

The work of Calderon and Kubota (2009) represents a study that unifies several crucial lines of research of the real exchange rate volatility literature. They offer a new vision with the help of the NOEM theory framework based on microeconomic foundations and also linking fundamental variables of the economy to obtain a tractable equation of the real exchange rate volatility that allow them to test the relationship between RER volatility and openness. This relationship is tested using a panel data sample, which is then estimated using an instrumental variables approach. They instrument trade openness following Frankel's and Romer's (1999) strategy. To summarize, their work develops a theoretical framework (considering price rigidities) to obtain a testable equation for real exchange rate volatility using econometric techniques that allow for a better identification of the relevance of each variable. The estimation approach considered by Calderon and Kubota is relevant in the sense that an openness regression could give us information in more detail of the relationship between real exchange rate volatility and trade openness.

2.3.4.1 A detour from Real Exchange Rate Volatility: The estimation of an Openness Equation

The hypothesis that more open economies register lower volatility of the real exchange rate is well established fact that has been proven by others. Among these we have that Bravo and di Giovanni (2006) also find evidence of this relationship; however, they also show that the impact of trade openness could be diluted when other factors are considered in the empirical estimation of the real exchange rate volatility. The other factors considered in this work are the imposed and natural trade restrictions. Based on these findings, we

[12]Calderon and Kubota (2009) not only analyze trade openness but also considering that the role of financial openness (as the reduction of frictions in the flow of capital across countries).

decide to explore further this idea by specifying and estimating an openness equation. This could help us establish a cleaner relationship between trade openness and real exchange rate volatility, or to consider other variables to be included in new RER volatility specifications.

In recent trade literature there are not many efforts to model an openness specification. Researchers focus more on the determination of bilateral trade with the implementation of gravity models.[13] The gravity equation is a frequently used estimation framework because its predictions are very similar to actual bilateral trade flows. In our case, we are more interested in multilateral trade flows (of a whole economy). It could be very insightful to analyse factors that affect this variable in order to have a better understanding of the relationship between openness and real exchange rate volatility.

The literature on this topic is not very extensive, but we can find the work of some authors that explore the idea of determining an openness specification. Some other works, as the one from Calderon and Kubota (2009), try to use this equation as an intermediate step in the estimation of a different dependent variable. As a matter of fact, these authors follow Frankel's and Romer's (1999) approach. They also include an openness equation in their estimations. They instrument openness with the help of geographic characteristics variables in order consider the effects of this variable in an economic growth model.

Jansen and Nordås (2004) estimate a gravity equation in their work and also use an openness specification as an intermediate step. The openness estimation is regressed to obtain the best proxies for variables that capture the effect of institutions and infrastructure. After they determine their institution and infrastructure variables from the results of the openness equation, they estimate a gravity model that includes these variables. Guttmann and Richards (2006) do a similar analysis by comparing the results of a gravity model and an openness equation to explain the low levels of trade that the Australian economy reports. They conclude that the results of the openness equation are more robust and reliable that the ones from the gravity equation.

Guttmann and Richards (2006) acknowledge the lack of a theoretical model to support their openness equation. However, they back up their results using the findings of other authors. We consider all the previous as good incentives to explore the determination of an

[13]See Armstrong (2007) for an extensive survey on the topic.

openness equation that could help us in future research to clarify even more the relationship of openness and real exchange rate volatility and the impact of some other variables on the latter.

Chapter 3

Real Exchange Rate Variance Decomposition

3.1 Introduction - Motivation

The real exchange rate is a crucial variable that can help us determine the soundness of an economy. Changes in this index have important effects on production, employment and trade. That is why it is important to have a better understanding of movements in this variable; these variations allow us to identify specific problems in the economy. This issue has become relevant in recent times because over the last three decades real exchange rates have fluctuated more than before. As a matter of fact, it is possible to be more precise about the moment in time when these higher fluctuations started. We can trace back the initial date of these higher movements to the years after the Breton Woods exchange rate regime came to an end.

Engel (1999) in his seminal paper shows that for the US economy variations in the (bilateral) real exchange rate are mainly driven by changes in the relative price of traded goods. This finding contradicts models like the ones developed by Balassa (1964) and Samuelson (1964) in which they describe economies with a real exchange rate affected exclusively by deviations in the relative price of non-traded goods. Real shocks affect the real exchange rate through the price of non-traded goods. In other words, the law of one price holds for traded goods, hence movements in the real exchange rate are caused by movements in the prices of goods found only in the domestic economy and not in international markets.

Engel focuses his analysis on the case of United States (US) and uses data from this economy and some other developed countries to run several empirical exercises.[1] The measures of real exchange rate considered in the study are constructed by the author using proxies for traded and non-traded goods. Previous to Engel's work we can find in the literature theories developed by other authors, which state that changes experienced by the real exchange rate are expected to be caused by movements in non-traded goods since these do not follow the law of one price. However, Engel (1999) shows, in the case of US, that almost all the variations in the real exchange rate come from the traded goods.

This work is an attempt to replicate Engel's empirical exercise and enhance it using a mixture of developing and developed economies in our sample to corroborate his findings. We use data from three countries (Canada, Mexico and Norway) covering a time span from 1983 until 2008. We pay special attention to Mexico since it is the only developing country included in the sample. All real exchange rates are constructed using price indices in a similar way to what Engel does in his study. We construct bilateral real exchange rates between the three countries listed above and the US economy, using different types of price indices to end up with two different real exchange rates for each country.

3.2 Related Literature - Previous works

Engel (1999) shows that variations in the real exchange rate proceed mainly from traded goods for the US real exchange rate, which means that the law of one price does not hold empirically. He focuses more on the construction of the real exchange rate using several types of price indices and then disaggregates them into two parts (traded and non-traded goods price ratios) so he can analyse these to find out which part is the most relevant one in the variations of the real exchange rate measures he constructs. His study starts by studying consumer price indices (CPI) and then he calculates the mean-squared error (MSE) of the change in the real exchange rate constructed with this type of index.

[1] The rest of the countries are: Japan, Canada, Denmark, Finland, France, Germany, Italy, Norway, Sweden and the U.K.

He then measures the contribution of tradable goods changes into the total MSE of the real exchange rate. After finishing his analysis using CPIs, he replicates the previous methodology with real exchange rates constructed from different price indices: Personal consumption deflators, producer price indices, and output prices. In all these exercises he reaches the same conclusion: Variations in the real exchange rate are mainly originated by changes in the traded goods price ratio. After Engel's work, there have been some other authors that try to check his results for other countries, or for the same ones as in Engel's but for different periods in time.

Morales-Zumaquero's (2006) work is one of these. She analyses real exchange rates constructed from CPI's subindices of several countries. In particular, she studies a decomposition of the real exchange rate similar to the one from Engel and also develops a vector autoregression model (VAR) including some of the variables that are part of the real exchange rate she constructs in the beginning in order to enrich the analysis.

With the help of these two empirical exercises she explains differences observed in the variations of the real exchange rate for developed and transition economies. The countries included in her research are Canada, Japan, and the United States in the developed countries set; and in the transition economies group we find the Czech Republic, Hungary, Poland and Romania. The first part of her work is based on the calculation of the MSE of the change in the real exchange rate. She computes the proportion of the MSE of the real exchange rate that is attributable to changes in the traded goods component for different horizons. The second part focuses on the construction of a VAR system in order to identify the relevance of real and nominal shocks in the variance of the real exchange rate. She concludes that for transition economies Engel's findings do not hold: the relative price of non-traded to traded goods between countries explains a high percentage of the variance in the real exchange rate. We can also say that for developed economies, the sources of fluctuation of the real exchange rate are not the same through time.

There are some other works that use the mean-squared error or some variant of this measure to analyse the variance of the real exchange rate for different countries and type of economies. For example, Çiplak (2007) takes the Turkish real exchange rate to study the relationship between non-traded goods prices and variations in the real exchange rate of that country. He uses the variance decomposition ratio (a statistic taken from an intermediate step of the MSE calculation) among some other methods to show that the link between non-traded goods and the real exchange rate is weak. He concludes that the main determinant of real exchange rate fluctuations is the relative price of tradable goods. However, he also adds that the contribution of non-traded goods has increased in recent years for this economy.

It is possible to find studies that focus on the Asian region: Parsley (2007) analyses Pacific-Rim countries. Using data of six small, open and to some extent fast-growing Asian-Pacific economies, he also finds that for this type of economy there exist deviations from purchasing power parity in the traded goods component of the real exchange rate that are reflected in its volatility. The economies included in his study are Hong Kong, Korea, Malaysia, Taiwan and Thailand. He also bases his results on the use of the mean-squared error statistic to asses the impact of both traded and non-traded goods price ratios into the volatility of the real exchange rate.

Parsley points out the relevance of the nominal exchange rate in periods where economies have a flexible exchange rate regime. This author refers to the work of Mendoza (2000) in this aspect. The latter does a detailed analysis of the Mexican real exchange rate and how the contribution of the traded and non-traded goods changes through time in accordance with the type of exchange rate regime the economy adopts. As a matter of fact, Mendoza's results show that variations in the relative price of non-tradable goods accounts for up to 70% of the variance of the peso-dollar real exchange rate in the period Mexico had a fixed exchange rate regime.

Despite finding some works in the literature with evidence pointing towards traded goods as the main source of variations of the real exchange rate (close to 90% of the total variance, according to Engel's findings), there are works that report evidence of a more active role of non-traded goods, like Mendoza. Betts' and Kehoe's (2001) work is another example of the previous, and they are able to show that non-traded goods can account for about one-third of deviations in levels of the real exchange rate, and about one fifth when the data are taken as yearly changes. Their work is also relevant because in order to obtain these results, they decompose the real exchange rate series using a different methodology to what we find in Engel's study.

In Betts and Kehoe (2008), we have that they extend the scope of their first study by including more countries in their sample and with more observations per country.[2] Their second work just confirms the conclusions of the first one: there exists a robust statistical relationship between the real exchange rate and the relative price of non-traded goods.

So far, most of the works mentioned above use the MSE in order to account for the contribution of either traded or non-traded goods in the real exchange rate variance. From the literature previously mentioned, only Morales-Zumaquero (2006) adds a different type of framework to analyse the variations of the real exchange rate. She constructs a VAR system to get a forecast error variance decomposition and an impulse-response analysis in order to obtain a more detailed work of this volatility. Although her VAR analysis is done just to distinguish between nominal and real shocks and observe how much these affect the real exchange rate variance, there are others that have developed a VAR to obtain more specific and robust results.

Alexius (1999) uses this methodology to study real exchange rates of Nordic economies. Her VAR not only consists of series of price indices, real and nominal exchange rates; she also includes exogenous variables such as oil prices and productivity measures in order to control for more specific shocks (real and nominal ones) that affect the system and in particular the real exchange rate. Similar to Alexius, Chaban (2006) and Farrant and Peersman (2005) construct a VAR system for the real exchange rate, but they impose restrictions on the long-run variance-covariance matrix in order to identify nominal from real shocks and are able to estimate a structural version of the original VAR. The former author just imposes zero aggregate effects for the nominal shocks included in the VAR as his long-run restrictions, while the latter work includes sign restrictions in their variance-covariance matrix in order to identify the type of shocks that affect the system.

Soto (2003) studies the case of a non-developed nation by implementing a VAR system for Chile. He constructs this identified VAR to analyse the impact of different types of nominal and real shocks to a system that includes a real exchange rate equation. He finds that in the case of Chile nominal shocks are relevant for explaining the volatility of the RER in the short-run, and for periods of more than three years the impact of nominal shocks is reduced to account for only 10% of the real exchange rate variation.

[2] In Betts and Kehoe (2001), their sample covers 21 years, 1980 to 2000, and now (Betts and Kehoe, 2008) they have observations until 2005.

3.3 Model

The model we develop borrows heavily form the analysis found in Engel (1999). We complement our first part with the construction of a VAR system for the real exchange rate in which besides the actual real exchange rate series we also include the nominal exchange rate and two types of price ratios to identify the shocks that affect the real exchange rate the most . For our model, we follow Engel's decomposition of the real exchange rate. This variable is disaggregated into relative prices of traded and non-traded goods of both nations.[3] The first step is to define the real exchange rate in logarithms between two countries, home and foreign (variables for the foreign economy are indicated by a star):

$$q_t = s_t + p_t^* - p_t \tag{3.1}$$

where q_t is the real exchange rate, s_t is the nominal exchange rate in terms of the home country's currency, p_t is the price index of the home country and p_t^* is the price index of foreign country. As we mention before, the price indices and exchange rates are expressed in logarithms . Then we decompose both price indices in order to have a geometric weighted average of traded and non-traded goods prices:[4]

$$\begin{aligned} p_t &= \alpha p_t^T + (1-\alpha) p_t^{NT} \\ p_t^* &= \beta p_t^{T*} + (1-\beta) p_t^{NT*} \end{aligned} \tag{3.2}$$

where p_t^T is the price of traded goods in the home country, for the foreign economy this is represented by p_t^{T*}. The non-traded price indices are p_t^{NT} and p_t^{NT*} for home and foreign countries respectively. Taking the price index decomposition of the equations included in (3.2) we can express the real exchange rate in the following way:

[3] Our work is based on the analysis of bilateral real exchange rates.

[4] The weighted average is a linear combination of traded and non-traded goods price indices when we consider the model in logarithms, however, the model in levels will show a geometric weighted average as we express here.

$$q_t = x_t + y_t \tag{3.3}$$

where:

$$x_t = s_t + p_t^{T*} - p_t^T \tag{3.4}$$

$$y_t = (1-\beta)(p_t^{NT*} - p_t^{T*}) - (1-\alpha)(p_t^{NT} - p_t^T) \tag{3.5}$$

Our analysis is based on equation 3.3. From this one we construct two measures to quantify the impact of variations on the relative price of non-traded to traded goods,[5] the impact of variations of y_t on the variance of q_t, or to corroborate Engel's finding: most of the variations in the real exchange rate come from changes in the x_t part, traded goods.[6]

3.3.1 Simple measures of the importance of the ratio of non-traded goods in the total variance of the RER

This work attempts to measure how great the impact of variations in the relative price of non-traded to traded goods is in the volatility of the real exchange rate. We start with four simple measures.

1) Simple correlations between the series. This first statistic is just the sample correlation between the real exchange rate and the relative price of non-traded to traded goods:

$$Corr(q, y) = \frac{Cov(q, y)}{StDev(q)StDev(y)}$$

2) The R^2 from a simple regression between the (first difference of the) real exchange rate

[5] The variable y is the difference of the price ratio of non-traded to traded goods of both nations; however, we might refer to this price ratio as the non-traded goods price component from now on in order to have a short name for the variable.

[6] The impact of s_t is negligible or zero in the long run, as this represents nominal shocks affecting the system.

and the (first difference of the) relative price of non-traded to traded goods. This second measure is a simple regression of the real exchange rate in first differences, dependent variable, on the first difference of y or x $(l = y, x)$, which are the regressors of the model.[7]

$$\Delta(q_t) = \beta\Delta(l_t) + \epsilon_t \tag{3.6}$$

3) Our third measure follows a similar path to the construction of the MSE. We report a ratio that measures how similar the fluctuations of the real exchange rate and the relative price of non-traded and traded goods are. We first consider the variance of the real exchange rate taken from the difference of the series at time $t-k$ and the one k periods ahead (observation at time t). We also take into account the (small sample, unbiased) variance measure proposed by Cochrane (1988):

$$Var(q_t - q_{t-k}) = \frac{K}{(K-k-1)(K-k)} \sum_{j=1}^{K-k} (q_{j+k} - q_j - mean(q_{j+k} - q_k))^2 \tag{3.7}$$

where

$$mean(q_t - q_{t-k}) = \frac{k}{K-1} (q_K - q_1)$$

Where K is the sample size and k is the horizon. Then, we focus our attention on the fraction of the total variance of the series $(Var(y_t - y_{t-k}) + Var(x_t - x_{t-k}))$[8] accounted for by $Var(y_t - y_{t-k})$.[9] This is what constitutes our third measure to determine the impact of non-traded goods in the variance of the real exchange rate. The equation for this measure is the following:

$$Non-traded\ goods\ share = \frac{Var(y_t - y_{t-k})}{Var(y_t - y_{t-k}) + Var(x_t - x_{t-k})} \tag{3.8}$$

[7] These models are run using first differences in order to avoid problems of non-stationarity in our results.

[8] In this simple measure we do not consider the role of covariances and that is why we take as the total variance the sum of the variance of the traded and non-traded components of the real exchange rate. That is the reason of not using $Var(q_t - q_{t-k})$ as our denominator to calculate our statistics

[9] This is also done for x_t.

We also calculate the same statistic for traded goods; in that case we replace the variance of y with the one of x as the numerator. The next and last (statistic) measure is the mean-squared error that we explain with more detail in the following section.

3.3.2 Mean-squared error

Engel bases his results on the variance of k-differences, which is a variance of the k-period difference series centered around the sample mean of that difference. He expects that the variance of the traded goods price ratio converges down to zero as k increases.[10] This is in line with the assumption that the law of one price might not hold in the short-run, but it does in the long-run for this type of goods. In our case, the MSE is calculated changing the value of k that goes from k=1 until k=200. With so many horizons for this measure we expect that the variance of k-differences of the price ratio of traded goods converges to zero as k gets larger, and that the one of non-traded goods grows linearly with k.

Our next and final measure in this preliminary analysis is the actual mean-squared error of the different price ratios in order to check the fraction of the MSE of $q_{t+k} - q_t$ accounted for by the MSE of the traded goods component $x_{t+k} - x_t$. We decide to use the mean-squared error since it is a comprehensive measure of movement that includes not only the variance but also the sum of the squared drift of the variable. The next step is to capture how much of the MSE taken from the changes in the real exchange rate is attributable to changes in the price ratio of traded goods. The equation is given next:

$$\frac{MSE(x_t - x_{t-k})}{MSE(x_t - x_{t-k}) + MSE(y_t - y_{t-k})} \tag{3.9}$$

where the MSE is defined as:

[10] Park and Ogaki (2007) argue that the findings of Engel are not that accurate. They claim that the variances of k-differences in the middle range of k's are more relevant to the long run that those at k's close to both ends of the time span, or sample.

$$MSE(x_t - x_{t-k}) = Var(x_t - x_{t-k}) + [mean(x_t - x_{t-k})]^2 \tag{3.10}$$

with the following definition for the mean change

$$mean(x_t - x_{t-k}) = \frac{k}{K-1}(x_K - x_1)$$

We should comment on the fact that in our methodology we calculate the percentage that the MSE of the price ratio of traded goods represents of the sum of the MSE of both traded and non-traded goods price. The reason behind using the sum of MSEs of the two types of good price ratios and not the actual MSE of the real exchange rate is that we are not taking into consideration the co-movements between x and y as we assume that these are not high.[11]

3.3.3 Vector Autoregressive Model (VAR)

The construction of a VAR system is the second part of the empirical analysis in our study. We are interested in developing this approach in order to calculate the forecast error variance decomposition of the real exchange rate and observe the contribution of different variables on that variance.[12] The data includes the actual real exchange rate, price indices, general and disaggregate ones, and nominal exchange rates. We find that the series included are integrated of order one, I(1), hence the vector of first differences of all the series is stationary.[13]

Let $\mu_{q,t}$, $\mu_{s,t}$, and $\mu_{w,t}$ denote the real exchange rate, nominal exchange rate, and w_t shocks. In the case of w, we can substitute this variable by either the price ratio of traded goods

[11]Engel (1999) calculates both ratios, one using the sum of traded and non-traded goods MSE and another using the real exchange rate MSE as denominators, however, he just reports his findings from the measure using the sum of MSEs. He argues that co-movements between the different price ratios do not change at all the results that he finds using the MSE ratio that does not consider them. In our case we find that the results are different in the sense that taking into consideration co-movements just makes stronger the relevance of traded goods in the real exchange volatility.

[12]The forecast error variance decomposition is the percentage of the variance of the error made in forecasting a variable due to a specific shock at a specific time horizon.

[13]All series are tested for the presence of unit roots using the Augmented Dickey-Fuller test (ADF) and Philips-Perron tests. The approximate p-values are calculated by means of the algorithm developed in Mackinnon (1996).

(x_t) or the non-traded goods (y_t) shocks in time t that affect our vector. Once again, since the vector of first differences $z_t = [\Delta q_t, \Delta s_t, \Delta w_t]'$ includes only stationary series, we can get the multivariate moving average representation in equation 3.11,

$$z_t = [\Delta q_t, \Delta s_t, \Delta w_t]' = C(L)\mu_t \tag{3.11}$$

or,

$$\begin{bmatrix} \Delta q_t \\ \Delta s_t \\ \Delta w_t \end{bmatrix} = \begin{bmatrix} C_{11}(L) & C_{12}(L) & C_{13}(L) \\ C_{21}(L) & C_{22}(L) & C_{23}(L) \\ C_{31}(L) & C_{32}(L) & C_{33}(L) \end{bmatrix} \begin{bmatrix} \mu_{q,t} \\ \mu_{s,t} \\ \mu_{w,t} \end{bmatrix} \tag{3.12}$$

The variable w_t is then replaced either by traded goods prices vector, x_t, or the one of non-traded goods, y_t, into the system. The variables included in every VAR analysed are explained in detail in sections 3.4 and 3.5.3. Nevertheless, this is a good representation of what the final model that is estimated looks like. The process starts only with the estimations of the VAR. After we obtain the results for the coefficients of the lags included, we then need to estimate now the variance-covariance matrix in order to get the structural representations of our model. After the previous steps, it is possible to calculate the forecast error variance decomposition and the impulse-response analysis for all the variables in the real exchange rate equation.

3.4 Data - Countries

There are two main sources for our data: International Financial Statistics (IMF database) and Main Economic Indicators (OCDE database). In each case we obtain different series that proxy for the prices of traded and non-traded goods. Three countries are analysed: Mexico, Canada and Norway. Our original interest is to investigate the behaviour of the real exchange rate between the Mexican Peso and the U.S. dollar. However, we decide to include two more countries trying to generalize and/or contrast our findings of the Mexican economy with high-income countries. This is an important point as Mexico is an oil producer and we can find in the literature empirical works highlighting the relevant role of oil prices in the behaviour of the real exchange rate.[14] The decision to include Canada, besides being a net oil exporter and exporting some other primary products, is somehow logical since this country together with Mexico and the US are trade partners in the North-America Free Trade Agreement (NAFTA). The inclusion of Norway is based on the argument that this is a very open, small, European developed economy that includes in its list of exported goods primary products (oil and gas), and, of course, on availability of data. If we go over the country selection with further detail, we can follow Lizardo and Mollick's (2010) criteria to complement our back up our decision of doing our analysis only for these three countries. These are the points considered by these two authors in their work:

- "The currency must be actively traded". We should add that the advantage of including Norway is the fact that we obtain a nominal exchange rate without structural breaks; as in the case of the Euro.
- "The set of countries are net oil exporters". Shocks in the oil market affect considerably any economy, however, the impact is different if we consider an oil importer or a net producer of the commodity. It is important to remark this fact once more because our sample includes periods in which we observe high volatility in the oil market.
- "Countries are trade partners with the US". In the case of Canada and Mexico, we can confirm this point by considering the NAFTA; as it goes for Norway, we find that the US imports more than what it exports to Norway, in particular we can highlight trade agreements in the area of telecommunications equipment, electromagnetic compatibility, recreational craft and marine equipment.
- "Data available for the Post-Bretton Woods era". Our sample starts in the year 1983 and concludes in 2008; with these data we do not include data on fixed nominal exchange rates.

The data are collected on a monthly basis. The initial date of our sample, for all the countries, is January 1983 and the final one is August 2008 for Canada and Norway, and December of the same year for Mexico.[15] The series that we get from the IFS and MEI sites

[14] Lizardo and Mollick (2010) is a clear example of the previous. In their work they conclude that oil prices significantly contribute to the explanation of movements in the value of the U.S. dollar in the long run.

[15] We do not include the last four months of 2008 in the case of Canada and Norway in our sample because the effects of the world financial crisis are already captured in the data of these two countries.

are mainly exchange rates and price indices that we use to construct the real exchange rate indices for each country. In the case of MEI database, the series collected are components of the total consumer price index of each country. The first one is the food excluding restaurants price subindex, which we use to proxy for the price of traded goods. The second one is the shelter price subindex component of the CPI - our proxy measure for non-traded goods.[16] The total consumer price index of these three countries is also part of our database in order to calculate the weights of traded and non-traded goods in the real exchange rate we construct. The final series taken from the MEI dataset are the nominal exchange rates of these three countries with respect to the US dollar (national currency units per one US dollar).

It is important to remark that these two proxies (food and shelter subindices) are imperfect measures of traded and non-traded goods prices, as Engel points out in his work. Both subindices might be constructed considering goods that could be regarded as traded (non-traded) in our proxy for non-traded (traded) goods. This is the reason of why we decide to consider, among the components found inside the CPI measure reported in MEI dataset, a simple subindex to proxy for traded goods prices and one more for the non-traded ones.[17]

We must say that the use of a shelter price subindex might raise concern as housing could be considered an asset and not a consumption good. This issue is contemplated by each national statistics office that incorporates the subindex as part of the CPI of each country. Each national statistic office tries to solve the problem in a different way, but the objective is the same for all of them: remove the capital content of housing in the construction of the index. In general the difficulties arise when the owner of the house lives in their own property.[18] The way national statistics offices solve the problem is different from one country to the other. In the case of our country selection the shelter price subindex is obtained by considering the imputation of actual rents approach, in the case of Mexico and Norway; and the rents estimated from the costs of consumption approach for Canada.[19]

[16]The shelter subindex is labeled as "Housing" subindex under the categories of MEI's CPI dataset.

[17]As a matter of fact, Engel uses not only the shelter subindex of CPI but also the services one to proxy for non-traded goods prices. It is this last subindex the one that he considers could be a source of distortion for his measurement of non-traded goods prices.

[18]There is another issue also considered by the national statistics office related to controlled rents, which is solved by taken into account quality control adjustments.

[19]The rental equivalence approach to measuring the costs of consumption assumes that these costs are equal to the rent that could be charged for the property. Thus the costs can be imputed from the rent that is being paid in the market for equivalent dwellings. In the case of the rents estimated form the costs of consumption approach considers the fact that a house owner would charge a rent which at least covers these

These imperfections does not allow us to capture a 100% pure measure for traded and non-traded goods prices; At the same time, these make us consider the use of different proxies for these prices. For this second set of proxies we choose the producer and consumer price indices as measures for traded and non-traded goods respectively. However, these proxies can also be scrutinized and considered flawed. Nevertheless, we ponder the advantages of using both CPI and PPI as proxies for non-traded and traded goods. In particular, all these come from the same source, which can be translated as a very homogenous calculation process.

The data collected from the IFS database include the consumer and producer price indices that are used as proxies for non-traded and traded goods prices respectively, and the nominal exchange rate (monthly average) from each country with respect to the US dollar. In this case it is not necessary to obtain a third price index since we do as Engel (1999) and assume that traded and non-traded goods affect in the same magnitude the real exchange rate (PPI and CPI), so there is no need to estimate any kind of weights when we construct the real exchange rate using IFS data.[20] Before we start with the real exchange rate construction we transform all the data by taking the natural logarithm of each series (for some series it was necessary to change the base year of the price indices). In the case of MEI data the base year is 2005 and for IFS data the year 2000 equals a hundred.

It is important to note that since we are taking different indices as proxies for the prices of traded and non-traded goods we have different methodologies in order to construct the real exchange rates. As we report the results of each database, we also comment the differences between these two. In both cases we analyse the bilateral real exchange rate for all the countries in terms of USA prices.

3.4.1 MEI real exchange rate (Weights' estimation for MEI data series)

As we note earlier, it is necessary to estimate the percentage of traded and non-traded goods included in the real exchange rate. This is done by running a simple OLS regression including the general consumer price index of each country against one of the subindices

items: repairs and maintenance, taxes, insurance, and cost of ownership.

[20]The construction of the real exchange rate using subindices of the consumer price index is also done following roughly what Engel (1999) does in his work.

that we have in our database, either food (excluding restaurants) or shelter index. The estimations are done with the data in (natural) logs and taken the first difference in order to capture the impact of changes in the exogenous variable in the change of the dependent one. The estimated regressions are expressed in the next equations:

$$\Delta p_j = \beta_{h,j} \Delta p_{h,j} + \epsilon_{h,j} \tag{3.13}$$

$$\Delta p_j = \beta_{f,j} \Delta p_{f,j} + \epsilon_{f,j} \tag{3.14}$$

Where p_j, $p_{h,j}$ and $p_{f,j}$ are the general consumer price index and two of its subindices: shelter and food (excluding restaurants) respectively. Once we get both $\beta_{h,j}$ and $\beta_{f,j}$ for country j, the following step is to calculate the weights using the following formula:[21] As a final note, we should mention that the estimations are done using all variables at time t and for the same reason we omit this subindex in the rest of this section.

$$\omega_i = \frac{\hat{\beta}_i}{\sum_i \hat{\beta}_i} \quad \text{where } i = h, f. \tag{3.15}$$

After we obtain ω_h and ω_f, the weights for non-traded and traded goods respectively, it is possible to construct the real exchange rates of Canada, Mexico and Norway using MEI series. The real exchange rate is constructed considering the following equation:

$$rer_j^{mei} = q_j = s_j + p_{f,us} - p_{f,j} + \omega_{h,us}(p_{h,us} - p_{f,us}) - \omega_{h,j}(p_{h,j} - p_{f,j}) \tag{3.16}$$

Where s_j is the nominal exchange rate of country j (domestic currency for one US dollar) and j can be either Canada, Mexico or Norway. We are also interested in two parts from the previous equation that we represent as follows:

[21]Due to the fact we use only two subindices out of several more that are part of the total CPI in the construction of our proxies, we must consider the sum of these two coefficients as our 100%, leaving no room for other subindex in our "total" CPI.

$$x_j = s_j + z_j \tag{3.17}$$

$$z_j = p_{f,us} - p_{f,j} \tag{3.18}$$

$$y_j = \omega_{h,us}(p_{h,us} - p_{f,us}) - \omega_{h,j}(p_{h,j} - p_{f,j}) \tag{3.19}$$

$$\Rightarrow$$

$$q_j = s_j + z_j + y_j \tag{3.20}$$

The final result is a real exchange rate constructed using three parts: the nominal exchange rate, s_j, the price ratio of traded goods, z_j, and the price ratio of non-traded to traded goods of both country j and the US, y_j. This is an important change with respect to the original real exchange rate decomposition of Engel. The purpose is to isolate the effect of the nominal exchange rate and introduce this by itself in the VAR system.

3.4.2 IFS real exchange rate construction

The real exchange rate constructed using IFS data is easier to calculate than what we have for MEI series. The main reason for this is that we assume that both CPI and PPI have the same weight in the real exchange rate. In this case, and as we mention above, the CPI is our proxy for non-traded goods and PPI is the one for traded goods.[22] With this assumption, we construct the real exchange rate without the need of extra regressions to estimate any kind of weights. The real exchange rate takes the following form:

$$rer_j^{ifs} = q_j = s_j + z_j + y_j \tag{3.21}$$

In this case we have that:

[22]It is important to mention that there are some drawbacks of using PPI as our proxy for traded goods price index. For a more detail analysis on this respect, see Engel (1999).

$$z_j = ppi_{us} - ppi_j \tag{3.22}$$

$$y_j = (cpi_{us} - ppi_{us}) - (cpi_j - ppi_j) \tag{3.23}$$

Once again we have that the real exchange rate can be divided in three parts: nominal exchange rate, price ratio of tradable goods or in this case the ratio of producers price index of both countries, and the non-traded to traded price ratio, consumer to producer price index ratio of each country.

3.5 Results

This section is divided in two parts. The first one reports the results for all the statistical exercises discussed in section 3.3, including the simple correlation measured between the real exchange rate and (a) traded goods and (b) non-traded goods. We also report the set of regressions between the real exchange rate and the ratio of traded goods (variable z_t) or the non-traded to traded one (variable y_t), all in first differences; the variance decomposition to obtain the percentage of variance generated by traded and non-traded to traded goods price ratios; and finally the mean-squared error between the same series.

The second subsection reports the results taken from the VAR system constructed using the following series: real and nominal exchange rates, traded and non-traded price good ratios, by combining some of these series in different ways. These two subsections are also divided into two extra parts in order to differentiate the results obtained with MEI and IFS data-sets. One final comment of relevance is the fact that the estimations for Canada and Norway are done using only their complete sample - 1983:01-2008:08. In the case of Mexico we not only calculate our results for its complete sample (1983:01-2008:12) but we also run all the empirical exercises for two subsamples. The first one goes from January 1983 until December 1994, while the second starts in January 1995 and finishes in December 2008.[23]

[23]The decision of dividing the sample in the case of Mexico is based on the fact that during 1994-1995, the country suffered a currency crisis and also divides the sample into periods with different exchange rate regimes. From 1988 to 1994 Mexico had a managed exchange-rate regime implemented. For more details see Mendoza (2000).

3.5.1 Preliminary and MSE analyses

In this section we report the findings from simple statistical measures that start with the sample correlation between the real exchange rate and either the traded goods price ratio or the non-traded goods price component. Then, we continue with a straightforward OLS regression where the real exchange rate (in first differences) is the dependent variable and the regressor could be either the traded goods price ratio (also in first differences) or the one from non-traded goods. The next part includes a measure of the fraction of the variance in the real exchange rate accounted for by the variance of x_t and y_t.[24] And finally, we report a measure to obtain the fraction of the mean-squared error of the real exchange rate accounted for by the traded goods price ratio and also by the non-traded goods part.

3.5.1.1 Preliminary analysis using real exchange rate constructed from CPI's subindices (MEI dataset)

The first table includes correlations between the real exchange rate and the variables that proxy for the price ratio of traded and non-traded goods. We find that traded goods and the real exchange rate have a correlation of more than the 90% for Mexico and Norway. In the case of Canada this value is close to 75%. The correlations for non-traded goods are quite low using data from Canada and even negative in the case of Norway.[25] Mexico is the only country with a correlation close to 50 percent for non-traded goods in the complete sample case.

Table 3.1: Correlations between Real exchange rate and "Variable"

Variable	Canada	Norway	Mexico	Mexico (1st)	Mexico (2nd)
Traded goods	0.74	0.99	0.99	0.99	0.98
Non-traded goods	0.13	-0.03	0.47	0.70	0.16

The last two columns of table 3.1 include the results of correlations of the first and second subsamples of Mexico. For the first one, 1983 to 1994, the correlation is quite high and then in the second subsample it falls to be just a 16%. During the first part of the sample

[24]The variance in this case is calculated taking into account the suggestion of Cochrane (1988) to correct for small-samples.

[25]It is important to remember that the non-traded goods part that we refer to in the whole document is a variable that also includes the price of traded goods. This price ratio is between non-traded and traded goods for both countries.

Mexico is a country with several restrictions to trade; this changes in the second subsample because the North-America Free Trade Agreement (NAFTA) was already implemented and assimilated by several sectors of the economy. All this means that Mexico became a more open country in the second part of the sample.[26] Hence the number of traded goods in Mexico experienced a relevant boost in the years that came after 1994.

Table 3.2: R^2 from OLS model of RER and traded or non-traded goods

	Dependent variable: Real exchange rate									
	Canada		Norway		Mexico		Mexico (1st)		Mexico (2nd)	
k	t	nt	t	nt	t	nt	t	nt	t	nt
Levels	0.77	0.16	0.99	0.27	0.99	0.01	0.99	0.02	0.99	0.00
1	0.80	0.03	0.93	0.00	0.95	0.02	0.93	0.05	0.97	0.00
6	0.87	0.11	0.95	0.01	0.96	0.01	0.95	0.00	0.96	0.00
12	0.91	0.13	0.97	0.00	0.97	0.03	0.97	0.00	0.97	0.13
36	0.90	0.03	0.96	0.00	0.96	0.17	0.96	0.12	0.96	0.21
60	0.87	0.02	0.97	0.01	0.98	0.43	0.99	0.55	0.95	0.35

Table 3.2 includes the results of the OLS regression between the real exchange rate (dependent variable) and one exogenous variable that could be either the price ratio of traded goods or the one for non-traded ones. The "k" column, the first one in table 3.2, represents how many lags are used to take the difference with respect to the level at time t; for example $k = 1$ represents series in first differences, and in the case of $k > 1$ we have that the difference is taken between the observation at time t and the one at time $t - k$. Columns 2, 4, 6, 8 and 10 include the R^2 for the regressions with traded goods as exogenous variable.

The rest of them (columns 3, 5, 7, 9 and 11) report the ones in which the non-traded goods component is the regressor. We have two well defined results for all countries and all periods analysed (in the case of Mexico): the goodness of fit for all the models with the traded goods variable inside is never below 0.77. The other result is a considerable low R^2 for non-traded goods; in rarely cases this statistic is above 20 percent. If we take a closer look to the results of Canada, this is the only country that reports a R^2 below 0.90 for traded goods.

The last two tables (3.3 and 3.4) include the contribution of traded and non-traded goods to the variance and MSE of the real exchange rate. In each table, columns two to four

[26] The NAFTA was established on January of 1994 and the effects of its implementation are not observed during the first subsample of Mexico.

Table 3.3: Contribution to RER Variance

Horizon	CAN (T)	MEX (T)	NOR (T)	CAN (NT)	MEX (NT)	NOR (NT)
1	0.83	0.95	0.94	0.17	0.05	0.07
6	0.88	0.90	0.96	0.12	0.04	0.04
12	0.93	0.97	0.97	0.07	0.03	0.03
36	0.96	0.95	0.96	0.04	0.05	0.04
60	0.96	0.95	0.97	0.04	0.05	0.03
120	0.93	0.96	0.98	0.07	0.04	0.02
180	0.89	0.98	0.95	0.11	0.03	0.05
200	0.84	0.96	0.85	0.16	0.05	0.15

Table 3.4: MSE % of each type of goods to the RER total

Horizon	CAN (T)	MEX (T)	NOR (T)	CAN (NT)	MEX (NT)	NOR (NT)
1	0.83	0.95	0.93	0.17	0.05	0.07
6	0.87	0.96	0.96	0.13	0.04	0.04
12	0.91	0.97	0.97	0.09	0.03	0.03
36	0.93	0.96	0.96	0.07	0.04	0.04
60	0.93	0.96	0.98	0.07	0.04	0.03
120	0.87	0.98	0.98	0.13	0.02	0.02
180	0.76	0.99	0.95	0.24	0.01	0.05
200	0.68	0.98	0.85	0.32	0.02	0.15

are the contribution of the traded goods and the next three are the ones that report the contribution attributed to non-traded goods.

Canada's results are the ones that offer more variations across time. Both the variance and the MSE are calculated using data in differences taken recursively from $k = 1$ to $k = 200$. Tables 3.3 and 3.4 report only some of the horizons of our complete set of results. Our estimations are done for all periods ($k = 1, ..., 200$). Once again, as in the case of the first two measures, we find that most of the variance and MSE of the real exchange rate can be attributed to traded goods. The relevance of non-traded goods is rather small for Mexico and Norway. In the case of Canada, this variable is responsible for a 32 percent of the total variation when we calculate the MSE between periods t and $t + 200$. These results are similar to those Engel (1999) obtains; even in the case of Canada we get results that show a reduction in the contribution of traded goods in the MSE of the real exchange rate.

As we mentioned above and corroborated in figure 3.5.1.1, Mexico and Norway register a similar percentage of traded goods' contribution of the sum of traded and non-traded goods

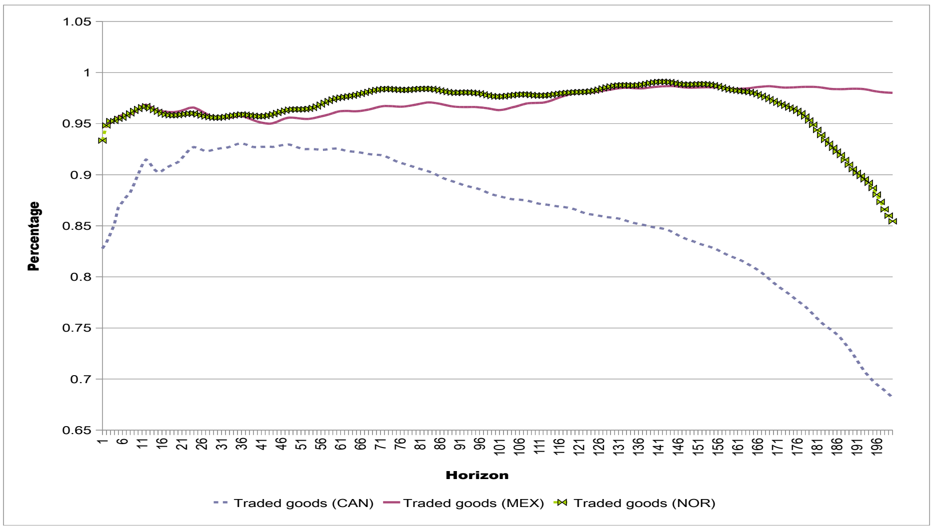

Figure 3.1: Contribution of MSE of traded goods to the sum of traded and non-traded goods' MSE, MEI data

MSE until $k = 180$. In the case of Norway after this period the percentage drops to 85 percent, for Mexico we have that this measure does not goes below 95%. The contribution of traded goods starts decreasing from $k = 80$ for Canada; although we have that the last result for this country still shows a high influence of traded goods in the variance/MSE of real exchange rates.

3.5.2 Preliminary analysis using real exchange rate constructed from CPI and PPI (IFS dataset)

This section includes the results of the statistical measures and regressions estimated but now using data from the IFS website. As we have remarked before, the difference between MEI and IFS data is the fact that the former uses part of the total consumer price index (subindices) of each country as proxies for the price ratio of traded and non-traded goods. In the case of IFS data, we have that the consumer price index is taken as proxy for non-traded goods and the producer price index is the one for traded goods.

Table 3.5: IFS Correlations between real exchange rate and variable

Variable	Canada	Norway	Mexico	Mexico (1st)	Mexico (2nd)
Traded goods	0.89	0.83	0.97	0.97	0.97
Non-traded goods	0.93	-0.07	0.22	0.54	0.03

The correlations of table 3.5 give us a similar picture for Mexico and Norway to what we observe with MEI data. Canada reports once again different behaviour because the correlation between the real exchange rate and non-traded goods is greater than the one taken from the former series with traded goods. The correlation of non-traded goods for Norway seems very low and it even displays a negative sign, which is also not an expected result. However, if we consider that non-traded goods price component of the real exchange rate includes not only these prices but also the traded goods price subindex, it is then possible that the influence of the denominator for the Norwegian case is quite strong to the extreme of having a negative correlation for the whole ratio. In the case of Canada and Mexico for its first subsample we find that the contribution of non-traded goods is not low. These results show that we can have cases where non-traded goods are very relevant in the total variations of the real exchange rate.

Table 3.6: R^2 from OLS model of RER and traded or non-traded goods

Dependent variable: Real exchange rate										
	Canada		Norway		Mexico		Mexico (1st)		Mexico (2nd)	
k	T	NT	T	NT	T	NT	T	NT	T	NT
0	0.90	0.24	0.99	0.06	0.99	0.07	0.99	0.80	0.99	0.03
1	0.66	0.5	0.53	0.05	0.91	0.07	0.84	0.05	0.93	0.09
6	0.74	0.56	0.75	0.03	0.91	0.11	0.89	0.09	0.92	0.13
12	0.72	0.59	0.79	0.04	0.92	0.13	0.91	0.16	0.93	0.11
36	0.78	0.75	0.77	0.01	0.92	0.31	0.90	0.57	0.95	0.07
60	0.83	0.84	0.81	0.01	0.95	0.27	0.95	0.41	0.95	0.10

The R^2 results of the regressions using PPI and CPI as proxies for traded and non-traded prices components show a different pattern to what we find using MEI data. Canada is again the country with a particular set of results; the goodness of fit of these regressions with the price ratio of traded goods does not go above 90% in any case; and in the results for non-traded goods, we observe an increase from a 0.24 for horizons close to time t to reach a R^2 close to 85% when we run the regression using a differentiated series between periods t and $t-200$. The relevance of non-traded goods increases as we take this measure between two periods that are farther apart from each other.

Norway reports interesting variations in this measure when we compare the results for different horizons. The regression done in levels obtains a fit of almost 1 and then it decreases to 0.53 when the OLS model is estimated in first differences. However, this statistic starts increasing again for Norwegian traded goods as k increases. Mexico's behaviour is similar to what we have seen before: a strong impact of traded goods for the complete sample, a low (but not negligible) number for non-traded goods; and when we analyse the two subsamples we find that for the first part, the relevance of non-traded goods is greater than in the next period, second subsample.

The results for the Mexican case are similar to what we have in the previous section using different proxies. The relevance of traded goods does not change considerably between the two subsamples; this is not the case for non-traded goods since in the second subsample we observe a reduction in the goodness of fit of the regression with this variable as the independent one.

Table 3.7: Contribution to RER Variance

Horizon	CAN (T)	MEX (T)	NOR (T)	CAN (NT)	MEX (NT)	NOR (NT)
1	0.60	0.92	0.67	0.40	0.09	0.33
6	0.63	0.91	0.80	0.37	0.09	0.20
12	0.59	0.91	0.82	0.41	0.09	0.18
36	0.53	0.89	0.80	0.47	0.11	0.20
60	0.49	0.91	0.84	0.59	0.09	0.16
120	0.39	0.88	0.82	0.61	0.12	0.18
160	0.46	0.85	0.79	0.54	0.15	0.21
200	0.19	0.82	0.63	0.81	0.18	0.37

Table 3.8: MSE % of each type of goods to the RER total

Horizon	CAN (T)	MEX (T)	NOR (T)	CAN (NT)	MEX (NT)	NOR (NT)
1	0.60	0.92	0.67	0.40	0.08	0.33
6	0.63	0.91	0.80	0.37	0.09	0.20
12	0.59	0.91	0.82	0.41	0.09	0.18
36	0.53	0.89	0.79	0.47	0.11	0.21
60	0.49	0.91	0.82	0.51	0.09	0.19
120	0.39	0.90	0.77	0.62	0.10	0.23
180	0.36	0.90	0.71	0.64	0.10	0.29
200	0.18	0.87	0.62	0.82	0.13	0.38

The last set of results in this section are the ones from the variance decomposition and the mean-squared error of the real exchange rate constructed with IFS data. As we have found in this section, Canada shows that the contributions of traded and non-traded goods are not that different in our results for the first horizons, but as we calculate the mean-squared error between two periods that are further apart, the importance of non-traded goods rises to reach more than 80%, while the traded goods part decreases to an 18%. Norway registers a contribution for traded goods that fluctuates between 60 and 82%. Now we can observe a greater impact of non-traded goods. Mexico gets the greater and more stable contribution of traded goods, close to 90% in all cases, as the impact of non-traded goods is never above 15%.

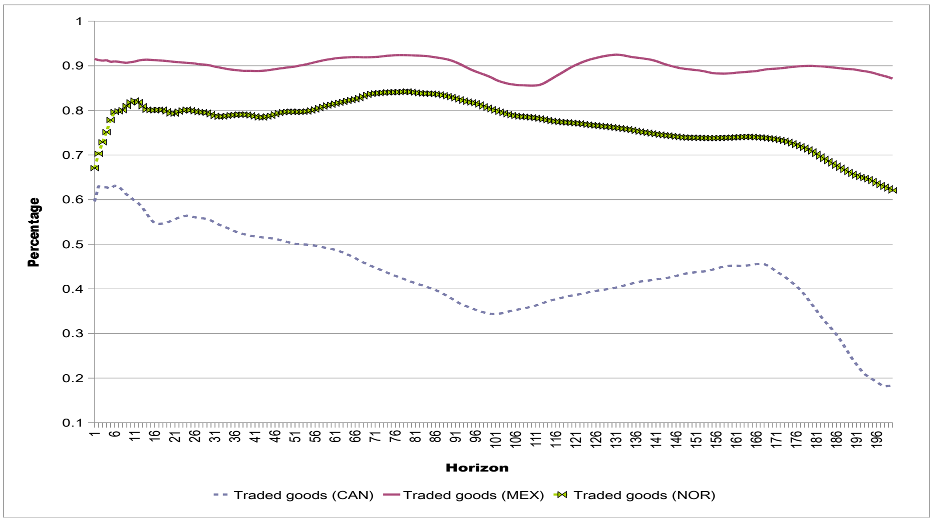

Figure 3.2: Contribution of traded goods MSE to the sum of traded and non-traded goods' MSE, IFS data

In figure 3.5.2 it is possible to observe the changes of the mean-squared error for these three countries as we increase the value of k (the differentiated series is calculated between two periods that are further and further apart from each other) until we reach $k = 200$. As we mention in the previous paragraph, the Mexican case is the most stable but also the one with the greater contribution of traded goods in the real exchange rate MSE since the results are never below an 85%. The case of Norway is a smoother picture of what we saw using a real exchange rate constructed from CPI subindices. There is a stable behaviour and then a reduction on the measure (not as drastic as in the case of MEI data in terms of the slope) that reaches a contribution just above 60%, the starting point is below 70%. Canada's results just show us that the relevance of traded goods could be quite low in the medium term, although not zero as PPP theory predicts.

3.5.3 VAR construction

In this section we follow what others have done like Morales-Zumaquero (2006), Farrant and Peersman (2005), Chaban (2006), in order to incorporate a vector autoregression model that includes the constructed real exchange rate, nominal exchange rate and either the price ratio of traded goods or the non-traded goods price component. All these series for both databases are tested to determine the existence of unit roots in their processes and also to check if they are cointegrated in the case of being integrated of order one, I(1).

The unit root tests are carried out in levels using the Augmented Dickey-Fuller and the Phillips-Perron tests. The results show that the null of the existence of a unit root in the series cannot be rejected in any case. Then, we run again the tests using now first differences and in these cases we can reject the null (existence of a unit root) at least the 5% level in all series. These results indicate us that the series we use are I(1). The next step is to test for cointegration among the series, for these tests we use several VARs specifications. The general dynamic structure can be defined as follows:

$$B_0 X_{t,j} = B(L) X_{t-1,j} + \epsilon_{t,j} \tag{3.24}$$

Where $X_{t,j}$ is a matrix that includes the series mentioned above that now are part of the VAR analysed, $B(L)$ is a polynomial in the lag operator L and $\epsilon_{t,j}$ is a vector of structural shocks with covariance matrix $\sum_{\epsilon}$. The reduced form of the model is shown in the next equation:

$$X_{t,j} = B_0^{-1} B(L) X_{t-1,j} + B_0^{-1} \epsilon_{t,j} \tag{3.25}$$

We use Johansen's methodology to test for cointegration among the series. The vectors tested using data from each country and each dataset are the following:

$$
\begin{aligned}
VAR_1 &= q_t, \quad s_t \\
VAR_2 &= q_t, \quad s_t, \quad z_t \\
VAR_3 &= q_t, \quad s_t, \quad y_t
\end{aligned}
$$

VAR_1 includes real exchange rate constructed by us, q_t, and nominal exchange rate, s_t. VAR_2 and VAR_3 also include the traded goods price ratio, z_t, and the non-traded to traded goods price ratio of both nations, y_t, respectively. The results of the Johansen's tests show that for Canada and Norway there is no evidence of cointegration among the series in any of the VAR specified in 3.5.3. In the case of Mexico, the Johansen's test results are not conclusive enough in some cases, and we use Engle-Granger's methodology to determine if there exists a cointegrating vector by checking if the residuals of the system estimated are stationary with results that signal for no cointegration among the series.

At this point, it is important to mention that we are only able to estimate VAR models that include at the most three variables (real and nominal exchange rates as the first two, and the index price of non-traded or traded goods as the final third). There are several reasons why we do not estimate a model including both type of price indices (non-traded and traded goods) in the VAR, however, the most important obstacle we face in the estimation of a VAR that includes our four relevant variables (both exchange rates and also both type of goods prices) is the fact that the real exchange rate is a linear combination of the previous three, which translates into the fact of ending up with a matrix that is not full rank that cannot be estimated.[27]

In order to reinforce these results we also apply the Saikkonen and Lütkepohl (2000a, b, c) cointegration test and we have different results according to the dataset used. In the case of IFS data we have that there is evidence of cointegration for the complete sample case in both three-variable systems. When the MEI data for Mexico is tested we have that there is at least one cointegrating vector in all samples.[28]

[27] Among the other reasons that might difficult a possible calculation of a four-variable VAR system we can mention the need to impose more long-term restrictions into our structural model and also the possibility of having several cointegration relationships that might not be sensitive to the economic analysis.

[28] We also applied the Saikkonen and Lütkepohl's cointegration test to Canada and Norway and in all cases we have that there is no cointegration among the series of any VAR constructed for these countries.

Since we have cointegrating relationships for Mexico, we need to estimate a vector error correction model (VECM) and not a simple VAR in first differences. Nevertheless, it could be constructive to have the results of the VAR for all Mexico's cases in order to have more straight forward results to compare with the ones from Canada and Norway. The estimations and results for VECM cases are included in a separate section.

The results of the statistical tests show that our series are integrated of order 1 in levels, stationary in first differences, and non-cointegrated, for most of the systems; Then, we estimate the VAR system. In order to have a clear idea of how the impact of the variables included in our system affect the real exchange rate, we apply the Wold Moving Average representation (Moving Average representation of our VAR system). The structural model after applying the transformation looks as follows:

$$\Delta X_{t,j} = A(L)\epsilon_{j,t} \tag{3.26}$$

where

$$A(L) = C(L)B_0 \tag{3.27}$$

and $C(L) = [I - B_0^{-1}B(L)L]^{-1}$ is a polynomial in the lag operator with $C(0) = I_n$. It is necessary that we impose some restriction on the $A(L)$ matrix, otherwise it is not possible to carry out the estimations of the structural VAR due to identification problems. In this case our restrictions are imposed to make nominal shocks being equal to zero in the long-run.[29] Restrictions based on assumptions relative to the long-run characteristics of the model are imposed similarly to what we find in the work of Blanchard and Quah (1989).[30] The final 2-variable moving average representation of our model is expressed next:

[29]When the 2-variable system is estimated, the impact of the nominal exchange rate in real exchange rate is equal to zero in the long-run. For the other cases, having 3 variables inside the VAR, it is necessary to include two more restrictions. The first one is just to make the impact of the nominal exchange rate in the price ratio equal to zero. And for the last one we assume that shocks in the real exchange rate does not affect the price ratios.

[30]Their work involves a model for output and unemployment. They identify two types of shocks: nominal and real shocks, and they assume that the former has no impact on the output level in the long-run. The variance-covariance matrix of their system is transformed using a Cholesky decomposition to have lower triangular matrices.

$$\begin{bmatrix} \Delta q_{j,t} \\ \Delta s_{j,t} \end{bmatrix} = A(L) \begin{bmatrix} \epsilon^{q}_{j,t} \\ \epsilon^{s}_{j,t} \end{bmatrix} \tag{3.28}$$

and in the case of the 3-variable VAR, this is the moving average representation:

$$\begin{bmatrix} \Delta \lambda_{j,t} \\ \Delta q_{j,t} \\ \Delta s_{j,t} \end{bmatrix} = A(L) \begin{bmatrix} \epsilon^{\lambda}_{j,t} \\ \epsilon^{q}_{j,t} \\ \epsilon^{s}_{j,t} \end{bmatrix} \tag{3.29}$$

where λ can be replaced either by z or y.

The main goal of the VAR analysis is to be able to capture the contribution of each variable in the forecast error variance decomposition to see which variable contributes the most to the variance of the real exchange rate and also observe how the real exchange rate reacts to individual shocks of the variables included in the system implementing a impulse-response analysis.

We try to identify the main forces that account for the variations on the real exchange rate in these three countries. The relevance of this study relies on the fact that not only we are considering a two endogenous variable VAR, but we also include a third endogenous variable (a price ratio, either traded or non-traded goods in the system).

What we have in the end is a decomposition of the real exchange rate movements into the ones caused by the nominal real exchange rate, a nominal shock, the price ratio of two different set of goods and the actual real exchange rate. If the law of one price holds for traded goods, then we expect that the percentage that accounts for real exchange rate movements should be low and close to zero (at least for k-steps far from time t). If we get results signaling to the opposite situation, then Engel's findings also hold in our sample and most of the volatility that the real exchange rate experiences comes from traded goods. By construction we expect that the contribution of nominal shocks (the nominal exchange rate), to the variance decomposition is a value very close to zero. It is possible that we find a high percentage of the real exchange rate variance is generated by innovations in itself. If that is the case, it is possible that our specifications are not detailed enough to identify the different effects interacting inside the variance of the real exchange rate (i.e. it is possible that the relevance of covariances among the variables included in the VAR system is greater than what we expected in the beginning).

Joyce and Kamas (2003) develop a VAR system for the real exchange rate of different Latin-American countries. In the case of Argentina, they get that all the variance in the real exchange rate is generated by the own series. In order to have more specific results they include more exogenous variables that really help in their results, however, in our case that means trying to find sources of volatility outside the variables that are part of our real exchange rate, and we disregard that option for the moment.

3.5.3.1 MEI Data

As we mention before the forecast error variance decomposition measures the proportion of forecast error variance in a variable explained by innovations in itself and the other variables. The first set of results of our VAR estimation are the ones using the MEI data-set. In table 3.9 we report the 2-variable VAR for the three countries in our analysis. The following table (table number 3.10) reports the results for the VARs calculated using Mexico's subsamples for the same system.

Table 3.9: FEVD. VAR= Δq_t+Δs_t

Country	Canada		Norway		Mexico	
Variable	q_t	s_t	q_t	s_t	q_t	s_t
Horizon						
1	0.99	0.01	1.00	0.00	0.44	0.56
6	0.99	0.01	1.00	0.00	0.44	0.56
12	0.99	0.01	1.00	0.00	0.44	0.56
36	0.99	0.01	1.00	0.00	0.44	0.56
60	0.99	0.01	1.00	0.00	0.44	0.56

The variables included in the VAR are the real exchange rate, q_t, and the nominal one, s_t. As we mention before, nominal (and temporal) shocks in the system are represented by variations in the nominal exchange rate. In the case of Canada and Norway we observe in the forecast error variance decomposition that the variance of the real exchange rate equation is generated in a 99% and entirely by the real shock respectively. The story is different for Mexico since the nominal shock generates more than half of the variance in the real exchange rate. When we observe the results of the two different subsamples of that country, we are able to detect changes on the impact of the nominal shock. In the first period more than half of the variance is generated by the nominal shock, 57% on average; for the second subsample, the impact of the nominal is reduced to a 41-43%. This is a surprising result since during the first period Mexico had established a managed exchange rate regime, which makes this result the opposite one to what is expected.

Table 3.10: FEVD. VAR= $\Delta q_t+\Delta s_t$

Country	Mex. 1st		Mex 2nd	
Variable	q_t	s_t	q_t	s_t
Horizon				
1	0.42	0.58	0.59	0.41
6	0.43	0.57	0.57	0.43
12	0.43	0.57	0.57	0.43
36	0.43	0.57	0.57	0.43
60	0.43	0.57	0.57	0.43

Table 3.11 and 3.12 include the results for the forecast error variance decomposition for our VAR system with 3 variables: nominal and real exchange rates plus the the ratio of non-traded goods prices (y_t).

Table 3.11: FEVD. VAR=$\Delta q_t+\Delta s_t+\Delta y_t$

Country	Canada			Norway			Mexico		
Variable	q_t	s_t	y_t	q_t	s_t	y_t	q_t	s_t	y_t
Horizon									
1	0.87	0.00	0.13	1.00	0.00	0.00	0.41	0.55	0.04
6	0.87	0.00	0.12	0.99	0.00	0.00	0.40	0.55	0.04
12	0.87	0.00	0.12	0.99	0.00	0.00	0.40	0.55	0.05
36	0.87	0.00	0.12	0.99	0.00	0.00	0.40	0.55	0.05
60	0.87	0.00	0.12	0.99	0.00	0.00	0.40	0.55	0.05

Now that we include more variables in the VAR system, it is possible to observe changes in the distribution of the variance decomposition: For Canada, now the contribution of the own real exchange rate is 87% , and the rest is generated by the price ratio of non-traded goods. In the case of Norway, things remain the same as in the case of the 2-variable VAR. And finally for Mexico in the complete sample VAR, we find that the new variable included, price ratio of non-traded (y_t), generates a 4% in the one and 6 months forecast, for the following periods the non-traded variable contributes with a five percent. As in previous results, the nominal exchange rate generates more than half of the variance of the real exchange rate.

Table 3.12: FEVD. VAR= Δq_t+Δs_t+Δy_t

	Mex. 1st			Mex 2nd		
Variable	q_t	s_t	y_t	q_t	s_t	y_t
Horizon						
1	0.78	0.22	0.00	0.66	0.34	0.00
6	0.76	0.23	0.02	0.63	0.36	0.01
12	0.75	0.23	0.02	0.63	0.36	0.01
36	0.75	0.23	0.02	0.63	0.36	0.01
60	0.75	0.23	0.02	0.63	0.36	0.01

Once more, the nominal exchange rate contributes considerably to the variance of the real exchange rate in both subsamples of Mexican data. There is one relevant difference now, though. The contribution of the nominal exchange rate is higher during the period of 1995-2008, which is in line with our expectations. The impact of the non-traded goods component is rather small in both periods and that could be seen as support for Engel's findings, although the fact of having a great contribution of the own real exchange rate could mean that the traded goods price ratio contribution and even covariances between traded and non-traded goods are very relevant but not possible to be identified in our work.

Table 3.13: FEVD. VAR=Δq_t+Δs_t+Δz_t

Country	Canada			Norway			Mexico		
Variable	q_t	s_t	z_t	q_t	s_t	z_t	q_t	s_t	z_t
Horizon									
1	0.99	0.01	0.00	0.98	0.00	0.01	0.84	0.00	0.16
6	0.99	0.01	0.00	0.98	0.01	0.01	0.82	0.00	0.17
12	0.99	0.01	0.00	0.98	0.01	0.01	0.81	0.00	0.18
36	0.99	0.01	0.00	0.98	0.01	0.01	0.81	0.00	0.19
60	0.99	0.01	0.00	0.98	0.01	0.01	0.81	0.00	0.19

In the case of the 3-variable system but now including the traded goods price ratio, we have that again the nominal exchange rate contribution is very close to zero, but also the percentage of the new variable is close to zero in the case of Canada and Norway. For Mexico, the picture is now similar to the results of developed economies: a huge percentage of the volatility is generated by the own real exchange rate and the rest of the variance is generated by the price ratio of the traded goods.

The last table of this section, table 3.14, once again shows that when we use MEI data, we

Table 3.14: FEVD. VAR=Δq+Δs+Δz

	Mex. 1st			Mex 2nd		
Variable	q_t	s_t	z_t	q_t	s_t	z_t
Horizon						
1	0.95	0.02	0.04	0.88	0.08	0.04
6	0.93	0.02	0.05	0.84	0.09	0.07
12	0.92	0.02	0.06	0.84	0.09	0.07
36	0.92	0.02	0.06	0.84	0.09	0.07
60	0.92	0.02	0.06	0.84	0.09	0.07

get that the variance of the real exchange rate is mainly generated by the own series. And in just a few cases we have an important contribution of the nominal exchange rate (just for Mexico and only in the 2-variable system).

If we now take a look to the results for the two sets of the Mexican sample, we find that for both subsamples the contribution of the nominal exchange rate is small, in particular for the first subsample, and just below ten percent for the second one. These results are more in line with our expectations: By construction we have long-run restrictions inside the VAR. The restrictions are set to have a zero effect of nominal shocks in the long-run. Hence, the nominal exchange rate should not contribute to the variance of the real exchange rate in the long-run. Despite the fact of not obtaining a non-zero result, it is possible to explain this result because the exchange rate of Mexico fluctuates more freely during the second subsample.

3.5.4 IFS Data

The results for IFS data give us a different picture to the one created with the information of the previous section. These are more in line with our expectations. We have to remember that the real exchange rate is constructed using the CPI and PPI and not from a pair of subindices that are part of the general CPI.

The bivariate model reports the same results as the ones from the previous section for the developed nations, and for Mexico there is a relevant change. Now most of the variance is generated from the own real exchange rate. We get the inverse result with MEI dataset. Although, we still find that the nominal shock is not assimilated completely by the real

Table 3.15: FEVD. VAR=Δq_t+Δs_t

Country	Canada		Norway		Mexico	
Variable	q_t	s_t	q_t	s_t	q_t	s_t
Horizon						
1	1.00	0.00	1.00	0.00	0.64	0.36
6	1.00	0.00	1.00	0.00	0.64	0.36
12	1.00	0.00	1.00	0.00	0.64	0.36
36	1.00	0.00	1.00	0.00	0.63	0.37
60	1.00	0.00	1.00	0.00	0.63	0.37

exchange rate in the long-run for Mexico, if we now observe the second table (table 3.16), in which we present the results of the two subsamples of the Mexican case, we obtain a result that can represent the different exchange rate regimes implemented by Mexican authorities: a managed exchange rate policy until 1994 and a more flexible regime later. The impact of the nominal exchange rate is higher for the second period.

Table 3.16: FEVD. VAR=Δq_t+Δs_t

	Mex. 1st		Mex 2nd	
Variable	q_t	s_t	q_t	s_t
Horizon				
1	0.58	0.42	0.43	0.57
6	0.60	0.40	0.46	0.54
12	0.59	0.41	0.46	0.54
36	0.59	0.41	0.46	0.54
60	0.59	0.41	0.46	0.54

Table 3.17: FEVD. VAR=Δq_t+Δs_t+Δy_t

Country	Canada			Norway			Mexico		
Variable	q_t	s_t	y_t	q_t	s_t	y_t	q_t	s_t	y_t
Horizon									
1	0.33	0.00	0.67	0.89	0.00	0.10	0.45	0.38	0.18
6	0.38	0.00	0.62	0.90	0.00	0.10	0.45	0.37	0.18
12	0.38	0.00	0.62	0.90	0.00	0.10	0.45	0.37	0.18
36	0.38	0.00	0.62	0.90	0.00	0.10	0.45	0.38	0.17
60	0.38	0.00	0.62	0.90	0.00	0.10	0.45	0.38	0.17

When the non-traded goods price ratio variable is included in our VAR, we get that for Canada a high percentage of the variance is generated by this variable, as a matter of fact this is the highest percentage for this country. This results shows us that non-traded goods are important in total variance of the real exchange rate. In the case of Norway, our results reveal a smaller contribution of this variable compared to the one of the other two countries, most of the variance is generated in the real exchange rate variable. For Mexico, we have again that the nominal exchange rate is very relevant and even more than the price ratio of non-traded goods.

Table 3.18: FEVD. VAR=Δq_t+Δs_t+Δy_t

	Mex. 1st			Mex 2nd		
Variable	q_t	s_t	y_t	q_t	s_t	y_t
Horizon						
1	0.49	0.39	0.12	0.38	0.48	0.15
6	0.51	0.38	0.11	0.37	0.47	0.16
12	0.50	0.39	0.11	0.36	0.47	0.16
36	0.50	0.39	0.11	0.36	0.47	0.16
60	0.50	0.39	0.11	0.36	0.47	0.16

In the case of the two shorter samples of Mexico, we confirm the results that we get for the two-variable system: the contribution of the nominal exchange rate is higher in the period when Mexico has a more flexible exchange rate regime. It is also important to mention that the contribution of non-traded goods increases in the second period, although this is a marginal change, and the own contribution of real exchange rate is reduced from a 50% to a 36%.

Table 3.19: FEVD. VAR=Δq_t+Δs_t+Δz_t

Country	Canada			Norway			Mexico		
Variable	q_t	s_t	z_t	q_t	s_t	z_t	q_t	s_t	z_t
Horizon									
1	0.44	0.01	0.55	0.91	0.00	0.09	0.83	0.01	0.16
6	0.48	0.02	0.51	0.91	0.00	0.09	0.83	0.01	0.16
12	0.48	0.02	0.51	0.91	0.00	0.09	0.82	0.01	0.17
36	0.48	0.02	0.51	0.91	0.00	0.09	0.82	0.01	0.18
60	0.48	0.02	0.51	0.91	0.00	0.09	0.82	0.01	0.18

If we substitute the non-traded goods price component for the traded goods price inside the VAR system of each country, things do not change considerably for Canada and Norway. For the former, the impact of nominal exchange rate is negligible and the real exchange rate's contribution is now barely greater than with non-traded goods. Traded goods represent more than half of the variance, although for future periods this percentage is just above the 50%. For Norway, the picture is almost the same one as before: the real exchange rate generates a 90% of its own variance and the rest is generated by traded goods. Mexico this time reports a similar picture to the one from Norway: the contribution of the nominal exchange rate is close to zero and the impact of traded goods increases from a 16% in period 1 to a 18% in the following periods. The rest is the contribution of the own real exchange rate.

Table 3.20: FEVD. VAR=Δq_t+Δs_t+Δz_t

	Mex. 1st			Mex 2nd		
Variable	q_t	s_t	z_t	q_t	s_t	z_t
Horizon						
1	0.90	0.00	0.10	0.66	0.14	0.19
6	0.89	0.00	0.11	0.64	0.15	0.20
12	0.88	0.00	0.12	0.64	0.15	0.21
36	0.87	0.00	0.12	0.64	0.15	0.21
60	0.87	0.00	0.12	0.64	0.15	0.21

Finally, table 3.20 reports the results of the two subsamples for the Mexican case. These show a quite interesting picture: variations in the nominal exchange rate have a higher weight of the total variance of the real exchange rate in the second period. This contribution is zero in the first period (1983 to 1994) and most of the variance at the time is generated by the own real exchange rate. For the last part, the distribution changes to a 65% (approximately) coming from the own real exchange rate, 15% comes from the nominal one and the rest (approximately 20%) is generated by the price ratio of traded goods.

For the first subsample, years 1983 to 1994, we have a null impact of nominal exchange rate, which could be explained once more by the exchange rate regime policy that Mexican authorities adopted at the time, and a smaller contribution of the traded goods price compared with the result of the second subsample; a probable explanation is the reduced number of traded goods in the Mexican economy during the first period of the complete sample.

3.5.5 A Vector Error Correction Model for Mexico

The 3-variable system for Mexico includes series that are cointegrated among them. For this reason we need to specify a vector error-correction model. The Johansen's cointegration tests results cannot determine how many cointegration relationships we have in each system, but using Saikkonen and Lütkepohl's test we are able to find a cointegrating vector in all cases (complete sample and the two subsamples), which means that the real exchange rate, the nominal one and either traded goods price ratio or the one of non-traded goods can be combined linearly to get a stationary relationship among the series.

3.5.5.1 MEI VECM results

When we use MEI's dataset, we find that all three-variable systems have one cointegrating vector. In other words, both real and nominal exchange rates and the traded goods price ratio are linked in a long-run relationship in the complete sample case as in the subsamples ones. The cointegration tests signal the same situation when we replace traded goods price ratio with the non-traded goods price component. The first table in this subsection (table 3.21) reports the results for the system that includes the non-traded goods price ratio. Columns two, three and four include the results for the complete sample case, while the following three do the same for the first subsample. The remaining three columns contain the second subsample results.

Table 3.21: FEVD. $VECM = q_t + s_t + y_t$

Sample	Complete Sample			1st Subsample			2nd Subsample		
Variable	q_t	s_t	y_t	q_t	s_t	y_t	q_t	s_t	y_t
Horizon									
1	0.84	0.13	0.02	0.67	0.18	0.15	0.70	0.06	0.23
6	0.87	0.09	0.04	0.60	0.08	0.32	0.51	0.06	0.43
12	0.87	0.07	0.06	0.47	0.05	0.49	0.43	0.06	0.52
36	0.71	0.05	0.24	0.21	0.01	0.78	0.29	0.04	0.67
60	0.56	0.04	0.40	0.14	0.01	0.86	0.22	0.03	0.74
120	0.35	0.03	0.62	0.09	0.00	0.91	0.15	0.02	0.83
200	0.24	0.02	0.75	0.07	0.00	0.93	0.10	0.01	0.89

The first thing to notice when we compare these first set of results with (all) the previous results of the VAR analysis is the fact that there are more dynamics in the VECM results. In the case of the complete sample we have that in horizons close to time $t = 0$ the variance is generated mainly by the own real exchange rate series (84% of the total variance), the nominal exchange rate's contribution is 13% and the rest (2%) is accounted for by non-traded goods price ratio. These numbers change as the forecast variance error is calculated for horizons that are farther away from time $t = 0$. If we get the variance of the forecast for 200 periods ahead, we obtain that the variance of the real exchange rate is generated mainly by the non-traded goods price ratio (75%), the nominal exchange rate contribution is close to zero and the rest, 24% is accounted for by own real exchange rate variations.

The results for the first and second subsamples are similar for the contribution of the own real exchange rate. The percentages for nominal and non-traded goods price component are different, though, as we have experienced in previous exercises. We can remark that the contribution of the nominal exchange rate is quite low in the three samples, in particular at higher horizons. At the same time, we find that the relevance of non-traded goods component increases with time and this variable becomes the greater source for the variance of the real exchange rate. We could even say that in the long-run we find hints of the (relative) PPP holding for Mexico, in particular in the second period.

If we now replace the non-trade goods price component with the traded goods price ratio we find that in the complete sample case the latter series accounts for 67%, most of the variance is explained by this variable. However, this percentage is reduced in the long run and it only accounts for a 21%. For horizons that are far away from $t = 0$, we have that most of the variations are generated by the own real exchange rate, a variable that includes the non-traded goods component.

Once again we observe that nominal exchange rate is not a relevant source of fluctuations for any of the cases. The role of the traded goods price ratio varies according to the sample results we observe. For the complete sample and the second subsample we obtain that the percentage contributed by this variable reduces with the length of the horizon. In the case of the first subsample, the contribution of the traded goods price is more or less constant but increasing through time.

Despite the previous remark, it is not difficult to observe that the behaviour of traded goods price ratio and the non-traded goods price component is the inverse one, and also contrary to Engel's results. As a matter of fact, these findings cannot be observed in our VAR system.

These results give us a picture in which the traded goods price ratio play an important role in explaining real exchange rate variance but only in the short run. As we observe these results for the long-run horizons the relevance reduces considerably. On the other hand, non-traded goods explain an important percentage of the real exchange rate variance in the

Table 3.22: FEVD. $VECM = q_t + s_t + z_t$

Sample	Complete Sample			1st Subsample			2nd Subsample		
Variable	q_t	s_t	z_t	q_t	s_t	z_t	q_t	s_t	z_t
Horizon									
1	0.20	0.13	0.67	0.70	0.16	0.14	0.02	0.06	0.91
6	0.24	0.09	0.67	0.87	0.06	0.06	0.14	0.06	0.80
12	0.28	0.07	0.64	0.93	0.04	0.04	0.20	0.06	0.74
36	0.47	0.05	0.48	0.86	0.01	0.13	0.37	0.04	0.59
60	0.58	0.04	0.38	0.82	0.01	0.18	0.47	0.03	0.50
120	0.70	0.03	0.27	0.78	0.00	0.21	0.61	0.02	0.37
200	0.77	0.02	0.21	0.77	0.00	0.23	0.68	0.01	0.30

long-run.

3.5.5.2 IFS VECM results

In the case of using CPI and PPI as our proxies for traded and non-traded goods prices to construct our real exchange rate, we find less systems that report a cointegrating vector between the variables. These are detected in the complete sample case only for both VAR systems that include three variables. The results are reported in table 3.23.

Table 3.23: VECM IFS. Complete Sample

Mexico	Complete Sample			Complete sample		
Variable	q_t	s_t	y_t	q_t	s_t	z_t
Horizon						
1	0.97	0.01	0.03	0.34	0.03	0.63
6	0.98	0.00	0.02	0.38	0.01	0.61
12	0.98	0.01	0.01	0.41	0.01	0.58
36	0.98	0.01	0.01	0.52	0.01	0.48
60	0.95	0.01	0.04	0.59	0.01	0.40
120	0.85	0.01	0.14	0.72	0.00	0.28
200	0.75	0.00	0.25	0.80	0.00	0.19

The reading we can make from the table above is the following: the role of the non-traded goods price ratio is greater in the long-run, but this variable only explains a 25% of the variations. The higher percentage of the variance is explained by the own real exchange rate series. If we have the traded goods price ratio variable inside the system, then the real exchange rate accounts for a 34% in the first periods and this percentage increases until reaching an 80% at $k = 200$. As this variable increases its presence in the variance of the real exchange rate, the one from traded good price ratio declines to obtain a minimum of 19% (from a 63%, in early horizons). The results for these two cases do not support, again, the conclusions of Engel's work. A final comment that must be made is that once more we get neutrality of the nominal variable in the system, the nominal exchange rate.

3.5.6 Impulse-Response Analysis

The final part of this work is an Impulse-Response analysis to study the effects of shocks on the series included in our VAR system on the real exchange rate variable. This analysis complements the previous section by giving us a picture of the intensity and direction of the real exchange rate's reaction to diverse types of shocks, and comparing these not only with the first set of results but also with the other nations' results. It is also possible to analyse the differences between the two types of real exchange rates constructed, the one using two subindices taken from the consumers price index (MEI dataset) and the one using two different types of price indices - IFS dataset. The graphs of the Impulse-Response exercise can be found at the end of this section and in the appendix.

3.5.6.1 MEI dataset

A shock in the real exchange rate is absorbed similarly in Canada and Norway by just reaching a maximum at the time of the shock; then it declines constantly towards zero and returns after four periods to the level it had before the shock. In summary, the shock is assimilated quickly. In the case of Mexico there are two cases where we observe a similar behaviour. A shock in the real exchange rate decays rapidly only when we are working with the 3-variable system that contains the traded goods price variable inside, the shock is absorbed in 2-4 periods . If we think about this, it is possible that controlling for traded goods in our specification helps the assimilation of the shock. For the rest of Mexican cases the pattern observed is different in terms of time needed to absorb the shock. The convergence to the level the real exchange rate had before can take up to 20 months.

There are two cases inside the Mexican results in which the initial depreciation becomes an appreciation of the real exchange rate, the movements are more volatile. One of these cases is observed for the complete sample, and the other occurs in the second subsample, when the exchange rate regime is more flexible. With no doubt, and as expected, the developing economy is the most volatile one of the three countries.

The reaction of the real exchange rate to a shock in the nominal one is the same for Mexico and Norway: there is an instantaneous depreciation in the former that turns into an appreciation after two months and then the real exchange rate comes back to equilibrium (or the level it had in period zero) a few periods after; it takes fewer months to reach the pre-shock level in the case of Norway. There is a special reaction for Mexico that is observed when the price ratio of traded goods is part of the VAR system: we have an instantaneous depreciation that becomes an appreciation very quickly afterwards and again there is a change in the direction of the shock (a second and greater depreciation). There is a third and final change of direction, smaller appreciation, before the real exchange rate absorbs the shock completely.

We can also add that for Mexico in its 3-variable system (including the traded goods price ratio) we observe the greatest depreciations and appreciations of all. For these two countries we find that the real exchange rate experiences an overshooting.[31] This behaviour could explain the appreciation suffered after the initial depreciation. In the case of the developing country the movements are more pronounced and more volatile.

Canada reports a different behaviour: at time zero the shock affects negatively the real exchange rate and then this movement changes direction to report a depreciation before showing a steady decay of the effects of the shock in the real exchange rate. This is the opposite reaction to what we observe in Mexico and Norway.

The rest of the shocks are the ones generated by movements in the traded goods price ratio and non-traded goods price component. In the case of traded goods, Canada and Mexico are now the ones with similar trajectories for the real exchange rate's reaction to a shock in this variable. We observe an instantaneous appreciation that turns into a depreciation after two periods. For Mexico the shock vanishes completely after several periods, and for Canada the real exchange rate experiences another appreciation that does not last long. So

[31] For more details on the overshooting of the exchange rate, see Dornbusch (1976)

despite more changes on the direction of the effect, Canada assimilates the shock faster. It is worth mentioning that the impact of this shock in the subsample of the second period of the Mexican data is greater (perhaps because there are more traded goods in the economy compared to the previous years) but not as persistent as in the case of the first subsample. Norway's real exchange rate reacts with an instant depreciation that is assimilated in the following period.

When we observe a shock in the non-traded goods price component, the real exchange rate of Canada depreciates at time zero reaching a maximum and then the reaction diminishes to reach the pre-shock level after 5 periods. Norway and Mexico (complete sample) are affected negatively at time zero. For Norway we observe a greater depreciation of the exchange rate after the initial reaction of the variable. The peak of the depreciation is reached after two periods and then the shock is completely absorbed at time $t = 6$. We can see more volatility in the Mexican case (complete sample) because the shock is not absorbed even after 40 periods. The real exchange rate suffers two depreciations before reaching the previous equilibrium. In the case of the subsamples, the reactions are more uniform by reporting an initial depreciation that reaches its peak in period one. Then, we have a decay in the effect towards zero. We have that there is no uniform reaction observed in the three countries.

A final remark that can be done related to the impact of nominal exchange rate shocks is that its magnitude is reduced whenever the price of traded goods is inside the VAR. In the other cases, this shock is at least as big as the one generated by the own real exchange rate. In all cases it is possible to observe an overshooting in the real exchange rate, even when the model includes the price ratio of traded goods.

3.5.6.2 IFS dataset

We start by describing the impact of a shock in the own real exchange rate. In the case of Mexico, we find that persistence of a shock is greater in the two-variable system VAR. It takes a year for the shock to be absorbed completely while in the developed nations this is done in just a quarter. Mexico exhibits a similar behaviour to the one of developed nations when traded goods price ratio is part of the VAR. A relevant remark is the fact that the variance of Canada is the smallest of the three countries observed after a shock in the real exchange rate and the one for Norway and Mexico is quite similar. Actually, in some specifications the variance of the European country registers the highest values of all the samples.

The reaction of the real exchange rate to a shock in the nominal exchange rate is not the same for all the countries and even in the case of Mexico there are different trajectories for the real exchange rate in accordance to the VAR system analysed. For Canada we have that the real exchange rate appreciates at time zero (negative impact) but after one period we observe a depreciation that peaks in the following period. The reactions of Norway's is to register an initial depreciation that after two months turns into an smaller appreciation, which disappears after four to six months. In the case of Mexico we have a similar behaviour in the short-run (instant depreciation followed by an appreciation). The appreciation converges slowly to zero but the shock is not completely absorbed after several periods. The assimilation of the shock is slower in all these cases.

In the case of a shock in traded goods price ratio we have that real exchange rates react in a similar way in terms of direction, a negative one (instantaneous appreciation) for all countries and all samples. For high-income economies, we have that the shock disappears after four to six months. This negative perturbation turns into a depreciation of the real exchange rate after a couple of periods in the particular case of Mexico using the complete sample and does not disappears even after 20 months. We encounter a similar reaction using the first subsample (years 1983.01-1994.12). But for the second subsample, the real exchange rate does go back to its equilibrium.

The impact of a shock in the price ratio of non-traded goods is almost the same for the three countries and for all periods (for Mexico). In broad terms, the reaction is in the opposite direction to the one observed after a shock to the traded goods price ratio. There is an initial depreciation in all cases that dies out after 3 to 4 months for Canada and Norway. In the case of Mexico we get that this initial movement turns into a very small appreciation observable in the sub-sample cases.

If we take a look at the results of both databases, we have that the reactions in the case of IFS dataset are more uniform, or at least with a lower number of possible trajectories. It is also the case that the responses of Mexico and the developed countries coincide more with IFS data.

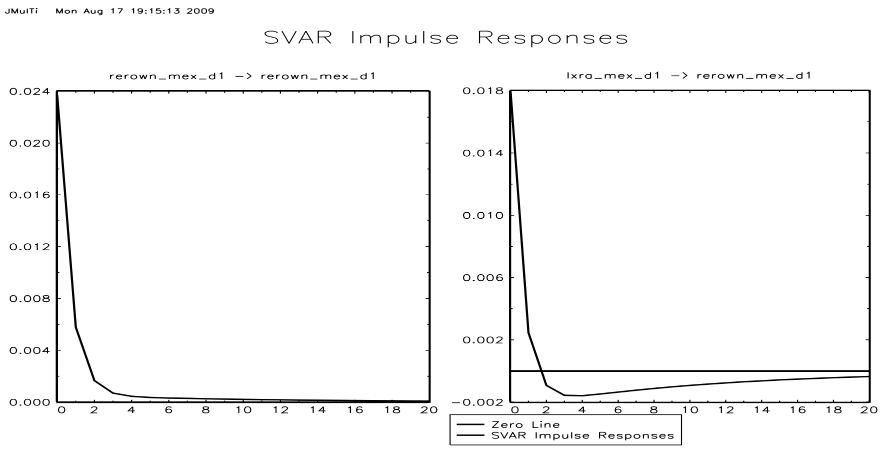

Figure 3.3: Impulse-Response:Mex, IFS data, VAR: s+q

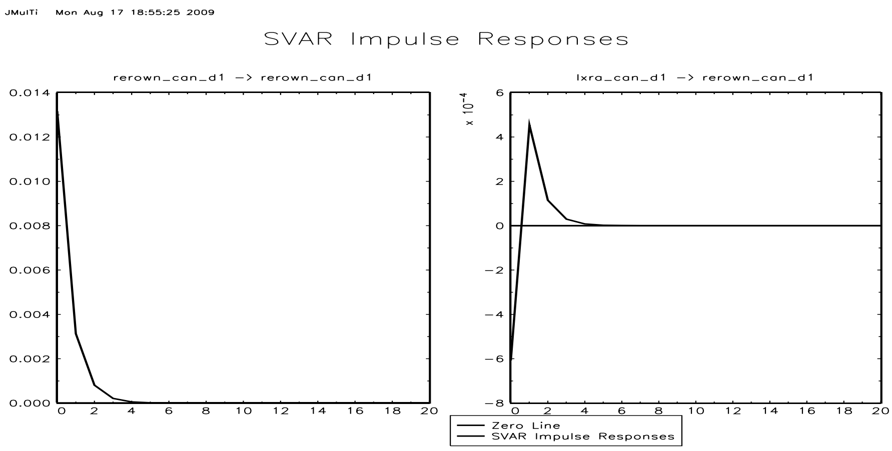

Figure 3.4: Impulse-Response:Can, IFS data, VAR: s+q

3.5.7 Impulse-Response Analysis for Mexico's VECM

It is important that we consider not only the impulse-response analysis taken from the VAR systems of Mexico, but also the ones generated by the vector error-correction model because in the forecast error vector decomposition we could observe a more dynamic response of the variance. In this case we are only studying the reaction of the real exchange rate in levels, however, it could be very useful to corroborate what we have for the VAR system or perhaps to get more detailed responses of the real exchange rate to the different type of

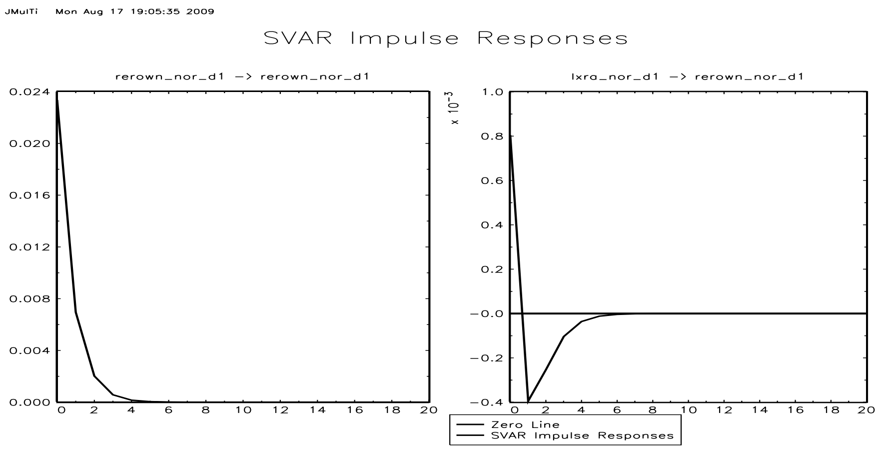

Figure 3.5: Impulse-Response:Nor, IFS data, VAR: s+q

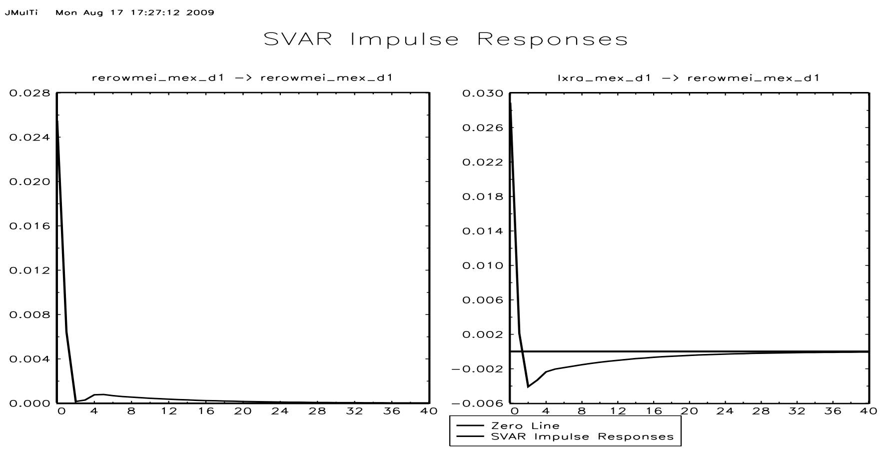

Figure 3.6: Impulse-Response:Mex, MEI data, VAR: s+q

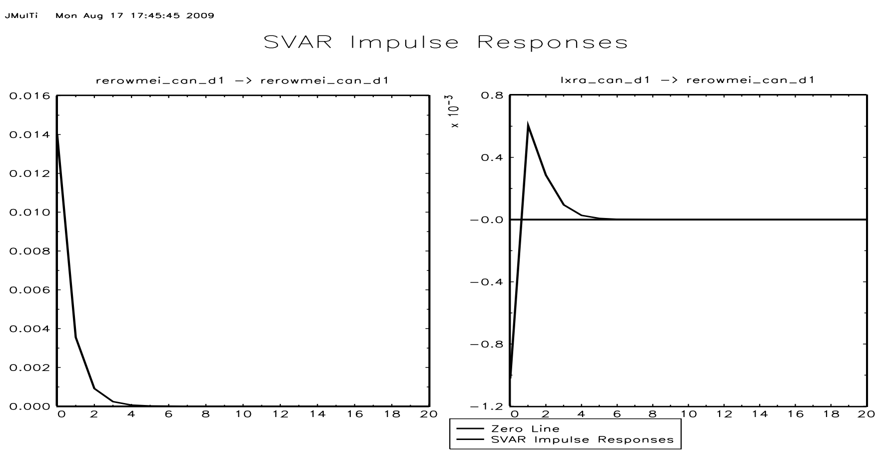

Figure 3.7: Impulse-Response:Can, MEI data, VAR: s+q

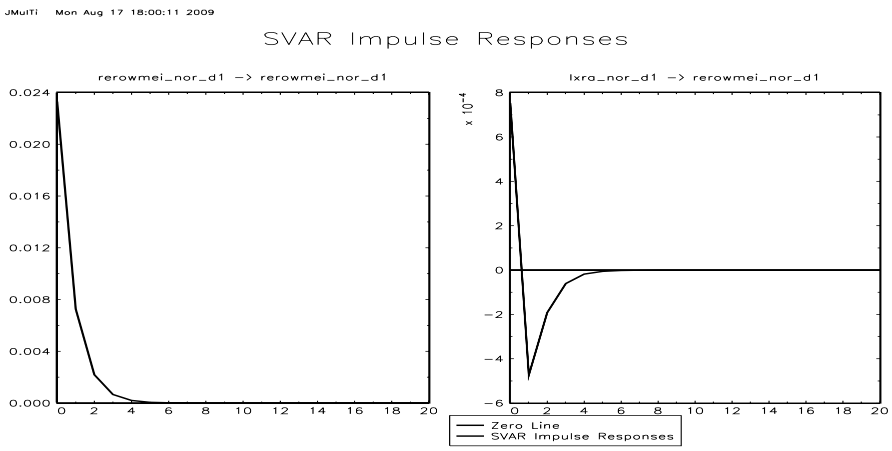

Figure 3.8: Impulse-Response:Nor, MEI data, VAR: s+q

shocks that can affect the system.

3.5.7.1 MEI data

We have that both 3-variable VAR systems are cointegrated for all samples in the Mexican case. That leaves us with six impulse-response exercises that can be taken from the VECM estimated with MEI data. We divide the description of the graphs taking as reference which type of goods price ratio is inside the system. We take first the one that includes traded goods price ratio. In this case the response of a shock in the actual real exchange rate is different for the subsamples and the complete number of observations. In the complete sample case we have that there is an instant depreciation of the real exchange rate that becomes lower as the time passes by; but there is an important difference to what we observe in the impulse-response analysis taken from the VAR. This difference is that the real exchange rate stabilizes above the original value (level before the shock), and even after 180 periods the shock is not assimilated. In the case of the subsamples, we observe the instantaneous depreciation of the real exchange rate, but the peak of this is not reached until some periods after and the real exchange rate stabilizes around the peak value. The equilibrium of the real exchange rate varies after a shock (permanent effect).

A shock in the nominal exchange rate generates an instantaneous depreciation in all the samples and its effects are assimilated completely. This process is achieved faster in the sample that contains data of a fixed exchange rate regime (first subsample).

To conclude with the impulse-response of a VECM that includes the traded goods price ratio, we have that the real exchange rate reacts with a instantaneous appreciation that steadily reduces its intensity and turns into a depreciation around 50 periods after the initial shock for the complete sample case, which we must add is a mixture of what we observe in the subsamples. In the first subsample we have that the initial appreciation is smaller than in the complete sample and the following depreciation is greater. As for the second subsample, the initial appreciation becomes smaller but the level of the real exchange rate converges to a value below the original value (permanent appreciation).

The case of a VECM including a non-traded goods price component reports similar situations in the impulse-response functions of the real exchange rate to the three different samples with one difference. The difference is the reaction to a shock in the non-traded goods price ratio. This generates a depreciation that at time $t = 0$ increases over time and converges at a greater rate in the complete sample and first period subsample cases. The response in the second subsample is to end up with an instantaneous depreciation that becomes lower and lower as we observe the response in higher horizons. The depreciation turns into an appreciation after five periods and reaches a minimum after 20 months and the real exchange rate stabilizes at this level. The responses to shocks to the real and nominal exchange rates are instant depreciations that are assimilated after 50 periods and the real exchange rate in these cases returns to the original level.

3.5.7.2 IFS data

For the VECM using IFS data we only have two systems to analyse. These are taken from the complete sample cases in the 3-variable VECM systems. The response to a shock in the own real exchange rate is an instantaneous depreciation that reaches a maximum after ten periods approximately, then it becomes smaller but we observe once more that the real exchange rate does not return to its original (equilibrium) level. In the case of a shock in the nominal exchange rate, we have once more a depreciation at time $t = 0$ that turns rapidly into an appreciation, then the real exchange rate converges towards its pre-shock value. If there is a shock in the traded goods price ratio, the real exchange rate appreciates and this effect becomes smaller as periods pass by, but it does not get back to its original level. The final case we have is the shock of the non-traded goods price component, the final result is a new and lower value of the real exchange rate but here we start with a depreciation of the real exchange rate that after 20 periods becomes an appreciation reaching a minimum.

3.6 Conclusions

Our results depict a scenario where traded goods are quite important in the first part of our work explaining the variance of the real exchange rate. However, this conclusion does not hold in the end of our work. In the same way our empirical exercises are divided in two sets (preliminary statistics and VAR analysis), we can divide our findings in the same way. The first part of our results shows that the role of traded goods is higher than the one of non-traded goods. This result is in line with Engel's findings, but that does not mean the contribution of non-traded goods is null. On the contrary, we observe that in the case of Canada the participation of this type of goods in the variance of the real exchange rate should be considered. As for Mexico and Norway, it is not as easy as with Canada to spot the relevance of non-traded goods, although we cannot say that all the variance is generated by movements in traded goods prices.

It is possible that for Canada the importance of non-traded goods is clearer due to the high integration of its economy with the one from the United States. In the case of Mexico, we can detect other events affecting the real exchange rate such as the change in the exchange rate regime and even currency crises episodes. As it goes for Norway, we can consider the obvious fact that this economy is more integrated with the European markets and this is reflected in our results of a RER analysis based on US dollars.

Despite all the previous, we find more results that support the idea of a higher contribution of non-traded goods in the real exchange rate volatility than Engel found for the United States as we move forward with our empirical exercises. These become more complex and it is possible to have a better identification of the effects. With MSE, Canada establishes that non-traded goods should be considered as an important source of variations of the real exchange rate. In the VAR analysis this fact can be corroborated for Canada. The problem for Mexico is that the high volatility of its nominal exchange rate makes it harder to identify the pure effect of non-traded goods, not to say that this volatility is transferred completely to the real exchange rate for the last ten years. However, with the VECM results we can see that non-traded goods are the important part.

And in the case of Norway, we encounter that a high percentage of the real exchange volatility is generated by the own series (when we analyse MEI results), that represents a weak specification and the possible need of exogenous variables to identify in a better way the sources of the real exchange rate's variance for this country. If we use the PPI and CPI as proxies for traded and non-traded goods, we obtain lower percentages of the variance generated by the own real exchange rate series, and in this case we have that the participation is not zero; it actually is quite similar to the percentage of non-traded goods.

If we go back to Mexico's data, we find that the role of nominal shocks is not that temporal. These reflect high persistence, in particular if we consider the results of the second subsample (1995 to 2008). We also find evidence to support the claim that the real exchange rate becomes more volatile in more flexible exchange rate regimes. The results of the VAR analysis allow us to conclude this, but it is necessary to study the results of the VECM framework to support the idea that in the long-run non-traded goods are very relevant. The picture depicted tells us that traded goods are important in the short-run, but its contribution to the real exchange rate reduces when we consider medium- and long-run periods. This result holds in both datasets.

The Impulse-Response analysis corroborates some of the things observed in the other sections. The response of Canada is in several cases different to what we observe in Mexico and Norway. In particular for Mexico we have that shocks in the nominal exchange rate are more persistent, specially in the last ten years. The presence of traded goods also modifies the response of the real exchange rate to different type of shocks. There is however a similar reaction in all the countries and that is the time it takes to assimilate a shock in the own real exchange rate series. With the Impulse-Response analysis we just confirm that developing countries are more volatile than developed economies.

It is also important to mention the role of the data, or in other words which dataset seems to be better proxies for our decomposition of the real exchange rate into traded and non-traded goods prices. We can say that by using subindices of the consumer price index we are capable of depicting in general terms the impact of these two types of goods in the variance of the real exchange rate. However, when the performance of these two are compared with the results we get by replacing them with the CPI and the PPI as proxies for non-traded and non-traded goods prices, we can conclude that working with consumer and producer price indices as proxies we obtain a more precise picture of impact of traded and non-traded goods in the variance of the real exchange rate.

Finally, we must admit that including more than one type of real shock into the VAR system falls short of solving the problem of getting a precise decomposition of the real exchange rate. However, our work represents an important step because now it is possible to have a better mapping of what contributes to the real exchange rate variance with a simple specification. Perhaps including exogenous variables and also considering a more dynamic set-up, or that contributions from an specific variable might not remain static, will help to have a better identification of the variables that have a greater impact on the real exchange rate variance.

Chapter 4

Explaining Real Exchange Rate Volatility

4.1 Introduction

The Real Exchange Rate is one of the most relevant indicators in an economy. It measures the relative price of two baskets of goods in the same currency from different economies at a specific period of time.[1] This variable can capture situations where an economy is not in equilibrium. For this reason it is relevant to study its fluctuations and its sources of variability.

One of the most influential studies that has been done recently in this subject is the one from Hau (2002) where he shows that real exchange rate (RER) volatility is negatively related to the level of openness of an economy. We can say, in other terms, that the more open an economy is the less RER volatility it will experience.[2] Bravo's and di Giovanni's (2006) work is based on Hau's paper but instead of exploring further the negative relationship between openness and the volatility of RER, they use variables that capture trade barriers for an economy to show that the higher these are, the more RER volatility an economy will

[1]This definition is one of the most standard ones because, as Chinn (2005) remarks, there are several real exchange rates, or "relative price", definitions used in the literature.

[2]In Hau's work, the variable openness is measured as consumption of traded goods on the economy in nominal terms divided by consumption of traded and non-traded goods also in nominal terms.

experience. They also expand their research to analyse subsets of countries according to their income level, with interesting results.

Instead of using only a measure of openness, Bravo and di Giovanni (from now on BDG) construct a remoteness index that measures how distant an economy is from the world trade centre.[3] As mentioned before, they turn their attention towards variables that reduce trade intensity.[4]

Some other studies have also observed that trade openness helps explain real exchange rate volatility, both effective and bilateral rates. BDG take into consideration that fact and find support for their hypothesis of higher volatility if trade costs increase, especially for distance, which is somewhat complementary to the Openness hypothesis. Previous works complement each other in the task of finding the main sources of real exchange rate volatility. However, neither openness nor remoteness explain entirely what are the main sources of volatility in the real exchange rate for different type of economies.

In this paper we extend the work of BDG by analysing the relevance of having more variables that capture natural barriers to trade. A different and interesting view is the one explored by Gonzaga and Terra (1997). They include inflation volatility as a new explanatory variable since it is a measure that is available in almost all the countries analysed in previous studies. Our results support the inclusion of the new variables and in most cases the impact of other variables is reduced.

Following the idea established in other works claiming that real exchange rate volatility affects economies differently according to their income level, we argue that inflation volatility is a variable that must be included in our RER volatility equation in order to control for the effects of high inflation rates records that developing and less developed nations experience; at the same time we include a variable that impacts differently high-income economies, a possible solution to this puzzle. We also add dummy variables in order to classify countries

[3]A Remoteness Index is just a weighted-average distance to all possible trade partners a country can have. In this case distance between two countries is the Great World Circle distance (the shortest path following the surface of the globe) between their two capital cities. The idea of using and constructing a remoteness index to proxy for trade costs (and more in particular transport costs) instead of using just distance is standard practice in the literature and the work from Frank and Romer (1999) and Wei (2000) is an example of this.

[4]They not only observe natural trade barriers, but also include variables that capture imposed trade barriers such as import taxes and export duties.

according to their income level. Bravo and di Giovanni attempt to control for income differences by including real GDP per capita and also a productivity measure. Their results do not support the inclusion of the productivity measure. They also divide their sample in three categories according to the income level of each country. They redo their analysis for each subsample obtained. Their results confirm that there are differences in RER volatility between regions with different income levels. However, their estimations for the subsamples present some problems related to the fact that the number of observations for each group is relatively small.

Our results support the idea of having a more disaggregated analysis of natural trade barriers and the idea that shocks in other economic variables can affect the actual volatility of the real exchange rate. We first replicate the findings of previous works; however, we construct models with a more detailed analysis, using variables not included before, that at the same time show a more discrete performance of the most relevant variables used before. The rest of the study is organized as follows: Section 4.2 analyses with more detail previous findings from other authors. The following section sets up the theoretical framework for the equation to be estimated. The data used in our estimations are described in Section Four. Section Five reports our results for Bravo and Di Giovanni's specifications and section six reports the findings of including new variables in the RER volatility equation. The last part includes our conclusions.

4.2 Previous Results

Most of the empirical literature on this topic is based on an econometric framework that uses either cross-section analysis, via OLS, or panel data estimation techniques due to the nature of the dataset. Hau's work is based on the former, and he finds results that support his hypothesis: Real exchange rate volatility is reduced the more open an economy is. Nevertheless, one thing to notice is the fact that Hau considers that openness could be an endogenous variable and that it might even be correlated with the stochastic error. For this reason, he estimates again several specifications but now using an instrumental variables (IV) approach to instrument openness using some geographic variables. Hau once again finds evidence to sustain his hypothesis using this approach.

Bravo and di Giovanni use a real effective exchange rate calculated from the consumer price index (CPI) of the countries as their dependent variable. They show that real exchange rate volatility is lower the closer a country is to the World Trade Centre.[5] In order to test this hypothesis the authors construct a remoteness index measure as the distance from one country to this World Trade Centre, where the World Trade Centre is just a weighted-average distance of a country to all its potential trade partners.[6] The main advantage of using this remoteness index and not openness is that the former is a homogenous measure for all the countries.[7]

BDG find evidence that supports their hypothesis: Regressing real exchange rate volatility on remoteness and including some other variables to control for different effects, they obtain a significant relationship between the first and the last variables. Their results are based on OLS techniques for cross-section data that represent an average of 20 years for each variable, from 1980 to 2000. They also estimate Panel Data regressions (Pooled OLS regression) using two time periods per country and each period represents a ten-year average, one for the decade of the 1980s and one for the 1990s (including the year 2000). Their study includes over 90 countries in total. However, some series are not available for all of them, and this is reflected in the number of observations used in each estimation.

In BDG's work there are two other variables included in their estimations in order to capture the effect of imposed trade barriers: duties on exports and taxes on imports, which are important variables in the theoretical framework, but empirical results are inconclusive for these two. Remoteness accounts for natural trade barriers, while duties and taxes are included to control for the imposed ones.

Another variable that is important in their model but does not perform well in the regressions is total factor productivity (TFP).[8] Their results do not support the idea of having

[5] The idea of distance to World Trade Centre is to capture the distance of a country to the rest of the world, or in specific to the trade partners this country has.

[6] In the case of BDG, they use as weights how much a country trades with respect to the total trade of the world.

[7] They consider that using a measure such as imports plus exports divided by GDP might not be an accurate measure to capture all the effects of openness. Markusen (2005) mentions a different type of proxy for openness that helps exemplify the previous point: It is possible that an endowment of some factor could make you trade even if you are not that open.

[8] TFP is considered in order to capture productivity shocks following the AK models of the Endogenous Growth literature. See Aghion and Howitt (1997) for more on the theory of this model and Pozzolo (2004) for an extensive survey on the topic applied to open economies.

TFP as an extra variable in their model. They add this variable only for the whole sample estimations and it is only in the panel data estimations that this coefficient is significant statistically at the 10 percent level. It has to be noticed that this term is part of the equation only when it is multiplied by the remoteness coefficient and not by itself. The authors' idea behind this is to control for productivity shocks, and to analyse how this changes the result for remoteness, since there are some studies where it is shown that high- and low-income countries report different levels of real exchange rate volatility (Bleaney (2006) and Hausman *et al.* (2004)).[9]

Gonzaga and Terra (1997) study real exchange rate volatility using something different from natural trade barriers as a source of fluctuations on RER. They consider that exporters are affected by uncertainty about monetary policy that is reflected in prices. Their initial claim is that the exporting decision of firms is affected by the volatility of the RER, and the primary source of these variations are monetary shocks. Their findings suggest that movements in inflation volatility are a great source of fluctuations in the real exchange rate. They analyse only three Latin American countries: Argentina, Brazil and Mexico. They use two RER measures; the first one is a multilateral (effective) RER and the second is the bilateral one between the United States and each country included in their sample.[10]

Hausmann *et al.* (2004) try to explain why RER volatility is much higher in developing countries and after controlling for different kind of shocks, they are not able to fully explain the difference. They conclude that shock persistence is different in developing and industrialized countries, and this could be probable cause of a higher RER volatility level. This idea can be easily linked to Gonzaga's and Terra's (1997) findings, asymmetric impact of diverse type of shocks in developed and developing nations.

Back to Hausmann *et al.* (2004), they include in their work estimates of a GARCH model to do research in the variance and not only the mean of RER volatility but they are not able to obtain a satisfactory answer that explains this existent difference between economies. Calderon (2004) shows that monetary shocks affect RER volatility in a lower degree if the economy is more open to international trade. He also relates the same idea to productivity

[9]Some authors have signaled that one of the main drivers behind different levels of RER volatility is how much an external shock affects an economy.

[10]Their RER are constructed using the following equation $RER = \frac{eWPI*}{CPI}$, where $WPI*$ is the U.S. whole sale price index and CPI is the consumer price index from Argentina, Brazil or Mexico respectively.

shocks and terms of trade fluctuations, these movements affect less the real exchange rate of more open economies. The literature can establish a relationship between real exchange rate volatility and trade openness; however, the results are not as detailed as we could hope for and this represents an incentive to continue the research on this topic.

4.2.1 Unclear issues in Bravo's and di Giovanni's work

All the estimations done in our work use as the main dataset the one constructed by BDG. Our goal is to extend (or at least expand the scope of) the conclusions reached by them. In order to achieve that objective, we first need to replicate their estimations. Their results are significant with very interesting findings, but there are some aspects from their set-up that are not quite clear or well developed in order to have very tractable results. The most important issue is that we are able to replicate their results in the cross-section part of their study, but only if we restrict the estimations to use data from the first decade of the whole sample (that is only observations where variable decade equals 1), from 1980 until 1989. This could be a problem when we include in the model the remoteness index, real GDP per capita, openness and the interaction term between remoteness and total factor productivity, because some of these measures are considering only the first ten years and not 20 as it is intended. To be more specific, this is a problem for openness, GDP per capita and even remoteness since the averages of the first and second part of the sample are different. The results using the following decade change mainly in magnitude of the coefficients.

The previous arguments are enough reasons to analyse some specifications from BDG, estimate them the way they did it now considering data taken from the second decade (sample from 1990 until 2000) to regress again the equation and compare the results from both decades. Nevertheless, it seems clear that one of the two approaches should be wrong since, as we pointed out above, some variables are 20-year averages that might be regressed with observations that represent either only 10 years of the sample or a point in the middle of the time span studied.

A different issue to be considered is that their Panel data results are obtained without including a dummy variable to indicate from which decade is every observation. We include this variable when we replicate their specifications using Panel data. The dummy variable is quite significant in most of the cases and it always reports a negative sign. One more thing about Panel data results is the fact that for import taxes and export duties the same number is reported in both time periods for each country. Although, econometrically this does not cause any conflict, the fact of having the same average tax rate during both decades does not seem to be very plausible due to the fact that trade barriers were probably lower in many countries during the 1990s.

A final point is the issue that we are not able to replicate several of the panel data results. If import taxes, exports duties and/or total factor production are part of the model, then our results do not even match the coefficient of each variable. When these are not included then the coefficients we obtain are the same as in Bravo and Di Giovanni but standard errors from our estimations and theirs do not match.

4.3 Theoretical Framework: A Ricardian trade model by Dornbusch, Fischer and Samuelson

In their seminal paper, Dornbusch, Fischer and Samuelson (1977) show that the conclusions observed in a Ricardian economy hold in a world economy with a continuum of goods. It is also possible to observe how the existence of trade costs translates into the creation of non-traded goods in their model. This set of non-traded goods could be modified endogenously by changing not only trade costs, but also demand for goods, wages, technical progress, to mention some of the possible sources of change. The variations in traded and non-traded goods also bring changes in price indices.

Their model consists of two countries and n commodities that are produced by using only one factor of production, labour. The production of each commodity requires a fixed amount of units of labour. These requirements differ from one good to the other and also between countries. The goods are conveniently indexed, where the ones closer to zero, when sorted on the real line, are produced more efficiently in the home country, i.e. fewer units of labour are required to produce them; in other words, the home country has comparative advantage in these goods. The commodity unit labour requirements are expressed as ratios in the following equation:

$$A(z) \equiv \frac{a^*(z)}{a(z)} \qquad A'(z) < 0 \tag{4.1}$$

The goods are indexed from $z = 0$ to $z = 1$, $a(z)$ and $a^*(z)$ are labour unit requirements to produce product z at home and foreign country, respectively. With this formulation we will have two sets of goods in the real line, which are divided by the borderline commodity $\tilde{z}$, where $a^*(z)$ and $a(z)$ are equal ($A(z) = 1$). The relative price of two goods to the left of $\tilde{z}$ is just the ratio of their unit labour costs. However, if two goods are not on the same section of the real line, one to the left of $\tilde{z}$ and the other to the right, we have that the relative price involves not only the ratio of unit labour costs but also relative wages since they are produced in different countries. The demand functions in this model are based on a strong homothetic structure Cobb-Douglas preferences. This assumption makes it possible to associate each *ith* commodity with a constant expenditure share as we observe next:

$$\begin{gathered} b(z) = \frac{P(z)C(z)}{Y} > 0 \\ b(z) = b^*(z) \\ \int_0^1 b(z)\delta(z) = 1 \end{gathered} \tag{4.2}$$

where Y denotes total income, C demand for commodity z and P represents its price. So we have that $b(z)$ is the income share spent on commodity z. In this way we have two important integrals that define the goods that are produced in the home country and the ones produced in the foreign one:

$$\upsilon(\tilde{z}) = \int_0^{\tilde{z}} b(z)\delta(z) > 0$$

$$1 - \upsilon(\tilde{z}) = \int_{\tilde{z}}^1 b(z)\delta(z) \tag{4.3}$$

We can obtain an equation for the balance of trade if we include wages (w and w^* for home and foreign country, respectively) and labour (L and L^* of the model):

$$wL = \upsilon(\tilde{z})(wL + w^*L^*) \tag{4.4}$$

That becomes an equation to determine the equilibrium ratio of real wages:

$$\omega = \frac{\upsilon(\tilde{z})}{1 - \upsilon(\tilde{z})}(L^*/L) = B(\tilde{z}; L^*/L)$$

where $B(z)$ is the trade balance equation that determines ω, relative wage, by intersecting with $A(z)$ function. So far, we have that in the model there are only two types of goods, domestically produced and imported ones, and that all goods can be exported to a different country than the one it has been produced.

In their work, they introduce non-traded goods as a an exogenous factor in a first stage. They assume that a fraction k of a country's income is spent on traded goods and the remainder is used to purchase non-traded goods. In order to have a little bit more intuition behind this assumption, we could think that countries are home-biased and reserve a fraction $1 - k$ of their income to buy, no matter what, domestic goods. With this modification, the model's equations of share of goods produce at each country is modified:

$$k = \int_0^1 b(z)\delta(z) < 1$$

And $\tilde{z}$ represents, as before, the marginal good that divides goods produced at home country from goods produced in foreign country. Now the maximum value of $\upsilon(1)$ is now k and not 1, where it is clear that $k < 1$. The trade balance equation changes to:

$$[k - \upsilon(\tilde{z})]wL = \upsilon(\tilde{z})w^*L^*$$

$$\omega = \frac{\upsilon(\tilde{z})}{k - \upsilon(\tilde{z})}(L^*/L) \tag{4.5}$$

In this case, we have that k is a constant that does not respond to changes in any of the other variables. If we now allow for positive transportation costs, we find that the existence and number of non-traded goods is endogenously determined. Transport costs are introduced as iceberg costs following the model of Samuelson (1954).[11] In this case the equations that suffer a modification are the following:

$$wa(z) \leq (1/g)w^*a^*(z) \tag{4.6}$$

or

$$\omega \leq A(z)/g \tag{4.7}$$

For the foreign country, we have a similar set up:

$$w^*a^*(z) \leq (1/g)wa(z) \tag{4.8}$$

or

[11] In these models a fraction $g(z)$ of commodity z shipped actually arrives. In other words, we need to ship $(1 + \omega)z$ to receive z, where ωz is "melted" on the way.

$$\omega \geq A(z)g \tag{4.9}$$

Now countries face transportation costs and we have two curves of relative productivities, one for each country that is affected by their own transport costs. These curves have a negative slope and intersect the balance of trade curve in two points.[12] From these two points, three subsets of goods are created that represent, starting from zero to the right, exportable goods of home country, non-traded goods - new kind of products available in each economy - and exportable goods of foreign country. The first subset are goods produced only by home country. The second group are goods that are produced by both countries since comparative advantage of one over the other disappears due to transport costs. These subsets can suffer modifications if transport costs change:

$$\begin{aligned} \tilde{z} &= A^{-1}(g\omega) \qquad & d\tilde{z}/d(g\omega) < 0 \\ \tilde{z}^* &= A^{-1}(\omega/g) \qquad & d\tilde{z}^*/d(\omega/g) < 0 \end{aligned} \tag{4.10}$$

Trade costs make production of goods in a country and selling them in another a more expensive process. They lose comparative advantage in producing goods close to the borderline. This is the reason behind the fact that a country that previously imported those now starts producing them; and the set of goods produce locally expands. This is observed in the first derivative from the last set of equations, the higher g (which represents an increase in the transport costs) means a lower $\tilde{z}$, more goods are produced abroad and the home country does not export as many goods as before. In the second equation we have a similar situation but now for the foreign country. An increase in transport costs represents a lower value for ω/g that increases the value of $\tilde{z}^*$. In other words, the sets of goods produced in the domestic economy expands.

In summary, we can say that the subset of non-traded goods is a dynamic one since it could

[12]Previously to the existence of trade costs we have only one curve of relative unit labour requirements, hence only one intersection with the balance of trade curve.

be modified by changing the ratio of relative wages and/or transports costs. If we think of these transport costs in general terms as trade costs, we can include tariffs in these extra costs. Then we have modifications in the following equations:

$$\begin{aligned} \tilde{z} &= A^{-1}\left(\omega(1+\tau)\right) \\ \tilde{z}^* &= A^{-1}((1+\tau^*)\omega) \end{aligned} \tag{4.11}$$

In this case we have that tariffs could be different in both countries. This is also a mechanism to have different values of $\tilde{z}$ and $\tilde{z}^*$, hence variations in the subset of non-traded goods:

$$\begin{aligned} d\tilde{z}/d(\tau) &< 0 \\ d\tilde{z}^*/d(\tau^*) &< 0 \end{aligned} \tag{4.12}$$

Once again, we have that changes in the level of tariffs can have repercussions for the number of non-traded goods. Our empirical exercise tries to analyse this in particular: changes in openness driven by variations in the number of non-traded goods. In our specification instead of having an equation for $\tilde{z}$ and $\tilde{z}^*$, that represents the location of margin goods that delimit the set of non-traded goods, we try to focus our attention in the complement of this set of goods as our dependent variable: openness (or how much countries export and import).

4.3.1 Determining Real Exchange Rate variance

Bravo and di Giovanni base their theoretical framework on Dornbusch *et al.* (1977) and Obstfeld and Rogoff (1996). In the original model, Dornbusch *et al.* set up an economy with a continuum of goods in a two-country world. Some of the goods are produced by Home country and the rest by the Foreign one. To define which goods are produced by which country, it is necessary to consider their marginal costs and productivities. The continuum of goods are sorted taking into account relative productivities (comparative advantages) where the goods more to the left (closer to zero) are produced more efficiently by Home country. This comparative advantage falls as we move along the curve constructed by the relative productivities to the right.[13] Foreign country starts producing goods from a border case where Foreign has the same productivity as Home country, and from that point on Foreign country has comparative advantage producing the goods to the right from the border case.

All this holds when there are no trade costs. When trade costs are taken into consideration the border case good becomes a region of goods that determines the existence of the non-traded sector for both economies. From this function (inverse function of relative productivities) BDG calculate the volatility of the real exchange rate and show that its variance increases as trade costs increase. Without showing the complete derivation, BDG, based on Obstfeld and Rogoff's work, find the following equation for the Real Exchange Rate:

$$\frac{P}{P^*} = \exp\left\{ \int_{z^F}^{z^H} \log\left(\frac{w_1 \cdot \alpha(z)}{w_1^* \cdot \alpha^*(z)} \cdot \frac{\exp(\epsilon)}{\exp(\epsilon^*)} \right) \mathrm{d}z + [z^F - (1 - z^H)] \log(1-\tau) \right\} \tag{4.13}$$

Since ϵ and ϵ^* are the only stochastic terms and assuming that both processes are independent, then we obtain the following expression for the variance of the Real Exchange Rate:

$$Var\left\{ \log\left(\frac{P}{P^*} \right) \right\} = 2(z^H - z^F)^2 \sigma^2 \tag{4.14}$$

The final step in Bravo and di Giovanni's theoretical part is to take the partial derivative with respect to τ (trade costs), which they find to be positive. This result means that there is a positive relation between real exchange rate volatility and trade costs. Their empirical results show this positive relationship between distance and RER volatility, where distance

[13]The Curve has a negative slope.

or remoteness is the proxy for trade costs. Since τ is the only variable included to take account of trade costs, then it is the case that τ represents not only natural trade barriers but also those imposed by the government like export duties and import taxes. In our case, we add more variables that represent natural trade barriers such as area (surface of a country).[14] So, in order to include Area in the theoretical framework from BDG, we just need to disaggregate trade costs.

$$\tau = \delta + \psi \tag{4.15}$$

If trade costs, τ, are now disaggregated as remoteness, δ, and $Area$, ψ, we can show that there is a positive relation between these two and Real Exchange Rate volatility. We already have an expression for the variance of Real Exchange Rate in equation 4.14, we now have to write the expressions for both z^H and z^F:

$$z^F = A^{-1}\left(\frac{w_1}{w_1^*} \cdot \frac{1}{1-(\delta+\psi)}\right) \tag{4.16}$$

$$z^H = A^{-1}\left(\frac{w_1}{w_1^*} \cdot 1-(\delta+\psi)\right) \tag{4.17}$$

Where A^{-1} is the inverse function of relative productivities and the sum $\delta+\psi$ accounts for our disaggregated trade costs represented by a τ in the original work from BDG. The next step is to take the partial derivative to these two with respect to δ and ψ,

[14] In our empirical specifications we also include a variable that proxies for imposed trade barriers but the results are not so relevant and for this reason we mainly focus on justifying the inclusion of a variable such as $Area$ and $Inflation$ which is explained in the following paragraphs.

$$\frac{\partial z^F}{\partial \delta} = \frac{\partial A^{-1}}{\partial \delta} \cdot \left(\frac{1}{(1-\delta-\psi)^2} \right) < 0 \quad (4.18)$$
$$\frac{\partial z^F}{\partial \psi} = \frac{\partial A^{-1}}{\partial \psi} \cdot \left(\frac{1}{(1-\delta-\psi)^2} \right) < 0 \quad (4.19)$$
$$\frac{\partial z^H}{\partial \delta} = \frac{\partial A^{-1}}{\partial \delta} \cdot (-1) > 0 \quad (4.20)$$
$$\frac{\partial z^H}{\partial \psi} = \frac{\partial A^{-1}}{\partial \psi} \cdot (-1) > 0 \quad (4.21)$$

We only need to remark that the partial derivatives of A^{-1} with respect to τ and ψ are negative since A^{-1} is a decreasing function by construction. The only thing to do now is just to obtain the partial derivative from the Real Exchange Rate's Variance with respect to δ and ψ.

$$\frac{\partial Var\left\{\log\left(\frac{P}{P^*}\right)\right\}}{\partial \delta} = \frac{\partial\left(2(z^H - z^F)^2\sigma^2\right)}{\partial \delta} = \frac{\partial z^H}{\partial \delta} - \frac{\partial z^F}{\partial \delta} > 0 \quad (4.22)$$
$$\frac{\partial Var\left\{\log\left(\frac{P}{P^*}\right)\right\}}{\partial \psi} = \frac{\partial\left(2(z^H - z^F)^2\sigma^2\right)}{\partial \psi} = \frac{\partial z^H}{\partial \psi} - \frac{\partial z^F}{\partial \psi} > 0 \quad (4.23)$$

And we also obtain a positive relation between trade costs and real exchange rate volatility. Then we expect a positive sign for remoteness' and area's coefficients on the empirical part of the study. Now, the other new part in our empirical analysis comes from including inflation volatility in a specification where trade costs are the relevant variables. Inflation volatility is, at the moment, not included on the real exchange rate volatility equation developed above. The reason is that this might make things a little bit more difficult to track and test since the analysis must include some sort of dynamics from price indices, this could be accomplished with the use of a New Keynesian Philips Curve specification which involves forward-, and sometimes backward-, looking expectations.[15] Our specifications are not set-up as time series framework since the data that we have at hand are not from this type. For the moment inflation volatility is added in an ad-hoc way.

[15]See Clarida, Gali and Gertler (1999) for more details on the New Keynesian Philips Curve approach of the relationship between inflation and productivity.

However, in order to do this we include one more assumption to the model. This assumption is related to how firms set their prices in both countries. Firms set their prices taking into account not only the results from their optimization problem but also considering inflation levels from their respective local economies.[16] In many aspects it might seem as if we are considering a model with nominal rigidities, but this is not possible since the framework is not a dynamic one.[17] Inflation is then included in the price index function from each country. The index for each region includes three parts: the first one is based on the prices for goods produced locally, the second one for goods produced abroad and the third is the inflation rate. Since the inflation rate is based on prices, then inflation is also a stochastic variable that might be relevant to real exchange rate volatility.

4.3.2 Hau's work in detail: The link between Inflation Volatility and Real Exchange Rate Volatility

In order to explain better the inclusion of inflation volatility in a real exchange rate volatility equation, we use Hau's (2002) study as a reference theoretical framework. We start the model with a small open economy endowed with a competitively priced export good and imports in a competitive market. The non-traded sector works under a monopolistic production framework. The representative house hold of the home country is endowed with a constant quantity $\hat{y}$ of an export good each period. It also participates in the non-traded sector as the monopolistic producer of good $z$on the unit interval of non-traded goods, $z \in [0, 1]$. With this information we now express the inter-temporal utility function of the household:

$$U_t^j = \sum_{s=t}^{\infty} \beta^{s-t} \left[\gamma ln C_{T,s}^j + (1-\gamma) ln C_{N,s}^j + \chi ln \frac{M^j}{P} - \frac{\kappa}{2} y_{N,s}(j)^2 \right] \tag{4.24}$$

where C_T^j represents consumption of a traded good with price P_T^j. The case of non-traded

[16]Khan (2005) explains that inflation is affected by the firm's price setting decision, what we are trying to do here is to complete the circle by considering that firms also consider in their decision the levels of inflation of the economy. Shocks in this variable will affect price decisions and the final result in probable changes in the level of inflation, which could be translated into inflation volatility and finally variations in the real exchange rate.

[17]Panel data estimations are done having only two time series observations for each country that represent data from a decade which makes difficult to consider this a time series analysis.

goods consumption is different as C_N^j is a composite good:

$$C_N^j = \left[\int_0^1 c_N(z)^{\frac{\theta-1}{\theta}} dz \right]^{\frac{\theta-1}{\theta}} \tag{4.25}$$

The other two variables observed in equation 4.24 are holding of real balances (which affect positively the utility of the household), $\frac{M^j}{P}$, and the production of the non-traded good z at quantity $y_N(j)$, which represents disutility in the objective function. The general price index, P, of the economy can be defined as the minimal cost of buying one unit of the composite consumption $C_T^{\gamma} C_N^{1-\gamma}$:

$$P = \frac{P_T^{\gamma} P_N^{1-\gamma}}{\gamma^{\gamma}(1-\gamma)^{1-\gamma}} \tag{4.26}$$

where P_N, the price index of non-traded goods, defined as:

$$P_N = \left[\int_0^1 p(z)^{1-\theta} dz \right]^{\frac{1}{1-\theta}} \tag{4.27}$$

Domestic import and export prices are identical ($P_T = P_T^{im} = P_T^{ex}$) and linked to a constant world price P_T^* by the exchange rate E, such that $P_T = EP_T^*$. The set-up of the model is finished by assuming the existence of an international bond market with real bonds denoted in terms of tradables with the following expression for the interest rate: $1 + r = \frac{1}{\beta}$. With the existence of a real bond it is possible to transfer wealth across periods, this also let us have an inter-temporal budget constraint that we express in the following equation

$$P_{T,t}B_{t+1}^j + M_t^j = P_{T,t-1}(1+r)B_t^j + M_{t-1}^j + p_{N,t}(z)y_{N,t}(j) + p_{T,t}\hat{y}_T - P_{T,t}C_{T,t}^j - P_{N,t}C_{N,t}^j - \tau_t \tag{4.28}$$

where B_t represents the bond portfolio at time t and τ_t is household taxes.[18] Seignorage

[18]The analysis is simplified by including the assumption of a balanced government budget in which taxes are redistributed to households and government consumption is equal to zero.

income returns to the households in the form of taxes: $-\tau_t = M_t - M_{t-1}$. With this set-up and assuming constant price elasticity θ, we obtain the demand for non-traded good:

$$y_N^d(z) = [\frac{p(z)}{P_N}]^{-\theta} C_N^A \tag{4.29}$$

After solving the maximization problem of the utility function subject to the inter-temporal budget constraint, we get four first-order conditions:

$$\begin{aligned}
C^j_{T,t+1} &= C^j_{T,t} && (4.30)\\
\frac{\gamma}{P_{T,t}C^j_{T,t}} &= \frac{\chi}{M^j_t} + \beta\frac{\gamma}{P_{T,t+1}C^j_{T,t+1}} && (4.31)\\
\frac{\gamma}{P_{T,t}C^j_{T,t}} &= \frac{1-\gamma}{P_{N,t}C^j_{N,t}} && (4.32)\\
\frac{\gamma}{P_{T,t}C^j_{T,t}} p_{N,t}(j) &= \frac{\theta}{\theta-1}\kappa y_{N,t}(j) && (4.33)
\end{aligned}$$

The first equation (equation 4.30) of the previous system represents the Euler equation for optimal inter-temporal consumption smoothing for traded goods; the result assumes a bond market discount rate equals to the utility discount rate, $(1 + r)\beta = 1$. The next one (equation 4.31) let us observe the utility maximizing trade-off between consumption spending in period t and a combination of one-period money holding and consumption spending in period $t + 1$. The third first-order condition (equation 4.32) states that the marginal utility of traded and non-traded goods must be equal at any given time. The last one (equation 4.33) represents the optimal monopolistic price setting for the time the house hold spends producing non-traded goods. If we combine equations 4.31 and 4.32, we obtain the demand for real balances:

$$\frac{M_t}{P_t} = \frac{\chi}{\gamma}\frac{C_{T,t}\frac{P_{T,t}}{P_t}}{\left(1-\beta\frac{P_{T,t}}{P_{T,t+1}}\right)} \tag{4.34}$$

Equation 4.34 help us analysing the effect of unanticipated permanent monetary shocks. The demand for real balances of a household depends on the consumption of traded goods ($C_{T,t}$), on the the price change of traded goods ($\frac{P_{T,t}}{P_{T,t+1}}$), and on the price ratio $\frac{P_{T,t}}{P_t}$. Combining all the previous equations and considering a log-linearized version of the system of equations, Hau continues with his analysis and reaches relevant conclusions of the impact of money supply shocks in the economy.

As it has been explained previously, non-traded goods do not react immediately if the economy suffers from a monetary shock, but traded goods do adjust instantly as they are determined by the constant world price of traded goods P_T^*. The optimal monopolistic price-setting behaviour of foreign exporters is reflected in the home economy as full exchange rate pass-through given constant price elasticities of the demand. This means that the price index is affected every time we observe unanticipated permanent monetary shocks as the domestic price of traded goods adjust to movements in the nominal exchange rate; more open economies have more pronounced impact on the overall domestic price level for a given (percentage) exchange rate change. With the previous setup is also possible to show that the short-run percentage change of traded prices and also variations in the exchange rate are proportional to the home money supply increase.

If we recapitulate the findings of the model (and this section), we observe the following: Money supply shocks have only a transitory effect on the real price of non-traded goods, while the real price of traded ones does not change. It can also be highlighted two more features. The first one is that exchange rate changes imply a proportional change in import prices. Optimal monopolistic price setting of the foreign exporters also implies full exchange rate pass-through if the demand elasticities are constant.

This means that economies with higher levels of openness have a more responsive aggregate price level. Second, this more flexible aggregate price level reduces the effect of the domestic money supply shock on the real household balances and therefore its scope for short-term consumption and real exchange rate changes. The higher aggregate price level flexibility implies lower real exchange rate volatility for a more open economy.

The previous represents Hau's line of research on how the degree of openness of an economy affect the volatility of the real exchange rate. In our work we follow a similar research line as we consider that money supply changes; the movements of the CPI; and the content of non-traded goods, which make more difficult the adjustment of the general price index, are relevant variables that affect real exchange rate volatility. We believe that the impact of some of these are included in other variables such as an openness proxy variable, however, we consider that it is possible to control for these more accurately by including an inflation volatility variable. This action represents a important achievement of our work by considering the framework of Bravo and di Giovanni, but at the same time we are aware of other effects not taken into account explicitly in their work that we do consider in our specifications.

4.4 Data

Most of the data used here are taken from Bravo and di Giovanni's dataset. However, there are extra variables not used in their work. These are Inflation volatility, Area, Population, Population density and a set of dummies that divide the sample into three groups of countries according to their income (Industrialized, middle-income and low-income countries).[19] Most of the new variables are taken either from the International Financial Statistics site at IMF or from the World Bank's World Development Indicators (WDI) database and they were just transformed into logs with the exception of Inflation volatility.

We construct our inflation volatility variable to be included in BDG dataset in order to run some regressions and confirm Gonzaga and Tera's findings. This inflation volatility variable ($Infl$) is based on CPI indexes taken from the International Financial Statistics database from the IMF. The variable is constructed as it follows:

1. The CPI inflation series obtained from IFS database are reported as the annual percentage change in the index. There is no need to take the log and we just continue by subtracting the one at time t from the record of 12 months before to have the annual change as in Bravo and di Giovanni. We obtain a similar measure as their rolling window for real exchange rates.

2. The next step is to obtain the standard deviation from the whole sample and from

[19] These dummy variables are found in the original set from Bravo and di Giovanni but they are not included in any estimation.

both decades.

3. Finally we take averages of each of the previous dispersion measures. This is the value included as an observation in the estimation process.

Population and *Area* (Surface or land) of a country are included with the purpose of disaggregating trade costs and also to have a robustness check in *Openness* and specially in *Remoteness* (*Remote* from now on) as natural trade barrier variables. *Area* is in square kilometres and *Population* is in millions of inhabitants. Finally, population density (*Pop_den*) is obtained by dividing area by population and then transformed by taking the logarithm.

The rest of the variables are the same as in Bravo and di Giovanni's work. We include a brief description of those.[20] Real exchange rate volatility is constructed using the monthly real effective exchange rate from the IFS database. They calculate the volatility by taking the annual real exchange rate change (in log differences) each month. The following step after having this rolling window of annual real exchange rates is to compute the standard deviation of these and taking the log of the series to be used as the RER volatility. *GDP pc* (GDP per capita) is taken directly from several sources and the only transformation that is done to this variable is taking the natural logarithm. *Openness* (*Open* for short) is our measure of trade intensity of a country and it is taken as in Hau's work: openness to trade (or trade volume) that is the sum of exports and imports of a country divided by its GDP. *Remote* is their most important variable and it is an index that measures the distance of a country to the world trade centre. This world trade centre is constructed considering the distance from a specific country to every trade partner and each distance is multiplied by a weight that represents how much trade these two countries have. Table 4.1 summarizes the main statistics from these series:

Table 4.2 contains correlations from all the series used as explanatory variables. There are two entries for inflation volatility because the first is the measure for the cross sectional database (standard deviation taken for 20 years, 1980 - 2000) and the second one measures the volatility for each decade (in order to have two observations per country). There is a second set of correlations which includes variables with the interactive terms, *GDP pc* and

[20]See Bravo and di Giovanni (2006) for more details.

Table 4.1: Summary statistics (all series are in logs)

Variable	Mean	Std. Dev.	Obs.
Remote (ln(km))	2.051	0.073	156
GDPpc	8.605	1.029	157
$RER\ volatility_a$	-2.341	0.723	172
$RER\ volatility_b$	-2.461	0.763	164
Open (ln(%))	4.178	0.594	299
Inf_a	2.675	1.904	318
Inf_b	2.289	1.81	280
Population (ln(thousands of inhabitants))	1.585	2.051	367
Area (ln(sq km))	11.43	2.619	339
Pop_den (ln(inhabitants per sq km))	3.912	1.514	334

Notes: Subindex a and b represents variables for our cross-section and panel data samples respectively.

Inflation volatility to analyse if it is correct to include these variables in any estimation (see appendix).

Table 4.2: Correlations table

Variable	*Remote*	*GDP pc*	*Open*	*inf_a*	*inf_b*	*Area*	*Pop_den*
Remote	1.00						
GDP pc	-0.24	1.00					
Open	-0.23	0.03	1.00				
$infl_a$	0.20	-0.46	-0.25	1.00			
$infl_b$	0.19	-0.48	-0.25	0.93	1.00		
Area	0.29	-0.01	-0.60	0.26	0.25	1.00	
Pop_den	-0.30	0.04	0.03	-0.25	-0.23	-0.57	1.00

Notes: Subindex a and b represents variables for our cross-section and panel data samples respectively. All series are in logs.

In the second set there are some correlations that are high (see table B.6 in the appendix). Some are just the result of having a variable for cross-section estimations and then the same one for use in panel data estimations. However, there are other cases that are high enough to worry about multicollinearity problems in our estimations. The most important case is the one between inflation volatility and the interaction term formed by this variable and GDP per capita. We should keep that in consideration.

4.5 Bravo and di Giovanni's Specification Results

Most of our findings are similar to the ones obtained by BDG. Although they have results for the complete sample and for each country group according to their income level, we mainly focus our attention on the complete sample results and instead of having estimations from subsamples we better consider the use of dummy variables to account for these income differences and take advantage of having a sample with more observations for our estimations.[21] We start the analysis by estimating the following two equations, which are the ones used by Bravo and di Giovanni and are our baseline specification for the rest of the paper:

$$RER\ volatility = \beta_0 + \beta_1 Remote + \epsilon \tag{4.35}$$

$$RER\ volatility = \beta_0 + \beta_1 Remote + \beta_2 Open + \beta_3 GDPpc + \epsilon \tag{4.36}$$

where *Remote* is the remoteness index variable, *Open* and *GDP pc* represent openness and real GDP per capita variables, respectively. Table 4.3 presents Bravo and di Giovanni's specifications estimated by us. The coefficients, standard errors and all other relevant information is exactly the same as theirs. There are also two extra columns (labeled Decade 2) containing the results from regressing the same specification but using second decade data that make possible a comparison and a richer analysis. So, when we use cross-section data, we regress using first decade 1 observations in order to get Bravo and di Giovanni's numbers and we also estimate the same specification but now using the observations from the second decade.

When we compare results from decade 1 and 2 using equation 4.36 (last two columns) we can see that they are very similar. The coefficient of *Open* is the only one that changes considerably (the value goes from -0.35 to -0.47) but the rest is almost the same, excluding

[21] For simple specifications that include inflation volatility, area and population density, we have results for every single subset of countries. Those results are not reported here because some of them are not robust enough due to lack of observations and asymptotic theory cannot be applied, hence we cannot rely on the results.

Table 4.3: Cross-section Results

	Dependent variable: RER volatility			
Variable	Decade 1	Decade 2	Decade 1	Decade 2
Remote	3.65***	4.96***	2.30***	2.33***
	(0.68)	(6.36)	(0.61)	(0.61)
Open			-0.35***	-0.47***
			(0.13)	(0.10)
GDP pc			-0.38***	-0.39***
			(0.06)	(0.05)
Constant	-9.84***	-12.63***	-2.33	-1.88
	(1.38)	(-7.94)	(1.74)	(1.67)
Observations	78	78	72	73
R^2	0.15	0.23	0.55	0.63
RMSE	0.66	0.63	0.49	0.44

Notes: *,**,*** denote significance at the 10%, 5%, and 1% level, respectively.
Standard Errors in parentheses.

the result for the constant. Some other differences are observed in the number of observations; using decade 2 we have one more (73) and both R^2 and $RMSE$ improve by using this data set. However, if *Remote* is the only explanatory variable then things are a little bit different. The coefficients for both *Remote* and the constant are not similar anymore. And once again, R^2 and $RMSE$ are improved when the estimation is done using second decade observations.

When we analyse the results for panel data regressions, table 4.4, there is once again an extra specification that is not found in Bravo and di Giovanni's work.[22] This regression contains a dummy variable that takes the value of one for the decade that goes from 1990 until 2000 and zero otherwise. The results are similar except for *Remote*, which has a higher coefficient when the dummy is part of the model. The most important thing to notice is the fact that the dummy is quite significant in these two estimations and it has a negative sign in both cases. The specifications including the dummy variable report a higher R^2, but this is most likely the result of having one more explanatory variable in the model. When we observe the $RMSE$, we have a lower number if the dummy is included but the difference is marginal.

Previous works are very relevant because they have shown the importance of natural trade

[22] We have to remind that only one specification from panel data Section is possible to be replicated by us and even in that case the standard errors are not exactly the same.

Table 4.4: Panel Data Results, simple specification

	Dependent variable: RER volatility			
Variable	B and dG	Own	B and dG	Own
Remote	3.45***	3.83***	1.58***	1.84***
	(0.56)	(0.54)	(0.54)	(0.54)
Open			-0.4485***	-0.4429***
			(0.10)	(0.09)
GDP pc			-0.36***	-0.35***
			(0.05)	(0.05)
Dummy Decade		-0.32***		-0.20**
		(0.11)		(0.09)
Constant	-9.58***	0.11***	-0.72	-1.26
	(1.14)	(1.09)	(1.52)	(1.51)
Observations	156	156	145	145
R^2	0.11	0.16	0.45	0.47
RMSE	0.71	0.70	0.57	0.56

Notes: *,**,*** denote significance at the 10%, 5%, and 1% level, respectively. Standard Errors in parentheses.

costs as one of the sources of real exchange rate volatility and in particular the role of distance or in this case remoteness. However, there are some points that have not been considered previously and, as observed in this section, could be important to a richer and better understanding of RER volatility.

The relevant thing to notice from this section are the differences that can arise if we do the regressions using data from decade 2 instead of decade 1. This is an important point to discuss since using data from decade 1 on the cross-section framework will represent using averages from the previous two decades combined with observations from the first ten years in the form of end of the period. Using decade 2 seems like a better and more logical choice since we are taking end of the period observations from the year 2000, which is more relevant than including observations from the middle of the sample.

4.6 New variables included

In this section we describe the results of using the basic model specified in equation 4.35 and adding some other variables such as inflation volatility ($Infl$), $Area$ (Land or Surface of a country) and dummy variables to account for income level of a country that helps control for different effects not considered in previous works.[23] There are three main estimation exercises reported here: The first one is to include inflation volatility, area and population density as a explanatory variables. In the second one, some variables are multiplied by GDP per capita in order to have interactive terms in the model. Finally, the regressions run in the last part include dummy variables for industrialized and for low-income countries, one dummy for each group of countries, and GDP per capita is removed from the specification.

4.6.1 Inflation Volatility

As mention above, the idea of including a variable that captures inflation volatility of a country is based on the findings from Gonzaga and Terra. In their paper, they obtain empirical evidence to sustain their hypothesis: there is a positive relationship between real exchange rate volatility and inflation volatility. However, their results are based on data from only three Latin American countries: Argentina, Brazil and Mexico. In our case, we use an inflation volatility measure constructed from CPIs of all the countries that are part of the sample, which is the variable included it in the baseline specification.

The results show a positive relationship between inflation volatility and real exchange rate volatility, which corroborates, the relationship found by Gonzaga and Terra. These findings are quite robust and consistent, no matter what the specification is considered since the estimated inflation coefficient is quite similar in each result. Another important aspect of having $Infl$ as explanatory variable is observed in the R^2 and in the RMSE, both of them improve and outperform the ones from the baseline model. Now, when the model includes only *Remote* and $Infl$, the coefficient of the later one is bigger than when *Open* and real GDP per capita are also in the model. Nevertheless, the elasticity of inflation volatility is always between 0.17 and 0.31 and always significant even at the 1 percent level. If we observe the results for *Open* we have that this coefficient is not as significant as before and for some specifications it is not even significant at the 10% level. The elasticity of $GDP\ pc$ is also reduced but in this case the results are significant. These results can be seen on table 4.5.

The model including $Infl$ is also run for subsets of the complete sample. These subsets are

[23]Either these variables are included on a RER volatility regression for the first time by themselves or the combination of those is what we consider a contribution to this topic literature.

Table 4.5: Inflation Volatility Cross Section Results

	Dependent variable: RER volatility					
Variable	Dec.1	Dec.2	Dec.1	Dec.2	Dec.1	Dec.2
Remote	3.09***	3.70***	2.81***	4.12***	2.25***	2.37***
	(0.53)	(0.65)	(0.74)	(0.70)	(0.61)	(0.57)
Open			-0.20	-0.31***	-0.22*	-0.34***
			(0.13)	(0.10)	(0.13)	(0.10)
GDP pc					-0.26***	-0.27***
					(0.06)	(0.06)
$Infl$	0.31***	0.28***	0.28***	0.24***	0.20***	0.17***
	(0.05)	(0.05)	(0.05)	(0.04)	(0.04)	(0.04)
Constant	-9.31***	-10.60***	-7.90***	-10.1***	-4.18**	-3.81**
	(1.04)	(1.31)	(1.85)	(1.57)	(1.69)	(1.55)
Observations	72	72	67	68	67	68
R^2	0.56	0.58	0.57	0.65	0.68	0.74
RMSE	0.49	0.48	0.50	0.45	0.44	0.38

Notes: *,**,*** denote significance at the 10%, 5%, and 1% level, respectively. Standard Errors in parentheses.

defined by the income level of each country (Low, middle and high-income countries).[24] The findings from these regressions support the hypothesis of including inflation volatility in the model for middle and low-income countries. As a matter of fact, for low-income countries $Infl$ is the only significant variable in the estimation and the R^2 is considerably higher. In the case of Industrialized or high-income countries, inflation volatility is not significant. This result just shows that price fluctuations do not have the same impact on the different subsets of countries and it can even distinguish nations that have experienced episodes of high inflation.

If we use panel data to run the regressions for the complete sample we find evidence in table 4.6 once again in favour of including $Infl$. The most important change when comparing cross-section and panel data results is observed in the coefficient of *Remote* because its magnitude is reduced considerably and in some cases the coefficient is close to 1. The results are quite similar for the rest of the variables. In BDG it is observed that *Remote*'s elasticity is lower than 1.75 and this is also the case when both *Open* and real *GDP pc* per capita are part of the estimation. If the second is not included, then the magnitude of *Remote* is reduced to be close to 2. The RMSE and the R^2 for any specification with inflation in it are better than in the original specification observed in equation 4.35 despite

[24]This division is based on the classification made by the World Bank.

Table 4.6: Panel Data Results w. Infl. Vol.

	Dependent variable: RER volatility		
Variable	(I)	(II)	(III)
Remote	2.42***	2.13***	1.37**
	(0.50)	(0.56)	(0.53)
Open		-0.34***	-0.37***
		(0.08)	(0.08)
GDP pc			-0.20***
			(0.05)
Infl	0.34***	0.31***	0.24***
	(0.04)	(0.04)	(0.04)
Dummy Decade	-0.16*	-0.16*	-0.14*
	(0.09)	(0.09)	(0.08)
Constant	-7.98***	-5.87***	-2.37*
	(1.00)	(1.27)	(1.43)
Observations	139	131	131
R^2	0.54	0.58	0.64
RMSE	0.52	0.50	0.47

Notes: *,**,*** denote significance at the 10%, 5%, and 1% level, respectively. Standard Errors in parentheses.

the fact we have less observations if Inflation is included, 131 on average.[25]

We have that the impact of inflation volatility is discretionary between high-income countries (not significant) and the rest of the economies in the sample with positive results for this last group. In this case we must say that the relevance of this variable must be seen as not at all as a shock that impact the economy but more as one that is suffering of unbalances in the internal conditions that are finally reflected in the volatility of the real exchange rate.

4.6.2 Area added as Explanatory variable

In Hau (2002) the author considers in one section of his paper that *Open* might be determined endogenously. This issue can be related to the volatility of real exchange rate, and hence connected to the errors of the estimation. For this reason, Hau instruments openness by the area of a country (Surface) with good results. Considering Hau's idea, we decide to include *Area* as an explanatory variable directly on RER's specification. When *Area* is

[25]It is not possible to have more than these because some low-income countries do not have a record of CPI that goes back that long in time, specially for African Countries. This is the reason of loosing some observations.

Table 4.7: New Variable Area, Cross Section

	Dependent variable: RER volatility			
Variable	Decade 1	Decade 2	Decade 1	Decade 2
Remote	1.62**	2.01***	1.75***	1.81***
	(0.64)	(0.65)	(0.56)	(0.61)
Open	-0.001	-0.17		
	(0.17)	(0.16)		
Area	0.08**	0.05*	0.07***	0.08***
	(0.03)	(0.03)	(0.02)	(0.02)
Infl	0.19***	0.17***	0.19***	0.18***
	(0.05)	(0.04)	(0.05)	(0.04)
GDP pc	-0.29***	-0.28***	-0.28***	-0.28***
	(0.06)	(0.06)	(0.06)	(0.06)
Constant	-4.45**	-4.25***	-4.77***	-4.93***
	(1.70)	(1.53)	(1.13)	(1.43)
Observations	66	68	68	71
R^2	0.70	0.76	0.70	0.74
RMSE	0.42	0.37	0.41	0.38

Notes: *,**,*** denote significance at the 10%, 5%, and 1% level, respectively. Standard Errors in parentheses.

an independent variable, *Open* is not significant in the cross section estimations. But this situation is reversed when the estimation is done using Panel Data: Openness is significant and Area is not.

Based on these results we remove openness from the model and use Area as another geographical variable related to the natural trade barriers that are mentioned in previous sections.[26] The results (table 4.7) show that *Area* is quite significant and so are the rest of the variables. *Area* obtains a positive sign; this means the following: bigger countries experience higher real exchange rate volatility.[27] Since the main hypothesis is based on trade costs, a possible explanation is that internal distribution costs affects prices of imported goods in the currency of the importer.[28]

[26]The other kind of trade barriers mentioned by them are the ones imposed by the government.

[27]This finding could be related to Parsley and Wei (2000) where they find intra-nation's relative prices to be volatile and distance is one of the variables that can explain this volatility on relative prices. They also study this fact for international relative prices. They conclude that this volatility is bigger for international prices because there is a border effect present in the price setting.

[28]According to the previous, prices are more locally determined and the nominal exchange rate cannot be used as an effective tool to adjust prices from abroad. Now, related to the volatility of RER, this is related to the variance of the nominal exchange rate if prices are sticky. This idea can also be linked to the existence of firms that only distribute imported goods and do not produce goods. Following this line of thought, firms exporting goods have to decide whether to sell directly their goods or send these to retailers in the foreign country.

It is important to note that *Area* is not significant when we run a regression for the subset of industrialized countries but *Open* is. Most of the countries included in this subset are small, in terms of surface, and located in Europe with the exception of Japan (which is also small geographically speaking), South Africa, Australia, United States and Canada. On the other hand, middle-income countries find in *Area* a significant variable that helps explain the behaviour of RER volatility. For the complete sample this is also the case: *Area* is significant and explains volatility of RER.[29] The specification which includes Inflation volatility and area performs better than any specification reported previously. However, these results also indicate that *Remote*'s coefficient is not as high as in BDG. The magnitude lies between 1.75 and 1.81.[30] The elasticity for area is positive on almost all specifications, and even though it is not a high coefficient it is very significant in statistical terms.

We also consider a model in which *Population* is included as an explanatory variable with satisfactory results.[31] It is worth mentioning that these are not as good as the ones where *Area* is part of the specification. The correlation between these two variables is extremely high and this is the reason to include only one at the time. Since *Area* reports better results than the ones from *Population* we decide to put more emphasis on this variable. However, it is worth mentioning that Population affects RER volatility positively. Haveman and Hummels (2004) find that countries with small populations tend to trade more. Following their logic, we might say that big countries could experience higher RER volatility since they are not as open to trade as small economies, we can interpret our results based on Haveman and Hummels' work.[32]

The variable *Area* is also significant when the estimations are done with panel data techniques, table 4.8. The sign obtained is positive as before. One thing to be noticed is the fact that *Remote*'s magnitude is still low, less than 1.5 and in some cases very close to 1, compared to previous results. This is relevant because controlling for volatility in prices and also for size of a country reduces the effect of how far a country is from the centre of world trade. This effect is still very relevant but not as important as when these two variables are

[29]There is a second model that includes also Population Density but this variable is not significant in most of the cases.

[30]In Bravo and di Giovanni's work this coefficient goes up to 3.65 and it never goes below 2.3 in the cross-section analysis.

[31]These results are not included in this work in order to keep the discussion centered on other variables.

[32]Guttmann and Richards (2004) also find this result where *Openness* is their dependent variable. These studies help us explain the positive relation between Population and RER volatility.

not included. Both R^2 and RMSE show improvements with respect to the ones observed in Bravo's and di Giovanni's estimations and very similar to the results of the specification without area in it.[33]

Table 4.8: Panel Data Results w. Area

	Dependent variable: RER volatility	
Variable	(I)	(II)
Remote	1.17**	1.19**
	(0.57)	(0.53)
Open	-0.28**	
	(0.12)	
Area	0.03	0.07***
	(0.02)	(0.01)
GDP pc	-0.21***	-0.21***
	(0.05)	(0.05)
Infl	0.24***	0.25***
	(0.04)	(0.04)
Dummy Decade	-0.14*	-0.15*
	(0.08)	(0.09)
Constant	-2.59*	-4.27***
	(1.42)	(1.21)
Observations	130	135
R^2	0.65	0.63
RMSE	0.47	0.47

Notes: *,**,*** denote significance at the 10%, 5%, and 1% level, respectively.
Standard Errors in parentheses.

4.6.2.1 IV framework to instrument Openness

We have previously mentioned that *Area* is used by Hau (2002) as an instrument for *Open* which is an explanatory on the real exchange rate volatility equation. So far, we have considered *Area* as an explanatory variable on *RER*'s equation. However, Hau's results are good enough to consider this set up as an alternative and include *Open* again inside our baseline model. Here we present the specification that we use for cross-section and Panel Data regressions.

[33]There are some papers where a relationship between the degree of trade openness of a country is measured empirically using geographical variables. This and the fact that Hau (2002) has considered openness as an endogenous variable and even instrumented this with Area are the main causes of trying an instrumental variables approach in order to include both Area and Openness in the estimation of Real Exchange Rate Volatility.

$$RER = \beta_0 + \beta_1 Remote + \beta_2 \widehat{Open} + \beta_3 Infl + \beta_4 Income + \epsilon \quad (4.37)$$
$$Open = z_0 + z_1 Area + z_2 Popden + z_3 Remote + z_4 Infl + z_5 Income + \nu \quad (4.38)$$

Before analysing the results of an IV approach is worth mentioning that our first thought for an *Open* specification includes only *Area* and *Population_density* but our estimations are carried out in STATA and the normal procedure in this software to do an IV regression is to include not only the variables specified by us on the first stage but also the rest of the explanatory variables used in the second specification. The results are interesting, but these do not outperform previous ones. For the cross-section part these are quite good. *Open* now has a higher coefficient, above 0.44, and *Remote*'s coefficient is between 1.33 and 2.4. If we observe the results from the Panel data formulation we have good results if we include *GDP pc* as the income variable. However, this is not the case if we use the dummy variables for Industrialized and low-income countries. The same result is observed on the cross-section estimation for decade 1.

As we mention before, the results (not reported here) support our hypothesis but these do not add anything new to what we find with previous specifications and we have a drawback which is losing *Area* as an explanatory variable. In general terms, all these results corroborate evidence for our previous results and not as our main specification. Previous specifications seem to be simpler with more robust results. Despite all the previous, it is interesting to remark that we can once again find similar results to what other authors have found; in this case, results obtained by Hau.

4.6.3 Interaction terms

So far we have excluded the discussion of income level subset regressions but we are aware that the explanatory variables can have different impacts on RER volatility conditional on the income level of each country. Hence, the effect of some, or maybe all, variables on the RER volatility equation could be different in accordance to the income level. One of the variables that seems to be affected by different levels of *GDP pc* is inflation volatility. This is why we decide to include interaction terms. These are constructed by multiplying the original series by $GDP\ pc$.

The main reason to include not only the new series but also the original series in the same specification is done in order not to impose an implicit restriction on the variables' coefficients. The results show that this new regressors are not relevant for the real exchange rate volatility estimation not even the one where $GDP\ pc$ multiplies $Infl$. Its coefficient is not significantly different from zero in any case. One more remark is the fact that some results are very sensitive to whether these interaction variables are included (in particular, some signs change and magnitudes differ considerably from one specification to the other).

The model does not perform well since just a few variables are significant and/or have a contrary sign to the expected one and observed in previous sections. The fit of the equation, or the R^2, improves for trivial reasons but the $RMSE$ is reduced although not considerably. So far we have only discussed results for the cross-section data, table 4.9, the pooled OLS results are not included in this section since the estimations report coefficients that are not sensible in economic and statistical terms.[34]

Including interaction terms in the model is not a trivial matter because these variables are highly correlated. In several cases the results for panel data specifications are very different to the ones from previous specifications and even between them there are considerable differences. For example, there are some results in which the coefficient of remoteness is negative, or in some others could report a value greater than 10. The results change considerably when we include these variables and their interpretation becomes difficult. Several irregularities arise when we include interactive terms inside the model.

4.6.4 Dummy variables for Industrialized and low-income Countries

This section represents a different exercise and its intention is to model and capture a differentiated income effect but instead of using $GDP\ pc$ as the variable to proxy for income, we include dummy variables in our estimations to control for these effects. The first step we

[34] The results are shown in the Appendix, table B.1.

Table 4.9: Cross-section results with Interaction terms

Dependent variable: RER volatility						
Variable	Dcd 1	Dcd 2	Dcd 1	Dcd 2	Dcd 1	Dcd 2
Remote	2.29***	2.32***	1.54**	1.85**	1.71***	1.68**
	(0.66)	(0.60)	(0.73)	(0.72)	(0.61)	(0.66)
Open	-0.22	-0.34***	-0.002	-0.16		
	(0.14)	(0.10)	(0.17)	(0.16)		
GDP pc (1)	-0.25**	-0.29***	-0.31**	-0.32***	-0.30***	-0.32***
	(0.11)	(0.09)	(0.12)	(0.10)	(0.11)	(0.10)
Area			0.08**	0.05*	0.08***	0.08***
			(0.03)	(0.03)	(0.02)	(0.02)
Infl (2)	0.25	0.12	0.12	0.04	0.15	0.04
	(0.33)	(0.23)	(0.35)	(0.25)	(0.33)	(0.27)
(1)*(2)	-0.01	0.01	0.01	0.02	0.01	0.02
	(0.04)	(0.03)	(0.04)	(0.03)	(0.04)	(0.03)
Constant	-4.40*	-3.57*	-4.15*	-3.68*	-4.62***	-4.36**
	(2.22)	(1.87)	(2.26)	(1.89)	(1.61)	(1.82)
Obs.	67	68	66	68	68	71
R^2	0.68	0.74	0.70	0.76	0.70	0.75
RMSE	0.43	0.38	0.42	0.38	0.41	0.38

Notes: *,**,*** denote significance at the 10%, 5%, and 1% level, respectively. Standard Errors in parentheses.

take is to include two dummy variables for industrial and low-income countries.[35] middle-income countries are represented by the result of the constant in the model.

In order to obtain the effects in industrialized or low-income countries we just need to add the coefficient from the dummy variable to the constant. We consider that including dummy variables to divide our sample in different groups of countries according to their income levels is an interesting exercise to check if these three type of economies experience, on average, similar levels of real exchange rate volatility. This exercise is similar to what Bravo and di Giovanni (2006) do in their work by estimating different subsamples, which are obtained by dividing the complete one according to the income level of the country, to check the robustness of their general results. At the same time we test for the stylized fact described in the work of Hausmann *et al.* (2004) that says that developing countries suffer a 2.5 times higher real exchange rate volatility than high-income economies. An extra remark before proceeding with the estimations is the fact that it is necessary to remove GDP per capita from the estimation in order to have sensible results.

[35]As mentioned earlier the original dataset from BDG includes three dummy variables for high, middle and low-income countries, we just include two of these in order to keep the constant in the model.

Table 4.10: Dummies for Income Levels-Cross Section

	Dependent variable: RER volatility			
Variable	Decade 1	Decade 2	Decade 1	Decade 2
Remote	1.10*	1.58**	1.88**	2.45***
	(0.60)	(0.66)	(0.72)	(0.72)
Open			-0.30**	-0.39***
			(0.14)	(0.12)
Area	0.09***	0.09***		
	(0.02)	(0.02)		
Infl	0.20***	0.20***	0.19***	0.19***
	(0.04)	(0.04)	(0.04)	(0.03)
Dum. Industrial	-0.53***	-0.45***	-0.46***	-0.44***
	(0.14)	(0.15)	(0.13)	(0.13)
Dum. low-income	0.31**	0.30**	0.35***	0.25*
	(0.14)	(0.13)	(0.13)	(0.13)
Constant	-6.00***	-7.07***	-5.28***	-6.06***
	(1.11)	(1.30)	(1.93)	(1.81)
Observations	69	72	67	68
R^2	0.72	0.73	0.70	0.73
RMSE	0.40	0.39	0.42	0.40

Notes: *,**,*** denote significance at the 10%, 5%, and 1% level, respectively. Standard Errors in parentheses.

The results in table 4.10 show that both dummies are significant and their signs are the expected ones. However, when we observe the complete set of results *Remote* is not significant even at the 10 percent level in one case: estimations done for decade 1 and including area as an explanatory variable. This problem is more notorious when we use panel data to carry the estimations out. In that case, the coefficient of *Remote* is below 1 (0.82) and its standard error is close to 0.62, so the result is clearly insignificant. If we try to run the regressions with *Open* included instead of *Area* all the results are significant in the cross-section part, and the coefficient for remoteness increases considerably to be in one decade close to 2 and in the other greater than 2. But, using *Open* instead of *Area* in a panel set up does not solve all the problems observed before. *Remote* is again insignificant. The only way to have a sensible specification using panel data is to remove both *Area* and *Open* from the equation and estimate the following equation:

$$\sigma_{RER} = \beta_0 + \beta_1 Remote + \beta_2 Infl + \beta_3 DInd + \beta_4 DLow + \beta_5 DDecade + \epsilon \qquad (4.39)$$

where $DInd$ and $DLow$ are dummy variables that represent high-income and low-income countries, respectively.

But, this is not the only problem: The dummy for industrialized countries is not significant. If we compare the results with the ones that include GDP per capita, we have that the coefficients are similar. The main difference is that remoteness is quite significant if we include GDP per capita. One drawback of using only GDP per capita is that it is not possible to analyse the results considering the effects of having specific country income level group dummy variables.

Table 4.11: Dummies for Income Levels-Panel

	Dependent variable: RER volatility		
Variable	(I)	(II)	(III)
$Remote$	0.98	0.82	2.06***
	(0.60)	(0.62)	(0.52)
$Openness$	-0.43***		
	(0.09)		
$Area$		0.08***	
		(0.02)	
$Infl$	0.24***	0.25***	0.29***
	(0.04)	(0.04)	(0.04)
Dum. Industrial	-0.41***	-0.36***	-0.10
	(0.12)	(0.13)	(0.11)
Dum. low-income	0.25**	0.29**	0.42***
	(0.11)	(0.12)	(0.11)
Dum. Decade	-0.15*	-0.16*	-0.16*
	(0.08)	(0.08)	(0.09)
Constant	-2.95**	-5.42***	-7.20***
	(1.49)	(1.19)	(1.05)
Observations	131	137	139
R^2	0.66	0.64	0.59
RMSE	0.46	0.47	0.49

Notes: *,**,*** denote significance at the 10%, 5%, and 1% level, respectively. Standard Errors in parentheses.

If we look at table 4.11 that includes the results for the panel data estimations, we notice that only when $Open$ and $Area$ are not part of the equation we observe results that are in line with the previous ones since it is with this particular specification that $Remote$ is significant. When $Open$ is part of the estimation its coefficient is surprisingly high, in absolute value, and the opposite effect is observed with $Area$'s coefficient: its value is reduced to be below 0.10. Both variables are significant in their respective estimations, but as noted before *Remote* is not. Nevertheless, the results for all dummy variables are in most of the cases significant and with the expected sign.

The most relevant specification in our case is the one in which *Open* and *Area* are left out. But if we compare these results with the ones where *GDP pc* is included instead of the dummy variables of income, we have that the former outperforms the later and the interpretation of the results is also richer since more significant explanatory variables are part of it. The importance of this section is just to show that there are differences between countries according to their income level and this can be observed in the coefficients of the industrial country dummy variable and the one for less developed countries. Using *GDP pc* is possible to control for this effect but having results from specifications with dummies we can observe these differences in a more explicit way.

4.6.5 Extra Specifications

As the final part of our study we include some sections where we analyse different options estimated by us that are not relevant as the ones reported in previous sections but that might give more information about real exchange rate volatility.

4.6.5.1 Trade-Policy variables, imposed trade barriers

Bravo and di Giovanni include import duties and export taxes as imposed trade barriers variables. The impact of these on the regression results is not very relevant in most of the cases. Nevertheless, it seems necessary to include a variable that can measure or capture how difficult it is to trade for a country. As the results of Bravo and di Giovanni show us, the existing datasets on import duties and export taxes are not the most efficient way to control for imposed trade barriers in cross-section empirical works that use samples with more than a hundred countries. The number of missing observations, in particular for developing and less developed countries, is considerably high number to the point that such effect is not statistically significant in the regressions. We acknowledge the importance of this type of effects and that is why we consider a different variable to proxy the effects of imposed trade barriers.

For this reason we include as an extra explanatory variable an index constructed by the Institute for Economic Freedom. The index used is named Freedom to trade and it includes the following components: Tariffs; Regulatory trade barriers; Actual/Expected size of trade sector; Difference between official, and black market exchange rates and International capital market controls. The expected sign for this variable is a negative one: The higher the index is the more freedom a country has to trade and this also means that the country has imposed less trade restrictions which will be reflected with less real exchange rate volatility.

We can use the work of Dawson (2007) to support our decision of including Freedom to trade. The author considers that the index constructed by the Institute for Economic Freedom is the most extensive measure available in terms of its coverage of countries, time, and attributes of economic freedom; although, it is obvious that we only use the components related to trade. This index has been more widely used than any of the other alternatives to capture trade policy effects and also attributes of freedom in an economy. The most likely reason behind this fact could be its coverage of a longer time period.

De Hann, Lundström and Sturm (2006) also make reference to the popularity of the index as they find that more than 194 articles cite this variable, and more than 25 use it in their empirical approach. As a matter of fact, the authors mention that this number could be higher, but other researchers might have been reluctant to use the index, as they doubt whether the data are reliable, given the strong ideological position of the organization providing them. However, De Hann *et al.* (2006) show that the index is reliable by applying sensitivity tests to the index. We do not need to worry about any of the fears that some other researchers have expressed as we only consider the component of Freedom to trade that is part of the general Economic Freedom Index.

As a final comment, we can include the research of Sonora (2008) on the index in which he mentions that the general index is an amalgam of two concepts: economic liberalism and good governance. We can highlight once more the fact that the coverage of the index is remarkable as the number of countries that are part in our sample and not considered by the index is relatively small. At the same time, the trade components that are included in the Freedom for trade index represent a complete measure to proxy for imposed barriers for trade that not only focuses on the role of tariffs but also on other type of regulatory trade costs.

The index is constructed from 1975 on a 5-year basis and yearly since 2000. In order to include this in our set up, we calculate a simple geometric average from the relevant observations to our study. The estimation results are not supportive for the inclusion of this new variable as it can be seen in table 4.12. Three equations where this trade policy variable is included are regressed and we do not have a significant result in any case.

Table 4.12: Trade Variables Added

	Dependent variable: RER volatility							
Variable	D 1	D 2	D 1	D 2	D 1	D 2	D 1	D 2
Remote	2.14***	2.56***	1.97**	2.06***	1.72	2.42**	1.24	1.90*
	(0.79)	(0.70)	(0.76)	(0.71)	(1.27)	(1.14)	(1.28)	(1.12)
Open	-0.19	-0.29**			-0.25	-0.31**		
	(0.15)	(0.13)			(0.16)	(0.14)		
Area			0.06**	0.07**			0.08***	0.08***
			(0.03)	(0.03)			(0.03)	(0.03)
Infl	0.19***	0.17***	0.19***	0.17***	0.19***	0.18***	0.19***	0.19***
	(0.04)	(0.04)	(0.05)	(0.04)	(0.04)	(0.03)	(0.04)	(0.04)
GDP	-0.20*	-0.21**	-0.20*	-0.27***				
	(0.11)	(0.09)	(0.11)	(0.10)				
Trade Policy	-0.06	-0.05	-0.06	-0.02	-0.05	-0.07	-0.05	-0.05
	(0.06)	(0.05)	(0.05)	(0.05)	(0.06)	(0.06)	(0.05)	(0.05)
Dum. Industrial					-0.37	-0.28	-0.41*	-0.31
					(0.25)	(0.27)	(0.23)	(0.23)
Dum. low-income					0.26	0.13	0.24	0.24
					(0.19)	(0.16)	(0.19)	(0.17)
Constant	-4.29**	-4.68**	-5.41***	-5.34***	-4.88*	-5.90**	-5.85**	-7.29***
	(1.94)	(1.76)	(1.79)	(1.81)	(2.85)	(2.44)	(2.59)	(2.23)
Observations	58	59	58	61	58	59	58	61
R^2	0.69	0.74	0.70	0.74	0.69	0.73	0.71	0.72
RMSE	0.44	0.40	0.43	0.40	0.44	0.41	0.43	0.42

Notes: *,**,*** denote significance at the 10%, 5%, and 1% level, respectively. Standard Errors in parentheses.

As stated above, these results do not support the addition of this index as a measure of trade policy in our real exchange rate volatility specification, but this does not mean that a trade policy variable is irrelevant to explain our dependent variable. This finding should encourage us to look for a better variable(s), perhaps more related to government revenue in the sense of taxes (for imports) and duties (for exports), although we also have evidence that it is necessary to obtain better measures of those variables too.[36]

The results for panel data estimations are quite similar to what we see in the cross-section results: *Remote* is not significant and neither *Open* and *Area* if these two variables are part of the estimated equation at the same time. The most relevant thing to notice here is the fact that Freedom for Trade reports a negative sign which means that a higher number (less imposed restrictions to trade) in this index reduces real exchange rate volatility. Despite the fact that this variable is in no case significant we must say that these results signal for a negative relationship between Freedom for Trade and Real Exchange Rate volatility. As we have remarked above, a database of import taxes and export duties should improve this results and quantify this relationship.

4.6.6 Own Remoteness Index

The distance between countries is the most relevant natural trade cost as it is seen as a good proxy for transportation costs. The importance of this variable is captured in our estimations on the coefficient of *Remote*, which is a remoteness index that captures the distance from a country to the world trade centre. So far we have used an index constructed by BDG. Their index is based on using weights taken from how much trade a country has with the rest of countries that are part of the sample. However, we decide that it could be more insightful to create this index but instead of calculating the measure with trade weights we replace these with GDP weights. The idea behind this decision is to take into account potential trade partners and not only actual ones and we can even get a more homogenous variable.

The way we construct the index is quite similar to BDG. The distance database is taken from the Centre d'Etudes Prospectives et d'Informations Internationales (Paris, France)

[36]Similar as what Bravo and di Giovanni did in their work but trying to obtain a better data set about taxes and duties.

and the GDP database comes from IFS from IMF. The Remoteness formula goes as follows:

$$Remoteness_i = \sum_{j \neq i}^{J} distance_{i \to j} w_j \tag{4.40}$$

where J is the sample of countries, i is the home country, j is the potential partner, and w_j is the weight of country j in global GDP (sum of all GDPs in the sample excluding the one from country i). The only difference between our index and the one from Bravo and di Giovanni is that they use log of distances and not the variable in levels to calculate the index. The results from using a different measure for remoteness are evident when we observe the coefficient for this variable. If we include the remoteness index constructed using GDP weights, ours, the coefficient for this variable is reduced considerably and in any case below 1. We have to remember that the value observed for this coefficient using the previous index is above 1.5 on average and in some cases reaching a value of 4. The results from this estimations can be observed in table 4.13.

Table 4.13: Including Remoteness index using GDP weights

	Dependent variable: RER volatility							
Variable	Dcd 1	Dcd 2	Dcd 1	Dcd 2	Dcd 1	Dcd 2	Dcd 1	Dcd 2
$Remoteness_o$	0.61***	0.30*	0.58***	0.37**	0.53***	0.34**	0.56***	0.31**
	(0.18)	(0.18)	(0.18)	(0.14)	(0.18)	(0.15)	(0.18)	(0.14)
$Openness$	-0.47***	-0.53***	-0.03	-0.13	-0.35***	-0.37***		
	(0.12)	(0.10)	(0.17)	(0.16)	(0.11)	(0.10)		
$Area$			0.10***	0.07**			0.10***	0.09***
			(0.03)	(0.03)			(0.02)	(0.02)
$Infl$			0.17***	0.19***	0.18***	0.20***	0.17***	0.20***
			(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)
$GDP\ pc$	-0.34***	-0.40***	-0.26***	-0.27***	-0.24***	-0.27***	-0.25***	-0.27***
	(0.06)	(0.05)	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)	(0.05)
Constant	-2.82	0.75	-6.57***	-3.90**	-3.87**	-1.76	-6.62***	-4.19***
	(2.04)	(1.94)	(2.15)	(1.61)	(1.93)	(1.59)	(1.76)	(1.50)
Observations	72	76	66	71	67	71	68	74
R^2	0.56	0.56	0.72	0.75	0.67	0.73	0.72	0.74
RMSE	0.48	0.48	0.40	0.38	0.43	0.39	0.40	0.38

Notes: *,**,*** denote significance at the 10%, 5%, and 1% level, respectively. Standard Errors in parentheses.

The first thing to notice is the reduction in the coefficient of *Remote*. In all the specifications considered in table 4.13 the value of *Remote* is not higher than 1, but this variable remains to obtain the greatest coefficient if we do not consider the constant. For the rest of the variables the magnitudes do not report high variations. The best specification is the same as before where *Remote*, *Area*, $Infl$ and GDP *pc* are the explanatory variables. As before, if *Area* and *Open* are included in the same equation, the results are not significant for *Open* but *Area* is, and if we compare the results from three specifications, the last six columns in table 4.13, the one including only *Area* without *Open* outperforms the other two as we observe R^2 and $RMSE$.

Table 4.14 shows the results for the Panel Data estimations. The first thing to notice is the inclusion of an extra specification not reported on the cross-section results.

Table 4.14: Remoteness index with GDP weights for Panel Data

	Dependent variable: RER volatility				
Variable	(I)	(II)	(III)	(IV)	(V)
Remote	0.34**	0.28*	0.26*	0.23	0.37**
	(0.16)	(0.15)	(0.15)	(0.15)	(0.16)
Open	-0.52***	-0.27**	-0.41***		
	(0.09)	(0.12)	(0.08)		
Area		0.04*		0.08***	0.11***
		(0.02)		(0.01)	(0.02)
$Infl$		0.25***	0.25***	0.25***	0.26***
		(0.04)	(0.03)	(0.04)	(0.04)
GDP *pc*	-0.34***	-0.19***	-0.19***	-0.20***	-0.18***
	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)
Pop_density					0.08**
					(0.03)
Dum. Decade	-0.15	-0.12	-0.11	-0.12	-0.15*
	(0.10)	(0.08)	(0.08)	(0.08)	(0.08)
Constant	-0.28	-2.92*	-1.76	-4.14***	-6.12***
	(1.67)	(1.67)	(1.60)	(1.57)	(1.77)
Observations	148	133	134	138	138
R^2	0.43	0.65	0.65	0.64	0.65
RMSE	0.58	0.46	0.47	0.47	0.46

Notes: *,**,*** denote significance at the 10%, 5%, and 1% level, respectively. Standard Errors in parentheses.

This extra specification (column V) includes *Population_density* as explanatory variable and it is included to show that *Area* and $Infl$ are also relevant in the pooled OLS regression. Column (IV) from table 4.14 shows that *Remote* is not significant even at 10%

level. However, when $Population\_density$ is part of the equation, the coefficient of *Remote* increases to 0.37 and it is significant at 1% level. There is an important difference with respect to the results using from the cross-section data part: *Open* is significant in all cases and *Area* is not when *Open* is part of the model. Somehow this situation is reversed in the cross-section results. However, *Remote* is not significant unless we remove not only *Area* but also $Inflation$ from the specification, which leaves us with the same specification as in Bravo and di Giovanni. Then adding $Population - density$ into the model becomes more relevant since we are able to find a specification that allows us to control for more natural trade barriers than just *Remote* and we are also able to observe the impact of volatility on different variables. This is the relevance of having an extra specification.

As before, when we compare these results with the previous ones using a remoteness index with trade weights we observe a considerable reduction in *Remote*'s elasticity by more than half. In some cases this coefficient is reduced to reach a maximum of 0.37 using the new index of remoteness while with the previous one we have a coefficient of 1.8. It is also worth noting that *Remote*'s coefficient is not as high as before but its standard deviation is also affected in the same way. So, we have a lower variance for the estimated values of remoteness when we use the new index. But, the reduction in the standard errors is not as high as the one observed in the coefficients, so we have that the t statistic is not as high as before.

We find the most notorious change is the one in the coefficient of *Remote*, the rest of the variables do not present considerable changes. After analysing variations not only in the coefficient, but also in the standard error of *Remote* and in its t statistic, we can say that the relevance of this variable in the estimation of real exchange rate volatility is significant but not at the same level as when we include this index constructed with trade weights.

4.6.7 A different measure for inflation

As a final section for this study we remove from our specifications the inflation volatility measure and instead we include a simple average taken from inflation annual growth. That is, we are focusing now in the first moment of the distribution instead of taking the standard deviation. The main goal from repeating several estimations reported before is not to dismiss the ones where inflation volatility is part of the specification. On the contrary, this should be interpreted as a robustness check on inflation as a explanatory variable for real exchange rate volatility.

In almost all the specifications $Average\_inflation$ is significant at the 5 or even 1 percent. There is a particular case in which this variable is not significant: when we include *GDP pc* multiplied by inflation average we have this insignificant result. However, this same result is obtained when inflation volatility is used. Some other results that we get using inflation volatility are also found with $Average\_inflation$: *Open* is not significant when *Area* is also part of the model, but also, it is not significant when the regression is run for the first decade even without *Area* being part of the equation.

All the previous applies for cross-section and panel data estimation results. There is just one difference worth mentioning here between cross-Section and Pooled OLS results, which is found in the specification that does not include *GDP pc* and instead we consider dummies to differentiate country's income levels. When the estimations are done using Panel Data, the results show that *Remote* is only significant if both *Area* and *Open* are not part of the equation. Whereas in the cross-section results, *Remote* is not different from zero in statistical terms with the exception of one case: using data for the first decade and *Area* and *Open* are not included.

As in the case of inflation volatility we choose to include *Area* instead of *Openness* and the results using inflation average are qualitative the same as before. The coefficients obtained are, in absolute value, higher for inflation in the average case but lower for the rest of the variables, although the differences are relatively small. After analysing the results we can say that inflation plays an important role in explaining real exchange rate volatility. Although, to finish this section we must emphasize that it is possible to obtain the same conclusions that we already got by using inflation averages.

If we turn to the panel data results,[37] we have the same pattern as with inflation volatility: *Open* works better than *Area* since the latter is not significant when both variables are part of the model. However, the results for *Remote* are not quite the same with inflation average since this variable is not as significant as in the model with inflation volatility. Using either

[37]Tables for both cross-section and panel data results are included in the Appendix.

the average or the volatility measure to include inflation in our analysis give us the same kind of conclusions but we must remark that the results seem to be more robust if inflation volatility is used.

4.7 Conclusions

We are able to replicate the results of Bravo and di Giovanni, and we confirm their findings: remoteness is a relevant variable in the estimation of the real exchange rate volatility. We also refine the estimations done by Bravo and di Giovanni by considering data of the last decade and not the one from 10 year before that. The relevant remark is that the results still hold and it does not matter which sample is taken. The relationships obtained with one sample are also found in the other. With this set of results the impact of trade openness is reduced by the inclusion of remoteness. However, remoteness only accounts for the effects of natural trade barriers and the imposed ones by economies cannot be considered in the estimations because the proxy variables are not that effective.

Even though we are able to replicate Bravo and di Giovanni's findings, specially if we consider cross-sectional data, there are some new and interesting results that we are able to obtain and some other that we are able to confirm with our specifications. An important contribution in our work is being able to control for more effects by including more variables; to be more specific we add to the analysis $Area$ and $Infl$ (volatility measure) that help us control for different effects in our estimations. With $Area$ we are able to include one more variable that accounts for an extra natural trade barrier and we do not rely only on distance to the World Trade Centre. In this sense, *Remote* still is a very relevant variable to explain real exchange rate volatility but the impact of this is reduced now that we include more variables that can be categorized as natural trade barriers and that allow us to control for some other effects. As we mention earlier this is what happens when $Area$ is included in the model to be estimated.

Considering the impact of remoteness, we not only consider this measure constructed with trade intensity weights but also taking into account each country's GDP to be weights in the calculation of the remoteness index. The results from previous sections hold and we still obtain a positive relationship between the remoteness variable and real exchange rate volatility.

$Infl$ (volatility measure) is also quite relevant when we consider the complete sample of countries. We are able to find a positive relationship between this variable and real exchange rate volatility. And the most relevant part is that this variable is always significant statistically speaking reporting a similar elasticity (coefficient) in almost every case. Since the inclusion of $Infl$ into the model is done in a very ad-hoc way, we try to make this results more robust by using a measure of average inflation of each country as a robustness check. The results are very similar to the ones where we have $Infl$ (inflation volatility) but the specification using this last variable outperforms the one using average inflation. This result in particular allow us to identify the impact of disequilibria in RER volatility.

We are also able to show that there are differences in terms of RER volatility among each group of countries in accordance to their income level. As expected, industrialized countries have lower RER volatility with respect to developing countries and, in the other hand, less developed countries have a higher variance in the real exchange rate. This is something that some authors have also found but, as in our case, it is not possible to give an explanation of why these differences arise between these groups.

However, not all the included variables have a positive response. The interaction terms are the ones that can be used as an example. The main problem when we include interaction terms in any specification is multicollinearity. In some cases this measure can reach a 0.95 correlation which is reflected in some results with signs opposite to the expected one and even found in other specifications. And in some cases the coefficients obtained vary considerably.

One more finding is the reduced relevance of trade openness in some of the specifications. To be more specific, in some cases this variable is just not significant and in some in which it is, the magnitude of its coefficient is reduced if some of the new variables are part of the specification like $Area$. As in Hau's work, we instrument this and the results are better than in most of the specifications. However, one of the instruments included is $Area$ and by doing this we lose an important explanatory variable. It seems to be the case that trade intensity, our measure for openness, is not the best way to control for this and some other, and more accurate, measures for openness should be considered. The importance of openness could also be re-established by considering better instruments for this variable and be included in a second stage regression of the IV estimation. We can establish the impact of natural trade barriers, but imposed ones can not be included by themselves in our estimations. This is why we should not disregard the role of openness. Perhaps we need to see openness as a complementary exogenous variable to new variables included in the RER specification and should not be seen as substitutes. The challenge for the future is to find ways to make this possible.

There are several approaches taken to explain RER volatility, none has found a complete and satisfactory (final) answer. However, every approach shed some light into the problem. In our case we can include some new factors to control for their effects that were not used together before. The important step to take is to know how to combine procedures in order to obtain better results.

Chapter 5

Explaining Trade Openness

5.1 Introduction

Several authors have analysed countries' openness to international trade in different ways: technology spillovers, market integration, and growth, just to mention a few. In the particular case of growth, it is claimed that the more open an economy is, the more it will grow. There is a vast literature that covers this topic; Alesina, Spolaore and Wacziarg's (2004) work is a good example of this. There are several empirical studies that try explaining the link between openness and growth.[1] However, there is a lack of literature devoted to explain openness in a more structural way; that is, openness to trade can be affected by other exogenous variables and just a few authors have explored this field of research. It is clear that one of the main ways to modify this measure of trade intensity is via the implementation of trade liberalization policies; but there are other aspects that can affect the impact of these. This work is an attempt to obtain an openness equation that can explain better those links.

Very recently, there have been some attempts to find an empirical model for trade openness. One of the first works in this area can be found in Frankel and Romer (1999), despite the fact that their main objective is not to estimate an openness equation. They try to establish

[1]Nevertheless, a high degree of openness by itself does not ensure to reach high growth rates: A high degree of openness should be combined with a stable and non-discriminatory exchange rate policy, consistent monetary and fiscal policies, all these combined with sound institutions.

a link between geographic characteristics of a country and openness. Their idea is to use these geographic characteristics as instruments to explain growth in a second estimation. Frankel's and Romer's work is inspired by the gravity equation framework and previous work of Linnerman (1966), Frankel *et al.* (1995) and Frankel (1997). All these studies show that geography is a powerful determinant of bilateral trade, and this is reflected in the gravity equation. Frankel and Romer attempt to shed light on how specific characteristics of a country can be used to determine the degree of "natural openness", as some others have called it.

In recent years, some authors have followed Frankel and Romer's work, and they have focused on the role of non-tariff barriers to trade. Previous studies that analyse openness base their findings on the results of a gravity model. This type of empirical work includes as determinants of bilateral openness variables like the GDP of both countries, and dummy variables for a common currency, size of a common border or common membership in a free trade agreement, among others. The empirical results of these models are very significant. However, the gravity model is based on bilateral trade that determines, mostly, changes in relative trade barriers between two countries and also trade flows between the two nations studied. Our work tries to establish a more general relation between these geographic characteristics and some other relevant variables to trade openness, where trade intensity of a country is our measure of openness.[2] In order to accomplish this we collect data for more than 100 countries from the previous 20 years to calculate averages, and to determine different links between openness and the exogenous variables.

It is important to notice that this branch of empirical trade literature has not been explored massively, but there are some authors that have studied this topic, either directly or indirectly, in their researches. Hau (2002) in his work on real exchange volatility gives a hint of a potential model for openness. He uses an IV approach to instrument openness, where the instruments are mainly geographic characteristics. The results of this first equation are significant and encouraging to continue with a deeper research on this matter. Some other authors, like Milner and Zgovu (2006), turn their attention to Africa. They take a closer look at Malawi to study the relative importance of trade policy, natural barriers to trade and the impact of liberalization on total levels of protection. They conclude that in landlocked

[2]We use as our measure of openness trade intensity of a country. We construct it as the sum of total imports and total exports of a country divided by its GDP.

countries such as Malawi, natural trade barriers have been a more important constraint on export supply than border taxes. Even though their work shows the importance of natural barriers to trade, they do not seek to identify or quantify the impact of these on export performance. Most of the research done on natural barriers to trade focuses on export performance in general and how these could be interpreted as "true" export taxation, as they call it.

So far we have put a special emphasis on natural characteristics because we find that in the previous literature these are used as exogenous variables to estimate an openness equation, mainly as a intermediate step. We combine this with some other variables to get a specification that explains in a simple way the openness level of the countries.

Some other authors have previously estimated an openness equation using a sample of several countries in a cross-section framework. There is even a group of them that have, once again, used as an intermediate step in their empirical work an estimation of an openness equation to explain some characteristics of the government, mainly its size. Rodrik (1996) analyses the relationship between the size of government and the level of openness of the economy, where the size of the government is measured by its expenditure. Alesina and Wacziarg (1998) show us a link between two ideas: a) big economies have smaller governments and b) small economies are more open to trade. Their final hypothesis goes as follows: the size of the government is related to the degree of openness. Wei (2000) also tries to find a connection between corruption and openness.

However, Wei takes his openness equation as an intermediate step and uses these results in a second regression to measure the level of corruption or good governance of a country. Both Wei's and Rodrik's works use openness as an explanatory variable to determine the optimal size of the government. Two more studies where we find an openness specification as the "main" subject of research are the ones from Jansen and Nordås (2004) and Guttmann and Richards (2004), which are discussed further below. Both works not only estimate an openness equation but also complement their results with the ones from a gravity model.[3]

In summary we can say that most of the previous efforts to analyse an openness equation

[3]The way they analyse the results from an openness estimation and a gravity model vary between these two works. While Guttmann and Richards compare the results from both models and conclude that the gravity model is not very consistent, Jansen and Nordås use the most robust results they obtain from the openness estimation to be included in a gravity equation set-up.

have either used this as an intermediate step, to study geographic characteristics and their impact in openness, or even to compare the results of an openness specification with a gravity model. If we aggregate all the previous ideas, we find that an economy has a certain level of openness that is modified by external factors (geographic characteristics) or endogenously (income, trade barriers, and other economic policies). In our opinion a study of openness using geographic characteristics and controlling for some other important effects could shed light on several aspects of international trade and some other economic disciplines.

5.2 Related literature

As we have mentioned before there are two studies where authors specify an openness equation as part of their main research. The first one is Guttmann and Richards (2004). In their work they not only estimate an openness equation but they also set up a gravity model and compare the results of these two. Their empirical work is based on cross-section and pooled OLS regressions for a sample that includes many countries. In their openness equation they use as explanatory variables imposed and natural trade barriers. Their analysis starts with a gravity model and they conclude that this model over-predicts levels of trade of Australia. Their next step is to estimate an openness equation that includes geographic characteristics of each country and policy variables in order to compare these results with the ones from the gravity model. They conclude that the second model's results, the ones from the openness equation, resemble more accurately the observed trade openness of Australia.

The openness equation gives good results using only five explanatory variables in a fairly parsimonious specification. The results from the openness equation reveals that population of each country is a very significant variable. Among the group of significant variables we also find surface area and economic location. The latter is a variable constructed by Guttmann and Richards in order to capture the effects of distance and/or trade costs.[4]

[4]This measure is similar to a remoteness measure constructed by Bravo and di Giovanni (2006) but instead of having a weighted distance measure of a country to the World Trade Centre, they aggregate the ratio of country *j*'s weight in the Global GDP and the distance of country *j* to country *i*. In other words, this measure is similar to the inverse of remoteness.

$$Economic\ location = \sum_{j \neq i}^{J} w_j / distance_{i \to j}$$

Their results are encouraging to continue analysing an openness equation and trying to disentangle further the effect of both geographic characteristics and imposed trade barriers to obtain more specific results. They conclude that low levels of openness in Australia can be explained by its remoteness and its large size, geographically speaking. And we have that openness in the case of Australia is affected by non-imposed trade barriers.

The second paper is the one from Jansen and Nordås (2004). They also analyse openness of a country[5] and factors that make this indicator to vary. They argue that domestic institutions and domestic infrastructure are very relevant in how much a country trades. In contrast to Guttmann and Richards, Jansen and Nordås start their study by estimating an openness equation and try to find support for the inclusion of domestic institutions and infrastructure in this equation. These variables are chosen based on the results from a first set of regressions where openness is the dependent variable. The most significant variables that proxy for institutions and infrastructure are then included in a different estimation, which also includes population and tariffs as exogenous variables.[6]

Their results support the inclusion of both infrastructure and institutions proxy variables. After these findings are fully explored, they include both variables in a gravity model where they also find that institutional variables have a significant and positive impact on trade flows. Their final contribution is to suggest that the impact of trade liberalization on actual trade flows can vary depending on the quality of institutions and infrastructure. Their findings show the relevance and necessity of doing a more detailed analysis on openness.

5.2.1 Openness and Real Exchange Rate volatility

Hau (2002) has already shown a direct relationship between the degree of openness of a country and the volatility of the real exchange rate. In addition, it is also claimed by Hau

[5]Their measure for openness is trade (exports+imports) over GDP.

[6]They use three different variables to proxy for institutions effects: "Governance Effectiveness", which refers to the quality of public service provision, the competence of civil servants, credibility of the government's commitment to policies, etc. The second is their "Rule of Law" that is based on several indicators that measure the extent to which agents have confidence in an abide by the rules of society. The last one is "Control of Corruption" that measures perceptions of corruption. They do something similar with infrastructure, where they consider the percentage of paved roads, the number of fixed and mobile telephone lines and credit to private sector divided by GDP.

and some other authors that real exchange volatility is higher in developing countries than in rich ones, after controlling for openness. If we take this premise as a starting point, we can try to explain indirectly why this difference exists in the levels of volatility by showing that openness differs among these countries. We could start by analysing basic characteristics of a country (geographic characteristics) that might represent an obstacle to a costless integration in international markets. These can be interpreted as each nations' natural level of openness that can be altered via infrastructure (Limão and Venables 1999), or through other economic policies that might be easier to implement in rich countries. In Hau's work openness reduces the impact of economic shocks in the real exchange rate volatility. It is possible to take some equations from Hau's work to illustrate his point:

$$
\begin{aligned}
Openness &= \frac{P_T C_T}{P_N C_N + P_T C_T} = \gamma \\
E - P = P_T - P &= (1-\gamma) P_T = (1 - Openness) X && (5.1) \\
Vol &= \left[\epsilon (E-P)^2\right]^{\frac{1}{2}} = (1 - Openness)\sigma_X && (5.2)
\end{aligned}
$$

where P_T and P_N are prices for traded and non-traded goods, respectively. C_T and C_N stand for levels of consumption, again, for traded and non-traded goods. The *Openness* equation is obtained from the solution of the utility maximization problem faced by the representative agent in Hau's model.[7] Equation 5.1 includes E, nominal exchange rate, P,[8] consumer price index, and X that can stand for either money supply or a parameter of marginal disutility of a household's non-tradable production. This equation is obtained from the demand for real balances in Hau's work, and combined with the previous one, *Openness*, show us the link found by Hau's set-up between the real exchange rate and openness. The following one, equation 5.2, is just the volatility of the previous one, where σ_X is an stochastic variable and its movements are what we interpret as monetary or productivity shocks. Either shock affects the economy with a higher impact if the level of openness is low.[9]

[7]This equation comes from equalization of the marginal utility of traded and non-traded consumption.

[8]Where

$$P = \frac{P_T^{\gamma} P_N^{1-\gamma}}{\gamma^{\gamma}(1-\gamma)^{1-\gamma}}$$

[9]It is easy to check a negative sign for the relation between openness and real exchange rate volatility,

For some authors, specially the ones working in New Open Macroeconomics models, the fact of considering openness an exogenous variable related to real exchange volatility is not as clear as we have considered. Gandolfo and Nicoletti (2002) are motivated by this premise to examine the causal relation between real exchange rate volatility and trade openness by using Gweke's (1982) work on causality measures. They use spectral analysis of time series as their building block. Despite the fact that they are not able to identify a specific dynamic pattern of casual relation, they do show that spectral analysis could be a powerful tool that has not been exploited enough so far. However, they are not able to find evidence to support any of the two hypothesis.

Bravo-Ortega and Di Giovanni (2006a) explore closely the connection between trade costs and real exchange rate volatility. Their model predicts that two countries which are close to each other and have similar technological endowments will also have a similar set of supplier countries for traded goods. As they claim in their model, the key impact of trade costs is not on traded/non-traded sectors' relative sizes, but instead on the differences found in the set of providers of traded goods that each country has.

It is also possible to invoke the results obtained by Dornbusch, Fischer and Samuelson (1977) to have a more theoretical framework to support our analysis. Their work develops a Ricardian model with a continuum of goods, as we explain in detail in section 4.3 of the previous chapter. They study a two-country model where trade flows are determined by a competitive margin in production between imported and exported goods. However, if trade costs are positive[10] we will have non-traded goods inside the model. The set of non-traded goods could change if trade costs (maybe preferences) change. This is then translated into changes in the set of goods that are exported and imported, hence changes in our measure of openness for both home and foreign countries. But not only that, there are modifications in the set of prices too. Before the existence of trade costs all prices are "international" prices, but now we have non-traded goods prices that are also affected by changes in trade costs. As a final outcome we have variations in both national price index and finally in their bilateral real exchange rate.

we just need to take the derivative with respect to openness in equation 5.2.

[10]Even with trade costs equal to zero we could have the existence of non-traded goods. For example if a country decides to spend a fix part of their income in domestic goods, we have a reduction in income spent in traded goods. We could say that preferences of consumers are home-bias. In this case it is the demand side, via preferences, and not production side, via efficiency, what causes the existence of non-traded goods.

5.3 Openness specification

Before stating our equation, it is worth taking a closer look at previous specifications since, as Guttmann and Richards (GR from now on) point out, it is not possible to find in the trade literature a theoretical model explaining openness. Nevertheless, there are quite a few works from different authors where they explain particular effects of different variables on openness that should help us as a guide in our empirical work.

Jansen and Nordås start their work with an openness specification which helps them explore correlations between actual trade flows and tariffs, controlling for variables such as institutions and infrastructure. Even though they try to establish a direct relationship between openness and tariffs, they are aware that tariffs are only a fraction of the total costs of trade. Transport costs and other transactions, such as entering and enforcing contracts between trading partners, are found to be significantly higher than tariffs when they are calculated on an equivalent basis. This is why their openness specification not only controls for tariffs, infrastructure and institutions, but also includes population to capture the effect of market size and number of varieties available in the economy.[11] Their main equation takes the following form:

$$\begin{aligned} Open = {} & \beta_0 + \beta_1 Population + \beta_2 Tariffs + \beta_3 Infrastructure \\ & + \beta_4 Institution + \beta_5 * (Institution * Tariffs) + \epsilon \end{aligned}$$

Their final step in their work is to estimate a gravity equation. However, it is possible to distinguish that some of the relevant variables in their gravity equation are included after being part of an openness estimation. With this thought in mind, we have that our model tries to test several relations that have been established before using a gravity equation framework. We have to state, as GR did, that the results from an openness regression should be taken with caution and mainly as an attempt to identify which variables are the most correlated with the openness level of an economy. Despite all, Guttmann and Richards explain Australia's level of openness based on the results they get from an openness equation.

[11] As they put it: Small countries trade more than large ones since the latter ones produce more varieties.

And not only that, they also conclude that this results outperform the ones obtained from a gravity equation since those were ambiguous in some respects. They conclude that the actual openness level of Australia is very similar to the one predicted by their openness equation, considering the geographic characteristics of that country.

We could actually think of an openness specification as a step forward from a gravity model since we want to move from a bilateral framework to a multilateral one. Coe, Subramanian and Tamirisa (2007) estimate a gravity equation that has several similarities with our openness equation. They take as their initial step a simple gravity model (based on Deardoff 1988):

$$Trade_{ij} = (Y_i Y_j)^{\alpha} C_{ij}^{\Theta}$$

Where Y_i and Y_j are each country's GDP[12] and C_{ij} are trade costs that are specified by the following equation in Coe *et al.*

$$C_{ij} = D_{ij}^{\beta'} \left(R_i R_j\right)^{\gamma'} \left(P_i P_j\right)^{\delta'} \epsilon^{\kappa' + \lambda' A_{ij} + \phi' L_{ij} + \sigma' F_{ij}}$$

Where D is the distance between countries i and j, R is remoteness, P is population and the rest of the variables are dummy ones: A takes the value of one if countries share a border, L is a dummy for same language and finally, F is a dummy for free-trade agreements between the countries. The final gravity equation is to obtain by substituting C_{ij} in the $Trade_{ij}$ equation.

$$Trade_{ij} = (Y_i Y_j)^{\alpha} \left(D_{ij}^{\beta'} \left(R_i R_j\right)^{\gamma'} \left(P_i P_j\right)^{\delta'} \epsilon^{\kappa' + \lambda' A_{ij} + \phi' L_{ij} + \sigma' F_{ij}}\right)^{\Theta}$$

A valid remark on the previous equation is that having remoteness and distance in the same specification could cause problems in a set up for openness since remoteness is a measure of weighted distance. Now, in our case we want to quantify total trade and not only bilateral

[12]We have to remember that the gravity equation is used to estimate bilateral trade and in our case we want to analyse total trade, or trade flows of a country with the rest of the world.

one, although we must say that several of the variables included in the Coe *et al.* gravity equation are part of our specification. We can say that an openness equation for country i could resemble an aggregation of bilateral gravity equations summed over all j countries leaving the i one fixed.

5.3.1 Own specification

Guttmann and Richards make it clear in their work that is not very helpful to look for guidance in the theory since there is no general theoretical model that explains openness. One thing that it is possible to do is to analyse what others have proposed or found in terms of particular effects that we should expect to observe in our results. Our primary goal is to establish a relationship between openness and several exogenous variables. In other words, we construct a model where the movements in openness to trade can be explained by different factors. Our results are obtained from the following equation, that can also be regarded as our baseline model:

$$L(Openness) = \alpha + \beta_1 L(Remoteness) + \gamma \mathbf{G} + \beta_2 (Income\ Proxy) + \beta_3 (Freedom\ for\ trade) + \epsilon \tag{5.3}$$

It must be said that our estimation takes some elements from previous works, as a matter of fact, our baseline model is based on Guttmann and Richard's model since they are able to develop a parsimonious equation for openness with good results.[13] With our estimations we first try to replicate what GR have found previously; and after having "calibrated" our model, we then start to build up new relationships that give us a better insight of openness. We try to capture the effects of distance with a remoteness variable. This variable measures how far is a country from a theoretical world trade centre.[14] Our specification includes several geographical variables such as surface area of a country, population density,

[13] So far it has not been stated but one of our objectives is trying to replicate the results from Guttmann and Richards; And by taking that as a starting point, we try to enrich their findings with new insights for an openness equation.

[14] Contrary to what Guttmann and Richards include in their study, we stick to the use of remoteness as a proxy for transport costs instead of using an "economic location" variable, which could be considered as an inverse measure of our index.

one dummy variable that signals if a country is landlocked or not, and coast length of a country. However, not all variables can be included in a single specification since some of the correlations are quite high. Equation 5.3 shows us our model that includes remoteness and a **G** matrix, which contains some of the geographical variables mentioned above and that we consider relevant to be included in our baseline specifications. Finally, we also include two more variables: an income proxy variable to the model, which could be either GDP per capita from each country or a dummy variable that takes the value of 1 when the country is a industrialized one or zero otherwise.[15] The last variable in equation 5.3 is a trade policy index variable constructed by the Institute for Economic Freedom, we take exclusively the trade-policy component of their Economic Freedom of the World Index.[16] The values of the index show a country more prepared to engage in trade as its index obtains a greater value.

The expected sign of the remoteness variable is negative. It is now a consensus that the farther countries are from each other, the lower the bilateral trade they will have. GR have shown that in the case of total trade, or openness, we have a negative relation with respect to remoteness. In the case of our landlocked dummy, we expect a negative sign. For area and population density we expect a negative sign since these variables capture the effect of market size or size of the economy: Large countries trade less than small ones. Small countries do not have the same opportunity to diversify their production, considering not only the production of several goods but also varieties, as a large country is capable to do. These results are observed empirically in Jansen and Nordås and Guttmann and Richards. The last geographic variable is coast length. This variable represents easier access to international markets as the number of km. increases. Based on the previous argument, we expect a positive sign. Finally, we have our index of trade policies (freedom for trade) and we expect a positive sign for this variable too, a higher number means that it is easier for an economy to trade.

The income level proxy variable deserves a special remark since the natural thing to expect is a positive sign, the richer the country is the more it will trade, but we have that Guttmann and Richards obtain a negative sign for this one in their openness equation. They run

[15]This classification is taken from the World Bank site.

[16]As a matter of fact, we exclude one component of the trade-policy index since it includes a ratio between actual trade and predicted trade, which is taken from an openness equation. That is the reason we remove it from our trade policy index variable.

their analysis by only using GDP per capita. In our case we also have the option of using a dummy variable that takes the value of 1 if the country is an industrialized (rich) one and zero otherwise that does not tell us how openness is affected if there are changes in the income level of a country, but it allow us to check for differences between high-income countries and the rest of them. So we have that most of the variables represent mainly barriers to openness (there are more variables with expected negative signs than positive ones).[17] There are some other variables that are not mentioned here, but as we include them in our model we describe what our expectations are for them.

5.4 Data

The data used in our estimations runs from 1981 until 2000. We use cross-section data from more than 190 countries (193 to be more precise). The variables are included as averages taken for that period of time (20-year averages). Due to problems of availability in some of the series, the number of observations varies from one specification to the other, on average our estimations include 111 observations but this could reach a maximum of 180 observations. The variables included in the estimations are the following:

- Openness (*Lopen*), which is generated by the sum of imports and exports and then divided by GDP. It is important to mention that we do some other transformations to openness before including it inside an specification. To be more precise, we add a unity to the ratio of imports and exports over GDP and then we take logs. Finally, we multiply the measure by a hundred. This is our final measure of openness included in all our regressions. Our data for exports and imports is taken from World Development Indicators (WDI) database of the World Bank.
- Remoteness (*Lremote*). It measures the distance from each country to a theoretical world trade centre. This variable, in essence, captures how far is each country from the rest of the world. For this reason the world trade centre is different for each country. We construct this measure by calculating a weighted distance measure of a country to the rest of countries that are part of our sample. The weights are constructed using

[17]We could expect a negative value in our trade policy variable, but what we have here is an index that tells us how imposed trade barriers have been reduced, and it is not a trade restrictiveness index.

each country's GDP divided by the Global GDP, which in this case is the sum of all countries' GDPs that are part of our sample. This variable is constructed using the distance database from CEPII.[18] That distance is measured taken the great circle distance between the most important cities of each country. The GDP weights are from the International Financial Statistics (IFS) from IMF.

- Area (*Larea*) is the surface in square kilometres from each country. Before this variable is included in our estimations we transform the series by taking logs of it. This data is obtained from WDI database of the World Bank.

- Population density (*Lpop den*). We also include this variable in logs in our estimations. Population density is constructed by dividing the population of a country over its area. Population is the number of inhabitants from each country, and it is given in millions of inhabitants. Source: WDI, World Bank.

- Landlockedness (*landlock*) is a dummy variable that takes the value of 1 if a country has no access to the sea and zero otherwise. In other words if the country has no coastline we have a value of 1. Source: CIA Factbook website.

- Real GDP per capita (*Lrgdpc*). This variable is included in order to control for income effects in the degree of openness. The data is collected from WDI, World Bank. It is transformed into logs before been introduced to our model.

- Industrialized countries Dummy (*highi*). This is also a dummy variable that takes the value of 1 if a country is an industrialized one, and it also represents a variable that, when it is included in the specification, controls for income effects. Source: WDI, World Bank.

- Coastline (*Lcoast*). Measures the length of coastline of each country in kilometres. All observations are obtained from CIA Factbook website. Same as in previous variables we modified this one by taking logs. There is one more thing to be remarked: we arbitrarily modify the series by shifting it upwards by one kilometre and we do not find any problem when we transform the series into the natural logarithm.[19]

[18] Website of the *"Centre D'Etudes Prospectives et D'Information Internationales"* at *http://www.cepii.fr/anglaisgraph/news/accueilengl.htm*

[19] This means that an observation with a value of zero now registers a value of one and this value is transformed into a zero entry when the log of the series is calculated. An extra remark is the fact that despite having a zero entry in countries with no coastline, we decide to include the *landlock* variable in all the specifications with *Lcoast* as regressor.

- Freedom for trade ($freetrad$). This is an index measure created by James Gwartney and Robert Lawson with William Easterly for the Economic Freedom of the World: 2007 Annual Report. In the words of the authors this variable *"measures the extent to which nations allow their citizens economic freedom. From the beginning, the freedom of people to trade internationally has been a featured area within the index"*.

- Infrastructure variable ($Linfra$). We use telephone mainlines per 1,000 people as our proxy for this variable. As before we transform the series by applying logs to it. The series is obtained from WDI, World Bank database.

As we state in each variable, all of them are in logs except for all the dummy variables and the Freedom for trade index. The estimations are done using Ordinary Least Squares. In parentheses we have the name that we give to each variable inside each specification. This is also the name we use from now on to refer to each of them.

5.5 Results

5.5.1 Baseline

Our first table of results includes what we consider our baseline model, which is a similar equation to GR's main model. The principal difference between both estimations is the fact that we include two new geographic characteristics as exogenous variables: *landlock* and *Lcoast* are these new regressors.[20] There is an additional modification to GR's model considered by us as an extra case to analyse. We run an extra set of regressions using a different income proxy variable. Instead of including *Lrgdpc* in our estimations, we use a dummy variable that takes the value of one if the country is a high-income one and zero otherwise.[21] Table 5.1 contains these results.

All the variables are significant at least at the 10% level, except for *Lrgdpc*, *Lcoast* and *landlock* when *Lcoast* is part of the regressors. We obtain a negative coefficient for *Lremote*, that is the expected sign since the farther a country is located from its economic centre of the

[20] One model includes only *landlock* and in the other we put both variables inside the specification.
[21] The classification of high-income countries is taken from the World Bank database.

Table 5.1: Baseline Results

	Dependent variable: Openness			
Variable	I	II	III	IV
Lremote	-9.86**	-9.51*	-12.28***	-12.65***
	(4.84)	(5.10)	(4.28)	(4.46)
Larea	-8.47***	-8.23***	-8.14***	-8.34***
	(0.87)	(1.11)	(0.75)	(0.90)
Lpop den	-7.00**	-6.89***	-6.98***	-7.07***
	(1.47)	(1.51)	(1.35)	(1.38)
landlock	-7.72**	-10.56	-6.71***	-4.12
	(3.68)	(8.67)	(2.53)	(7.30)
Lcoast		-0.42		0.37
		(1.17)		(0.95)
highi			-14.88***	-15.30***
			(3.82)	(3.83)
Lrgdpc	-2.33	-2.15		
	(1.48)	(1.59)		
freetrad	3.16***	3.18**	3.83***	3.77***
	(1.21)	(1.23)	(0.95)	(0.98)
Constant	268.43***	263.56***	266.69***	270.33***
	(0.5246)	(0.5420)	(0.4501)	(46.87)
Observations	111	111	118	118
R^2	0.58	0.56	0.64	0.64
RMSE	13.26	13.32	12.21	12.26

Notes: *,**,*** denote significance at the 10%, 5%, and 1% level, respectively. Standard Errors in parentheses.

world the less it trades. As GR mention, transport costs could have a bigger role in overall trade costs as trade barriers have been reduced in the previous decades by governments. Our second regressor, *Larea*, reports a negative sign and confirms that bigger countries, geographically speaking, trade less since these countries can diversify their production and depend less on imported goods. We have the opposite situation with small countries since the great majority specialize in the production of a few goods and need to import several goods that are not produced domestically. Population density also has a negative coefficient. In this case we can argue that countries with smaller populations per squared kilometre tend to have fewer opportunities to engage in within-country trade, and in terms of imported goods, the distribution of these become more difficult and expensive to achieve.

As we have stated before these equations clearly resemble the main model from GR. If we compare both results, we have that *Lpop den*, $freetrad$ and *Lremote* are significant in both studies. In our case, we have that our income proxy variable is only significant when we use the high-income dummy and not when *Lrgdpc* is included. We can also add that our income proxy variable obtains a negative sign in any case, as in GR's work. The rest of the variables also have the same sign as the one these obtain in GR's estimations, except for our variable that captures transport costs. GR use an economic location variable whilst we include a remoteness one. In their case they obtain a positive sign and we get a negative one, both of them are the expected ones.

The new variables included in our model, *landlock* and *Lcoast*, are not significant when both are part of the same specification. The former one obtains a negative sign as it indicates that countries with no access to the sea have reported lower levels of trade on average during the period of 1981-2000. The coast length is not significant in any case and it changes sign direction; however we expect a positive sign: the longer the coast length of a country the more it trades. Frankel and Romer (1999) reached the conclusion that trade intensity of a country can be affected by its geographic characteristics. We can corroborate that finding with our *landlock*'s results plus the rest of geographic variables that are present in our work and in the one from GR.

If we now compare our two sets of results, using *Lrgdpc* and *highi* as counterpart, we have that most of our coefficients are similar in magnitude except for the own income proxy variable and our remoteness variable. In the case of the income proxy variable, *highi* is very significant and greater in absolute value compared to the results of *Lrgdpc*.[22] When we use the dummy variable we are just capturing one more characteristic of each country and we have our sample divided in two groups. It could be worth trying to explore more this obvious division between countries in our sample. The result in our dummy variable could be signaling something more besides a change in the average value of trade intensity of different countries according to their income level.

5.5.1.1 Landlocked countries

Limão and Venables (1999) argue that trade costs are considerably determined by the remoteness of each country and some other geographic characteristics. However, the effects of remoteness and its geographical situation in trade costs can be alleviated or exaggerated by the infrastructure of each country. So far, we can confirm the first part of the previous statement. If we consider our *landlock* dummy variable, we have a very significant result for this one in our baseline specification. If we compare the results of our estimations when we have real GDP per capita and the ones with high-income dummy variables as proxy for income level, we have that the t statistic of *landlock* in the latter case is higher (in absolute value). This variable represents quite well the idea of having a different level of openness with respect to a country with similar characteristics except for their geographic situation. As we find in the previous section, a landlocked economy has a lower degree of openness confirming the difficulties that a country with no direct access to the sea encounters when it decides to engage in trade with some other nation.

Mbabazi, Milner and Morrisey (2006) have previously observed a low openness degree in Sub-Saharan African countries and how this is then reflected in their growth rates. They reach the conclusion that low levels of growth can be explained by a low degree of openness and high natural trade barriers. This is another example where *landlock* becomes a relevant variable. Milner and Zgovu (2006) explore in more detail the export performance of Malawi, a landlocked economy in the Sub-Saharan Africa. They identify the impact of natural barriers in the export level of a country. They also conclude that non-traditional exports barriers have an important impact in exports, and ultimately in country's openness.

[22]The difference between both coefficients is considerable high and both fit and the root mean-squared error ($RMSE$) are better for the model where *highi* is included as our income proxy.

The result we have with landlocked economies in our estimations (when this variable is not accompanied with *Lcoast*) is a very relevant example of how natural trade barriers have an impact in the level of trade openness. There is, however, something missing from Limão and Venables' first statement in this subsection: the impact of infrastructure in our measure of openness. If we consider that industrialized countries must have a higher level of infrastructure, then we can consider our income proxy also as a reference for this effect expecting a positive relation, but so far we have just obtain a negative relation between our measures of income and the level of openness.

5.5.2 Infrastructure as Income proxy

In the previous section we discussed the relevance of geographic characteristics in the level of openness, and in order to explore more what we can find in the literature, specially in the work of Limão and Venables, we consider very relevant to include a variable that can proxy for infrastructure and check their findings.[23] With this thought in our mind, we decide to run some more regressions including $Linfr$ as one of our exogenous variables. We run two different sets of regressions, the first one includes $freetrad$ as one of the regressors, the second set drops out the same variable, $freetrad$, and we continue with a similar analysis for the infrastructure variable.

[23]It is possible to see the inclusion of infrastructure as new income proxy variable and analyse the results from these estimations against the ones obtained using *Lrgdpc* and *highi*.

Table 5.2: Infrastructure as Income proxy variable

	Dependent variable: Openness					
Variable	I	II	III	IV	V	VI
$Lremote$	-8.75*	-7.61	-11.60**	-11.71**	-12.43***	-11.23**
	(4.79)	(5.16)	(4.47)	(4.79)	(4.44)	(4.62)
$Larea$	-8.27***	-7.64***	-8.01***	-8.07***	-7.13***	-6.55***
	(0.83)	(1.04)	(0.77)	(0.96)	(0.58)	(1.17)
$Lpop$ den	-6.91***	-6.63***	-6.95***	-6.97***	-6.71***	-6.78***
	(1.52)	(1.51)	(1.34)	(1.36)	(1.17)	(1.06)
$landlock$	-5.45*	-12.66*	-5.45*	-4.81	0.38	-3.68
	(3.34)	(7.83)	(2.78)	(7.43)	(2.72)	(7.18)
$Lcoast$		-1.08		0.10		-0.69
		(1.11)		(1.02)		(0.96)
$highi$			-15.68***	-15.76***		
			(3.78)	(3.83)		
$Linfr$	-0.16	0.24	0.98	0.95	1.54**	1.84**
	(0.99)	(1.12)	(0.99)	(1.05)	(0.66)	(0.75)
$freetrad$	2.17**	2.22**	3.29***	3.30***		
	(1.03)	(1.04)	(1.14)	(1.14)		
Constant	244.00***	231.27***	258.28***	259.51***	265.85***	254.99***
	(51.06)	(54.43)	(47.02)	(50.16)	(44.43)	(45.81)
Observations	118	118	118	118	171	171
R^2	0.58	0.58	0.64	0.64	0.53	0.53
RMSE	13.20	13.20	12.22	12.27	14.13	14.15

Notes: *,**,*** denote significance at the 10%, 5%, and 1% level, respectively. Standard Errors in parentheses.

The first four columns with results (I to IV) in table 5.2 are specifications that include $freetrad$, the last two columns are the results for regressions that make use of a greater sample (excluding $freetrad$ from the regression).[24] The first thing to notice when $freetrad$ is part of the model, besides the number of observations, is that $Linfr$ is not significant if the former is included in the estimations. In general terms most of the variables not only obtain the expected sign but they also report a coefficient similar in magnitude to what we have seen in the baseline case. The only exceptions to the previous are: *Lremote*, $Linfr$, $freetrad$ and *landlock* in some cases show differences in their coefficients.

The case of *Lremote* is observed also in previous tables. When we include *highi*, there seems to be a greater impact of remoteness in our estimations, a similar thing happens when $freetrad$ is left out of the model. Our infrastructure variable behaves in a similar way since it is not significant when our trade policy variable is part of our model, and even in some cases $Linfr$ reports a negative sign. Now, when $freetrad$ is not included, then the infrastructure variable is significant and positive. The *landlock* dummy variable is also affected by the presence or omission of some other regressors; it is affected by the inclusion of *Lcoast*, which is not significant once more in our estimations, and also when the trade policy variable is not part of the specification (even reporting a positive sign and being not significant).

The inclusion of $Linfr$ seems to be redundant whenever $freetrad$ is part of the equation. However, $Linfr$ is an interesting option to control for income level effects. Perhaps its performance could improve if we are able to find a different variable to control for trade policy effects like an index that focuses only in import and export taxes.

5.5.3 Baseline model, excluding the trade policy variable

One of our concerns after of our first sets of results is the number of observations included in our estimations. In GR we find that they have a minimum of 101 observations, but this number could go up to 645 observations in their pool cross-section results. In our case we do not make use of pooled OLS estimations since our observations are 20-year averages for just one time period. Instead of doing 5-year averages of our observations, we decided to

[24]Columns V and VI from table 5.2 are the complement to the last two columns in table 5.3.

try a different approach by just estimating a similar model to what we have above with only one difference: we remove $freetrad$ from our model. With this modification our sample can now reach 172 observations with a minimum of 150. We also can check how robust are the results when we remove $freetrad$ for the remaining variables in the estimation; all this based in the results obtained for infrastructure in the previous section. The results are reported in table 5.3.

Table 5.3: Greater sample case (no *freetrad* regressor included)

	Dependent variable: Openness					
Variable	I	II	III	IV	V	VI
Lremote	-13.45***	-13.11***	-19.06***	-19.86***	-14.12***	-13.74**
	(4.73)	(4.85)	(3.89)	(3.91)	(4.28)	(4.46)
Larea	-7.28***	-7.17***	-7.52***	-7.73***	-6.85***	-6.76***
	(0.60)	(0.66)	(0.53)	(0.58)	(0.57)	(0.64)
Lpop den	-6.80***	-6.74***	-7.21***	-7.31***	-6.80***	-6.75***
	(1.26)	(1.27)	(1.09)	(1.08)	(1.06)	(1.06)
landlock	-2.11	-3.88	-2.74	1.44	-0.31	-1.79
	(3.28)	(5.76)	(2.89)	(5.36)	(2.57)	(5.39)
Lcoast		-0.28		0.63		-0.23
		(0.78)		(0.71)		(0.74)
highi			-6.24***	-7.17**	-12.73***	-12.5***
			(2.65)	(2.97)	(3.29)	(3.43)
Lrgdpc	0.84	0.96				
	(0.84)	(0.91)				
Linfr					2.97***	3.02***
					(0.75)	(0.78)
Constant	276.93***	273.5***	337.14***	342.63***	274.59***	271.43***
	(49.29)	(50.36)	(37.28)	(37.21)	(42.82)	(43.98)
Observations	150	150	172	172	171	171
R^2	0.51	0.51	0.53	0.53	0.57	0.53
RMSE	14.48	14.53	14.14	14.16	13.61	14.12

Notes: *,**,*** denote significance at the 10%, 5%, and 1% level, respectively. Standard Errors in parentheses.

The first thing to notice besides the lack of a trade policy variable is the inclusion of $Linfr$ in specifications V and VI. The infrastructure variable is included as an additional one in order to control in a better way income effects.

Most of the variables are significant except for *landlock*, *Lcoast* and *Lrgdpc*. In the case of GDP per capita, we have to add that this variable changes sign to obtain a positive one now. If we continue our analysis of income proxy variables, we can add that the new variable, $Linfr$, included is quite significant and with a positive coefficient. In their work, GR expect a positive sign for their income proxy variable. In their main model they are not able to obtain this sign. However, they are able to get a positive relation between openness and GDP per capita by controlling for different effects not considered in their first set of results or by considering possible non-linear effects in the relationship of income levels and trade intensity. In our case, as mentioned above, we obtain this result by just expanding our sample and considering countries with no observation for our $freetrad$ variable.

The results of infrastructure (in order to capture income level effects) support the idea of a positive relation between openness and an income proxy variable. In the case of $Linfr$, we have a significant result. However, the result for *highi* is again a negative coefficient.

There's another relevant difference between this set of results and the ones in table 5.1. The coefficient of *Lremote* is greater in absolute value in the estimations that omit the trade policy variable. Most of the countries that now are part of the estimation are either middle or low-income countries. It seems as if remoteness becomes even more relevant for these nations to access world markets.

5.5.4 Structural Breaks

There are two variables that affect the results of the rest when these are part of the model. These two are $freetrad$ and *highi*. This has raised some concerns about the stability of our regression results. In order to check for this issue, we decide to run stability tests to our baseline model and some other specifications. We test for a structural break into two cases. The first one involves the division of our sample in high-income countries and a second subset that includes both middle and low-income countries. The second stability test is run between countries that have an observation for $freetrad$ and the ones that do not.

The tests are calculated in STATA using the "test"' command, for this reason what we obtain is an "F"'-test and not the χ^2 statistics used regularly in Chow tests. The "F"'-test is generated from a regression that includes all exogenous variables plus a dummy constructed by us and divides the sample into the relevant groups that are tested for a structural break, and all the exogenous variables multiplied each by this dummy. The regression is run and then the "F"-test is applied to all the interaction terms (dummy times exogenous variable) and the dummy. The null hypothesis is that all these are equal to zero. We do not have a structural break when the null cannot be rejected.

Table 5.4: Structural stability between high-income countries and the rest

Variable	I	II	III	IV	V	VI	VII	VIII
Lremote	✓	✓	✓	✓	✓	✓	✓	✓
Larea	✓	✓	✓	✓	✓	✓	✓	✓
Lpop den	✓	✓	✓	✓	✓	✓	✓	✓
landlock	✓	✓	✓	✓	✓	✓	✓	✓
Lcoast		✓		✓		✓		✓
Lrgdpch	✓	✓	✓	✓				
highi	✓	✓	✓	✓	✓	✓	✓	✓
Linfr					✓	✓	✓	✓
freetrad			✓	✓			✓	✓
Constant	✓	✓	✓	✓	✓	✓	✓	✓
Stability test								
F(Ex. vars; df)	(6;138)	(7;136)	(7;97)	(8;95)	(6;159)	(7;157)	(7;104)	(8;102)
F-Statistic	4.00	3.66	3.48	3.23	6.79	5.62	5.54	4.94
Prob>F=	0.001	0.001	0.002	0.003	0.00	0.00	0.00	0.00
	Break	Break	Break	Break	Break	Break	Break	Break

Table 5.4 contains the models tested for a structural break between high-income countries and the rest of the sample. The tests give evidence in favor of the presence of a structural break in our sample. The first four columns are testing for a structural break in specifications based in the model observed in table 5.1, columns I and II. The differences between columns I and II with III and IV (in table 5.4) is that in the last two columns we include the trade policy variable, however, in all cases we have statistical evidence of a structural break between developed countries and the rest of them. The last four columns in table 5.4 are the same as the previous four with the exception that the last ones also include an infrastructure variable in the model. Once again the tests signal for a structural break.

Table 5.5: Structural Stability. Freedom for trade case

Variable	I	II	III	IV	V	VI	VII	VIII	IX	X
Lremote	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Larea	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Lpop den	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
landlock	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Lcoast		✓		✓		✓		✓		✓
Lrgdpch	✓	✓								
highi					✓	✓	✓	✓	✓	✓
lowin									✓	✓
Linfr			✓	✓	✓	✓			✓	✓
freetrad dum	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Constant	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Stability test										
F(vars.,d.f.)	(6,138)	(7,136)	(6,159)	(7,157)	(7,157)	(8,155)	(6,160)	(7,158)	(8,155)	(9,153)
F-Stat.	1.15	1.01	1.26	1.03	1.45	1.25	2.31	2.10	1.22	1.08
Prob.>F=	0.38	0.42	0.28	0.41	0.19	0.27	0.04	0.05	0.29	0.38
Break?	No	No	No	No	No	No	at 5%	at 5%	No	No

The picture depicted in table 5.5 is different to the case of high-income countries and the rest. There is no evidence of a structural break between countries with observations in our trade policy variable and the ones that do not. However, columns VII and VIII report a structural break at the 5% level. It should be noted that this model includes our dummy variable for high-income countries as the income proxy variable. It seems necessary to run some extra tests focusing only in developing and less developed countries, one more structural test for these countries, in order to have a better understanding.

Table 5.6: Structural Stability. Freedom for trade (Middle and low-income countries)

Variable	I	II	III	IV	V	VI
Lremote	✓	✓	✓	✓	✓	✓
Larea	✓	✓	✓	✓	✓	✓
Lpop den	✓	✓	✓	✓	✓	✓
landlock	✓	✓	✓	✓	✓	✓
Lcoast		✓		✓		✓
Lrgdpch	✓	✓				
lowin					✓	✓
Linfr			✓	✓	✓	✓
freetrad dummy	✓	✓	✓	✓	✓	✓
Constant	✓	✓	✓	✓	✓	✓
Stability (F) test						
F(vars., d.f.)	F(6,110)	F(7,108)	F(6,130)	F(7,128)	F(7,128)	F(8,126)
Statistic	0.92	0.83	0.92	0.86	0.91	0.87
Prob >F=	0.485	0.563	0.484	0.537	0.502	0.545
Break?	No	No	No	No	No	No

The specifications tested in table 5.6 are the same as the ones included in table 5.5, except for columns V to VIII since those include *highi* as exogenous variable. The results in table 5.6 show evidence of structural stability in our estimations only considering middle and low-income countries.

To summarize the results we obtain in this section, we have that the structural break tests point to the existence of a break in our sample between high-income countries and the rest. It is also tested if there is a structural break between countries that include an observation of our trade policy variable and those that do not. The tests for the whole sample indicate that there is no break in most of the specifications. In order to confirm the existence of structural stability we run the tests again, but this time only using a subsample (removing high-income countries from the complete sample). These results indicate no signs of structural breaks.

5.5.5 Developing Countries Only

As we mentioned before the tests in the previous section confirm the structural stability of our specifications when these are estimated using only middle- and low-income countries, but now it is necessary to estimate all these and check if there are considerable changes in our results caused by the fact of using a reduced sample.

Table 5.7: Baseline Results, subsample case

	Dependent variable: Openness			
Variable	I	II	III	IV
Lremote	-17.19***	-18.72***	-16.34***	-17.4***
	(5.27)	(5.29)	(5.63)	(5.88)
Larea	-6.96***	-7.39***	-7.51***	-8.19***
	(0.66)	(0.68)	(1.03)	(1.35)
Lpop den	-7.36***	-7.70***	-6.79***	-7.32***
	(1.28)	(1.25)	(1.78)	(1.92)
landlock	-0.40	6.8	-6.26	1.28
	(3.31)	(5.97)	(3.39)	(9.37)
Lcoast		1.16		1.14
		(0.81)		(1.33)
Lrgpdc	4.46***	4.13***	1.15	0.84
	(1.22)	(1.25)	(1.52)	(1.61)
freetrad			3.85***	3.65**
			(1.41)	(1.43)
Constant	284.04***	298.19***	285.60***	300.62***
	(55.71)	(55.36)	(63.87)	(68.49)
Observations	122	122	84	84
R^2	0.57	0.58	0.62	0.62
RMSE	14.11	14.10	12.93	12.96

Notes: *,**,*** denote significance at the 10%, 5%, and 1% level, respectively. Standard Errors in parentheses.

The first thing to notice is the obvious lack of the variable *highi* as our income proxy variable. In table 5.7 *Lrgdpc* is our only variable that captures the effects of different income levels. If we compare the results of this table to the ones from our baseline model, we have that the coefficient of *Lremote* is greater in absolute value. This result just confirms what we have just mentioned in previous paragraphs: middle- and low-income countries suffer greater modifications in their levels of openness when there is a change in their remoteness index. There is a very well documented debate in the literature about what some authors called "the death of distance". These authors argue that the globalization process has made transport costs negligible in total trade costs. However, there are others that claim the opposite by showing that trade costs are still relevant in the decision of trading or not.[25] Perhaps, the main problem is the inclusion of different type of countries (high, middle and low-income) in the sample since the impact of distance, or similar measures, could be considerably different according to the income level of the economy.

The fit of the model and the $RMSE$ of our estimations using a subsample are better than the ones from the whole sample estimations. In previous estimations we observe considerable changes in this coefficient when $highi$ and/or $freetrad$ are part of the specification. We still observe some differences now between models that include our trade policy variable and the ones that do not, but the changes are now marginal.

The coefficient for *Lrgdpc* is now positive. We have a positive relation between income levels and openness. This result is also found by GR in their work, but they follow a different approach to achieve this result by including some other exogenous variables such as price indices or even consider estimations that capture non-linear effects into their equations. The results of their main equation show a negative sign for their income proxy variable. In our case, we find the same sign for the coefficient of *Lrgdpc* when we do our estimations for the whole sample, including high-, middle- and low-income countries. However, we are able to obtain a positive relation between GDP per capita and openness by just restricting our sample to developing and less developed countries.

If we use $Linfr$ instead of *Lrgdpc* as our income proxy variable, we find similar results for most of our variables. In the case of infrastructure, this variable is only significant when $freetrad$ is not part of the model, same result as before. Despite the fact if it is significant or not, its coefficient is positive.

In general terms we have a better fit of the models that use a subsample (only middle and low-income countries) compared to the results of regressions where the whole sample is used (including high-income countries). The results for our models using just middle and low-income countries seem to give a better picture of our openness equation. Before we finish this section, it is important to mention that we do not report the results for the other subsample (including only high-income countries) as we consider that the results are not relevant as several coefficients are not significant(the subsample is rather small with less

[25] See, for example, Disdier and Head (2003) and Buch, Kleinert and Toubal (2003).

Table 5.8: Infrastructure results, subsample case

	Dependent variable: Openness			
Variable	I	II	III	IV
Lremote	-13.37***	-14.09***	-13.30**	-14.70**
	(5.06)	(5.17)	(5.43)	(5.75)
Larea	-6.85***	-7.01***	-7.34***	-8.00***
	(0.65)	(0.69)	(0.94)	(1.18)
Lpop den	-7.41***	-7.52***	-6.83***	-7.30***
	(1.15)	(1.12)	(1.71)	(1.76)
landlock	-0.19	2.52	-4.94	2.15
	(2.74)	(5.57)	(3.01)	(8.23)
Lcoast		0.43		1.09
		(0.79)		(1.15)
Linfr	3.29***	3.20***	1.37	1.09
	(0.80)	(0.82)	(1.08)	(1.14)
freetrad			3.56***	3.49***
			(1.34)	(1.33)
Constant	269.46***	275.40***	261.65***	277.52***
	(50.90)	(51.33)	(58.65)	(62.12)
Observations	142	142	91	91
R^2	0.58	0.58	0.65	0.66
RMSE	13.81	13.85	12.53	12.55

Notes: *,**,*** denote significance at the 10%, 5%, and 1% level, respectively. Standard Errors in parentheses.

than 30 observations available); however, we include the results of three more specifications (baseline models) for this subsample (high-income countries) in the appendix of the chapter (Appendix C).

5.5.5.1 Graphic representation of the break between High-income countries and Developing economies

Before we start analysing a different specification, we consider it is important to report graphically our findings related to the differences between industrialized economies and the rest of countries in our sample. In order to obtain a proper representation of our results we do as follows: We first observed the differences in the coefficient of the real GDP per capita of our openness equation. For this reason we use the results obtained for this variable in three different estimations.

The first one is the one estimated using the complete sample of countries, for the second one we take the coefficient of the regression using a reduced sample that does not include rich countries, and the final one makes use of the real GDP per capita's elasticity obtained from the high-income subsample regression.[26] The next step is just calculated the impact of $Lrgdpch$ on trade openness for each country (multiply the estimated coefficient of each regression by the observation of each country). The final step is to sort the impact of $Lrgdpch$ from the smallest result to the highest one in order to continue by creating a plot of the new-sorted series.

[26]The results of the high-income countries' subsample are included in the appendix of this chapter (Appendix C).

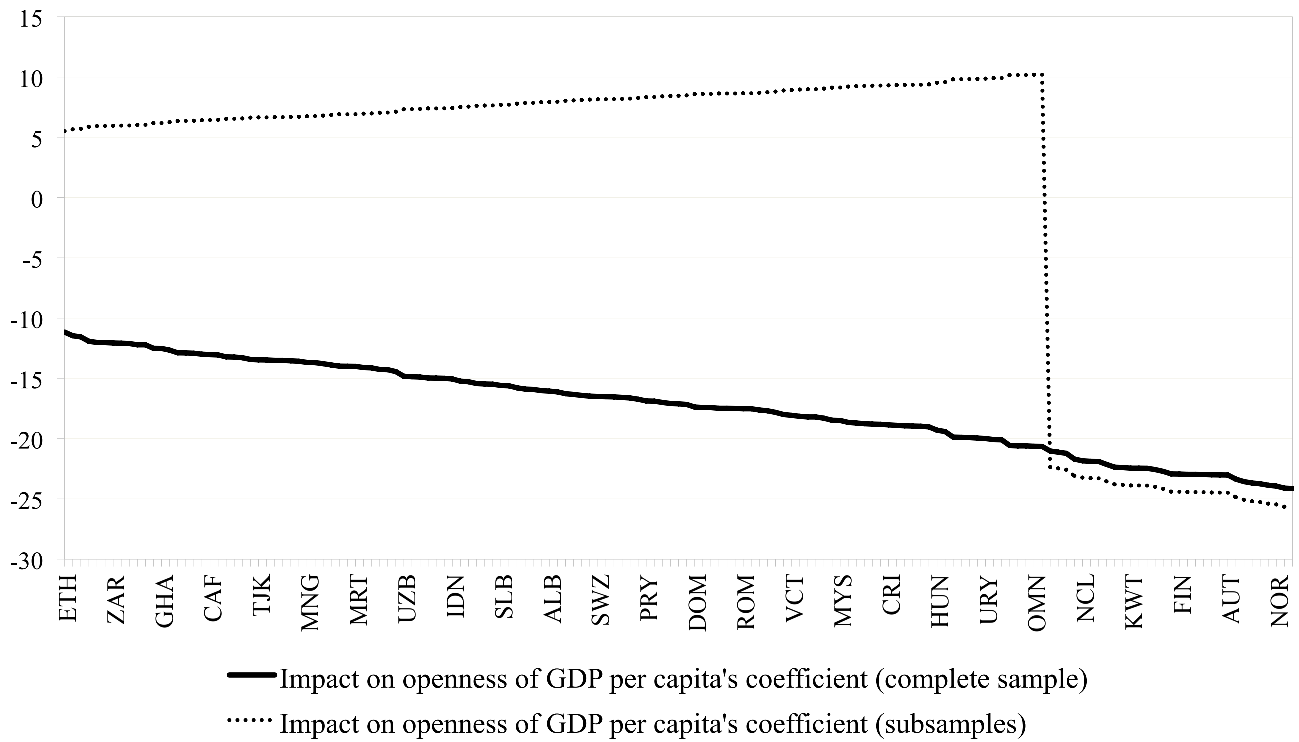

Figure 5.1: Structural break between High-income countries and the rest of the Economies. Elasticities obtained from Baseline Model+*freetrad*.

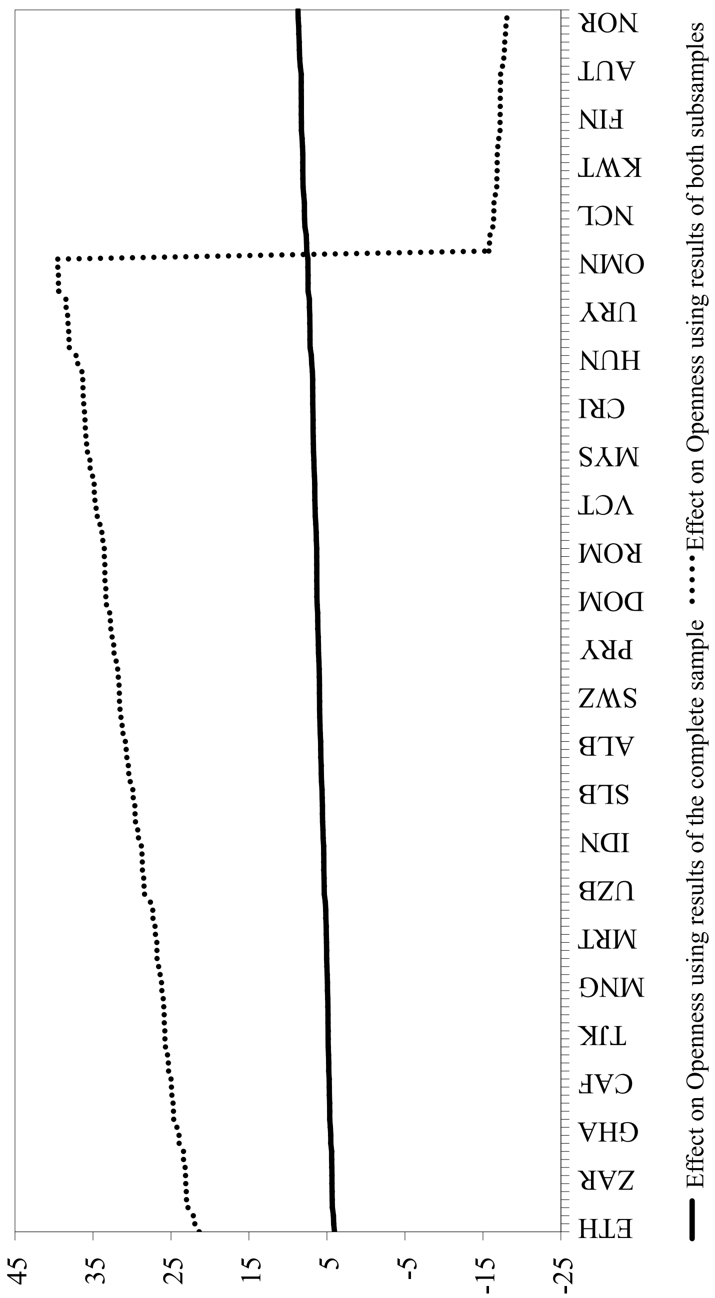

Figure 5.2: Structural break between High-income countries and the rest of the Economies. Elasticities obtained from Baseline Model.

In figures 5.1 and 5.2 we observe that the impact of *Lrgdpch*, obtained from our complete sample regression, is depicted by a solid line with a constant slope (in the case of the coefficient taken from the baseline model plus $freetrad$ we find a negative slope, and in the other case, removing $freetrad$, the slope is close to zero). The other line (dotted one) shows depicts a jump that represents the different impact of *Lrgdpch* on openness according to the income level of the subsample estimated.

The first part represents the impact of developing and less developed countries (positive slope) and the final part correspond to the results of high-income economies (negative slope). In conclusion, the impact of the variable *Lrgdpch* is opposite in direction on openness according to the income level of a country, and this difference is significant enough to be detected by the tests we apply to our specifications in the previous section.[27]

5.5.5.2 A positive relation between real GDP per capita and Openness

In Guttmann and Richards, the expected sign for real GDP per capita in an openness equation is a positive one. The authors include this variable as a proxy for economic development of the nations included in their sample, we decide to follow them and include this variable to capture the same effect in our estimations. In our basic results we obtain a negative sign for the coefficient of this variable (GR obtain the same result in their first set of regressions).

It is difficult to compare our results with previous studies as most of the literature is focused on the relationship between economic growth and trade openness. For this reason, we take as a reference the findings of the growth literature. Some authors have found that the relationship between economic growth and openness is not always positive. Rodriguez and Rodrik (2000) and Rodrik *et al.* (2004) are part of the studies that have a more skeptical view. These two argue that the quality of institutions is a more relevant variable than openness in income variations of an economy. In the former, the authors argue that the measures of openness are often poor proxies for trade barriers, or are highly correlated with other causes of economic performance, or have no link to trade policy. The latter study finds

[27]We include two more figures in appendix C to represent the impact of our baseline model (with and without $freetrad$ in all the countries considering the three results available for the coefficient of *Lrgdpch* (complete sample and the other two subsamples.

that more favourable geography affects income levels through the quality of institutions and not through trade integration.[28] Sarkar (2007) argues that it is not possible to observe a positive relation between openness and growth for all countries at all time periods. He finds support for the hypothesis that besides middle-income countries the rest of the countries in his sample exhibit no positive long-term relationship.

Nevertheless, there are several empirical works that find evidence to support a positive relation between income changes, GDP growth, and openness. Acemoglu *et al.* (2002) show that greater access to trade may facilitate growth by inducing the adoption of institutions that protect property rights. Sachs and Warner (1995) find that growth is positively related to openness.[29] Dollar and Kraay (2004) find that trade increases the income of the poor. Panagariya (2004) argues that countries perform better with trade openness than with import substitution policies. As a final example, we have the work of Romalis (2007), where he shows that the reduction of trade barriers in developed countries increases trade activity of developing countries. This induced trade expansion causes acceleration in the growth rate of developing countries.[30]

In our work we obtain specific results for the existing relationship between income levels and trade openness; and we can establish the following relationships: We find a negative relation between economic development, using as proxy variable GDP per capita, when our estimations include all type of countries (high, middle and low-income countries). This negative sign is also observed when we include a dummy variable to divide our sample in high-income countries and the rest. However, we find a positive relationship between income levels, captured by GDP per capita, and openness when we restrict our sample to middle and low-income countries.[31]

In summary, before running any of our regressions we expect a positive relation for income levels with openness, similar to what GR expect in their estimations; but, after a more

[28] The work of Rodrik *et al.* does in fact analyse the relationship between income levels (the authors also use the term "development") and openness.

[29] In the case of Sachs and Warner's work, the measure of openness is based on a number of policies that affect international economic integration.

[30] It is important to remark, however, that more than one of the previous works mentioned above include in their estimations as their growth variable the natural logarithm of GDP per capita in levels and not the observed change in time.

[31] We also find a positive relationship between our income proxy variable and openness when we include in the model $Linfr$ to control for income levels effects.

detailed analysis of our results, we conclude that the relationship between these two variables is as simple as expected in the beginning of our study. Our results support the idea of a positive relation mainly for middle and low-income countries.

5.5.6 Trade Policy variables

In our baseline estimations we include a trade-policy variable that allows us to capture the effects of imposed trade-barriers from each country in their level of openness. The variable we use to proxy for this is an index constructed for and distributed by the Economic Freedom of the World, as we mention earlier in our work. Despite the good results (in terms of statistical significance) of this variable in our estimations, we feel that it is important to analyse our results using a different measure of trade policy. This section must be seen as a robustness check for our basic results and at the same time to show that our first choice for the trade-policy proxy variable is the one delivering the best results (in terms of statistical significance and economically speaking).[32]

We replace our "Freedom to Trade" variable with two different types of indexes. The first one is constructed by the World Bank as part of its research project "Distortions to Agricultural Incentives" by measuring differences between the price of traded goods in the border and the ones charged by retailers. The second measure that we use as a robustness check is a globalization index constructed using the data set from Dreher (2006) and updated by Dreher, Gaston and Martens (2008).

Before we explain the with more detail the construction of the new trade-policy proxy variables considered and the regression results, it is important to highlight once more that we consider "Freedom to trade" our best proxy to control for imposed trade barriers. However, it is worthwhile to investigate the impact of estimating our specifications using alternative trade barrier proxies, and we get the opportunity to check the robustness of our basic results. For this reason we discuss the main findings of our estimations using these two alternatives in advance.

[32]De Hann, Lundström and Sturm show that not only the index for economic freedom constructed by the Institute for Economic Freedom is widely used and also a reliable index to control, in our case, for trade-policy effects in our empirical exercises.

In general we find that remoteness, the area of a country and its density are also relevant exogenous variables (we obtain the expected sign with significant coefficients) with these specifications, but the rest of the variables obtain mixed results. In particular the new trade-policy variables, in the case of the KOF index, the results are not significant and with the opposite sign to the expected one, which support even more our decision of using "Freedom to Trade" as our trade-policy proxy variable.

5.5.6.1 World Bank trade-policy variable

The measures constructed by Anderson *et al.* (2009) are distortions for global trade policy. They try to measure direct protection or taxation to individual agricultural industries, although they complement these measures with the ones from industries that produce non-agricultural traded goods. They mention that the most common distortion to competing imports is an add valorem tax, a tariff. And if the tariff on the imported good is the distortion, its effect on producer incentives can be captured as the nominal rate of assistance to output conferred by border price support (NRA), which is the unit value of production at the distorted price less its value at the undistorted free market price expressed as a fraction of the undistorted price:

$$NRA = \frac{EP(1+t_m) - EP}{EP} = t_m \tag{5.4}$$

Where E is the exchange rate, P is the foreign currency price of the product in the international market. The NRA calculated for all the products Anderson *et al.* analysed in their work is our new proxy for trade policy variable. What the NRA variable is trying to capture is the difference between prices of a good at international markets and in a foreign country. Hence, the higher the value of the NRA measure, the greater the distortion is, and the harder is for a foreign product to be consumed in the country.

We should mention that the number of countries included in Anderson *et al.*'s work is not as big as with our previous variable used, "Freedom to trade", and hence our sample available to run the regressions could be reduced considerably.

5.5.6.2 KOF Index of Globalization

The economic globalization index is our second trade policy variable that we use in order to check the results obtained in our baseline specification when we use the Freedom for trade variable. This index is different to what we have with the NRA measure constructed but similar to the "Freedom to trade" index we implement at the baseline estimation.

The KOF Index of Globalization is divided into three parts: economic, social and political globalization. We are only interested in the economic globalization part of the index. This is also divided into two parts: Actual flows and Restrictions. From these two we consider the last one as a proxy for our trade policy variable. The Restrictions part from the Economic Globalization Index includes hidden import barriers, mean tariff rate, taxes on international trade (percent of current revenue) and capital account restrictions.

Contrary to what we have with the NRA measure, we have more countries considered inside the index database, hence we get more observations available to run our regressions using the KOF index rather than the Freedom for trade one. The part that we are use for our estimations is the restrictions index, the scale for this one is as follows: from 1 to 10 it signals that a country has more trade restrictions with a value closer to 1.

5.5.6.3 Results

The regressions run using a different trade policy variable are taken from: a) our baseline model; b) the model without high-income countries as part of the sample; c) a set of regressions where our infrastructure variable is our proxy for income effects. The next four tables, tables 5.9 to 5.12, show the results of our baseline regressions using these two new trade policy variable in our specifications.

The estimation results in table 5.9 include the new trade policy variable obtained from the World Bank project run by Kym Anderson, the distortions to agriculture incentives. In this case we use the nominal rate of assistance NRA calculated for a bundle of non-agricultural goods that are traded. The coefficient for this variable is significant in 3 of the 4 cases, and it signals for a negative relation with trade openness. The greater the natural rate

Table 5.9: Results, using Trade Policy var. from World Bank project

	Dependent variable: Openness			
Variable	NRA nonag	NRA nonag	NRA nonag	NRA nonag
Lremote	-10.02*	-8.66	-11.81**	-9.81
	(5.70)	(6.09)	(5.21)	(6.23)
Larea	-7.23***	-7.52***	-8.84***	-8.14***
	(1.26)	(1.22)	(1.41)	(1.55)
Lpop den	-3.99**	-3.92**	-4.35**	-4.11**
	(1.69)	(1.79)	(1.73)	(1.87)
landlock	-0.35	-1.30	21.4*	5.6
	(4.39)	(4.28)	(11.28)	(10.62)
Lcoast			2.94**	0.97
			(1.40)	(1.42)
Lrgdpc	-1.86		-3.18**	
	(1.30)		(1.30)	
Trade policy	-41.42**	-26.14*	-42.40**	-25.79
	(19.35)	(15.83)	(18.51)	(15.76)
Linfr		-0.27		–0.66
		(1.07)		(1.14)
Constant	260.22***	237.29***	284.70***	249.84***
	(59.58)	(59.84)	(55.76)	(62.58)
Observations	62	66	62	66
R^2	0.52	0.54	0.55	0.54
RMSE	12.21	12.20	11.95	12.26

Notes: *,**,*** denote significance at the 10%, 5%, and 1% level, respectively. Standard Errors in parentheses.

of assistance is, the lower the trade flows a country experiences. This sign is in line with our expectations since a greater number in NRA represents a major difference between a good's price at the border and the price of the same good but now charged by retailers to consumers.

Despite the good results on the variable NRA, we must say that this does not generalize to the rest of the variables. *Larea* and *Lpop den* are very significant as in previous estimations. Remoteness obtains a similar coefficient in terms of sign and magnitude, but it is significant only in half of the cases. The rest of the variables (*landlock* , *Lcoast*, *Lrgdpc* and $Linfr$) are not significant in any of the four specifications run, or they obtain the opposite sign to the expected one. Finally, the number of countries included in the sample is just above half of what we have using $freetrad$ (66 vs. 118). The relevant point here is that important variables such as *Lremote*, *Larea* and *Lpop den* are in line with our previous results in a smaller sample.

In table 5.10 we have the results of the estimations using now as trade policy variable the KOF globalization index, actually it is just the index for trade restrictions. As we explain above, trade restrictions are lower as the number of the index gets closer to 10, for this reason we expect a positive value for the coefficient of this variable. However, the results for the estimations report a negative sign in all regressions and they are not significant in any case. These variables *landlock*, *Lrgdpc* and *Lcoast* are also not significant in any of the four regressions, although in the case of the last two we have the expected sign.

There are some good results, though, that should be mentioned and the first one is that *Lremote* is significant at least at the 5 percent level and with a similar magnitude in its coefficient in all regressions. Infrastructure is also significant and with the correct sign in both of the equations in which it replaces *Lrgdpc* as our income proxy variable. Finally, the number of observations increases even when we compare these estimations with our original baseline ones since we have, in the best of the cases, 33 extra countries to reach 151 observations. Once more we are able to observer the robustness of our first estimations in the results of *Lremote*, *Larea* and *Lpop den*, but the results for the new trade policy variable are rather disappointing.

Since we encounter that there is a structural break between the results of high-income

Table 5.10: Results with KOF globalization index

	Dependent variable: Openness			
	Trade Restrictions			
Variable	I	II	III	IV
Lremote	-13.48***	-12.10***	-13.16***	-11.00**
	(4.78)	(4.55)	(4.92)	(4.83)
Larea	-7.35***	-7.27***	-7.20***	-6.89***
	(0.70)	(0.67)	(0.89)	(0.84)
Lpop den	-6.81***	-6.68***	-6.75***	-6.50***
	(1.37)	(1.23)	(1.37)	(1.22)
landlock	-1.72	0.76	-3.85	-4.72
	(3.79)	(2.95)	(8.89)	(7.85)
Lcoast			-0.32	-0.81
			(1.16)	(1.06)
Lrgdpc	1.34		1.46	
	(1.14)		(1.23)	
KOF restric	-0.65	-1.07	-0.63	-1.02
	(0.86)	(0.73)	(0.86)	(0.74)
Linfr		2.17***		2.41***
		(0.80)		(0.87)
Constant	277.80***	267.97***	274.33***	257.88***
	(49.58)	(45.30)	(51.23)	(47.68)
Observations	132	151	132	151
R^2	0.50	0.53	0.50	0.53
RMSE	14.63	14.15	14.68	14.17

Notes: *,**,*** denote significance at the 10%, 5%, and 1% level, respectively. Standard Errors in parentheses.

Table 5.11: Results w/ high-inc. dum. & diff. trade policy vars.

	Dependent variable: Openness			
Variable	NRA nonag	NRA nonag	Trade rest.	Trade rest.
Lremote	-10.08*	-13.38**	-12.97***	-12.79***
	(5.64)	(5.40)	(4.56)	(4.75)
Larea	-7.38***	-9.00***	-7.08***	-7.02***
	(1.04)	(1.26)	(0.65)	(0.82)
Lpop density	-4.15***	-4.70***	-6.71***	-6.69***
	(1.49)	(1.62)	(1.14)	(1.14)
landlock	-0.50	17.92*	-0.18	-1.05
	(3.25)	(9.79)	(2.83)	(7.91)
Lcoast		2.58**		-0.13
		(1.29)		(1.06)
highi	-14.11***	-16.63***	-10.99***	-10.88***
	(4.40)	(4.68)	(3.39)	(3.52)
Trade policy	-29.57*	-29.28*	-0.51	-0.51
	(15.94)	(15.38)	(0.75)	(0.75)
Linfr	1.91	1.27	3.07***	3.1***
	(1.31)	(1.25)	(0.87)	(0.91)
Constant	244.11***	278.63***	269.30***	267.67***
	(54.79)	(53.88)	(45.24)	(46.79)
Observations	66	66	151	151
R^2	0.61	0.63	0.56	0.56
RMSE	11.27	11.03	13.80	13.85

Notes: *,**,*** denote significance at the 10%, 5%, and 1% level, respectively. Standard Errors in parentheses.

countries and the rest of them, we decided to report in a different table results of estimations including a dummy variable for high-income countries. This variable is very significant as we observe in table 5.11. Here we include specifications with both new trade policy variables, the first two columns report the results using the variable from the World Bank project and the next two include the one from the KOF globalization index. The trade policy variable is significant only in the first two columns, using NRA, and the results for the trade restrictions index part of the KOF index are again reporting a negative sign and are not significant.

The dummy variable is also very significant and reports a negative sign with a similar coefficient to the one obtain in the baseline estimations. In the case of the rest of the variables we have that $Linfr$ is only significant when we use the KOF index as trade policy variable, but when we include the one from the World Bank we now get a positive sign for infrastructure, which is the expected one. We confirm the same result we obtain using our preferred trade-policy variable (Freedom to trade) in which our income levels proxy variable obtains a negative result that represents a break between high-income countries and the rest of economies in our sample. At the same time, we corroborate the robustness of our findings for *Lremote*, *Larea* and *Lpop den* in these specifications.

The last table in this subsection, table 5.12, include results from specifications similar to the baseline one but the regressions use a subsample, removing high-income countries from the complete sample. The only differences that we find in this set of results are observed in columns three and four, using KOF trade policy variable, as the sign of this variable is now positive, not significant still, but we have the expected sign. *Lrgdpc* reports a positive sign in all cases and it is significant when the trade policy variable is trade restrictions index from the KOF globalization one.

5.5.7 Instrumental Variables Framework: GDP per capita instrumented

Over the previous decades there has been a debate in the literature on the causality between openness and income levels (GDP per capita case). As some authors have described it: trade openness is likely to be partially caused by growth or other factors that may have a direct

Table 5.12: Results w/ different trade policy variables (Subsample)

	Dependent variable: Openness			
Variable	NRA nonag	NRA nonag	Trade rest	Trade rest
Lremote	-15.69**	-18.56***	-17.42***	-18.92***
	(6.92)	(5.34)	(5.79)	(5.71)
Larea	-7.07***	-10.2***	-6.94***	-7.6***
	(1.36)	(1.43)	(0.76)	(0.94)
Lpop density	-2.97	-4.83***	-7.22***	-7.66***
	(2.16)	(1.72)	(1.43)	(1.41)
landlock	0.90	37.66	-1.00	8.63
	(4.79)	(10.83)	(3.97)	(10.01)
Lcoast		5.19***		1.48
		(1.39)		(1.32)
Lrgdpc	2.06	0.14	4.26***	3.83**
	(1.89)	(1.62)	(1.51)	(1.57)
Trade policy	-39.03**	-35.79**	0.05	0.04
	(18.09)	(17.08)	(0.90)	(0.91)
Constant	276.92***	323.51***	286.66***	302.18***
	(71.99)	(51.25)	(59.86)	(59.07)
Observations	42	42	106	106
R^2	0.59	0.67	0.54	0.54
RMSE	12.13	11.06	14.74	14.73

Notes: *,**,*** denote significance at the 10%, 5%, and 1% level, respectively. Standard Errors in parentheses.

effect on growth.[33] And some others argue that the direction is the opposite.[34] We have to accept the possibility of endogeneity problems in our estimations that include GDP per capita as exogenous regressor. In this section and the last one from our work, we decide to change our estimation technique to solve a possible problem of endogeneity. In order to achieve the previous we use an Instrumental Variables approach.

In our previous sections where $Linfra$ is part of the model we have that this variable is significant only when $freetrad$ is left out of the estimation. If the latter is included then the former is not significant. This result could rise some doubts about the relevance of infrastructure as our income proxy variable in our model. For this is reason, we try a different approach in our last set of regressions: Based on the theoretical work of Arrow and Kurz (1970), where they show that investment in infrastructure increases production given a certain level of employment and private capital, and Ogura and Yohe (1977), and the empirical studies (using data of the United States) of Aschauer (1989a, 1989b, 1990) and Munell (1990) we try to exploit the link between (public) infrastructure and GDP.[35] Our estimation methods change now to be instrumental variables, where GDP per capita is instrumented with at least two, or even more, variables. One of the instruments that is included always in our estimations is our infrastructure variable. The other instruments are taken from either our set of geographic characteristics, and even our $freetrad$ variable can be included in this instruments' list. We have a maximum of four instruments to estimate GDP in a first stage regression.

Our first set of results are regressions that use the whole sample to be estimated. Despite the existence of a structural break between high-income countries and the rest we continue with the estimation since these results might give a different picture to what we find in our first regressions. The most notorious difference that we find in our IV estimations is the change in the sign of GDP per capita, we now have a positive one, although this variable is only significant when we remove our trade policy variable from our estimations, similar result to what we find including $linfr$ as exogenous regressor of openness. Remoteness is the other variable that reports changes from one specification to the other. The magnitude of *Lremote*'s coefficient is reduced in absolute value once again when we include high-income

[33]See Frankel and Romer (1999).
[34]See section 5.5.5.2.
[35]The hypothesis that Aschauer tries to prove is the following one: Slowdown in infrastructure spending can cause a poor performance of the economy.

Table 5.13: Instrumental Variables, Complete sample

	Dependent variable: Openness					
Variable	I	II	III	IV	V	VI
Lrgdpc	1.16	1.02	1.80**	1.76**	2.01**	1.92**
	(1.33)	(1.33)	(0.88)	(0.88)	(0.89)	(0.89)
Lremote	-7.75*	-8.12*	-11.52**	-11.66***	-8.90*	-9.3**
	(4.81)	(4.77)	(4.57)	(4.56)	(4.70)	(4.67)
Larea	-7.90***	-7.89***	-7.14***	-7.11***	-7.95***	-7.95***
	(0.85)	(0.85)	(0.60)	(0.60)	(0.87)	(0.87)
Lpop den	-6.13***	-6.04***	-6.53***	-6.43***	-6.63***	-6.57***
	(1.46)	(1.44)	(1.21)	(1.21)	(1.36)	(1.35)
freetrad	1.01	1.07				
	(1.16)	(1.15)				
Constant	223.68***	227.20***	249.89***	251.00***	235.34***	239.57***
	(0.5081)	(0.5151)	(0.4726)	(0.4729)	(0.5004)	(0.5064)
Obs	111	111	150	150	111	111
R^2	0.52	0.53	0.51	0.51	0.51	0.51
RMSE	13.32	13.30	14.25	14.25	13.52	13.51
Hansen test	2.58	3.26	0.075	0.98	3.17	3.93
P-value	0.11	0.20	0.79	0.61	0.37	0.27
Instruments	landlock	landlock	landlock	landlock	landlock	landlock
	Linfr	Linfr	Linfr	Linfr	Linfr	Linfr
		lcoast		lcoast		lcoast
					freetrad	freetrad

Notes: *,**,*** denote significance at the 10%, 5%, and 1% level, respectively. Standard Errors in parentheses.

countries in our estimations, we even obtain a maximum value for this variable (-7.75) in this set of regressions.[36] The results for the trade policy variable are also different to what we get in previous sections since we now have insignificant results. As a matter of fact, the estimations with the trade policy variable included are the ones with more insignificant variables.

Table 5.14: Instrumental Variables, subsample

	Dependent variable: Openness					
Variable	I	II	III	IV	V	VI
Lrgdpch	4.11**	4.19**	5.33***	5.33***	5.72***	5.76***
	(1.68)	(1.68)	(1.31)	(1.30)	(1.36)	(1.36)
Lremote	-14.92***	-14.47***	-17.32***	-17.46***	-17.42***	-17.37***
	(5.19)	(5.21)	(4.84)	(4.82)	(5.19)	(5.19)
Larea	-6.92***	-6.93***	-6.84***	-6.95***	-7.52***	-7.54***
	(0.97)	(0.0097)	(0.65)	(0.65)	(0.98)	(0.98)
Lpop den	-5.99***	-6.01***	-7.31***	-7.57***	-7.59***	-7.64***
	(1.77)	(1.76)	(1.18)	(1.16)	(1.34)	(1.34)
freetrad	2.30	2.33				
	(1.54)	(1.54)				
Constant	247.79***	243.35***	277.43***	280.81***	283.73***	283.35***
	(57.36)	(57.65)	(51.22)	(50.96)	(55.39)	(55.4)
Obs	84	84	122	122	84	84
R^2	0.60	0.60	0.57	0.57	0.56	0.56
RMSE	12.75	12.76	13.79	13.80	13.25	13.26
Hansen test	2.5241	3.01	0.0391	1.45	3.95	4.16
P-value	0.11	0.22	0.84	0.48	0.14	0.24
Instruments	landlock	landlock	landlock	landlock	landlock	landlock
	Linfr	Linfr	Linfr	Linfr	Linfr	Linfr
		lcoast		lcoast		lcoast
					freetrad	freetrad

Notes: *,**,*** denote significance at the 10%, 5%, and 1% level, respectively. Standard Errors in parentheses.

The main objective of using instrumental variables is to have more robust results since there are some fears with respect to the exogeneity of *Lrgdpc* in the openness of equation. We are able to obtain good results in this last part of our study. Looking at the coefficient of GDP per capital in this second set of IV regressions, we should state that obtaining a positive sign for that variable is now a regular feature of our openness equation, in particular now that we reduce our sample to include only developing and less developed nations. The results that we get from the reduced sample are the same in terms of signs of the exogenous

[36] Or, we could say that this is the lowest value for this variable in all our exercises if we take the absolute value for all of them.

variables, however, the magnitude of some of these is now greater, in absolute value, and they are more significant than in the complete sample case, except for our trade policy variable. This variable is again not significant, and it should be also noted that when this variable is part of the model estimated, the Hansen test for over-identification performs the worst (highest values on the statistic and $P - values$ closer to significant regions).

A very interesting result is found in these two last set of results: Our income proxy variable, GDP per capita, becomes more relevant, specially in the case of our estimations using a subsample. This last finding and the fact that we get a negative sign for this coefficient in our first set of regressions are similar to the findings of Sarkar (2007) as he can only find a positive relation between openness and income levels for middle-income countries. It is also interesting that our trade policy variable has a minor role in these estimations. With respect to the validity of our instruments there is not a single case in which the Hansen tests gives back a significant statistic at the 10% level.

5.6 Conclusions and further work

The determination of an openness equation by using a few variables is our main result. We are able to obtain this by combining geographic characteristics with proxy variables for income levels and also controlling for trade policy effects. Our specification is similar to the one from Guttmann and Richards plus the inclusion of some other relevant factors into our model.

In the very first part of our work, we are able to replicate the results that Guttmann and Richards obtain in their work. That is, we find a specification that help us explain trade openness well with only a few variables. We also realize the importance of both imposed and natural trade barriers to trade, and how these can have different effects on the level of openness. This is our starting point to obtain and describe new results for our specification.

In this sense, we have some mixed results with respect to the relation between real GDP per capita, our income proxy variable, and openness. At first we find the same result as GR, a negative link. We decide to include some other income proxy variables to our equation. The results once again report a negative relation. Since one of our variables is just a dummy one that divides our sample into developed economies and developing and less developed countries, we decide to check for the stability of our model considering these two sets of countries. Our tests signal for a break between developed economies and developing and less developed countries.

Our decision of having a smaller sample with only middle and low-income countries is based on our findings of a structural break between high-income countries and the rest. The results of the regressions done only for the subsample just confirm most of our findings from the baseline model using all countries, but now we have a solid positive relation between GDP per capita and openness. It is very important that the relations we find in our complete sample hold with the subsample.

Despite our findings, it is necessary to do a better analysis in high-income countries, although the number of observations is very limited (we have to remember that we use 20-year averages for our observations). Our last exercise estimating an Instrumental Variables model gives a hint of what the next step could be like since we can extend that exercise to a panel data estimation framework in order to capture the evolution of these and possible new variables and how they affect the level of openness.

Finally, we also try to use different variables from the ones we find in Guttmann and Richards to capture income and trade policy effects in our estimations. In the case of the new income proxy variable, we use an infrastructure variable that delivers good results for some specifications. For the trade policy variable we use two new measures. The first one is based on the research of Kym Anderson for the World Bank in the topic of distortions to agriculture incentives; the second is again an index, this time a globalization index, named KOF Globalization index, that includes a trade restrictions subindex. This subindex is the one we use as our trade policy variable. However, the results for the new trade policy variables are not as interesting as the ones with the Freedom for trade index. Perhaps in a dynamic framework the impact of these could become more relevant.

Chapter 6

Openness to International Trade Across Time

6.1 Introduction

Over the last three decades there has been an important discussion of the relevance of trade openness for the development of a country. During the eighties, the debate was centered on the implementation of trade liberalization policies by developing economies in order to achieve higher growth rates.[1] We also find several works that claim a positive relationship between trade and income convergence, or at least a faster growth in developing countries that open to trade compared with the ones that do not. Even in the case of rich nations there are studies in which we find evidence of income convergence. Ben-David (1991) investigates the case of European economies during the creation of the European Economic Community.

In following years, the topic under the spotlight is what some authors have named "globalization", which we can interpret as the phenomenon of the rapid increase in international trade as consequence of trade costs reduction. There is a higher trade intensity in the economies of the world and Baier and Bergstrand (1997) reach the conclusion that this is the result of trade liberalization policies (to be more precise they refer to fall of import tariffs) and lower transportation costs. Researchers have devoted several works to analyse

[1] See for example Edwards(1998) and Rodríguez (2006).

the repercussions of different levels of trade openness in the economic performance of a country. It is easy to distinguish the relevance of openness for the economy. Before going any further perhaps it is better to define what we understand, or use as proxy, for openness. We limit ourselves to use openness as a synonym of trade intensity of a country.[2]

The recent changes in the degree of openness that several countries have experienced in the past 25-30 years are mainly related to the ideas of trade liberalization and reduction of trade barriers between the nations. However, it is important to mention that there are conditions that cannot be modified via trade policies. As examples of the previous we can mention the geographic situation of a country,[3] or the current wealth of the economy, or perhaps even the wealth of neighbor countries. These topics and the answer to similar questions are explored in the literature of the gravity model. This approach focuses on bilateral trade among nations. The model gives results that match almost perfectly data observed in real life but there is no specific theory developed to back up the model, and, in terms of estimation issues, it is not straight forward regarding the inclusion and mixture of dynamic variables and time-invariant ones in the same specification.

The relevance of having a set of variables that do not change through time in the case of an openness equation is high if we turn our attention to geographic factors, just to mention an example of this type of variables. Perry and Schönerwald (2009) find that measures of geography could have an important impact on the economic performance of a country because of its impact on transaction costs.[4] These factors are important and could help creating a better profile of country's trade levels.

Back to the relevance of openness, we have that it not only important for the growth of the economy. Hau (2002) finds a strong link between openness and the real exchange rate volatility. The more open a country is, the lower volatility it experiences in its real exchange rate. Iliev and Marinov (2008) try to make clear the idea that the search of the notion of "open economy" is in fact a search for the ways of interaction between national and global macroeconomics systems, real processes and their (positive and negative) effects on various

[2]Leamer (1987) discusses several ways to measure openness using the trade data available for the economy.

[3]In this case we could say that political borders could be modified due to wars or different diplomatic conflicts, however, the changes experienced are rare and are not frequent. We can say then that in this cases we have a very static factor or variable.

[4]Even Sachs (2003) finds that geography has a stronger impact on economic growth than variables that capture the effects of institutions.

levels. Our work tries to reduce the lack of works that centre their attention on an openness specification as we have explored a few ideas that reveal its importance and analyse how several variables affect this in a non-static framework. In order to achieve this goal, we use a combination of time-varying and (almost) time-invariant variables to explain openness using a new estimation technique developed by Plümper and Troeger (2007). This study can also help not only having a better understanding of the factors that affect the level of openness but also to comprehend the importance of openness in different economic indicators.

6.2 Literature Review

Guttmann and Richards (2006) consider in their work that the construction of an openness specification is done with limited help of the theory; and as they do, we are aware of the lack of a general theoretical model explaining openness. However, we follow Guttmann and Richards and use the findings of several authors in order to analyse our results and the effects of the variables we use to explain openness. In their work, they estimate a pooled cross-section time-series regression models with significant results. Their openness specification includes five independent variables of which population and economic location are the most relevant ones.

They also decide to estimate their model using several cross-section estimations with 5-year average data, and the previously mentioned pooled OLS regression that makes use of that data. They avoid using a fixed-effects panel regression because this approach is problematic for time-invariant variables (in their case, they include total area in their model) or the ones that change only slowly through time, and the result of the previous situation is not being able to get good estimates for the explanatory variables in a fixed-effects panel regression. This problem is what we try to address in our work by using a new estimation technique developed by Plümper and Troeger called "Fixed-Effects Vector Decomposition" in order to be able to include time-invariant variables on a fixed-effects type estimation.

As we mentioned earlier, the level of openness of a country has changed notably in the last three decades and several authors have devoted their works to explain this phenomenon. Andriamananjara and Nash (1997) study the case of developing countries by observing several indicators that reflect trade openness and analyse them across time. They find that openness has increased in these countries, but the variations in the indicator have been gradual movements and not instantaneous ones just right after implementing trade policies (liberalization instruments).

There is a big strand of literature devoted to the study of bilateral trade among nations. This type of literature is impulsed by the fact of having very encouraging empirical results that fit almost perfectly the figures observed in real life. These empirical models are based on the Gravity model. With the help of this model, researchers have studied the rapid increase in international trade thanks to technological advances that have made possible lower trade costs. It is possible to map these increases on trade with certain variables.

However, there is a key variable that seems to have a static relation with trade as some works based on gravity equation's results have claimed. More than one study have obtained results that highlight the relevance through time of this variable on openness in the same direction, which is not a result that can easily explained by theory. The variable we are referring to is distance; Disdier and Head (2003) do a meta-analysis of 51 empirical studies that analyse the relationship. They conclude that the negative impact of distance on trade is not shrinking, but increasing over time starting around the year 1950. Coe, Subramanian and Tamirisa (2007) have as their original premise that existing empirical literature does not find changes in the coefficient of distance. However, they estimate a gravity model and implement a non-linear estimation of the level of bilateral trade of the economies and they find that there is a declining importance of geography in the levels of trade of a nation.

Our work is similar to the ones of Guttmann and Richards and Jansen and Nordås (2004) by constructing an openness estimation but obtaining results that are more related to the ones of Coe, Subramanian and Tamirisa. In other words, we are able to find a good and parsimonious openness specification that shows reductions in the impact of relevant variables to trade through the years, and also the dynamics of the impact of other variables on trade openness. It is also important to remark that our findings are not the result of non-linear estimations as in the case of Coe, Subramanian and Tamirisa, but the result of using a new estimation technique developed by Plümper and Troeger (2007), which allows us to estimate panel data using fixed-effects framework and allowing to have time-invariant variables.

6.2.1 An openness equation, the lack of theory

In the trade literature it is hard to find works where the central subject of study is an openness equation. We have already established that fact in the previous section. Even Guttmann and Richards mention that their model has to be taken as an attempt to find better explanations to countries' trade flows without a general theoretical model to support the empirical exercises. For this reason, we do as these two authors and we use the work of others in which they propose particular effects that we should expect to find in the data analysed.

In this section, we try to mention some of the works with relevant results to our study. Levine and Renelt (1992) find a robust and positive correlation between the share of investment in GDP and the average share of trade in terms of GDP. As a matter of fact, they explain that the linkage between trade and growth probably happens through investment. The idea of having more trade, in our case more openness, due to more investment has been explored in a more specific way by other authors. Limao and Venables (1999) show that country geography and the levels of infrastructure, which we can consider an type of investment, are very relevant on the determination of transport costs' impact on trade.

One of the important effects that we explore in our work is the one of distance on openness. It is a well-established result that trade decreases with distance. However, there is an intense debate on how this effect has been changing over time. With our set-up it is possible to explore more in detail this fact and shed light on the issue. There are several empirical studies where it is claimed that the effect of distance has not become lower, it has remain constant or it has even increased across the years as Disdier and Head (2008) show in their work.

As we have noted earlier there is a vast literature focused on the systematic relationship that exists between trade openness and economic growth. We want to explore a different issue that could be regarded as something that is related to the problem stated just above. During the decade of the seventies, eighties and nineties we have seen the results of different models of trade openness implemented by different economies around the world. Latin-American and African countries based their access to world markets by producing and exporting crude primary commodities with a low degree of diversification of the goods sold to different countries. A different strategy is the one followed by several East-Asian nations by considering an important aspect the diversification of the goods exported (processed and manufactured goods). However, it is also possible that the wealth of the nations plays an important role in terms of how fast a country could open to trade (or to what extent it could open to trade).

It is also interesting to consider the size of a country as a relevant factor in the determination of an openness equation. Feenstra (1998) mentions that it is a well known fact that large economies trade less with others, and they focus more on do it internally.[5] Alesina and Wacziarg (1998) try to prove that the relationship between trade openness and the size of the government that Rodrik (1996) claims in his work is not a direct one. They argue that there is an intermediate link between trade openness and government size, and that link is the relation between openness and country size.

Lutz and Singer (1994) explore the link between openness and terms of trade. However, in this case they try to establish a link between a higher level of openness and a higher volatility in terms of trade. Their work is an attempt to warn about the risks of having a more open economy and the volatility of prices.[6] They show that an economy becomes more vulnerable when it has to face world market prices.[7]

The previous works serve us as reference for the interpretation of our results. However, it is not possible to include here all the potential relations we find in our empirical exercises we are just making remarks on the most relevant works related to the openness literature analysing some of the variables we work with in the following sections.

[5]It is also true that in several models with increasing returns to scale in the production function, market size influences the level of economic activity.

[6]Their argument is very valid, however, the scope of the research could be also found and with more literature devoted to this in the topic of real exchange volatility and openness.

[7]If we consider what Obstfeld (1982) has to say about the relationship between terms of trade and trade openness, we have that the relationship is not a trivial one. It all depends on the nature of changes, if these are anticipated or not so we can have a better idea of how much these will last. If we are facing permanent variations in the terms of trade, then consumption levels are modified. If the changes are temporal then the economies will adjust via the current account.

6.3 Data and Model

In this section we describe in detail the data and their sources we use in the estimation of our openness equation. In the following sections we explain the basic set-up of our model and report the results of these first estimations that we use afterwards to explore different, and perhaps more specific, relationships between the independent variables and trade openness. The sample we use to carry our empirical analysis includes more than 120 countries on average using a panel that goes from the year 1980 until 2005 that includes yearly observations. The building block of our analysis is the fixed-effects regression framework. We must add that our most robust results are not obtained using this approach but a new technique that allows us to include variables that do not change through time in a fixed-effects model.

Our measure of openness (the ratio of exports plus imports over GDP) is obtained from the World Development Indicators (WDI) database from the World Bank. We get exports and imports expressed as GDP percentage for each country and then add these two series up to obtain our measure of openness. This is our dependent variable for all our estimations. We do some more transformations to our openness measure by expressing the original series (percentages) as a ratio, then we add a unit and take the natural logarithm of that number. We conclude by multiplying by a hundred each series. After these modifications we have our final openness series that are used in the estimations.

The next series are terms of trade of all the countries in our sample. It is important to bear in mind that from this point onwards, the rest of the variables, including the terms of trade, constitute the set of regressors that we use in our estimations.[8] In order to construct these series we obtain the import and export value indices of each country from the WDI database at the World Bank website. We then calculate the ratio from the exports value index in terms of the imports one; the following step is to multiply by a hundred and take natural logarithms to the percentage ratio.

Our next regressor is a trade policy proxy variable. This is a measure created by James Gwartney and Robert Lawson with William Easterly for the Economic Freedom of the World: 2007 Annual Report. In their own words this variable *"measures the extent to*

[8] A second remark that must be made is the fact that not all the exogenous variables are included at once in our specifications.

which nations allow their citizens economic freedom. From the beginning, the freedom of people to trade internationally has been a featured area within the index". The Annual Report of the Economic Freedom of the World is a publication of the Fraser Institute.[9]

We do not transform this index and it is included as it is reported in the Economic Freedom of the World Annual Report. However, there is one assumption we make in order to increase the number of observations available for our estimations. This assumption is related to the following issue: the construction of the index began in 1975 and it was calculated on a 5-year basis until the year 2000. From that date onwards it is done on a yearly basis. Since our data starts at the year 1980 and ends in 2005, we might lose several observations of other exogenous variables every time we include this trade policy proxy variable inside our model.

In order to preserve the maximum amount of observations, we decide to interpolate the value of the index to the previous four years for the entries of the following years: 2000, 1995, 1990 and 1985. This assumptions allow us not to lose observations. However, there is a drawback in our procedure and that is having an almost time invariant variable as our trade policy proxy index. The scale of the index goes from 1 to 10, where the former represents a closed economy with several barriers to reach trade agreements with different nations and ten (at the other extreme of the scale) represents the opposite: a very open economy that engages easily in trade with other nations.

The following variable is investment as percentage of GDP. This measure is taken from the IFS database constructed by the IMF. The variable that we use to control for investment is the gross capital formation in terms of GDP. We include this variable in our estimations as a percentage without any extra modification. We also control for income levels and our proxy variable for that effect is the real GDP per capita of each country (in dollars of 2000). The source of this variable is again the World Bank's WDI database. This variable is included in the model after applying natural logarithm to the series.

The rest of the variables are part of the model with the intention to capture features of the country and not so much its performance. We are mainly talking about geographic characteristics that we consider might influence the level of openness. The first one is an

[9]The report can be downloaded from the website of the Institute (http://www.freetheworld.com) for several years.

index related to distance between countries. What we are really controlling for is remoteness of a country from a theoretical world trade centre. This remoteness index is constructed considering every country's contribution to a global GDP, which is the sum of all countries' GDP included in the sample; then the GDP of each country divided by this global GDP is the weight used to calculate how remote a country is from a theoretical world trade centre.[10] This variable, in essence, captures how far each country is from the rest of the world and it is a proxy for transport costs.

We construct this measure by calculating a weighted distance measure of a country to the rest of countries that are part of our sample. The weights are constructed using each country's GDP divided by a Global GDP, as we mentioned above this is just the sum of all countries' GDPs. This variable is generated using the distance database from CEPII.[11] The distance measures are calculated with the great-circle distance between the most important cities of each country. The GDP series are obtained from the International Financial Statistics (IFS) from IMF. After we get the remoteness measure for every economy, we transform the series by applying natural logarithms to them.

The (surface) area of a country is also part of our set of exogenous variables. This is the surface in square kilometre from each country. Before this variable is included in our estimations we transform the series by taking logs of it. Population density is also included in our regressions. We also include this variable in logs in our estimations. Population density is constructed by dividing the population of a country by its area. The source of these two variables is the WDI dataset.

The last variable of the geographic characteristics group that we consider is a dummy variable that signals for landlocked countries. As we have just mentioned this is a dummy variable that takes the value of 1 if a country has no access to the sea and zero otherwise. In other words if the country has no coastline we have a value of 1 for the index. Source: CIA Factbook website. The final variable is the inclusion of a time trend in our estimations.

[10]The distance of one country to another is measured by the great-circle distance that considers the capital or most important city of each country.

[11]Website of the *"Centre D'Etudes Prospectives et D'Information Internationales"* at *http://www.cepii.fr/anglaisgraph/news/accueilengl.htm*

6.3.1 Investment ratio as exogenous variable

As a final comment on our set of exogenous variables, we add some extra arguments to support our decision of including an investment measure in terms of GDP. The reason behind this section is the fact that there are works that have found a relationship between investment and trade openness; however, the direction of the relationship is the opposite one to the one we try to establish in our work.[12]

The argument we consider to add investment as a percentage of GDP in our regressions is completely different. We take into account the findings of three works: The first one is from Eaton and Kortum (2001); they show that there are few countries that produce capital goods needed in the are of research and development, mainly equipment goods. The production of these goods is concentrated in rich economies, and developing nations need to buy these type of goods in international markets; these are considered by the authors as a type of investment done by medium- and low-income countries.

The second work we consider as argument to include the investment ratio as an exogenous variable is the one from Engel and Kletzer (1989); in their work they construct a trade model to show that economies with scarcity of capital goods observe movements in their trade balance as they use international markets to overcome the lack of this type of goods. Finally, in Madden, Savage and Thong (1999) find support to the hypothesis that non-price factors can affect considerably the level of exports of a country. One of these non-price factors is the fact that exports increase with higher gross-fixed investment levels and technology. The combination of these three arguments makes us believe that investment as a percentage of GDP is an important variable in the determination of trade flows of a country.

In summary, we include the investment ratio as an exogenous variable in our specifications because exports of tradable capitals goods are much more geographically concentrated than those of tradable consumption goods, so countries that invest more are likely to import (and therefore also to export) a larger share of their input.

[12]The relationship work as follows: In growth literature, we find that the channel to affect growth with trade liberalization is through capital productivity. Export oriented firms are affected positively with trade liberalization as the productivity of capital input boosts. For further detail, see Baldwin and Seghezza (1996).

6.3.2 Baseline Model

In order to analyse openness in a time series framework we work with panel data estimations. We regress our models using Fixed- and Random-Effects frameworks in order to test afterwards which of the two is a more adequate approach by applying the Hausman test. The baseline specification is the following equation:

$$\begin{aligned} Openness = \beta_0 + \beta_1(Terms\ of\ Trade) + \beta_2(time\ trend) \\ +\beta_3 Freedom\ for\ trade + \beta_4 \frac{Investment}{GDP} + \epsilon \end{aligned} \tag{6.1}$$

The expected signs for the previous variables are:

- Terms of trade (ToT): If terms of trade improve then we have a positive wealth effect for the country that experiences it. This could be due to an increase in export prices, a reduction in import prices or a combination of both. Nevertheless, this sign could be either positive or negative according to price elasticities. However, we expect a positive relationship between this variable and trade openness.
- Time trend ($Time$): In recent years world markets have integrated more and more. It is claimed that openness has been increased through the years as trade barriers and trade costs have been reduced, specially in the last couple of decades.[13] So we expect a positive sign in this variable.
- Trade Policy proxy ($Freedom$): This is the freedom for trade index variable. A higher value in this index means that the country is more receptive to engage in trade with the world, hence a higher openness of its economy. A positive sign is expected.
- Investment (Inv/GDP): Some authors have studied the probable relationship between openness and investment. They find a positive relationship between these two. However, the causality investigated goes on the opposite direction. In particular,

[13]The claim is that trade costs are smaller in recent times, but it is not possible to obtain a clear picture of this effect from recent empirical works. See Anderson and van Wincoop (2004) for more details.

Razin, Sadka and Coury (2002) show in a theoretical model that in a Ricardian set-up with overlapping generations, an open economy can cause boom or bust in the investment levels of a country. These oscillations are produced by self-fulfilling expectations. We have mentioned the work of Levine and Renelt (1992) and Limao and Venables (1999). These works support a positive relation between trade openness and investment and we expect the same direction for this effect in our estimations.

In the previous list we detail the variables included in what we can call our baseline specification (in equation 6.1). The next variables are series not included in our first set of regressions, but are part of following equations.

- Land Area (*Area*): What other authors have found and we also expect to obtain here is a negative sign in the coefficient of area. Smaller economies are in need of opening the economy in order to satisfy the demand of goods that are not produced domestically.
- Landlocked economies dummy variable (*Landlocked*). We expect a negative sign for this variable. It is harder for economies that do not have access to the sea to engage in trade due to more expensive trade costs when we compare these countries with the ones that have access to the sea. In this case landlocked countries have an extra non-tariff barrier to trade.
- Remoteness (*Remote*). In the case of distance (or in our case remoteness, which is a measure of weighted distance) we expect a negative sign. Transportation costs remain a determinant factor for nations in their decision to trade or not. The farther apart two countries are from each other, the higher the transportation costs are and the less likely these two are willing to trade.
- Population density ($Pop - den$). The expected sign for this coefficient is a negative one. The argument in which we based our expectations is similar to the one of land area: small economies, low population rate in this case, tend to trade more than big economies (high amount of inhabitants in the country). We could assume that small economies behave as in a model in which the "love of variety" argument (Krugman 1979) is observed. The previous (combined with increasing returns to scale) are a good reason for small economies to be more pro-active towards trade than big ones.

- Income level proxy ($rGDPpc$). The effect of this variable on trade openness is ambiguous and we do not include an expectation for the direction of this effect. Guttmann and Richards obtain a negative relationship between their income proxy variable and openness, although they were expecting a positive effect for this variable. They argue that this could be due to the omission of inflation in their estimations and also to a probable non-linear relationship. In an own cross-section estimation we also obtain a negative relation between these two variables. However, it does not seem like a wrong idea to think that there might be a positive relationship between income level and openness. In particular if we think that some of the "natural trade barriers" are abolished with infrastructure spending and this is easier to accomplish for rich nations.

6.4 Estimation Results - Baseline specification

We start the section by reporting table 6.1 that contains the results of our baseline model. We have more than 2200 observations included in the estimation that come from 121 different countries for two different specifications reported. We present the results for estimations using both fixed- and random-effects regressions.

The first two columns show the baseline model that includes GDP per capita, and in the last two we remove this variable from the specification in order to observe the changes in the coefficients of the other variables when we do not control for income levels. Terms of trade is the variable with the greatest coefficient in the estimations when GDP per capita is not part of the model. Most of the variables are significant at the one percent level. Actually, freedom for trade, our trade policy proxy variable, is the only one not significant at this level, but it is at the five percent level. If we take a closer look to the standard errors in all our specifications, we have that these are greater under fixed-effects estimations. The Hausman test signals in favour of a fixed-effects estimation. However, we include both estimations for the time being to observe initial differences between the two approaches.

In a more detailed analysis, we have that terms of trade impact positively openness, which is the expected sign. We can interpret this as follows: an improvement in terms of trade, which could be translated into a wealth improvement, increases trade flows of a country

Table 6.1: Baseline model

Dependent variable: Openness				
Variables	Fixed	Random	Fixed	Random
	I	II	III	IV
ToT	2.6050***	2.6475***	2.8498***	2.9004***
	(0.6151)	(0.6118)	(0.6137)	(0.6118)
$Time$	0.3589***	0.3679***	0.4110***	0.4108***
	(0.0293)	(0.0275)	(0.0260)	(0.0259)
$Freedom$	0.3097**	0.3014**	0.2794**	0.3121**
	(0.1408)	(0.1397)	(0.1411)	(0.1403)
Inv/GDP	0.4937***	0.5080***	0.5286***	0.5408***
	(0.0385)	(0.0378)	(0.0375)	(0.0373)
$rGDPpc$	3.6094***	3.2860***		
	(0.9470)	(0.7356)		
Constant	-9.5748	-3.8977	15.1915***	18.1222***
	(7.2479)	(6.1609)	(3.2206)	(3.7090)
Obs	2231	2231	2231	2231
Groups	121	121	121	121
F/Wald	126.39	659.47	153.37	634.06
Prob. $> F/\chi^2$	0.00	0.00	0.00	0.00
Hausman test				
χ^2		35.67		14.48
P-value		0.00		0.006

Notes: *,**,*** denote significance at the 10%, 5%, and 1% level, respectively. Standard Errors in parentheses. F- tests are used in Fixed-effects coefficients, and for Random-effects estimations we use Wald tests.

(more imported goods can be consumed). We also observe a positive relationship between openness and freedom for trade. This result seems to be more a robustness check of our specification than an actual contribution. We are able to obtain higher openness when we have lower trade barriers in the economy. However, this variable is only significant when the estimations are done under random-effects. It is possible that our trade policy variable is not significant in the fixed-effects estimation due to the elimination of the unobserved individual effects in order to carry out the regression. Despite this, the estimations become more efficient using fixed-effects. It seems that by using this framework it is possible to capture in a better way some of the heterogeneity of all the countries included in our sample. This is easier to notice if we take a look at the Hausman test that in both cases signals against of using random-effects.

In summary, these set of results are encouraging and they send a clear message: economies have experienced higher levels of trade in recent years. We have a positive growth of rate of trade flows in time and it also seems like trade policy variables are being effective in their objective of stimulate (or at least reduce barriers to) trade.

6.4.1 Removing freedom for trade from the baseline model, a greater sample

This exercise is motivated by the fact that our variable freedom for trade is an index published in the *Economic Freedom of the World, Annual report* in a yearly basis only since the year 2000. The reports of previous years were published just once every five years. This is an important drawback in our sample since we lose an important amount of observations. That is the reason behind our assumption of including the same value of the index for the year of publication and the four previous years. If we rephrase a little the previous: we include the index value of the most recent publication for the entry of years in-between two reports. This is a strong assumption that allow us not to lose observations, but the trade-off is to have now an index that does not change much through time, we have an almost time-invariant variable. With this set of regressions we want to analyse the results of the estimations without this variable and observe the changes generated.[14]

[14]Once again we try to avoid the problem of variables that do not change considerably through time and the use of fixed-effects regressions.

Table 6.2: Baseline model w/o trade policy variable

Dependent Variable: Openness				
Variables	Fixed	Random	Fixed	Random
	I	II	III	IV
ToT	4.1612***	4.1354***	3.3972**	3.4554***
	(1.4080)	(0.6453)	(1.4068)	(0.6228)
$Time$	0.3615***	0.3643***	0.2761***	0.2887***
	(0.0727)	(0.0232)	(0.0785)	(0.0255)
Inv/GDP	0.4149***	0.4240***	0.3644***	0.3756***
	(0.0934)	(0.0413)	(0.0969)	(0.0425)
$rGDPpc$			5.8867**	5.2067***
			(2.6724)	(0.8087)
Constant	17.9783**	20.3919***	-19.7355	-13.0658*
	(7.4858)	(3.9269)	(18.0135)	(6.8837)
Obs	2870	2870	2815	2815
Groups	144	144	141	141
F/Wald	13.92	328.15	14.55	357.98
Prob. $> F/\chi^2$	0	0	0	0
Hausman test				
χ^2		2.38		4.73
P-value		0.497		0.3158

Notes: *,**,*** denote significance at the 10%, 5%, and 1% level, respectively. Standard Errors in parentheses. F- tests are used in Fixed-effects coefficients, and for Random-effects estimations we use Wald tests.

Table 6.2 reports this results.

Our sample size increases significantly to at least 2815 observations that comprehends more than 140 countries.[15] The results remain similar to what we have in our first set of results: only positive coefficients, terms of trade gets the greatest elasticity. We not only observe that standard errors in this second set of estimations are reduced, we once again have that these are even smaller in the case of random-effects estimations.

There is one considerable difference with respect to the model in table 6.1 and it is observed in the coefficient of terms of trade, in the most recent estimation its magnitude increases considerably. It seems like this coefficient now includes the effects we control for with our trade policy index variable. But the most likely reason of having a higher impact of terms of trade in our new specification is the fact of including more developing and less developed

[15]Actually this is not even half of the complete sample that is considered in the STATA dataset, the problem is that not all years are available for all the series in all the countries, different missing observations for different series in different year entries.

Table 6.3: Baseline model w/o trade policy and income level variables

Depedent Variable: Openness				
Variables	Fixed	Random	Fixed	Random
	I	II	III	IV
ToT	2.7755***	2.8177***	2.5310***	2.5671***
	(0.6130)	(0.6107)	(0.6107)	(0.6112)
$Time$	0.4431***	0.4465***	0.3960***	0.4021***
	(0.0203)	(0.0203)	(0.0239)	(0.0225)
Inv/GDP	0.5389***	0.5519***	0.5062***	0.5190***
	(0.0372)	(0.0369)	(0.0381)	(0.0375)
$rGDPpc$			3.4916***	3.3119***
			(0.9464)	(0.7350)
Constant	16.2641***	19.3158***	-7.5809	-2.9439
	(3.1770)	(3.6876)	(7.1975)	(6.1423)
Obs	2231	2231	2231	2231
Groups	121	121	121	121
F/Wald	202.9	628.5	156.49	653.68
Prob. $> F/\chi^2$	0	0	0	0
Hausman test				
χ^2		—		143.48
P-value				0.00

Notes: *,**,*** denote significance at the 10%, 5%, and 1% level, respectively. Standard Errors in parentheses. F- tests are used in Fixed-effects coefficients, and for Random-effects estimations we use Wald tests.

economies as part of our sample. For these countries shocks in terms of trade are more relevant since it several cases they trade a small amount of goods, in particular primary commodities. Similarly, the income proxy variable is around 50 percent larger and it could also be explained by the higher amount of developing and less developed countries.

We have that the Hausman test statistic signals again in favour of using fixed-effects estimation procedure, however, there is one detail that we should consider in order to make the estimations with and without the freedom for trade variable comparable, we need to have the same countries in our estimations. For the previous reason we consider once again the estimations of the baseline model without our trade proxy variable but now the regressions are constrained to include only the countries that are part of the model in table 6.1.

The results in table 6.3 are very similar to the ones in table 6.1. We observe that the variables included in the first and last set of results are not affected by the presence of a trade policy variable that has been with our intra-polation exercise in order to expand the number of observations per country. Perhaps the only problem that can be raised at the moment is the fact that the variable might not vary as much as the others. We deal with that problem in the following sections. We can, however, observe the importance of controlling for the effects of imposed barriers to trade by the countries.

6.5 FEVD

In our baseline estimations we do not include any of the variables that can be called as "geographic characteristics type". The reason is the fact that some of these are time-invariant or almost time-invariant variables. In order to "correct" the previous situation, we change the estimation technique to one that considers this type of variable. The framework was developed by Plümper and Troeger (2007); their approach is called Fixed-Effects Vector Decomposition (FEVD). It consists of three stages: the first one runs a fixed-effects model without time-invariant variables; the second stage decomposes the unit effects vector into a part explained by the time-invariant variables and an error term; and the third stage re-estimates the first stage by pooled-OLS including the time-invariant variables plus the error term of stage 2. Using the Fixed-Effects Vector Decomposition technique we can get better estimates of our previous models in which our trade policy proxy variable is included and we can also include variables that do not vary (considerably) through time. The new model is the following one:

$$\begin{aligned} Openness = \beta_0 + \beta_1(Terms\ of\ trade) + \beta_2 Time\ trend + \beta_3 \frac{Investment}{GDP} \\ + \beta_4 Freedom\ for\ trade + \beta_5(Real\ GDP\ per\ capita) + \beta_6 Remoteness \\ + \beta_7 Population\ density + \beta_8 Area + \beta_9 Landlocked + \epsilon \end{aligned} \tag{6.2}$$

Harrison (1996) mentions in her work the relevance of doing an analysis that could go beyond only observing a cross-section analysis of the data. With a cross-section analysis it is not possible to control for unobserved country-specific differences, and also by using long-run averages only we ignore the importance of changes that occur in the variables over time for the same country. The use of this new approach, FEVD, has a final objective to overcome the previous caveats raised by Harrison. At the same time, we exploit the benefits of a dynamic framework that overcomes the difficulties of the gravity model when we try to use (almost) time-invariant variables.

6.5.1 FEVD Theory framework

Before we report the results of our estimations using this new estimation technique it is worth describing in a few steps how the FEVD works. The main idea is based on the estimation of a Fixed-effects model that includes time-invariant variables. The data generating process of such model can be represented as follows:

$$y_{i,t} = \alpha + \sum_{n=1}^{N} \beta_n x_{n,i,t} + \sum_{m=1}^{M} \gamma_m z_{mi} + u_i + \epsilon_{i,t} \tag{6.3}$$

where the $x_{n,i,t}$ variables are time varying ones, and z_{mi} are the ones considered time-invariant or almost time-invariant. The individual effects (Fixed-effects) are represented by the variable u_i, the error term is included in the model using the variable $\epsilon_{i,t}$, and finally the alpha variable is the intercept of the model. The first stage of the procedure developed by Plümper and Troeger involves the estimation of the previous, equation 6.3, using Fixed-effects (within estimator) that is based on the transformation of the original series into modified ones:

$$\tilde{y}_{i,t} = \sum_{n=1}^{N} \beta_n \tilde{x}_{n,i,t} + \tilde{\epsilon}_{i,t} \tag{6.4}$$

In this case we have that $\tilde{y}_{i,t} = y_{i,t} - \bar{y}$, $\tilde{x}_{i,t} = x_{i,t} - \bar{x}$ and $\tilde{\epsilon}_{i,t} = \epsilon_{i,t} - \bar{\epsilon}$ are the demeaned variables of the original ones. The rest of them are removed from the model after applying the transformation since they are constants. We have that the within transformation removes the individual effects u_i and the time-invariant variables z_{mi}. The main objective of running the Fixed-effects estimation in the FEVD framework is to obtain an estimate of the unit effects u_i. As Plümper and Troegger put it: "...these estimated unit effects include all time-invariant variables, the overall constant term, and the mean effects of the time-varying variables $x_{n,i,t}$". The fixed (unit or individual) effects can be expressed in the following equation:

$$\hat{u}_i = \bar{y}_i - \sum_{n=1}^{N} \hat{\beta}_n x_{n,i,t} - \hat{\epsilon}_i \tag{6.5}$$

Equation 6.5 shows the way we obtain an estimate of the individual effects. We subtract from the average of the y variable the average of the error term and the result of multiplying the variable x (also in averages) times the $\hat{\beta}$ coefficient. After getting an estimate for u_i it is possible to regress the second stage equation. In this stage we regress $\hat{u}_i$ on the observed time-invariant and rarely changing variables, the z variables, to decompose these and obtain the unexplained part h_i, which allow us to run the entire model via panel OLS. The equation estimated in the second stage is expressed in the next equation:

$$\hat{u}_i = \sum_{m=1}^{M} \gamma_m z_{mi} + h_i \tag{6.6}$$

With equation 6.6 we are able to isolate the unexplained individual effects from the time-invariant variables. In other words, we decompose the estimated unit effects into two parts, in explained and unexplained parts; this last part is represented by the variable h_i. The estimate for these unexplained unit effects, h_i, is calculated by taking the residuals of equation 6.6:

$$\hat{h}_i = \hat{u}_i - \sum_{m=1}^{M} \hat{\gamma}_m z_{mi} \tag{6.7}$$

The estimates of the unexplained part are then used in the third stage of the procedure by introducing a new variable in the specification of equation 6.3. As mentioned above this equation is estimated in the first stage, without variable h_i, using a fixed-effects regression. Now the same equation plus h_i is estimated by pooled OLS. The FEVD allows us to have estimates that are unbiased; by design h_i is not correlated anymore to any of the time-invariant variables. We are assuming that these time-invariant variables are orthogonal to the unobserved individual effects.[16]

6.5.2 FEVD results

As we mention above the first stage of FEVD involves a fixed-effects estimation that cannot consider either *Area* nor *Landlocked*, our time-invariant variables. The rest of them can be included in the first stage. In the second stage regression, we have that the fixed (unit) effects variable is the dependent one and *Area*, *Landlocked*, *rGDPpc*, *Freedom*, *Remote*, $Pop - den$ and Investment as percentage of the GDP can be part of the regressors set of variables. Some of the previous can also be part of the estimation in the first stage. In the case of variables that are included in the first two stages, we have that the final result for these is a coefficient in the third stage regression that includes information taken from the fixed-effects estimation and also the cross-section one. We first report the results of equation 6.2, which is a very similar model to our baseline one from the previous section. We only report the results of the third stage regression and in the first set of results from the new procedure we include the results of a fixed-effects estimation to have a better perspective of how the FEVD procedure can help improve the results.

Up to this point we have only considered two new variables that help us to control for more cross-country effects (geographic characteristics) of each economy. These two are our measure of remoteness and population density. The first one allows us to control for transport costs of each country to a hypothetical world trade centre, and at the same time we are testing whether distance is still a relevant variable in trade intensity; the latter variable is related to market size. These two new regressors are part of estimations reported in the first two columns of table 6.4. The coefficients we obtain for the remaining variables are very similar to what we get in previous sections. In the case of the new variables, both of them report a negative sign; that is, the further away a country is located from its theoretical world trade centre, the less it trades with the world. Distance is a relevant factor that could modify the amount of trade of a country. As for our market share proxy variable, population density, we have that the more inhabited a country is, the lower its necessity to engage trade. Countries with a small population face more difficulties producing a greater

[16]If the assumption does not hold then the estimated coefficients for the time-invariant variables are biased, due to the normal omitted variable bias.

Table 6.4: Fixed-Effects Vector Decomposition Results

Dependent variable: Openness				
	FE	FEVD	FE	FEVD
	I	II	III	IV
ToT	2.750***	2.750***	2.808***	2.808***
	(0.616)	(0.414)	(0.615)	(0.414)
$Time$	0.526***	0.526***	0.412***	0.412***
	(0.053)	(0.022)	(0.026)	(0.021)
$Investment/GDP$	0.496***	0.816***	0.525***	0.849***
	(0.038)	(0.021)	(0.038)	(0.021)
$rGDPpc$	2.033**	-1.441***		
	(1.037)	(0.142)		
$Pop-den$	-8.181***	-6.857***		
	(2.156)	(0.131)		
$Remote$	-0.266	-9.449***	-2.434	1.122**
	(2.621)	(0.545)	(2.599)	(0.492)
$Freedom\ for\ trade$	0.374***	1.428***	0.302**	1.241***
	(0.143)	(0.101)	(0.143)	(0.074)
$Area$		-8.678***		-6.006***
		(0.089)		(0.074)
$Landlocked$		-7.001***		-1.297***
		(0.422)		(0.379)
Unexplained Fixed-effects		1.000***		1.000***
		(0.011)		(0.010)
Constant	31.655	228.430***	36.408	67.776***
	(26.366)	(5.634)	(22.885)	(4.512)
Obs	2231	2231	2231	2231
Groups	121		121	
F	92.89	2088.44	122.86	2574.929
Prob > F	0	0	0	0
R^2		0.91		0.91
Adjusted R^2		0.90		0.90
RMSE		6.33		6.37

Notes: *,**,*** denote significance at the 10%, 5%, and 1% level, respectively. Standard Errors in parentheses.

number of products (varieties) and they need to satisfy their demand of products (varieties) that they do not produce in the international market. Small countries face more difficulties to satisfy the domestic demand with internal's trade and have to go out to the world markets in order to obtain the goods needed.

If we go back to the FEVD results of real GDP per capita in table 6.4, we have that this variable obtains a significant and negative sign. In our first set of estimations using just fixed-effects regressions we get a positive and significant coefficient for our income proxy variable. It seems like the inclusion of these two new characteristics change the direction of the income level effect on trade openness. This is not a surprising result: Guttmann and Richards (2006) also find a negative relationship between these two variables in their work. We also find the same result in our estimation of an openness equation using a cross-section dataset. As a matter of fact, we find that this negative relation between openness and real GDP per capita arises if both high-income and middle-income countries are included in the estimation sample.

There are two more estimations (last two columns) in table 6.4. These results do not include two variables that could be considered trended ones. These two are the income proxy variable and the recently added population density. The results of this regression can be compared immediately with the ones at the left of them in the same table. We try to capture the effect of the time trend on openness without being influenced by the variables excluded in these two regressions. We observe that the actual trend of openness is a positive one and we can confirm that trade among nations has increased in the last 25 years.

We also find an unexpected result, however, because the sign for remoteness is now positive. If the distance between a country and its theoretical world trade centre is higher, then the country trades more. This result is not in line with what we observe in real life and also with the relevance of trade costs. The area of a country and the landlocked dummy variable also report considerable changes in their coefficients, but in these cases we only have a change in the magnitude of them whilst the direction of the effect remains the same. The rest of the variables do not change considerably with respect to the results of previous models. We can conclude that despite the fact of having two variables with a trend of their own, these two are relevant for our specification and their presence in our model is important to control for income level effects and for market size.

It is not difficult to detect the advantages of using the FEVD approach. We are not only able to include variables such as *Area* or the dummy variable for landlocked countries; it is easy to spot a reduction in the standard errors of variables that are only part of the first stage. In the case of the variables that are estimated in all stages we obtain the effect more information of the impact of the regressors on openness. The results are evidence in favour of the new estimation technique we use.

6.5.3 Interactive terms

In the first set of FEVD estimations we have more than 120 countries included in our sample. This means that individual effects are quite relevant in our results. We have included in our model variables to control for the effects of the exogenous variables alone. However, it seems that some of these variables could have a different impact in our dependent variable, trade openness of a country, if we make some of the regressors to interact among themselves. In this section we include interactive variables in order to control for this type of effects.

The decision to construct an interaction between the income proxy variable and remoteness is done in order to observe if the effects of distance (transport costs) suffer a variation in relation with the income level of the country. Table 6.5 includes this interaction. In the previous section we observe that the impact of income level varies according to the estimation procedure we use (either via a pure fixed-effects estimation procedure or by combining this effect with the one of a cross-section estimations, which is the result of including real GDP per capita in stage 2 of FEVD procedure).

We start the analysis by commenting on the rest of the variables inside the specification. Terms of trade and the time trend do not report a different behaviour in their coefficients. Investment also affects openness in a similar way, with a positive coefficient in FE and FEVD estimations. In the case of the two variables that are part of the interaction analysed, we report that once again we have a positive relation between income level proxy variable and trade openness, however, we also have to consider the coefficient of the interactive term. In this case, the interaction with the income level variable obtains a negative coefficient, which means that the effect of distance is reduced if the country is a rich one. We can also add that the impact of income is also minimized if the country is farther from its world trade centre.

The last remark done on table 6.5 is the result of remoteness by itself. The coefficient of this variable is positive and this is not the expected result nor the obtained one in previous specifications. However, we should add that this coefficient is not significant and in order to obtain a proper interpretation of the effect of remoteness we need to take into account the interaction term.[17]

6.5.3.1 Variables Across Time

The time trend, which is included in all the previous estimations, is one of the variables with significant coefficients in all our specifications. The results for this variable signal an increase in trade intensity for all countries in time. However, it is possible to exploit more this idea of changes in time not only for the dependent variable but also on the effects that some of the regressors have in openness. We accomplish the previous by expanding our idea of generating more interactions of the independent variables and the time trend. These new set of regressors are constructed by multiplying the independent variables we used in previous estimations and the time trend. The variables we use to construct these new regressors are real GDP per capita, remoteness, freedom for trade, area, population density and the landlocked dummy.

Before we report the results of this exercise it is important to remark that not all these new variables are included at the same time due to reasons of possible multi-collinearity between the new variables. The way we estimate and analyse the new regressions is by including one by one the interaction terms. The results are divided in two tables, in the first one (table 6.6) the interactions between real GDP per capita, remoteness, freedom for trade and the time trend are included; in table 6.7 we report the rest of the variables (area, population density and landlocked dummy).

The first thing we report from table 6.6 are the results of the variables that are part of the previous FEVD estimations. Terms of trade, investment as a percentage of GDP, population density, area and the landlocked country dummy variable report a coefficient similar to

[17] In order to observe the effect of remoteness isolated, we need to have a coefficient of rGDPc equals to zero.

Table 6.5: FEVD. Interactive Effects

Dependent variable: Openness		
	FE	FEVD
	I	II
ToT	2.612***	2.612***
	(0.617)	(0.413)
Time	0.506***	0.506***
	(0.053)	(0.022)
Investment/GDP	0.490***	0.825***
	(0.038)	(0.021)
rGDPpc	36.959***	9.850***
	(12.691)	(3.757)
$Pop - den$	-7.688***	-6.811***
	(2.160)	(0.131)
Remote	30.568***	1.583
	(11.470)	(3.695)
Freedom	0.374***	1.418***
	(0.143)	(0.103)
Area		-8.621***
		(0.091)
Landlocked		-7.169***
		(0.426)
*rGDPpc*Remote*	-3.988***	-1.309***
	(1.444)	(0.434)
Unexplained Fixed-effects		1.000***
		(0.011)
Constant	-239.473**	133.221***
	(101.660)	(32.388)
Obs	2231	2231
Groups	121	
F	82.490	1905.253
Prob> F	0	0
R^2		0.909
Adjusted R^2		0.903
RMSE		6.320

Notes: *,**,*** denote significance at the 10%, 5%, and 1% level, respectively. Standard Errors in parentheses.

Table 6.6: FEVD. Variables across time

Dependent variable: Openness			
	I	II	III
ToT	2.60***	3.17***	2.6***
	(0.41)	(0.42)	(0.41)
Time	1.24***	-1.71***	0.81***
	(0.1)	(0.55)	(0.07)
*rGDPc*Time*	-0.10***		
	(0.01)		
*Remote*Time*		0.25***	
		(0.06)	
*Freedom*Time*			-0.05***
			(0.01)
Investment/GDP	0.80***	0.81***	0.81***
	(0.02)	(0.02)	(0.02)
rGDPpc	0.99***	-1.6***	-1.35***
	(0.35)	(0.14)	(0.15)
$Pop - den$	-6.81***	-6.83***	-6.78***
	(0.13)	(0.13)	(0.13)
Remote	-9.55***	-15.87***	-9.44***
	(0.54)	(1.7)	(0.54)
Freedom	1.35***	1.63***	2.55***
	(0.1)	(0.1)	(0.22)
Area	-8.65***	-8.68***	-8.67***
	(0.09)	(0.09)	(0.09)
Landlocked	-6.8***	-7.03***	-6.8***
	(0.42)	(0.42)	(0.42)
Unexplained Fixed-effects	1***	1***	1***
	(0.01)	(0.01)	(0.01)
Constant	212.12***	284.27***	222.29***
	(6.05)	(14.74)	(5.85)
Obs	2231	2231	2231
F	1918.94	1910.6	1905.93
Prob> F	0.00	0.00	0.00
R^2	0.91	0.91	0.91
Adjusted R^2	0.9	0.9	0.9
RMSE	6.3	6.31	6.32

Notes: *,**,*** denote significance at the 10%, 5%, and 1% level, respectively. Standard Errors in parentheses.

the estimation of our model without interactive variables. However, there are variables that experience changes. The most notorious variations are observed in the variables by themselves that are part of the interactions. When we include the interaction between real GDP per capita and the time trend, we get a positive sign for our income proxy variable and the interaction term reports a negative sign. This can be interpreted as follows, the nations are more open to trade as they are richer. However, as time passes by, this positive relationship is reduced and it could even change direction. It is possible that the effects of income level on openness change according to the specific characteristics of the country we analyse.

In the second column, we have the results of our specification that includes the interaction between remoteness and time. We observe that remoteness, distance, is negatively related (with a greater coefficient than in previous estimations) to trade openness and the interaction term is positively related to the endogenous variable. This means that the impact of distance is more determinant during the decade of the 80's than in recent years. This represents evidence in favour of lower transportation costs that could be explained with the technological progress economies have experienced in past years. However, there is a result not expected by us and this is the negative sign of time trend's coefficient.

The last estimation in this table is the one that includes the interaction between the time trend and our trade policy index variable. The results are similar except for the magnitude of the freedom for trade index and time trend. These report the expected signs, which we also observe in previous estimations, but with a greater coefficient in the case of freedom for trade and a lower one in the case of the time trend. Once more we have a reduction through time of the effect of the independent variable, in this case the trade policy index variable. So we have that trade policies were also more effective or more "aggressive" in the past; perhaps trade policies must be more specific in order to achieve the same type of results now that economies are more open than in the past.

Table 6.7 presents the rest of the estimations that include an interactive variable. As we did in the first table of this section, we start by mentioning the regressors that do not report a remarkable change. We find in this group terms of trade, investment as a percentage of GDP, real GDP per capita, remoteness and the freedom for trade index variable. As a matter of fact we do not observe any relevant change in the magnitudes of the regular variables that

Table 6.7: FEVD. Variables across time II

Dependent variable: Openness			
	I	II	III
ToT	2.39***	2.76***	2.86***
	(0.41)	(0.41)	(0.41)
Time	-0.41***	0.6***	0.52***
	(0.12)	(0.06)	(0.02)
*Area*Time*	0.07***		
	(0.01)		
$Pop-den$*$Time$		-0.02	
		(0.01)	
*Landlocked*Time*			0.02
			(0.05)
$Investment/GDP$	0.81***	0.82***	0.82***
	(0.02)	(0.02)	(0.02)
rGDPpc	-1.67***	-1.46***	-1.46***
	(0.14)	(0.14)	(0.14)
$Pop-den$	-6.76***	-6.36***	-6.86***
	(0.13)	(0.34)	(0.13)
Remote	-9.66***	-9.47***	-9.49***
	(0.54)	(0.54)	(0.54)
Freedom	1.72***	1.45***	1.44***
	(0.1)	(0.1)	(0.1)
Area	-10.25***	-8.68***	-8.68***
	(0.24)	(0.09)	(0.09)
Landlocked	-6.93***	-6.99***	-7.39***
	(0.42)	(0.42)	(1.29)
Unexplained Fixed-effects	1***	1***	1***
	(0.01)	(0.01)	(0.01)
Constant	253.86***	226.81***	228.46***
	(6.37)	(5.75)	(5.63)
Obs	2231	2231	2231
F	1948.23	1899.09	1901.21
Prob> F	0	0	0
R^2	0.91	0.91	0.91
Adjusted R^2	0.91	0.9	0.9
RMSE	6.26	6.33	6.33

Notes: *,**,*** denote significance at the 10%, 5%, and 1% level, respectively. Standard Errors in parentheses.

interact with the time trend (variables Area, population density and landlocked country dummy variable). In the case of the time trend we obtain, once more, a negative sign when we include an interaction between area and the time trend.

We continue with the analysis of land area of a country and we have that there is a increase in the magnitude in absolute value of its coefficient. And once again the interaction term registers the contrary sign of area's coefficient, so we have once more a reduction in the effects of this variable (area) in the level of openness of an economy through time. This set of results are presented in column (I) of table 6.7. In column (III) of the same table, we have that being a landlocked country affects negatively the economy's level of openness. However, the effect eases with time as we observe a positive coefficient in the interaction term generated by the time trend and the landlocked country dummy variable.

The last interactive variable we have is the one constructed with population density and the time trend. This is the only case in which both the interaction term and the variable by itself obtain the same sign, a negative one. In other words, the effect of population density has become stronger through time. As we have said above, countries with smaller population density require more trade intensity to satisfy the domestic demand (either by consuming or producing a small amount of goods to be sold in international markets). The lack of some goods in the domestic market and the need to buy foreign products in international markets is reduced as the number of inhabitants per square kilometre increases in the economy. The interaction term reinforces this effect, that is as years pass by, the role of population density in the amount of trade increases, the negative relationship gets stronger.

Our interactions show interesting changes that the impact of our variables have suffered in the last decades. Perhaps the most relevant one of our exercise is the one of remoteness, distance proxy, which represents evidence in favour of a lower relevance of transport costs in the decision of opening to trade. But, our results cannot confirm what some others have labeled as "death of distance" in trade.

6.6 Conclusions

The results of our estimations represent support of our openness specification. It is possible to explain trade openness with variables that capture the effects of relevant variables across time and at the same time taking into account the importance of country-characteristics in our regressions. We can easily observe that trade openness has increased in the last couple of decades and that several factors can account for this change. An obvious result is the one of our trade policy variable proxy index that shows how countries have worked to reduce their trade barriers. However, not all trade barriers are imposed by governments and in these cases it is necessary more than trade policies in order to impulse trade. This situation is well recognized with our results for investment.

We also find that country characteristics are relevant even in a panel data estimation. In our estimations we find evidence in favour of geographic characteristics because we apply the fixed-effects vector decomposition procedure. This technique allow us to include time-invariant variables (such as country characteristics) in a three-stage estimation in which the results are a mixture of fixed-effects and cross-country effects. Our results improve when we use this estimation technique and we can also control for effects such as land area of a country or to specify if a country has access to the sea (these two work as disincentives for having higher levels of trade). The empirical results show that our openness estimation improves considerably by moving from a fixed-effects panel regression to the use of the FEVD procedure.

In the last part of our work we present results that show how the effects of relevant variables for trade openness have changed across time. One of this is the impact of distance, controlled for in our estimations with the remoteness variable, through time. We can confirm the importance of transport costs for trade openness, but we can also observe that the effects of these have reduced in the last couple of decades. In other words, we have that distance affected more trade volumes during the eighties that what it does today (or 2005, last year of our sample). This is not the only variable, remoteness, that we analyse across time: The effects of income levels have also been reduced in recent years. This result helps us to clarify a little more some of the results we obtain for this variable in fixed-effects regression and also when we combine this with the results of a cross-country estimation. The results that include the interaction between real GDP per capita and the time trend tell us that richer countries are more open to trade, but the impact of this variable has diluted in recent years considerably to even reverse its direction. In cross-section regressions of an openness equation income level proxy variables signal for a negative relationship.

We also have evidence that show more difficulties of trade policies to increase the levels of trade openness observed during the first five years of the last decade compared with the impact of the variable during the eighties. The effects of countries' land area and the landlocked country dummy variable are also lower in recent years. Our last interaction shows a different behaviour since it shows a stronger effect of the variable across time: Population density has a greater impact in the amount of trade a country has.

Our results represent an important effort in the search for an specification that help us explain trade openness in a dynamic framework and also applying an efficient and new estimation technique. There are, however, some factors that are left aside in our work and could represent a new line of research in this topic.

Chapter 7

Measuring RER Volatility

7.1 Introduction

The term volatility is a fundamental one in economic literature. Its main objective is to capture fluctuations of economic and financial variables. One of these relevant variables is the real exchange rate. However, it is difficult to have an accurate measure of variability in exchange rates because there is no widely accepted theory of its determination. The problem is not a trivial one if we consider that volatility is not an observable variable and we need to try out several proxies and decide which one is the best. This aspect makes even harder the existence of a single volatility measure.

Dwyer, Nguyen and Rajapakse (1996) consider the existence of at least three notions of volatility in the literature. The first one defines volatility as the change from one period to the next one of the relevant variable: the more it fluctuates between one period and the following, the more it is regarded as volatile. The second notion considers that risk and uncertainty are two things that are closely related. The key characteristic of a volatile series is its unpredictability, the difficulty to have an accurate forecast of future movements. In this case, volatility is measured by prediction errors. The third one (and the one we are interested in analysing) is more focused on fluctuations of the variable around a (sample) mean. This notion is more related to statistical measures of dispersions around that mean. If we consider this concept, we have that the more dispersed an exchange rate series is around its mean, the more volatile it is.

Bui and Pippenger (1990) claim that it is hard to link (real) exchange rates directly with economic fundamentals. This idea combined with the fact that there is no consensus on a definitive model for exchange rates makes it harder to calculate an appropriate measure of variability for exchange rates. The authors use a measure of volatility for their empirical work widely used in finance literature, which is the variance of the series in percentage changes. If we turn our attention to finance models, we find that stock price models rely heavily on a good measure of volatility in order to have more precise price (or stock return) forecasts. For this reason, the concept of volatility is also one of the main indicators in finance. In general, researchers in this field focus their attention on volatility generated in stock markets. However, they do not measure volatility of stock prices frequently. They are more interested in the returns of these stocks and the variations that these suffer. To be more precise, instead of measuring the variance in levels:

$$Vol\left(P_{a,t}\right) = \frac{\sum_{t=1}^{T}\left(P_{a,t} - \bar{P}_a\right)^2}{T-1} \tag{7.1}$$

where $Vol\left(P_{a,t}\right)$ is the price volatility of stock a, $P_{a,t}$ is the price of that particular stock a at time t, $\bar{P}_a$ is the arithmetic mean of price a, and T is the size of the sample, they rather use this (the variance in first differences):

$$Vol\left(R_{a,t}\right) = \frac{\sum_{t=1}^{T}\left(R_{a,t} - \bar{R}_a\right)^2}{T-1} \tag{7.2}$$

$$R_{a,t} = P_{a,t} - P_{a,t-1} \tag{7.3}$$

Their main interest is in to how much uncertainty exists in stock price changes, or in stock returns. There are even times that the measure of volatility is calculated focusing exclusively on negative changes because an investor is more worried about how much value a stock could lose and not about how much it might gain. In general, it is more important in stock and asset markets to analyse movements in price changes rather than actual levels.

If we now analyse the case of real exchange rates, we find that there is no consensus on what measure of dispersion should be used to capture volatility in this variable. We find frequently in the literature - in particular empirical studies - that volatility measures are constructed using data in first differences and not from the series in levels. From an economic point of view, it seems more interesting to observe the volatility taken from series in levels rather than the one taken from monthly-change series. This chapter is an attempt to shed light on the issue of what volatility measure should be used for real exchange rates, the one in levels or the one in first differences.

We obtain real exchange rate time series from several countries and we assume that these series follow a specific data-generating process (DGP). Our first step is to estimate a time series model that real exchange rate series are assumed to follow, in order to obtain coefficients that we use as parameters in the next part of our empirical work. We then generate artificial data via a Monte Carlo exercise, using the parameters obtained previously, to calculate the sample standard deviation of the new series with artificial data. In order to make several comparisons of our volatility measures in levels and first differences against a reference value that we calculate from the DGP's variance, we show the details of this procedure in the following sections. We analyse the proximity of the measures taken from the different samples, in levels and first differences, and the actual volatility value of the DGP.

Our objective is to compare how different the volatility of the real exchange rate calculated from samples in levels is from a reference value for the series in levels. We repeat the exercise, now taking a volatility measure for the real exchange rate (RER) in first differences, and compare this against another reference value, this one corresponding to series in first differences. We want to establish which measure is more similar to the respective reference value. At the same time we can analyse how much each measure we calculate differs from our artificially generated series' volatility.

7.1.1 Motivation of our work

In recent times, researchers have done an effort to obtain a more systematic relationship between real exchange rate volatility and fundamental variables of the economy. The main goal is to obtain a better explanation of the high volatility this variable has experienced in recent times. As examples of the previous statement, we can mention the work of Hau (2004), Hausmann *et al.* (2004), Bravo and di Giovanni (2006), Calderón and Kubota (2009), among others. However, none of the previous has found a definitive answer to explain in a better and more systematic way the volatility of the real exchange rate.

If we take a closer look to their empirical approach, we find that the volatility measure in Hau's work is the standard deviation for the percentage change of the real exchange rate over an interval of 36 months. The author does not check for unit roots in the real exchange rate data. Similarly, Bravo and di Giovanni use as their measure of RER volatility the annual real exchange rate change (in log differences) each month.[1] We encounter again an empirical work in which real exchange rate series are not tested for the existence of unit roots and the authors only consider the first difference of the data without any further exploration.

In Hausmann *et al.* (2004), we find that the authors calculate RER volatility from the growth rate of the real exchange rate. Formally, their measure is given by calculating the standard deviation of the log of the real exchange rate at time t minus the observation at $t-n$ using annual data on real effective real exchange rate over the 1980 - 2000 period. Once again there is no discussion of why the authors prefer the use of series in first differences over the levels. As a final example, we mention the work of Calderón and Kubota (2009) to show that the common measure found in the literature of real exchange rate volatility is the standard deviation of the natural logarithm of the RER variation between periods t and $t-12$ as this is also their choice to model real exchange rate volatility.

All the previous works focus on the real exchange rate series in differences because they assume the series in levels are integrated of order one without further exploration. In recent years, we find in the literature evidence in favour of the PPP holding for some countries as researchers consider different ways to test stationarity. There are several works in which the order of integration of the real exchange rate series is tested with positive results in favour of the hypothesis that these are stationary. Lothian and Taylor (1996) investigate the long-run, mean reverting properties of real exchange rates as they consider existing unit root tests suffer problems of lower power. Ahking (2003) shows that 18 out of 21 countries

[1] In other words, they take the change between February of 1994 and February of 1995, and then do the same for the next month and so on (i.e. a "rolling window" of annual changes over different time periods.)

in his sample are stationary applying the unit root test developed by Elliot *et al.* (1999). This means that considering volatility measures in first differences for the complete sample of an empirical work exploring the real exchange rate might not be the best approach as some countries might be in fact stationary.

Our work is an attempt to observe differences between simple volatility measures (standard deviation) taken from RER series in levels and in first differences. Some of the works that obtain evidence in favour of a PPP that holds make use of long time series (Lothian and Taylor use two centuries of data to test the real exchange rate of France, the United Kingdom, and the United States). As a matter of fact, data availability for long periods of time is also an issue when it comes not only to test properties of the real exchange rate, but also to model empirically its behaviour; for this reason some authors make use of Monte Carlo simulation techniques to generate long real exchange rates.[2] This is our main motivation to explore in detail if there exist considerable differences between volatility measures taken from series in levels and in first differences.

7.2 Related Literature

As Maravall and Bentolila (1986) argue in their work, measuring the volatility of economic series is a difficult but also relevant task. They take into account the fact that the concept of volatility is closely related to unpredictability and they focus on the analysis of residuals of macroeconomic time series, in particular of the M3 money aggregate.

Engle and Patton (2000) describe the desirable characteristics that should be found in a good volatility model.[3] They also enlist a number of stylized facts about asset price volatility. These facts are: 1) Volatility exhibits persistence; 2) Volatility is mean reverting; 3) Innovations may have an asymmetric impact on volatility; and 4) Exogenous variables may influence volatility.

For the first stylized fact (volatility exhibits persistence), we can recall what Mandelbrot (1963) and Fama (1965) mention in their works: large changes in the price of an asset

[2]See Taylor, Peel and Sarno (2001) as an example of works that make use of Monte Carlo simulations.

[3]In their work, Engle and Patton (2000) enlist six stylized facts, however, we just mention four of them since we consider the remaining two are more related to the case of asset prices.

are often followed by more large changes, and small changes are often followed by small changes. In the case of the real exchange rate, we find that there is high persistence, and this issue has raised some doubts about the validity of purchasing power parity (PPP) in empirical works. These studies quite often are not able to replicate the features of the PPP framework. It has sometimes been argued that high persistence in real exchange rates is to blame for these empirical results.

As for the second fact, volatility is mean reverting, we find that in the case of asset prices volatility comes and goes. A streak of high volatility periods does not last forever and eventually one will give way to periods with lower volatility. This is also the case when we observe the opposite situation, periods with unusual low volatility. Real exchange rates, as we mention above, exhibit high persistence. There is no evidence in empirical studies supporting the PPP at any point in time; but there are others that report evidence of the PPP holding in the long-run, PPP is not a short-run feature. These works argue that real exchange rates return to an equilibrium level in the long-run.

In the case of the third fact (Innovations may have an asymmetric impact on volatility) we can say that for equity returns is unlikely that positive and negative shocks have the same impact on the volatility. Black (1976), Nelson (1991) and Engle and Ng (1993) among others find evidence of volatility being negatively related to equity returns. However, this issue has not been explored enough for exchange rates. Bleaney and Li (2009) is a recent example of this topic analysed for exchange rates. They find evidence against the hypothesis that dollar based real exchange rates of several countries adjust at a different rate to return to equilibrium compared to the speed observed when these move away from it.

Exogenous variables may influence volatility: There are other variables with relevant information that can explain drastic changes in asset prices (or any other price series). We can relate this fact to the case in nominal and real exchange rates in the following way: These two are prices too and there are exogenous factors that affect their variability. The former is the price of one currency in terms of another. The latter is a relative price index that can be constructed using several variables and in different ways. There are a great number of factors that can alter the components of these prices. As a matter of fact, we can obtain real exchange rate equation derived from different theory models that include diverse variables to explain its behaviour: PPP based using CPI or WPI or any other price index;

or we can take the UIP framework and employ interest rates differentials and exchange rate expectations; Using a monetary approach and our real exchange rate is based on the money demand and GDP changes. All these models include different exogenous variables that affect in different ways the results of the real exchange rate models.

We must also consider the puzzle in international economics about the possible existence of a unit root in real exchange rate time series. We mention above that PPP (mean reversion in the real exchange rate) does not hold in the short-run, but it does in the long-run as several authors claim. Yotopoulos and Swada (2006) are able to find support for mean reversion in the real exchange rate in periods of 20 years, and for some countries even of ten, years for more than 130 countries. Their results are based on a cross-country estimation method.

The use of cointegration analysis is a more common tool used to test the validity of the PPP: Kugler and Lenz (1993) implement this multivariate methodology in exchange rates and domestic and foreign price series to obtain evidence in favor of the PPP.[4] It is not in the scope of this work to prove the validity of the PPP; however, if the concept holds, the variance of the real exchange rate is finite in the data generating process that fits the series observed in real life and it is possible to obtain measures of the volatility with the series in levels.[5]

Keeping in mind the previous puzzle, we present this work as an attempt to start a discussion on what measure of volatility is more relevant in the case of real exchange rates from a macroeconomic point of view. Actually, there is no recent work in which the topic is raised and analysed. Honohan (1983) mentions in his work that it is hard to reach a consensus on a generally appropriate measure of variability not only in real exchange rates but in all time series. He enlists three main sources of ambiguity: a) the frequency of sampling; b) the reference path; and c) the weighting of sample deviations from the reference path. Deciding which measure to use as the proxy for real exchange volatility is a difficult process that, as Honohan points out, involves several dynamic factors.

[4] There are several attempts to prove the validity of the PPP finding; the evidence can be divided in works that obtain results in favor and against it. Engel (2000) is an example of the literature that does not obtain empirical support for the validity PPP. Taylor (2006) does a critical review of the existing literature on real exchange rates stability at the time.

[5] If we have that PPP does not hold, the we cannot just measure the volatility of the real exchange rate between two points in time and we would not have the same value of this statistic. This makes harder the task of finding explanations to such behaviors; the movements are erratic and driven by a random-walk process.

Pinches and Kinney (1971) test 8 different measures of volatility to see if all these give the same kind of information to the researcher. The authors calculate the measures for different set of prices taken from a group of fifty companies Among their measures they include to measure variability in levels: a) Range Divided by Mid-range, b) Variance, c) Mean Absolute Deviation, d) Coefficient of Variation of Prices, e) Coefficient of Variation of Prices Changes and f) Semi-variance. For all the previous we report their mathematical expression in table 7.1. And to capture volatility using specifically price changes, they construct two more measures: g) Coefficient of Variation of Price Changes and h) Modified Quadratic Mean Considering Only Adverse Returns.

Table 7.1: Measures of Volatility - Pinches and Kinney (1971)

Volatility Measure	Expression
Range Divided by Mid-range	$\frac{P_h - P_l}{(P_h + P_l)/2}$
Variance	$\sum_{i=1}^{n}(P_i - \hat{P})^2/n$
Mean Absolute Deviation	$\sum_{i=1}^{n}\lvert P_i - \hat{P}\rvert/n$
Coefficient of Variation of Prices	$\left(\sqrt{\sum_{i=1}^{n}(P_i - \hat{P})^2/n}\right)/\hat{P}$
Coefficient of Variation of Prices Changes	$\left(\sqrt{\sum_{i=1}^{n}(d_i - \hat{d})^2/n}\right)/\hat{d}$
Semi-variance	$\sum_{i=1}^{n}(P_i' - \hat{P})^2/n$

Notes: P_h and P_l are the price highest and lowest quotes respectively. P_i is the price of asset i, $\hat{P}$ is the mean value of the P_i series, and $\hat{d}$ is the price difference. $P' = P_i$ if $P_i < \hat{P}$ and zero otherwise.

They conclude that all these measures return a similar measure of volatility. However, they put emphasis on the fact that some of these could be more useful than others according to the individual decision maker's definition of risk. A contemporaneous study to the previous is the one from Altman and Schwartz (1973). They use data taken from several firms and then aggregate these into industries to analyse if different measures of volatility have a consistent performance for a specific period of time. Their results show that the measures are in fact reasonably consistent. They use a simple measure of volatility and several other more complex measures that are based on the results of different econometric models estimated by the authors.[6] All the previous measures are applied to price level series. The relevance of this work lies in the fact that the variance of prices, no matter how simple this volatility measure could be, is a very consistent indicator.

For the stock market, Robles-Fernández (2002) analyses several measures of volatility to obtain one that could be seen as the best in terms of predictability.[7] She is not able to find a measure that outperforms the rest and concludes that it is necessary to choose our volatility measure based on the final objective of the research.

Finally, we have to say that despite the lack of studies in which the real exchange rate and its measures of volatility are the central topic of research, there are some works that try to measure the volatility in nominal exchange rates. These pay particular attention to the period starting after the collapse of the Bretton Woods system, or in other words, after the moment several economies started adopting a flexible exchange rate system. Hakkio (1984) is a good example. In his work the author documents that exchange rates have been both variable and unpredictable in the post-Bretton Woods times.

Frenkel and Mussa (1980) are another example of an analysis of nominal exchange rate's volatility. Despite the fact that nominal exchange rates do not give dividends, they consider a different approach by assuming exchange rates have a similar behaviour to stock prices in a volatile market. The authors analyse the extent of turbulence in foreign exchange markets.[8] They explain this turbulence in exchange rates in terms of the "asset market theory" since exchange rates, as the price of any other asset determined in organized markets, are influenced by market's expectations of future events.

Bagshaw and Humpage (1986) and Rana (1981) not only try to analyse the volatility of nominal and real exchange rates using a dispersion measure (second sample moment). They also attempt to determine the complete statistical distribution of exchange rates, or at least the first four sample moments (mean, variance, skewness and kurtosis) in order to check if

[6]These regressions are done using the price of stocks as dependent variable and time trends and its returns as explanatory variables; the volatility measure is taken from the coefficients estimated.

[7]In her work we find that the measures are divided in two categories: Simple and Structural measures. The former includes the standard deviation, exponential smoothing and two more measures taken from Fama's and Luce's works. The latter includes models based on the ARCH framework (GARCH, EGARCH, etc.) and regression models.

[8]The simplest measure of turbulence used by Frenkel and Mussa is the average percentage changes in exchange rates over an specific period of time.

the series resemble a normal distribution or not.

In our opinion, it is possible to have a better understanding of not only the high volatility observed in exchange rate markets, but also of the behaviour of real exchange rates by having a more accurate measure of volatility for this variable.[9]

The present work does not include the construction of volatility measures based on diverse models. It is important to mention that we are not trying to focus our study on the stock market and its returns. Our scope is to have a better understanding if a simple volatility measure such as the standard deviation of a series in levels and in first differences, in our case of the real exchange rate, give us the same profile of the volatility of the variable investigated. Our results can give a better idea if the approach taken by several other authors is the appropriate one, or even if it is necessary to devote more resources in the search of a better measure of volatility for real exchange rates.

7.3 Model

Researchers quite often choose as their volatility measure the standard deviation or the variance of the monthly change. This is used without any significant discussion of what the measure is intended to capture, and whether this is an optimal measure of volatility. From an economic point of view, we are more interested in the volatility of the level than of monthly changes. By taking the first difference of the series we could be destroying important information. At this point, we should mention the difficulties researchers face in order to establish if real exchange rate series are stationary or not. The problem becomes relevant because if we detect a unit root in the previous series, then we have no choice but to use differences in our analysis. However, the most common practice found in empirical literature on real exchange rate is to overlook this fact and continue with the analysis using first difference series without considering a preliminary set of tests to verify if stationarity conditions are satisfied or not.

In our work, we want to focus only on our main question and we assume that our series are

[9] It might be the case that the measures of volatility studied here are the simplest we could imagine, however, our work tries at least to disregard the ones that are not accurate enough, or understand in which situations we can trust some measures and in which others we cannot.

stationary and do not apply any type of unit root test to the real exchange rate series.[10] It could be claimed that by having most of our coefficients close to 1, some series might include a unit root in their process. However, it is difficult to apply and rely on unit root tests; and some authors have expressed their concern about this type of test. Because of issues such as the lack of power in unit root tests. Some of these go even further by saying that this lack of power could be one of the main reasons of why there is no more empirical evidence in favour of the PPP.[11] Assuming that our series are stationary is a very strong but also important assumption we need to make in order to carry out our work and shed light on a discussion that has been avoided in recent literature.

The model we use to proxy the DGP of the real exchange rate series and to analyse its volatility is based on a standard mean reversion model with a "twist" because the $\alpha_{j,t}$ term of equation 7.4 is also a stochastic process. Equation number 7.5 is the one that describes the dynamics of this $\alpha_{j,t}$ term.

$$\Delta X_{j,t} = \alpha_{j,t} - \beta_j X_{j,t-1} + u_{j,t} \tag{7.4}$$

$$\alpha_{j,t} = \rho_j \alpha_{j,t-1} + v_{j,t} \tag{7.5}$$

Where $X_{j,t}$ represents the real exchange rate series for country j, and $\Delta X_{j,t}$ is the same series after we have applied first differences to it. For the two innovation terms $u_{j,t}$ and $v_{j,t}$, we assume they are two independent and identically distributed processes with mean zero and the following finite variances:

$$u_{j,t} \sim N(0, \sigma^2_{u_j})$$
$$v_{j,t} \sim N(0, \sigma^2_{v_j})$$

The objective of including a stochastic $\alpha_{j,t}$ process is to model the possibility of having

[10] As we mention earlier there is a huge debate in the literature in this sense: studies are devoted to either trying to prove that the real exchange rate is stationary or that there exists a unit root in this process.

[11] See Lothian and Taylor (1997) for further details.

a real exchange rate equilibrium that might be able to adjust through time. The idea of having this long-run level that varies through time can be linked to the literature on the Fundamental Equilibrium Exchange Rate (FEER) mainly developed by Williamson (1994). The FEER recognizes that the equilibrium real exchange rate varies across time as there are modifications on the internal and external balances of the economy across time.[12]

We also assume that both $X_{j,t}$ and $\alpha_{j,t}$ are stationary processes. This requires that both $(1-\beta_j)$ and ρ_j are lower than one in absolute value.

If we go back to our model, we rearrange equation (7.4). The first step is to use the lag operator L to obtain an expression for $X_{j,t}$ from the previous system and make easier the estimation of the parameters that are going to be used later. We have that the initial expression is:

$$\begin{aligned} X_{j,t} &= \alpha_{j,t} + (1-\beta_j)X_{j,t-1} + u_{j,t} \Rightarrow \\ X_{j,t} &= \alpha_{j,t} + (1-\beta_j)LX_{j,t} + u_{j,t} \Rightarrow \\ (1-(1-\beta_j)L)X_{j,t} &= \alpha_{j,t} + u_{j,t} \end{aligned} \tag{7.6}$$

and in the case of the alpha equation, mean process of the real exchange rate (equation 7.5), we do a similar transformation and define an equation that depends only on variables at t and the lag operator. We end up with:

$$\begin{aligned} \alpha_{j,t} &= \rho_j \alpha_{j,t-1} + v_{j,t} \Rightarrow \\ \alpha_{j,t} &= \rho_j L \alpha_{j,t} + v_{j,t} \Rightarrow \\ (1-\rho_j L)\alpha_{j,t} &= v_{j,t} \Rightarrow \\ \alpha_{j,t} &= \frac{v_{j,t}}{(1-\rho_j L)} \end{aligned} \tag{7.7}$$

The next step is to have just one equation that includes both processes. We substitute (7.7)

[12]See Siregar and Rajan (2006) for a survey on equilibrium real exchange rates models.

in (7.6):

$$
\begin{aligned}
(1-(1-\beta_j)L)X_{j,t} &= \frac{v_{j,t}}{(1-\rho_j L)} + u_{j,t} \Rightarrow \\
(1-\rho_j L)(1-(1-\beta_j)L)X_{j,t} &= v_{j,t} + (1-\rho_j L)u_{j,t}
\end{aligned}
\tag{7.8}
$$

The only thing that is left to be done is to expand the expressions to eliminate the lag operators in equation (7.8):

$$
\begin{aligned}
X_{j,t} - [(1-\beta_j)+\rho_j]X_{j,t-1} + (1-\beta_j)\rho_j X_{j,t-2} &= v_{j,t} + u_{j,t} - \rho_j u_{j,t-1} \Rightarrow \\
X_{j,t} - \phi_{1,j}X_{j,t-1} - \phi_{2,j}X_{j,t-2} &= v_{j,t} + u_{j,t} - \rho_j u_{j,t-1} \\
\text{where} & \\
\phi_{1,j} &= (1-\beta_j)+\rho_j \\
\phi_{2,j} &= -(1-\beta_j)\rho_j
\end{aligned}
\tag{7.9}
$$

We also assume that $v_{j,t}$ and $u_{j,t}$ are uncorrelated stationary process; also both processes have a zero mean and finite variance (σ_v^2 and σ_u^2). With this set-up, we encounter an important inconvenience for the estimation of $(1-\beta_j)$ and ρ_j. This time we must figure out how to end up with an expression that includes only one stochastic term in the $X_{j,t}$ process so that we can estimate it without a problem.

As we mentioned above, we have two innovation terms that are part of $X_{j,t}$, $u_{j,t}$ (which is an MA(1) process) and $v_{j,t}$ (noise process). The existence of these two becomes an issue when we have to define the actual process to be estimated in order to obtain relevant parameters that are necessary for our empirical exercises (in this case to run our Monte Carlo experiment).

Since we assume that the latter, $v_{j,t}$, is a well behaved process with mean equal to zero and unknown but finite variance, we need to consider an external result to define what type of process we are dealing with. We just have to find out the result of having a white noise process such as $v_{j,t}$ and an MA(1) process, like $u_{j,t}$. Hamilton (1994) derives the sum of these two process with a final result of a new MA(1) process, with the same mean but different variance for this new MA(1).

Let's suppose that $Y_{j,t} = u_{j,t} + \theta u_{j,t-1}$, MA(1), and as we have mentioned above $u_{j,t}$ has zero-mean and

$$E(u_{j,t}u_{j,t-i}) = \begin{cases} \sigma_u^2 & \text{for } i = 0 \\ 0 & \text{otherwise.} \end{cases} \tag{7.10}$$

Then, we have the following properties for $Y_{j,t}$:

$$E(Y_{j,t}Y_{j,t-i}) = \begin{cases} \sigma_u^2 & \text{for } i = 0 \\ \theta\sigma_u^2 & \text{for } i \pm 1 \\ 0 & \text{otherwise.} \end{cases} \tag{7.11}$$

In the case of $v_{j,t}$ we have:

$$E(v_{j,t}v_{j,t-i}) = \begin{cases} \sigma_v^2 & \text{for } i = 0 \\ 0 & \text{otherwise.} \end{cases} \tag{7.12}$$

And as we mention above, both $v_{j,t}$ and $u_{j,t}$ are uncorrelated ($E(u_{j,t}v_{j,t-i}) = 0 \Rightarrow E(X_{j,t}Y_{j,t-i}) = 0 \quad \forall i$). Now suppose that series $Z_{j,t}$ represents the sum of the MA(1) and $v_{j,t}$ white noise process:

$$\begin{aligned} Z_{j,t} &= Y_{j,t} + v_{j,t} \\ &= u_{j,t} + \theta u_{j,t-1} + v_{j,t} \end{aligned}$$

With the following properties: $E(Z_{j,t}) = 0$ and

$$
\begin{aligned}
E(Z_{j,t}Z_{j,t-i}) &= E(Y_{j,t}+v_{j,t})(Y_{j,t-1}+v_{j,t-1}) \\
&= E(Y_{j,t}Y_{j,t-i}) + E(v_{j,t}v_{j,t-i}) \\
&= \begin{cases} (1+\theta^2)\sigma_u^2 + \sigma_v^2 & \text{for } i = 0 \\ \theta\sigma_u^2 & \text{for } i \pm 1 \\ 0 & \text{otherwise.} \end{cases}
\end{aligned} \tag{7.13}
$$

So we have that adding an MA(1) process to a white noise series which is uncorrelated at all leads and lags produces a new MA(1).[13] And coming back to our original model, we end up with the following expression for our real exchange rate process, $X_{j,t}$:

$$
X_{j,t} = \phi_{1,j}X_{j,t-1} + \phi_{2,j}X_{j,t-2} + \epsilon_{j,t} + \theta_j\epsilon_{j,t-1} \tag{7.14}
$$

A second remark we must make in the estimation of $X_{j,t}$ that arises from the solution to the first dilemma is now a problem of identification for some of the coefficients of $X_{j,t}$. This problem arises because in our original model we find $(1-\beta_j)$ and ρ_j as part of the model, and these are the coefficients we want to use as parameters for the following sections. Instead, we estimate $\phi_{1,j}$ and $\phi_{2,j}$ as stated in equation (7.14). Now, we just need to find the way to recover the relevant parameters from the estimated coefficients.

We know that $\phi_{1,j}$ and $\phi_{2,j}$ are a combination of both $(1-\beta_j)$ and ρ_j, then it must be possible to obtain the value of these parameters for each country using our estimation results for the first set of parameters. The identification of $(1-\beta_j)$ and ρ_j of each country from estimated values of $\phi_{1,j}$ and $\phi_{2,j}$ involves solving a quadratic polynomial. To make our point clear we show next the algebra of the situation just described. We start by re-stating the relevant identities:

$$
\phi_{1,j} = (1-\beta_j) + \rho_j \tag{7.15}
$$

$$
\phi_{2,j} = -(1-\beta_j)\rho_j \tag{7.16}
$$

[13]To see the complete demonstration please refer to Hamilton (1994), chapter 4.7.

And we want to solve for $(1-\beta_j)$ and ρ_j using estimates from ϕ_1 and ϕ_2. The first step is to solve for $(1-\beta_j)$ in 7.15 and then substitute this in 7.16:

$$\begin{aligned}(1-\beta_j) &= \phi_{1,j} - \rho_j \Rightarrow \\ \phi_{2,j} &= (\rho_j - \phi_{1,j})\rho_j \\ \phi_{2,j} &= \rho_j^2 - \phi_{1,j}\rho_j \Rightarrow \\ \rho_j^2 - \phi_{1,j}\rho_j - \phi_{2,j} &= 0 \end{aligned} \tag{7.17}$$

Equation 7.17 is the expression we have to solve to obtain the value of ρ_j and then use this result to obtain the value of $(1-\beta_j)$ as we show next:

$$\begin{aligned}\rho_j &= \frac{\phi_{1,j} \pm \sqrt{(-\phi_{1,j})^2 + 4\phi_{2,j}}}{2} \Rightarrow \\ (1-\beta_j) &= \phi_{1,j} + \left(\frac{\phi_{1,j} \pm \sqrt{(-\phi_{1,j})^2 + 4\phi_{2,j}}}{2}\right) \end{aligned} \tag{7.18}$$

The solution to the system of equations is not unique, though. In the following paragraphs we discuss in further detail which set of solutions is chosen. In order to have a more specific pair of parameters, we need first to estimate $\phi_{1,j}$ and $\phi_{2,j}$ (and θ_j) in equation (7.14). With this proxy model of our original one, we then need to re-establish the stationarity conditions for the ARIMA(2,0,1) so we also obtain the same condition in the new DGP. In this case we need to obtain the values for $\phi_{1,j}$ and $\phi_{2,j}$ that make our ARIMA(2,0,1) be stationary. These conditions are:

- $\phi_{1,j} + \phi_{2,j} < 1$
- $\phi_{1,j} - \phi_{2,j} < 1$
- $-1 < \phi_{2,j} < 1$

If we now go back to the original model, we have that ρ_j and $(1-\beta_j)$ should be less than one in absolute value in order to ensure stationarity of both $X_{j,t}$ and $\alpha_{j,t}$. However, we need to link both stationarity conditions (the ones from our original model and the ones from the ARIMA(2,0,1) process). In that case, we require that:

$$\begin{array}{lll} \text{(a)} & \rho < 1 & \\ \text{(b)} & (1-\beta)(1+\rho) < \rho & \Rightarrow (1-\beta)(1+\rho) - \rho < 0 \\ \text{(c)} & -1 < (1-\beta)\rho < 1 & \end{array}$$

This is the set-up we use as the DGP of our real exchange rate series. The next steps include the actual estimation of the ARIMA(2,0,1) to obtain coefficients that help us get the parameters we use in a Monte Carlo experiment to generate artificial data that captures the actual characteristics of real exchange rate series of several countries.

7.4 Data

Our database includes 104 countries. For each country we estimate individually an ARIMA (2,0,1) model to calculate a set of parameters in each case. However, it is possible to have more than 104 set of parameters because for some countries it is necessary to do more than one estimation. These extra estimations are calculated using just a subsample of the original time series in order to eliminate outliers. We want to exclude periods in which nominal exchange rates or price indices are extremely volatile. One of these countries is Bolivia, just to mention one example.

The data are of monthly frequency. A country with a complete sample has as a starting observation the month of January of 1980 and the final one is December 2007.[14] The series collected to estimate our ARIMA processes are real effective exchange rate indices (CPI based) of the International Financial Statistics database from the IMF for most of the economies. However, there are countries' real exchange rate series that are not found in the IFS database and we need to look for the data in different sources. We obtain these series

[14]The maximum number of observations for countries with a complete sample is 336.

from their respective central banks websites. The countries included in the last category are: Turkey, Argentina, Brazil, Mexico, Peru, Hong-Kong, India, Azerbaijan, Belarus, Georgia, Latvia and Lithuania. The data are modified by only changing the mean of these to be zero.[15]

7.5 An approximation via an ARIMA(2,0,1)

We start this section by discussing the results of an ARIMA(2,0,1) estimation. Then we explain the design of a Monte Carlo experiment to generate artificial data of real exchange rates and report the results of comparing volatility measures taken from the artificial data with the one from the standard deviation of the original model in equations (7.4) and (7.5) for each country. It is possible that with the help of an ARIMA(2,0,1) we get a good representation of the real exchange rate DGP, despite the problems we have already described in terms of the parameters' estimation for the Monte Carlo exercise. It is important to remark that we only use the ARIMA(2,0,1) to estimate proxies for parameters of our initial model in (7.4). In the following sections we discuss in further detail how these coefficients help us obtain the parameters ($(1-\beta_j)$, σ_{u_j}, σ_{v_j} and ρ_j) which we need to calibrate our original model and simulate data that resemble real exchange rate series of all the countries considered in our sample.

7.5.1 Estimation of an ARIMA(2,0,1) for all countries

In section 7.3 we show that our original model is hard to estimate; nevertheless, we also consider that a way to obtain proxy values of the parameters $(1-\beta_j)$ and ρ_j of the original model considered by us is via the estimation of an ARIMA(2,0,1). In this subsection we report the results from these estimations using the real effective exchange rate series of each country and also the results of our calculated parameters. Equation (7.9) shows the way we get these parameters for our Monte Carlo simulation from the results of the ARIMA(2,0,1) estimations. The average values of these and other statistics are reported in table 7.2, last three columns.

[15]There are differences in the construction of the REER indexes between IMF and each central bank; however, these differences do not affect our results since each series is estimated and analysed by itself.

Before showing these results, we review once more how we recover the value of $(1-\beta_j)$ and ρ_j from the estimates of $\phi_{1,j}$ and $\phi_{2,j}$. The procedure involves solving a quadratic equation that we obtain from the ARIMA model and the identities between the coefficients of the ARIMA and the parameters of our original model:

$$
\begin{aligned}
\Delta X_{j,t} &= \alpha_{j,t} - \beta_j X_{j,t-1} + u_{j,t} \\
\alpha_{j,t} &= \rho_j \alpha_{j,t-1} + v_{j,t} \\
\Rightarrow & \\
X_{j,t} &= \alpha_{j,t} + (1-\beta_j) L X_{j,t} + u_{j,t} \approx \\
X_{j,t} &= \phi_{1,j} X_{j,t-1} + \phi_{2,j} X_{j,t-2} + \epsilon_{j,t} + \theta \epsilon_{j,t-1} \\
\text{where} & \\
\phi_{1,j} &= (1-\beta_j) + \rho_j \qquad (7.19) \\
\phi_{2,j} &= -(1-\beta_j)\rho_j \qquad (7.20)
\end{aligned}
$$

The previous equations show us the original model and how we end up with an ARIMA(2,0,1) that we estimate to get the values of $\phi_{1,j}$ and $\phi_{2,j}$. We obtain the values for $(1-\beta_j)$ and ρ_j by solving the following quadratic equation:[16]

$$\rho_j = \frac{\phi_{1,j} \pm \sqrt{(-\phi_{1,j})^2 + 4\phi_{2,j}}}{2} \qquad (7.21)$$

We end up with two set of solutions for $(1-\beta_j)$ and ρ_j. In the first set of values, we obtain a $(1-\beta_j)$ close to zero and ρ_j closer to one, in absolute value. In other words, this set of results is telling us that $\alpha_{j,t}$ process is not quite stationary and shows high persistence. The second set give us the opposite situation: a value of $(1-\beta_j)$ close to 1, and a very stationary $\alpha_{j,t}$ process with a value close to zero for ρ_j. In our case, we decide to work only with the pair of $(1-\beta_j)$ and ρ_j close to one and zero respectively. Our decision is based on the empirical results that are found in the real exchange rate literature in which there is evidence of a very persistent process for this variable; see for example Lothian and

[16] The solution is derived in detail in the previous section in equation 7.17.

Taylor (1996) and Cheung and Lai (2000) for empirical evidence on the topic and Johri and Lahiri (2008) and Bergin and Feenstra (2001) for the development of a theoretical model that explains the situation. At the same time we would like to have a stationary process for the equilibrium term of the real exchange rate series.[17]

It is not straightforward to detect if a country's real exchange rate behaves as a stationary series just by considering the results of our ARIMA(2,0,1) estimations. We need to consider the stationarity conditions we report in previous sections.[18] Figure 7.1 shows the coefficients we obtain for our AR(1) and AR(2) parts of the model and we observe that the values vary between -2 and 2, for the AR(1), and between -1 and 1 for the AR(2) part. In our case, we are more interested in the values of $(1 - \beta_j)$ and ρ_j, which makes more sense in our case because we are only interested in the ARIMA(2,0,1) to obtain the proxies of these parameters. However, we cannot disregard the stationarity conditions for an ARIMA(2,0,1).

We now present some descriptive statistics of the ARIMA(2,0,1) coefficients we estimate for all the countries in our sample, and also the calculated parameters of the original model. Although our complete sample includes 104 countries, we can obtain a higher number of estimations due to the presence of outliers in some countries and the need to remove from the countries' sample and consider these as a separate case. However, the final set of coefficients is a smaller number because some countries cannot be estimated. The total number of cases in the results we analysed is 99.

The first column (I) of table 7.2 shows us the descriptive statistics of the first autoregressive coefficient from the ARIMA estimations. The average value of all the country estimates is very close to 1, although this value is reduced when we eliminate cases with outliers in their samples. In the case of the second autoregressive coefficient, we encounter a different story: there is considerable variation in its value for samples with and without outliers.

The next column reports the error term's standard deviation. These are also very different when we compare the results of the complete set of countries with the ones that do not include countries with outliers. The average value of the complete sample case estimates is several times higher than the one containing reduced samples. This difference shows us

[17] Considering the case in which $\alpha_{j,t}$ is not stationary and end up with an equilibrium level that changes every time is affected by any type of shock is not useful for our analysis.

[18] The conditions are $\phi_{1,j} + \phi_{2,j} < 1$, $\phi_{1,j} - \phi_{2,j} < 1$ and $-1 < \phi_{2,j} < 1$.

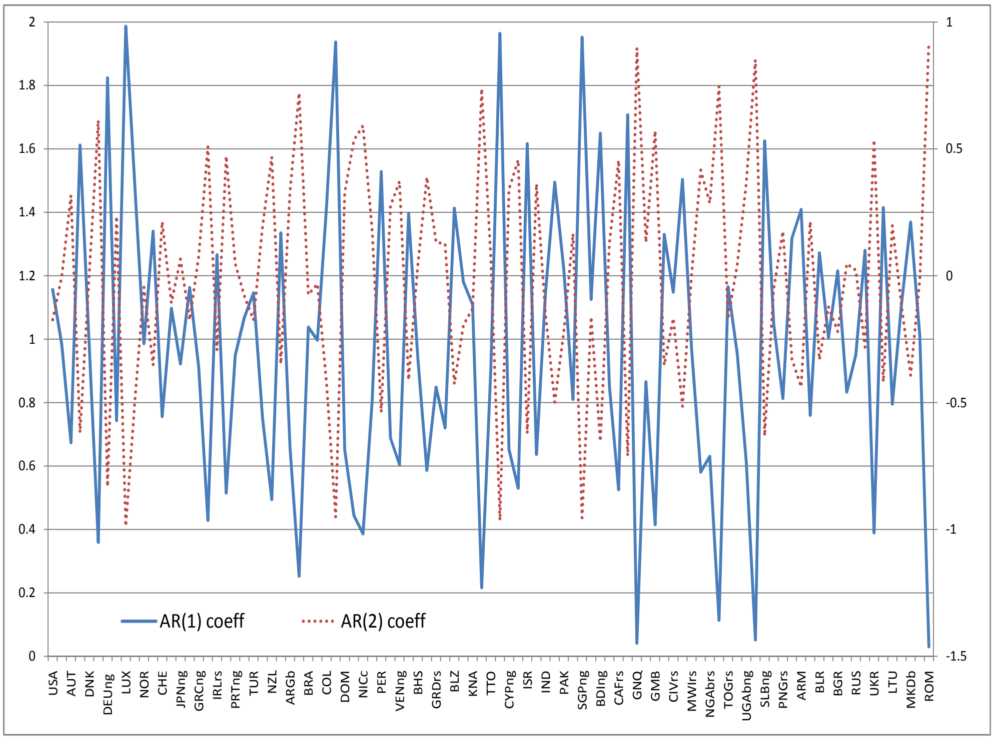

Figure 7.1: ARIMA coefficients

Table 7.2: Estimation results of ARIMA(2,0,1) model

Statistics	AR1	AR2	MA1	$\hat{\sigma}_{\epsilon_j}$	$1-\hat{\beta}$	$\hat{\rho}$
	I	II	III	IV	V	VI
	Estimated Coefficients				Parameters	
Average (all)	0.9941	-0.0229	0.1454	3989.74	0.9724	-0.0278
Max. (all)	1.9860	0.9244	0.9841	(a)	0.9988	0.8875
Min. (all)	0.0304	-0.9869	-0.9768	0.6697	0.7237	-0.9464
Dispersion (all)	0.4607	0.4454	0.4800	(b)	0.0349	0.4155
Avg. (No Out.)	0.9851	-0.0100	0.1653	3.0336	0.9751	-0.0318
Max. (No Out.)	1.9860	0.9244	0.9841	23.4849	0.9988	0.8875
Min. (No Out.)	0.0304	-0.9869	-0.9768	0.6697	0.8631	-0.9464
Dispersion (No Out.)	0.4478	0.4356	0.4578	2.8751	0.0257	0.4069
Average (Stationary)	0.6399	0.3274	0.4864	3.2658	0.9759	-0.3360
Max. (Stationary)	0.9833	0.9244	0.9841	10.6776	0.9988	0.0026
Min. (Stationary)	0.0304	-0.0025	0.0262	0.6697	0.8639	-0.9464
Dispersion (Stationary)	0.2632	0.2517	0.2389	2.4410	0.0260	0.2602

Notes: Dispersion is measured by taking the standard deviation of the vector that contains the volatility measures calculated for the artificial series. Values not included: (a)= 449,978.89; (b)=42,329.74

the impact of outliers on our estimates, and how we should be careful with specific events for some countries that are reflected in these outliers. There is a third set of descriptive statistics (labelled as "Stationary") that represents the cases in which the three stationarity conditions for an ARIMA(2,0,1) are satisfied.[19] We report the results of all the estimated cases but we separate the ones that do satisfied all the stationarity conditions.

The statistics for the stationary cases show a reduced average for the first autorregresive coefficient of the ARIMA estimation. Another relevant change is the dispersion of all the coefficients, which are lower than what we have in the previous cases.

The last two columns (V and VI) include the averages of the actual parameters that are employed in the Monte Carlo exercises. The column of $(1-\hat{\beta}_j)$ reports the values of the autoregressive coefficient of the original model. These are very close to 1 as the mean of all countries is 0.97 with a maximum value of 0.99. In the case of $\hat{\rho}_j$ we have a low, negative and close to zero average value of the parameter for all countries. This could be translated into an $\alpha_{j,t}$ process that is stationary on average. However, there are countries with a high value of this parameter (the maximum is 0.89, in two sets out of three results, and a minimum of -0.95).

[19]There are several countries' estimates that do not meet the stationarity conditions.

In summary, we can infer from the parameter calculations of our original model that the $X_{j,t}$ process of several countries shows high persistence, and the $\alpha_{j,t}$ process is much less persistent. In terms of the dispersion of $(1-\hat{\beta}_j)$ and $\hat{\rho}_j$, we find different values that depict an interesting story and at the same time corroborate the results of the point estimates obtained: The dispersion of the former is low and could be translated into having values of $(1-\hat{\beta}_j)$ that are not far from the mean nor the value of 1; in the case of the latter $(\hat{\rho}_j)$, we have a higher variance in the parameters calculated. Hence, despite having several countries with a very stationary process in the mean term of $X_{j,t}$, there are some cases that also show high persistence in this nested process.

Back to our estimation results, we have that the case of the third relevant parameter for our Monte Carlo experiment, $\hat{\sigma}_{\epsilon_j}$, is a little bit different from the previous two because we obtain this parameter directly from the ARIMA(2,0,1) estimation. However, we still need to link this result to the actual $\hat{\sigma}_{u_j}$ and $\hat{\sigma}_{v_j}$ which are the original innovation terms of our model used in the Monte Carlo simulation. This parameter is also affected by the presence of outliers in the sample. For the moment we consider and analyse the results for $\hat{\sigma}_{\epsilon_j}$ since this variable give us a simple dispersion measure for the $X_{j,t}$ process. The statistics of $\hat{\sigma}_{\epsilon_j}$ for samples without outliers are not that exaggerated. From an average value of more than three thousand with the complete sample, we go down to obtain a mean close to three when the outliers are not taken into account in the estimation. This value is very relevant to the following parts of our study because the standard deviation of our original model considered in equations (7.4) and (7.5) and sample standard deviations of artificial data generated in the Monte Carlo exercise rely heavily on this value. We still need to link this value to the actual error terms of our original real exchange rate model. This issue is explored in the following section.

A related comment that we should make now is to remember that the variance of the original innovation process (error term) and the one from the real exchange rate are not the same due to the influence of the other parameters. However, if the value of $\hat{\sigma}_{\epsilon_j}$ is high, as we have in some cases (due to the presence of outliers), the value of the other parameters cannot influence much the final value of the real exchange rate's standard deviation. For this reason we try to include the results of countries with outliers as reference values and then just do the analysis using results taken from samples that do not include them.

7.5.1.1 Error terms of the original model

Our original model includes two error terms: one comes from the $X_{j,t}$ process, and the other one included in the mean process of the previous, $\alpha_{j,t}$. As we have discussed above, we estimate an ARIMA(2,0,1) as our proxy for this model. From this model we only get an estimate for a single innovation process. For this obvious reason the stochastic part of a particular characterization of the ARIMA(2,0,1) model (by considering specific values of $(1-\beta_j)$ and ρ_j) is not the same as the one in the original model unless we include the particular values of σ_{v_j} and σ_{v_j} that mimic the dynamics generated by σ_{ϵ_j}. Therefore, we need to include some assumptions in order to obtain the specific values for both error terms in the original model. The first assumption is to recall that both are taken from a normal distribution, both are noise processes.

In order to make our ARIMA(2,0,1) conform as close by as possible to our original $X_{j,t}$ process, we need to obtain the mean and variance of the ARIMA(2,0,1) with only one innovation term, and make these values equal to the mean and variance of the original model, which depends on two error terms. This is the origin of our next problem because we try to get the value of two variables using just one estimated value. We are able to obtain a single expression, but we still need an extra relationship to identify both variables. It is necessary that we add an extra assumption in order to obtain a solution to the system of equations. We assume that the variance of $v_{j,t}$ is the same as of $u_{j,t}$, or that $\sigma_{v_j} = \sigma_{u_j}$. With this extra assumption we can identify the values of the previous variables and incorporate that information in our Monte Carlo experiment. We start by stating both processes:

$$(1-\rho_j L)(1-(1-\beta_j)L)X_{j,t} = v_{j,t} + u_{j,t} - \rho_j u_{j,t-1} \tag{7.22}$$

$$(1-\rho_j L)(1-(1-\beta_j)L)X_{j,t} = \epsilon_{j,t} + \theta_j \epsilon_{j,t-1} \tag{7.23}$$

These two have a similar structure except for the innovation process; the lower one is just one stochastic term ($\epsilon_{j,t}$) whilst the first one includes two error terms ($v_{j,t}$ and $u_{j,t}$). For both right-hand sides of the equations we have that the expected value is zero, hence we only need to equate the variance of (7.22) with the one of (7.23) in order to obtain parameters that can match the characteristics of the real exchange rate that we observe in real life. We need to solve:

$$VAR(v_{j,t} + u_{j,t} - \rho_j u_{j,t-1}) = VAR(\epsilon_{j,t} + \theta_j \epsilon_{j,t-1}) \tag{7.24}$$

This is the only equation that we have in order to identify the value of σ_{u_j} and σ_{v_j}. Our ARIMA(2,0,1) allows us to have an estimate of σ_{ϵ_j} that we use to obtain the other two.[20] If we now include our assumption of the relationship between σ_{u_j} and σ_{v_j} and also consider our previous assumptions for $u_{j,t}$ and $v_{j,t}$ of independence between them ($E(u_{j,t}v_{j,t-i}) = 0 \quad \forall i$), and of course that both are well behaved covariance-stationary processes with mean equal to zero and variance equal to $\sigma^2_{u_j}$ and $\sigma^2_{v_j}$, we can derive a solution for either σ_{u_j} or σ_{v_j} (assuming they have the same value) in terms of a known coefficient, which in this case is σ_{ϵ_j} (Remember that $\epsilon_{j,t}$ is also well behaved with mean zero, covariance-stationary and variance equal to $\sigma^2_{\epsilon_j}$). Expanding equation 7.24

$$\begin{aligned} VAR(v_{j,t} + u_{j,t} - \rho_j u_{j,t-1}) &= VAR(\epsilon_{j,t} + \theta_j \epsilon_{j,t-1}) \Rightarrow \\ VAR(v_{j,t}) + VAR(u_{j,t}) + \rho_j^2 VAR(u_{j,t-1}) &= VAR(\epsilon_{j,t}) + \theta_j^2 VAR(\epsilon_{j,t-1}) \Rightarrow \\ \sigma^2_{v_{j,t}} + \sigma^2_{u_{j,t}} + \rho_j^2 \sigma^2_{u_{j,t}} &= \sigma^2_{\epsilon_{j,t}} + \theta_j^2 \sigma^2_{\epsilon_{j,t}} \end{aligned} \tag{7.25}$$

In equation 7.25 we have an expression that depends only on the variance of the innovation processes ($v_{j,t}$,$u_{j,t}$) and $\epsilon_{j,t}$. We just need to solve for either $\sigma^2_{v_j}$ or $\sigma^2_{u_j}$ considering our previous assumption of the equality of these two ($\sigma^2_{v_j} = \sigma^2_{u_j}$). We present the solution next solving for $\sigma^2_{v_j}$:

[20] We have to remember that the values of θ_j and ρ_j are also obtained from the estimations of the ARIMA(2,0,1) model. The first one is taken directly from these results (the moving average coefficient of the estimation) and the second involves a combination of the autoregressive coefficients, as discussed in previous sections.

$$\begin{aligned}
\sigma^2_{v_{j,t}} + \sigma^2_{v_{j,t}} + \rho_j^2 \sigma^2_{v_{j,t}} &= \sigma^2_{\epsilon_{j,t}} + \theta_j^2 \sigma^2_{\epsilon_{j,t}} \Rightarrow \\
(2 + \rho_j^2)\sigma^2_{v_{j,t}} &= (1 + \theta^2 \sigma^2_{\epsilon_{j,t}} \Rightarrow \\
\sigma^2_{v_{j,t}} = \sigma^2_{u_{j,t}} &= \frac{(1 + \theta_j^2)\sigma^2_\epsilon}{2 + \rho_j^2} \qquad (7.26)
\end{aligned}$$

7.5.2 Theoretical standard deviation calculated

Before we start with the analysis of our Monte Carlo experiment, it is necessary to know which is the value we expect for our volatility measures. This reference value is the standard deviation (variance) of our original model, the reversion model with a stochastic process for the mean term. It is also worth mentioning that the reference value changes according to what volatility measure we are evaluating, the one for the series in levels or the one for first differences. In this section we present the calculation of the variance for each case. We first proceed with the one for the series in levels. The original DGP is

$$\begin{aligned}
\Delta X_{j,t} &= \alpha_{j,t} - \beta_j X_{j,t-1} + u_{j,t} \\
\alpha_{j,t} &= \rho \alpha_{j,t-1} + v_{j,t}
\end{aligned}$$

where $u_{j,t}$ and $v_{j,t}$ are random variables that behave as we have previously discussed (normally distributed noise processes with mean zero and finite variance equal to $\sigma^2_{u_j}$ and $\sigma^2_{u_j}$). In words, we are dealing with two stationary processes that are not correlated. The stationarity property allow us to have covariances of $u_{j,t}$ and $v_{j,t}$ between two different periods equal to zero. We also need the estimated values of $(1 - \hat{\beta}_j)$, $\hat{\rho}_j$ and $\hat{\sigma_\epsilon}$. It is relevant to mention that these values of $(1 - \hat{\beta}_j)$ and $\hat{\rho}_j$ are lower than 1 (absolute value), which allows us to consider both the $X_{j,t}$ and $\alpha_{j,t}$ processes as stationary. This simplifies the variance calculation of the whole system. The easy part is to state the variance of the $\alpha_{j,t}$ process since we are just calculating the variance of an AR(1):

$$
\begin{aligned}
VAR(\alpha_{j,t}) &= \frac{\sigma_v^2}{1-\rho_j^2} \\
COV(\alpha_{j,t}, \alpha_{j,t-p}) &= \frac{\rho_j^p \sigma_v^2}{1-\rho_j^2} \qquad \forall p
\end{aligned}
$$

This variance depends on the one of $v_{j,t}$ and the value of ρ_j. Since our $X_{j,t}$ is also a stationary process, we can calculate its variance using these results.

$$
\begin{aligned}
VAR(X_{j,t}) &= VAR\left(\alpha_{j,t} + (1-\beta_j)X_{j,t-1} + u_{j,t}\right) \\
VAR(X_{j,t}) &= E\left[\left(\alpha_{j,t} + (1-\beta_j)X_{j,t-1} + u_t\right)\left(\alpha_{j,t} + (1-\beta_j)X_{j,t-1} + u_{j,t}\right)\right] \\
VAR(X_{j,t}) &= VAR(\alpha_{j,t}) + (1-\beta_j)^2 VAR(X_{j,t}) + \sigma_u^2 + 2(1-\beta_j)E[\alpha_{j,t}X_{j,t-1}] \qquad (7.27)
\end{aligned}
$$

From the previous, we need to expand and calculate the last term of equation (7.27), the expected value between $\alpha_{j,t}$ and $X_{j,t-1}$.

$$
\begin{aligned}
E[\alpha_{j,t}X_{j,t-1}] &= E\left[\left(\rho_j\alpha_{j,t-1} + v_{j,t}\right)\left(\alpha_{j,t-1} + (1-\beta_j)X_{j,t-2} + u_{j,t-1}\right)\right] \\
&= \rho_j E[\alpha_{j,t-1}^2] + (1-\beta_j)\rho_j E[\alpha_{j,t-1}X_{j,t-2}] + \rho_j E[\alpha_{j,t-1}u_{j,t-1}] + \\
&\quad E[\alpha_{j,t-1}v_{j,t}] + (1-\beta_j)E[v_{j,t}X_{t-2}] + E[v_{j,t}u_{j,t-1}] \qquad (7.28)
\end{aligned}
$$

We have expanded $E[\alpha_{j,t}X_{j,t-1}]$ in equation 7.28 and we can obtain a reduced version because the third, fourth, fifth and sixth terms of that equation are equal to zero as they involve a covariance between $u_{j,t}$ and $v_{j,t}$. The expression now includes the term $E[\alpha_{j,t-1}X_{j,t-2}]$, which is the term we are calculating but for one period behind. We continue with the recursive expansion backwards to obtain a simplified result:

$$
\begin{aligned}
E[\alpha_{j,t}X_{j,t-1}] &= \rho_j E[\alpha_{j,t-1}^2] + (1-\beta_j)\rho_j E[\alpha_{j,t-1}X_{j,t-2}] \\
&= \rho_j VAR[\alpha_{j,t-1}] + \\
&\quad (1-\beta_j)\rho_j \left(\rho_j E\left[(\rho_j\alpha_{j,t-2} + v_{j,t-1})\left(\alpha_{j,t-2} + (1-\beta_j)X_{j,t-3} + u_{j,t-2}\right)\right]\right) \\
&= \rho_j VAR[\alpha_{j,t-1}] + (1-\beta_j)\rho_j^2 + (1-\beta_j)^2\rho_j^2 E[\alpha_{j,t-2}X_{j,t-3}] \Rightarrow \\
E[\alpha_{j,t}X_{j,t-1}] &= \rho_j VAR(\alpha_{j,t-1}) + (1-\beta_j)\rho_j^2 VAR(\alpha_{j,t-2}) + \\
&\quad (1-\beta)_j^2\rho_j^3 Var(\alpha_{j,t-3}) + \cdots \qquad (7.29)
\end{aligned}
$$

In (7.29) we find an expression for the covariance of $X_{j,t-1}$ and $\alpha_{j,t}$ as the infinite sum of variances of the latter multiplied by the parameters $(1-\beta_j)$ and ρ_j.[21] If we factorize the previous equation we obtain:

$$
\begin{aligned}
E[\alpha_{j,t}X_{j,t-1}] &= \rho_j VAR(\alpha_{j,t})\left[1 + (1-\beta_j)\rho_j + (1-\beta)_j^2\rho_j^2 + (1-\beta_j)^3\rho_j^3 + \cdots\right] \\
\Rightarrow \\
\rho_j VAR(\alpha_j)\sum_{i=0}^{\infty} &= \rho_j VAR(\alpha_j)\left(\frac{1}{1-(1-\beta_j)\rho_j}\right) \\
\Rightarrow \\
E[\alpha_{j,t}X_{j,t-1}] &= \frac{\rho_j VAR(\alpha_j)}{1-(1-\beta_j)\rho_j} \qquad (7.30)
\end{aligned}
$$

With the result of equation (7.30), we have an expression of $X_{j,t}$'s variance that depends only on the values of known variances:

$$
VAR(X_{j,t}) = VAR(\alpha_{j,t}) + (1-\beta_j)^2 VAR(X_{j,t}) + \sigma_{u_j}^2 + \frac{2(1-\beta_j)\rho_j}{1-(1-\beta_j)}\rho_j VAR(\alpha_{j,t}) \qquad (7.31)
$$

If we factorize and substitute these, we end up with an equation that depends only on the estimated parameters. Our final expression for the variance of $X_{j,t}$ is:

[21] In this case we have that $VAR(\alpha_{j,t}) = VAR(\alpha_{j,t-n}) \quad \forall n$, and this is possible due to stationarity of the $\alpha_{j,t}$ process. As a results of this we drop the t subindex from the variance term in the following equations.

$$VAR(X_{j,t}) = \left(\frac{\sigma^2_{v_j}}{1-\rho_j^2} \left(1 + \frac{2(1-\beta_j)\rho_j}{1-(1-\beta_j)\rho_j} \right) + \sigma_u^2 \right) \left(\frac{1}{1-(1-\beta_j)^2} \right) \tag{7.32}$$

The previous equation is what we use to obtain a reference value for the variance of the real exchange rate series in levels that follow a process described for $X_{j,t}$. It is important to mention that the expression above can be simplified a little more in our case because we are taking the value of σ_v and σ_u to be the same. For the variance of the series in first differences ($VAR(\Delta X_{j,t})$):

$$\begin{aligned} VAR(\Delta X_{j,t}) &= VAR\left(\alpha_{j,t} - \beta X_{j,t-1} + u_{j,t}\right) \\ &= E\left[\left(\alpha_{j,t} - \beta X_{j,t-1} + u_{j,t}\right)\left(\alpha_{j,t} - \beta X_{j,t-1} + u_{j,t}\right)\right] \\ &= E\left[\alpha^2_{j,t} - 2\beta_j \alpha_{j,t} X_{j,t-1} + 2\alpha_{j,t} u_{j,t} + \beta_j^2 X^2_{j,t-1} - 2\beta_j X_{j,t-1} u_{j,t} + u^2_{j,t}\right] \\ &\Rightarrow \end{aligned}$$

$$VAR(\Delta X_{j,t}) = VAR(\alpha_{j,t}) - 2\beta E[\alpha_{j,t}, X_{j,t-1}] + \beta^2 VAR(X_{j,t-1}) + VAR(u_{j,t}) \tag{7.33}$$

Equation (7.33) shows that the variance of the $\Delta X_{j,t}$ process depends on the variance of the $\alpha_{j,t}$ process, the covariance between $X_{j,t-1}$ and $\alpha_{j,t}$, the variance of the actual $X_{j,t}$ process, and the variance of the innovation term of $X_{j,t}$. All these are known to us; we just need to cary out the substitution of the previous terms with expressions that depend only on the parameters estimated. The final result is the following expression:

$$\begin{aligned} VAR(\Delta X_{j,t}) &= \frac{\sigma^2_{v_j}}{1-\rho_j^2} - 2\beta_j E[\alpha_{j,t} X_{j,t-1}] + \beta^2 VAR(X_{j,t-1}) + \sigma^2_{u_j} \\ &= \frac{\sigma^2_{v_j}}{1-\rho_j^2} - \left(\frac{2\beta_j\rho_j}{1-(1-\beta_j)\rho_j} \right) \left(\frac{\sigma^2_{v_j}}{1-\rho_j^2} \right) + \\ &\frac{\beta_j^2}{1-(1-\beta_j)^2} \left(\frac{\sigma^2_{v_j}}{1-\rho_j^2} \left(1 + \frac{2(1-\beta_j)\rho_j}{1-(1-\beta_j)\rho_j} \right) + \sigma^2_{u_j} \right) + \sigma^2_{u_j} \end{aligned} \tag{7.34}$$

7.5.3 The need for long time series: A Monte Carlo simulation approach

The end of the Bretton Woods system represents a structural break in the research of real exchange rates. This break is reflected on the empirical analysis of real exchange rates, if researchers take into consideration data observed before the end of the Bretton Woods system. The other alternative economists have is to analyse data generated only after the year several industrialized economies let their currency to float and be determined by the markets. The previous situation represents a problem that has been acknowledge by several authors (for instance, Taylor, Peel and Sarno, 2001, and Taylor and Sarno, 1998): the real exchange rate series available at the moment might not be long enough to describe and model accurately their characteristics observed in real life.

The most representative example of the previous dilemma can be found in the literature related to the order of integration of the RER. In recent years, the number of works obtaining results in favour of the real exchange rate being stationary has increased. Most of these works base their results on the use of more advanced unit root test, which make use of Monte Carlo methods to obtain the relevant statistics as standard distributions have shown a lack of power to reject the unit root hypothesis.[22] Lan (2001) studies long-run characteristics of the real exchange rate using a Big-Mac index. The author uses Monte Carlo methods to analyse the whole distribution of the estimated equilibrium exchange rate and derive the adjustment paths of actual rates into the future. Despite the good results found in Lan, there are two relevant points raised by the author: (a) the results extend only to only a few countries (the ones included in his sample); and (b) the time span is rather short.

In our case, we use Monte Carlo simulations to generate artificial data with a considerable amount of observations. Our main goal for the use of a Monte Carlo exercise is to being able to work with long time series that depict the characteristics of more than a 100 countries. It is important to remark once more that the objective of this work is to analyse the differences between measures of volatility obtained from the real exchange rate series in levels and also from first differences. In order to calculate relevant volatility measures in levels, we assume stationarity otherwise the comparison becomes irrelevant, however, some of the series generated resemble a lot a unit root process. For this reason we use the characteristics of countries that are difficult to distinguish from a unit root process and

[22] See Taylor, Peel and Sarno (2001) and Taylor and Sarno (1998) for more details.

generate long time series in order to overcome problems of short time series that resemble as an integrated of order 1. In the following section we describe extensively our Monte Carlo approach.

7.5.4 Designing the Monte Carlo exercise

In this section we explain in detail how we generate the artificial data that we use to calculate volatility measures we compare with the variance reference values of the $X_{j,t}$'s and $\Delta X_{j,t}$'s DGPs (see previous section). As we mention before, in order to carry out this exercise we need to generate the data using the parameters estimated in previous sections. These parameters are the standard deviation of the error term of $X_{j,t}$ (σ_{u_j}), the one from $\alpha_{j,t}$ (σ_{v_j}), the AR(1) coefficient of $X_{j,t}$ -($1-\hat{\beta}_j$)- and the AR(1) coefficient of $\alpha_{j,t}$. As we have mentioned before, we first estimate $\phi_{1,j}$, $\phi_{2,j}$ and σ_{ϵ_j}, and then we calculate the previous parameters. We generate artificial data that resemble the real exchange rate series of the countries included by using the set of parameters estimated for these. The Monte Carlo simulation generates data taking into account the model we have in equation 7.4, the matrix that contains the parameters calculated from our ARIMA(2,0,1) estimation results and two error terms that are drawn from a normal distribution with mean zero and standard deviations equal to the ones from the stochastic parts of the mean and $X_{j,t}$ processes. These two represent what we use as our original observation; The next step is to generate the rest of the series using the original model in (7.4) and (7.5), not the ARIMA(2,0,1). The creation of $\Delta X_{j,t}$ is straightforward since we just need to take the first difference of each series generated.

The series are the result of the previous process using the different sets of parameters of all countries. After all the series have been constructed, we take the standard deviation of each series (country) and create a matrix that stores these. Then, we repeat the procedure as many times as we have specified in our programme (number of replications in our Monte Carlo experiment). Each time a replication finishes we have an extra standard deviation for each country. At the end of the exercise we have as many standard deviations per country as number of replications.

We follow the standard procedure and use only the mean of the standard deviations of all the replications for each country. So we only compare this statistic with the reference value (the standard deviation of the DGP, or the result of equation (7.32) for each country. We not only take the mean of each standard deviation's vector, we also calculate a dispersion statistic (the standard deviation of the same vector) in order to see if the distribution of the volatility measure is degenerating to an specific value.

In the case of the series in first differences, we apply the same procedure with an extra step. This step is the first one in order to generate the series: subtract the value of the observation $t-1$ to t. The rest of our exercise is the same one explained for the data in levels. We repeat once more that our comparisons are done between the volatility measure of the artificial series in levels and the reference value calculated for the process, also in levels. The second comparison is done between the measure of the artificial series in first differences and the reference value of the series in first differences. The Monte Carlo simulation uses 100,000 replications and we create different cases as we vary the size of the data generated. We can have samples of artificial data with 100, 5,000, 1,000, ten thousand, fifty thousand and one hundred thousand "observations".[23]

7.5.5 Monte Carlo Simulation Results

Before we comment on any type of results, it is important to remark that we only report series that are generated from the estimated ARIMA(2,0,1)'s coefficients that satisfied the stationarity conditions stated in earlier sections.[24] We start by comparing the standard deviation of the artificial data in levels with a sample size of 100. This volatility measure is quite different to our reference value and we also observe that the dispersion in this case is the largest of all the different sample sizes. As the number of "observations", sample, increases we obtain results (volatility measures) that are closer to the reference values (volatility of $X_{j,t}$) and the dispersion of these results is reduced considerably. These results

[23] The number of replications is a hundred thousand for all sample sizes. It is important to notice that the last option for the number of observations could seem exaggerated and implausible to observe in real life. Nevertheless, we try to exploit the Law of Large Numbers and determine, if possible, the maximum number of observations required to obtain convergence to the variance of the real exchange rate. If we calculate the number of years necessary to get a sample size of 100,000, we will need more than 200 years of daily observations.

[24] Despite we only report results for only a subset of our series generated, we run the Monte Carlo Simulation for all set of parameters generated from the ARIMA(2,0,1) estimated coefficients. Due to space limitations we prefer to focus our analysis in the series presented in this section.

can be observed in figures 7.2 to 7.4.

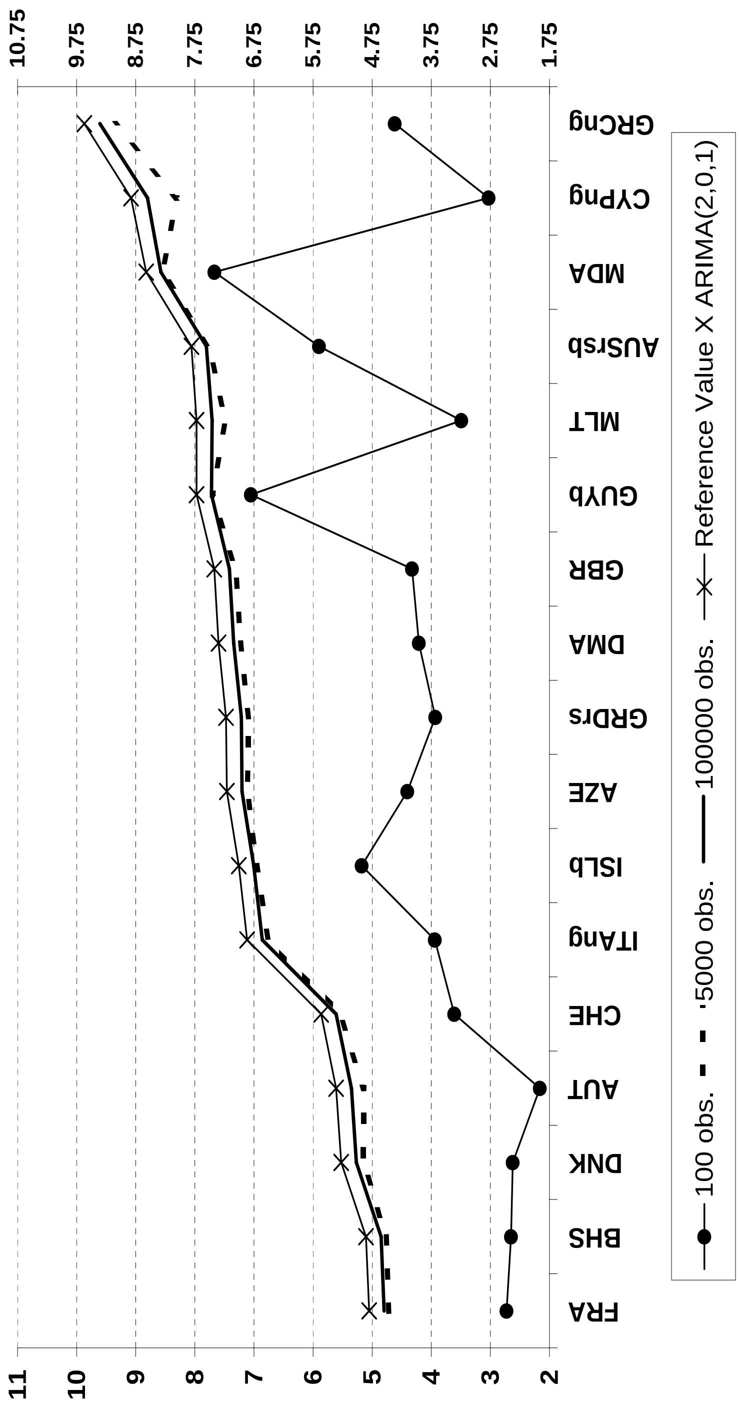

Figure 7.2: Volatility measures from different sample sizes of artificial data in levels and reference its reference value.

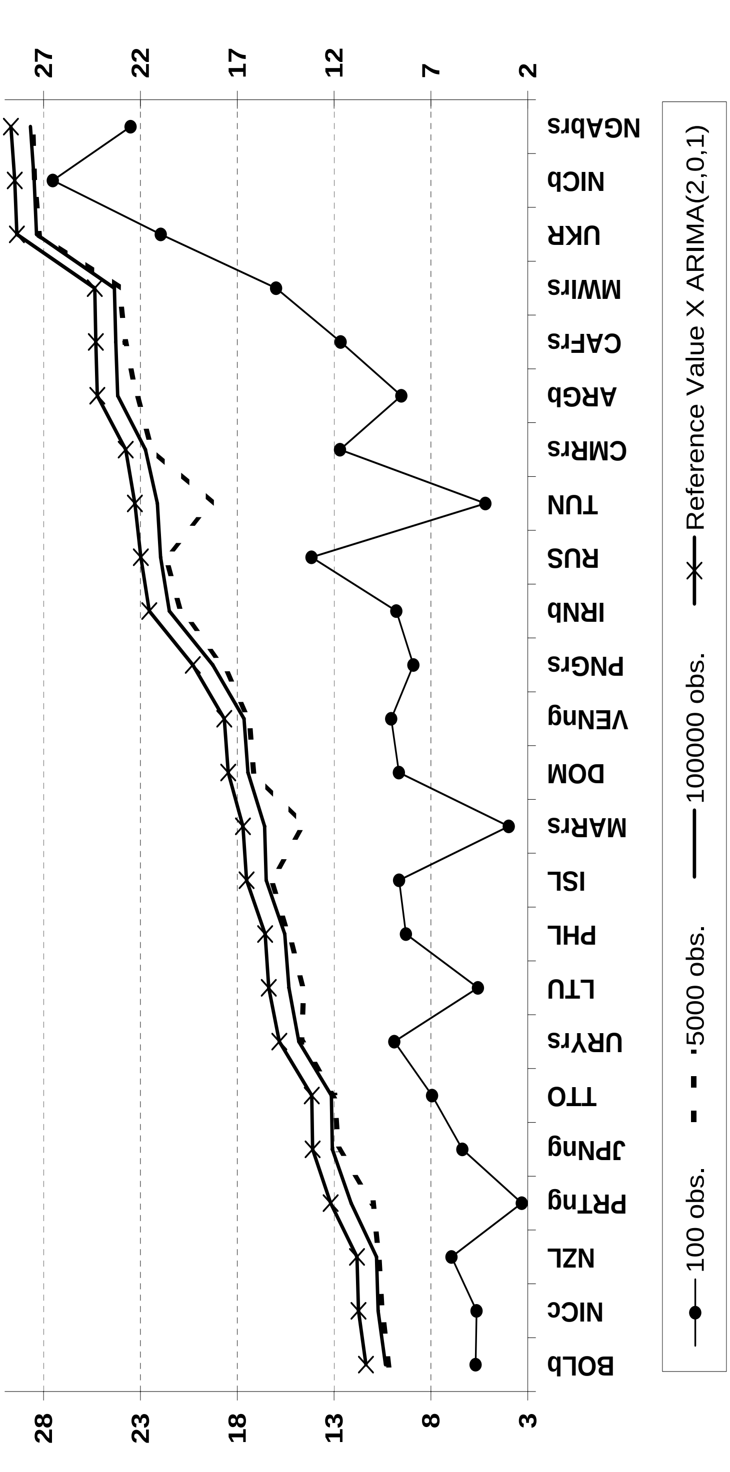

Figure 7.3: Volatility measures from different sample sizes of artificial data in levels and reference its reference value. II

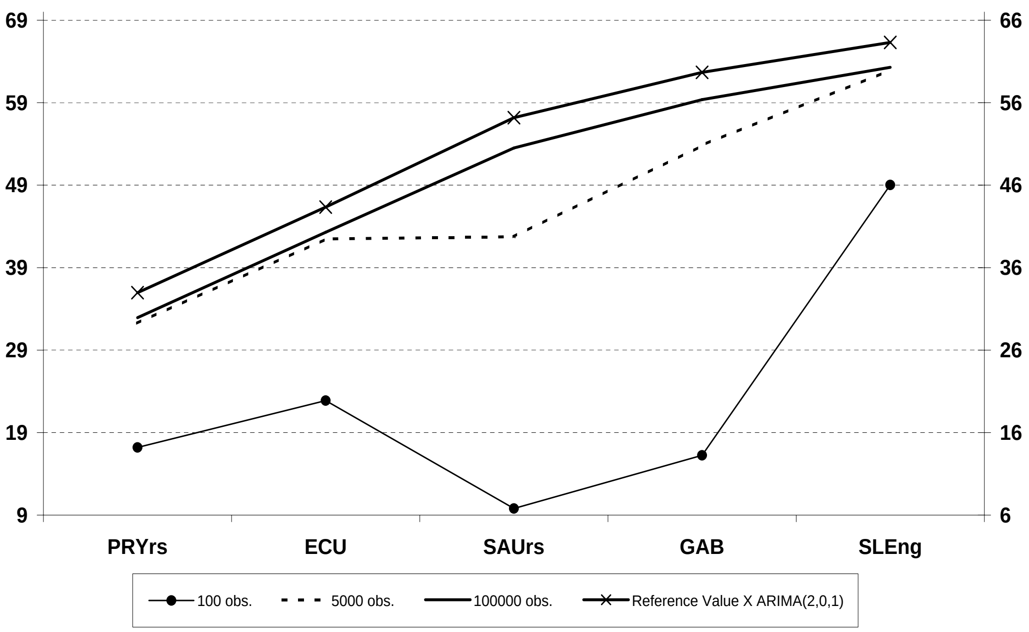

Figure 7.4: Volatility measures from different sample sizes of artificial data in levels and reference its reference value. III

The previous set of figures show the differences between the volatility measures calculated from the artificial series with different sample sizes (100, five and hundred thousands). It is straight forward to observe that the difference between the line on top (volatility reference value) and the other lines is smaller as these represent a greater sample size. It is important to notice that the graph for the volatility reference value is measured on the right axis and not on the left one as the rest of the lines. We shift upwards the axis to have a better display of all the measures at once.[25] There are four countries that we do not include in the previous graph because their results affect its scale making more difficult to observe the differences that exist between the measures of the artificial data and the reference value. Table 7.3 includes these countries (Ghana, Uganda, Poland and Guyana).

[25]If we leave the left axis as the one for the reference volatility measure line, we would have a superimposition of this line with the results of the 100,000 observations sample case.

Table 7.3: RER volatility measures, series in levels, rest of countries

	Reference Value	Std. Dev. - Artificial sample				
Country	$X_{j,t}$	100	5,000	10,000	50,000	100,000
GHA	681.281	665.655	677.968	679.631	680.934	681.088
UGA - n.o.	14.703	13.373	14.423	14.562	14.674	14.688
POL	301.156	222.663	281.608	291.136	299.098	300.126
GUY	191.670	150.228	181.814	186.686	190.668	191.166

Notes: (n.o.) represents a country's series without outliers.

The data in first differences report a similar pattern when we compare the results of all cases calculated: The volatility measures of the artificial data are closer to the reference values as the sample size increases. However, there is an important difference we should mention and it is easy to detect: the standard deviation we obtain with these series, in first differences, is very close to the reference value (in this case standard deviation of $\Delta X_{j,t}$), even when we have a small number of observations. And it is not surprising that the dispersion measure for these series is rather small.

Our results of the series in first differences show that it is not necessary to have a great amount of observations in order to obtain a measure of volatility that proxies quite well the standard deviation of our original DGP in first differences. The volatility of the series in first differences taken from the artificial data sample is a good measure to capture the volatility of the theoretical process. In the case of our measures for the series in levels, we have that the volatility we obtain is close to the standard deviation of the $X_{j,t}$ process only when we have a considerably high amount of observations available.

In figure 7.5 we observe that the lines of the artificial data volatility measure (only depicting the one for 100 observations case) and the one of the reference value are almost identical. For this reason we decide only to include the extreme case of 100 observations and not the others with a greater amount of observations as these might become an obstacle to present a clear picture of the results in first differences. Once more we decide to use the right axis for the line of the volatility reference and shift it upward so we do not have a clash of both graphs. As with the measures of the series in levels, we remove from the previous graph the data of four countries (Ghana, Uganda, Poland and Guyana) and include these results in table 7.4.

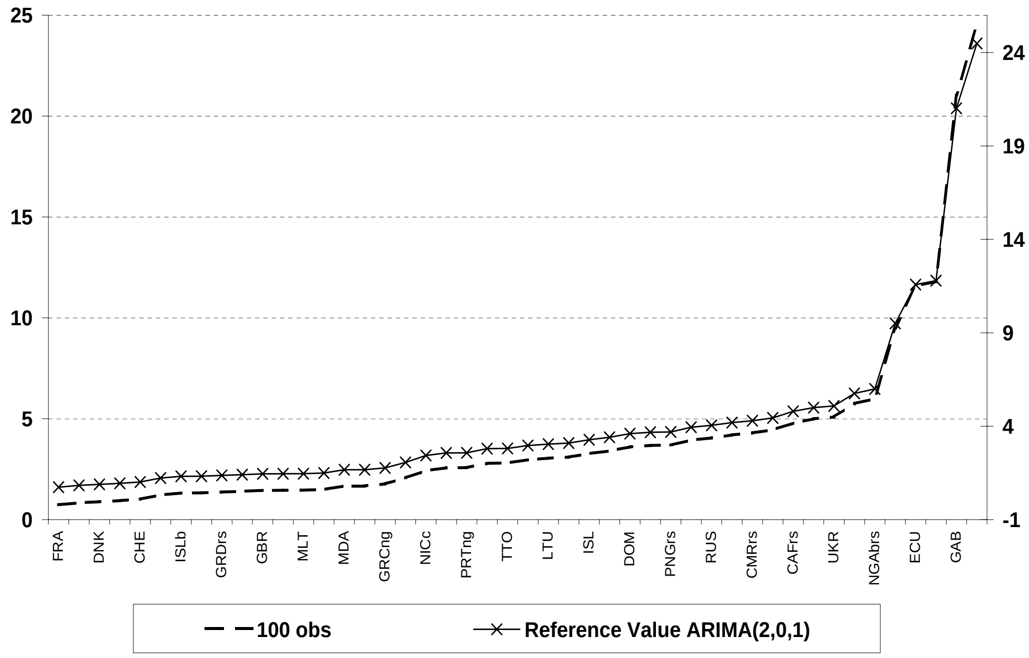

Figure 7.5: Volatility measures from different sample sizes of artificial data in 1st diff. and reference its reference value.

Table 7.4: RER volatility measures, series in 1st diff., rest of countries

	Reference Value	Std. Dev. - Artificial sample				
Country	$\Delta X_{j,t}$	100	5,000	10,000	50,000	100,000
GHA	249.380	249.407	249.385	249.370	249.369	249.371
UGA - n.o.	132.345	132.293	132.325	132.337	132.340	132.344
POL	32.837	32.840	32.837	32.835	32.836	32.835
GUY	23.833	23.834	23.833	23.832	23.832	23.832

Notes: (n.o.) represents a country's series without outliers.

The discrepancy between the results in levels and first differences could be related to the fact that the series in levels resemble very much a unit root process for several of the countries. There is one thing to notice, though. This remark is the following: after this first look at our volatility measures comparisons, we can easily notice that the series in levels are rather different to the transformed series.

The transformation of the series from levels to first differences is a relevant one and it could also represent the loss of relevant information in the process. There are considerable differences between the two (levels and first differences) that should be seriously considered before taking the value of a sample standard deviation in first differences (levels) as proxy for the volatility of a process in levels (first differences), despite how similar our volatility measures in first differences are to the standard deviation of the process in first differences.

It is important to make a further point. Our first results show that volatility measures taken from samples in first differences are closer to the value of the standard deviation of the DGP in first differences than the measures in levels to the standard deviation of X_t process. It is important to take into account these differences in our decision of which volatility we want to model or analyse (the one from the process in levels or the one in first differences). It could be the case that our measures taken from samples in levels give us more information for what we try to model than the ones in first differences, despite our results. We also have to consider that the results for the measures in levels improve considerably with a high number of observations.

There are a few countries, however, that obtain similar results in their sample standard deviation taken from the artificial data in levels with the respective reference value. All of them report a low value of $(1-\hat{\beta}_j)$; these countries are Guyana, Moldova and Nicaragua. This represents evidence in favour of the use of volatility measures in levels when the DGP resembles a stationary process. In this case, even when we have a small amount of data, we can obtain measures that proxy well the actual volatility of the process in levels. In the case of Nicaragua (sample that excludes outliers), which is the country with the smallest coefficient for $(1-\hat{\beta}_j)$ (with a value of 0.724), we have that the reference standard deviations for levels and first differences are quite similar between them. The high value in the theoretical standard deviation could be explained by its high estimated value of sigma.

It is possible to enrich our analysis by sorting our results with respect to the value of parameter $(1 - \hat{\beta}_j)$, (in an ascending way) from the lowest to the highest value. We find that the three countries mentioned in the previous paragraph occupy also the first three places of the list. These new cases we detect after sorting the data are mostly developing and transition economies. As a matter of fact, Australia, Iceland, Switzerland and New Zealand are the only developed nations between the first 15 nations in this list. We report the first and last ten countries of the list after using the value of $(1 - \hat{\beta}_j)$ to sort them out in table 7.5.

In the lower part of the table, countries with sample standard deviation far from the reference value, we encounter also several transition nations; but in these cases the value of $(1 - \hat{\beta}_j)$ is hard to differentiate from 1. In the bottom part of table 7.5 we include the last ten countries after sorting our results. Finally we can say that by sorting our results with help of the value of $(1 - \hat{\beta}_j)$, we also sort almost perfectly the results from the ones with the closer value of the sample standard deviation to the one of the $X_{j,t}$ process to the ones that show a very low similarity.

It looks as if the relevant driver of our results is the parameter $(1 - \hat{\beta}_j)$ and its proximity to zero, that is having a country real exchange rate series that behaves as a stationary process. The more it does the better our volatility measures are. These comments are valid for the case when we generate series with a hundred observations. In the case of generating series with 100,000 observations, we have that for all countries our volatility measures are an almost perfect representation of the volatility of the population.

Instead of using the value $(1 - \hat{\beta}_j)$, we can sort the results using the value of $\hat{\sigma}_j$. In this case we find it hard to detect a pattern in the volatility results of the artificial data sample because these are all mixed. As we increase the sample size we are not able to distinguish any other regularity in the results; with more observations the measures of all countries become closer to the volatility of the population (reference values).

If we now sort the results using as a reference the value of the $\hat{\rho}_j$, we get a similar picture as with $\hat{\sigma}_j$: no pattern is found. It is not a surprise that this value is not the main driver of our results in levels. Once more this is done using the results of the series in levels with a sample of 100 observations. We do not include a similar report of our results in first differences

Table 7.5: Results sorted by value of $(1-\hat{\beta}_j)$.

Country		Vol. Reference Value		Std. Dev. - Artificial sample			
	$(1-\hat{\beta}_j)$	$X_{j,t}$	$\Delta X_{j,t}$	100	5,000	10,000	100,000
First ten countries							
NIC - n.o.	0.72368	28.485	24.485	27.519	28.464	28.476	28.484
Dispersion				3.178	0.474	0.333	0.106
GUY- n.o.	0.86387	7.720	4.292	7.049	7.707	7.713	7.719
Dispersion				1.218	0.199	0.141	0.045
MDA	0.88607	8.573	4.194	7.668	8.554	8.563	8.572
Dispersion				1.459	0.245	0.173	0.055
NGA - n.o.	0.93573	28.684	11.792	23.506	28.554	28.620	28.677
Dispersion				5.499	1.088	0.774	0.247
GHA	0.93984	681.281	249.380	549.238	677.968	679.631	681.088
Dispersion				132.502	26.987	19.191	6.130
SLE	0.94944	63.303	21.013	49.023	62.968	63.1224	63.282
Dispersion				12.483	2.746	1.954	.0622
UKR	0.95173	28.377	11.580	21.949	28.210	28.192	28.367
Dispersion				5.508	1.238	0.879	0.281
AUS - n.o.	0.95485	7.809	2.576	5.897	7.762	7.784	7.806
Dispersion				1.539	0.358	0.253	0.081
ISL - n.o.	0.95948	7.005	2.569	5.179	6.955	6.981	7.002
Dispersion				1.368	0.335	0.238	0.076
URY - n.o.	0.97121	14.830	4.048	9.893	14.676	14.755	14.822
Dispersion				2.843	0.849	0.606	0.194
Last ten countries							
ARG - n.o.	0.99330	24.226	3.275	9.525	23.188	23.693	24.171
Dispersion				3.363	2.753	2.026	0.658
GUY	0.99435	191.670	23.833	70.482	181.814	186.686	191.166
Dispersion				25.302	23.624	17.354	7.960
LTU	0.99449	15.374	1.771	5.572	14.566	14.965	15.333
Dispersion				2.016	1.906	0.646	0.461
CYP	0.99519	8.828	1.014	3.027	8.299	8.560	8.801
Dispersion				1.102	1.163	0.860	0.283
POL	0.99559	301.156	32.837	99.443	281.608	291.136	300.126
Dispersion				36.517	41.080	30.475	10.082
PRT	0.99715	12.181	0.941	3.309	10.986	11.562	12.119
Dispersion				1.257	1.944	1.495	0.507
GAB	0.99715	59.678	4.796	16.248	53.822	56.660	59.373
Dispersion				6.194	9.564	7.318	2.482
MAR	0.99788	16.706	1.320	3.981	14.567	15.573	16.591
Dispersion				1.520	2.923	2.311	0.803
TUN	0.99797	22.285	1.450	5.186	19.310	20.709	22.123
Dispersion				2.013	3.959	3.146	1.095
SAU	0.99883	54.181	3.101	9.803	42.742	47.819	53.506
Dispersion				3.845	10.568	9.225	3.467

because the values of our measures are quite close to the reference value for all sample cases. However, we do include a table that reports the values of the volatility measures of series in first differences after we sort them using the value of $(1-\hat{\beta}_j)$. Table 7.6 includes the first and last ten countries of our complete set of results.

We can summarize our results by saying that the measures taken from artificial data samples in first differences are very close to our reference value of the process in first differences. However, the measures of volatility calculated for the series in levels are not that bad if we observe the results of big samples. As we reduce the number of observations, we need to consider more the value of the parameter $(1-\hat{\beta}_j)$ to obtain good results. The smaller this parameter is the better results we get with a small sample. The driver of this finding, as we have mentioned above, is the fact of having series that behave more as stationary ones and not so much as unit root processes.

7.6 Theoretical standard deviation value and the sample standard deviation using an AR(1) as benchmark model.

There is a simple exercise that could give us more information about the real exchange rate's behaviour. We compare in this section the sample standard deviation of the observed data with the standard deviation of the original model in equations (7.4) and (7.5) calculated using the parameters estimated in previous sections. In addition, we also include in this comparison an extra volatility measure calculated from an AR(1). In other words, we estimate an autoregressive model of order 1 for each country to obtain the relevant coefficients and calculate the standard deviation of that particular process.[26]

It should be clear that these exercises are done using only observed real exchange rates data and the coefficients obtained from time series models estimation using these observations. In other words, we do not include any type of artificial data volatility measures. There is a good reason to include the standard deviation of an AR(1) process as a possible reference value for the volatility of the countries included in our sample. We start our work by assuming the model in equations (7.4) and (7.5), but that is just an assumption of the DGP

[26]The analysis of the parameters obtained from an AR(1) model fitted for the real exchange rates are analysed in the following sections.

Table 7.6: 1st. Differences Results sorted by value of $(1-\hat{\beta}_j)$.

Country		Reference Value		Std. Dev. - Artificial sample			
	$(1-\hat{\beta}_j)$	$X_{j,t}$	$\Delta X_{j,t}$	100	5,000	10,000	100,000
First ten countries							
NIC - n.o.	0.72368	28.485	24.485	24.521	24.485	24.485	24.484
Dispersion				1.908	0.269	0.190	0.060
GUY- n.o.	0.86387	7.720	4.292	4.296	4.292	4.292	4.292
Dispersion				0.314	0.044	0.031	0.010
MDA	0.88607	8.573	4.194	4.198	4.194	4.193	4.194
Dispersion				0.304	0.043	0.030	0.010
NGA - n.o.	0.93573	28.684	11.792	11.804	11.792	11.791	11.791
Dispersion				0.872	0.123	0.086	0.027
GHA	0.93984	681.281	249.380	249.629	249.385	249.370	249.371
Dispersion				17.951	2.532	1.775	0.564
SLE - n.o.	0.94944	63.303	21.014	21.039	21.012	21.013	21.013
Dispersion				1.515	0.213	0.150	0.047
UKR	0.95173	28.376	11.580	11.587	11.580	11.579	11.580
Dispersion				0.956	0.135	0.095	0.030
AUS - n.o.	0.95485	7.809	2.576	2.578	2.576	2.576	2.576
Dispersion				0.187	0.026	0.018	0.006
ISL - n.o.	0.95948	7.005	2.569	2.570	2.569	2.569	2.569
Dispersion				0.207	0.029	0.020	0.006
URY	0.97121	14.830	4.048	4.050	4.049	4.049	4.048
Dispersion				0.297	0.042	0.029	0.009
Last ten countries							
ARG - n.o.	0.99330	24.226	3.275	3.272	3.275	3.275	3.27
Dispersion				0.242	0.034	0.024	0.008
GUY	0.99435	191.670	23.833	23.827	23.833	23.832	23.832
Dispersion				1.763	0.246	0.174	0.055
LTU	0.99449	15.374	1.771	1.769	1.771	1.771	1.771
Dispersion				0.128	0.018	0.013	0.004
CYP	0.99519	8.829	1.014	1.013	1.014	1.014	1.014
Dispersion				0.075	0.010	0.007	0.002
POL	0.99559	301.156	32.837	32.807	32.837	32.835	32.835
Dispersion				2.422	0.341	0.239	0.076
PRT	0.99715	12.181	0.941	0.940	0.941	0.941	0.941
Dispersion				0.067	0.009	0.007	0.002
GAB	0.99715	59.678	4.796	4.788	4.796	4.796	4.796
Dispersion				0.343	0.048	0.034	0.011
MAR	0.99788	16.706	1.320	1.319	1.320	1.320	1.320
Dispersion				0.100	0.014	0.010	0.003
TUN	0.99797	22.285	1.450	1.447	1.450	1.450	1.450
Dispersion				0.103	0.015	0.010	0.003
SAU	0.99883	54.181	3.101	3.096	3.101	3.101	3.101
Dispersion				0.231	0.032	0.023	0.007

that represents real exchange rates. With a second (and simpler) model of the real exchange rate's DGP we can observe if there exist considerable differences between the two models considered.

There are some differences in the number of volatility measures of each category. As we mention in the previous sections, we have 85 countries in our ARIMA(2,0,1) estimations and we end up with 99 measures of volatility for this DGP (taking into account countries with subsamples), of which only 50 countries' coefficients satisfied stationary conditions of an ARIMA(2,0,1). The number of countries of our complete sample is 104 with a total of 119 cases, which also represent the number of sample standard deviations of the observed data. In the case of the volatility measure of the AR(1) DGP we also calculate a total of 119 cases.

These volatility measures for the observed real life data and the two models (original and AR(1)) can be found in tables E.1 to E.6 (in the appendix of this chapter). Columns I to III report the sample standard deviation from our country series in levels. The rest of the columns show the values from series in first differences. The results of the standard deviations of the observed data are very close to the ones from our new approach, the volatility measure of an AR(1) DGP for the real exchange rate of all countries. The results of several countries are even closer than what we get using parameters from an ARIMA(2,0,1) estimation. To be more precise only twenty four cases register a closer volatility measure using the ARIMA(2,0,1) parameters to the sample standard deviation of the observed data than the measure taken from AR(1)'s parameters for our data in levels. If we now consider the data in first differences, we get a similar picture. The number of this type of cases gets reduced to be only nine and in some cases we find this for a different set of countries.

This is an unexpected result and allow us to consider the AR(1) model as a possible DGP for the real exchange rates and not only the model in equations 7.4 and 7.5. We observe good results using an ARIMA(2,0,1) to obtain the parameters for our Monte Carlo exercise, but, there are several countries that seem to work better with an AR(1) for their real exchange rates series. Despite this we have to mention that there are results considerably different to the sample standard deviation of the observed data. However, it could be interesting to expand our analysis using an AR(1) as second option. This also represents an exercise with more tractable steps. Before doing an analysis with a different model for the DGP of the real exchange rate series, we should report other characteristics we find in our comparisons.

When we observe all measures at the same time we find that for some countries, in the case of the series in levels, there are considerable differences between the values of the two DGPs and the standard deviation from the actual data. In particular we find this in transition economies and less developed countries.[27] We have to add that in the case of transition economies, it is possible that the results are driven mainly by the fact of having small samples. This makes the standard deviation obtained from the sample less reliable because the relevance of observations away from the mean is stronger in these cases. This problem is solved as we obtain a greater number of observations so we can get a closer value to the population dispersion. However, this does not help our model selection and it is possible that the sample statistic does not represent a good approximation of the true DGP of the series with a small number of observations.

On a different issue, we find that the impact of outliers in the series estimates and statistics is easy to detect. We just need to compare the results of a country with two or more entries. The standard deviations in all cases are lower when we do not consider the outliers. Once again we have that the results for the series in first differences are very close to each other. Even in cases where there are considerable discrepancies between the volatility measure of the theoretical DGP models and sample standard deviations in levels, these are no longer there when we calculate the measures in first differences.

With the results obtained from our Monte Carlo experiment, we find that the volatility of both measures considered are, for most of the series, quite different, and using a measure in first differences to model a characteristic of real exchange rates in levels might not be the best approach to obtain more information about the series. However, most of the series in levels are not "very" stationary, and the use of series in first differences might be the solution to the previous dilemma.

The results of our previous sections using an ARIMA(2,0,1) are encouraging if we consider that the differences between the artificial data's standard deviation and the one from the DGP in levels disappear as we increase the number of observations in our measures of volatility; however, using a different model as a representation of the real exchange rate

[27]Nevertheless, we also observe considerable differences in developed countries such as Ireland, Germany and Belgium.

DGP of all countries could allow us to find some other relevant aspects.

7.7 AR(1) a simpler model, variance calculation

There are some drawbacks in our previous procedure; the most important one is the need to impose some assumptions in order to carry out the estimations of the parameters used in the Monte Carlo exercise. In order to simplify our analysis and also exploring more the idea found in the previous section, we now estimate an AR(1) to get the coefficients that serve now as parameters to generate new artificial data that follows an AR(1) data generating process. We want to compare the results using a simpler set-up and confirm what we have using a more complex framework.

We start this new analysis with one problem. This problem is the lack of a simple reference value that can be used to check the proximity of our results using artificial data to the volatility the real exchange rate should register now following an AR(1) DGP. This reference has to be taken from the actual DGP; this is similar to how we obtain a reference value using our original model as the DGP of real exchange rates. We need to calculate the variance and then the standard deviation of an AR(1) process. The model to be estimated in order to obtain the coefficients, which are also parameters that feed our second simulation exercise, is the following one:

$$X_{j,t} = (1 - \beta_j)X_{j,t-1} + \epsilon_{j,t} \tag{7.35}$$

In our estimations we get values for the coefficient $(1 - \beta_j)$ and the standard deviation of the error term $\epsilon_{j,t}$. These values are going to be used in a simulation of an AR(1) process to calculate the variance for each country using artificial data obtained from each simulation. It is important to mention how we obtain our theoretical standard deviation value (or volatility reference value), the value we consider our measures of volatility should approach to. We calculate this theoretical standard deviation from equation (7.35) and we substitute the coefficients of $(1 - \beta_j)$ and σ_{ϵ_j} by using the fitted values of these two. The variance and standard deviation expressions are the following:

$$\begin{aligned}
VAR(X_{j,t}) &= VAR((1-\beta_j)X_{j,t-1}+\epsilon_{j,t}) \Rightarrow \\
VAR(X_{j,t}) &= \frac{\sigma^2_{\epsilon_j}}{1-(1-\beta_j)^2} \Rightarrow \\
Volatility(X_{j,t}) &= \sqrt{\frac{\sigma^2_{\epsilon_j}}{1-(1-\beta_j)^2}} \qquad (7.36)
\end{aligned}$$

where $\sigma^2_{\epsilon_j}$ is the variance of our innovation term inside our AR(1) model and $(1-\beta_j)$ is the coefficient of the AR(1) term. We should mention that this standard deviation is easy to calculate because we have assumed that $X_{j,t}$ is a stationary process.

One last remark we need to make: the standard deviations we expect to obtain in first differences series cannot be compared using the reference volatility value obtained for $X_{j,t}$ process. It is not accurate either to compare this with the standard deviation of the innovation process since by construction we eliminate the possibility of having a Martingale process. The reference value for the standard deviation in first differences is derived as follows:

$$\begin{aligned}
VAR(\Delta X_{j,t}) &= VAR(-\beta_j X_{j,t-1}+\epsilon_{j,t}) \\
&= \beta_j^2 VAR(X_{j,t-1}) + VAR(\epsilon_{j,t}) \qquad (7.37)
\end{aligned}$$

We solve 7.37 by using the result in equation 7.36 for the variance of $X_{j,t}$ and also the stationarity assumption of the same process:

$$\begin{aligned} VAR(\Delta X_{j,t}) &= \beta_j^2 \left(\frac{\sigma^2_{\epsilon_j}}{1-(1-\beta_j)^2} \right) + \sigma^2_{\epsilon_j} \\ &\Rightarrow \\ VAR(\Delta X_{j,t}) &= \frac{2\sigma^2_{\epsilon_j}}{1+(1-\beta_j)} \end{aligned} \tag{7.38}$$

$$\Rightarrow$$

$$Volatility(\Delta X_{j,t}) = \sqrt{\frac{2\sigma^2_{\epsilon_j}}{1+(1-\beta_j)}} \tag{7.39}$$

From equation (7.39) we can say that for small values of β_j, series with very persistent shocks, the variance is quite similar to the one from the error term, in this case $\sigma^2_{\epsilon_j}$. This is not surprising because with a value of zero in β_j, we would have a unit root in our $X_{j,t}$ process and the variance of a first difference process is just the variance of the innovation.

7.7.1 Results from AR(1) Estimations

From equation 7.35 we obtain $(1-\beta_j)$, one of the coefficients that also works as a parameter in our Monte Carlo set-up and also to calculate what we call reference standard deviation of an AR(1). The second parameter that we get from our estimations and need for our tasks is the standard deviation of the error term of each $X_{j,t}$ process, σ_{ϵ_j}.[28]

We fit an AR(1) model for each country with results showing us real exchange rates for some countries with estimated value for $(1-\beta_j)$ that is quite close to one. We cannot overlook the fact that these estimates could be interpreted as very persistent processes when in fact we do have a unit root in the series that is not captured in the fitted coefficients due to biases in the estimations; in particular for countries with a estimated value of the AR(1) coefficient that is marginally different from one. We will assume that these estimates are unbiased and we take these values as parameters to generate the artificial series. We also have to remember that since we transform the series to have a zero mean process, our estimations are done without including a constant term in them. The only regressor in each estimation

[28]The estimations are done using the software STATA version 10. The decision to use STATA software in our estimations is based on the fact that it allows missing observations and these are handled using the Kalman filter.

of the autoregressive model is the one period lag of the dependent variable (real effective exchange rate of each country). The results for the $(1-\beta_j)$ coefficient of each country show that our series have very persistent processes. The estimated coefficients for all countries are depicted in figure 7.6.

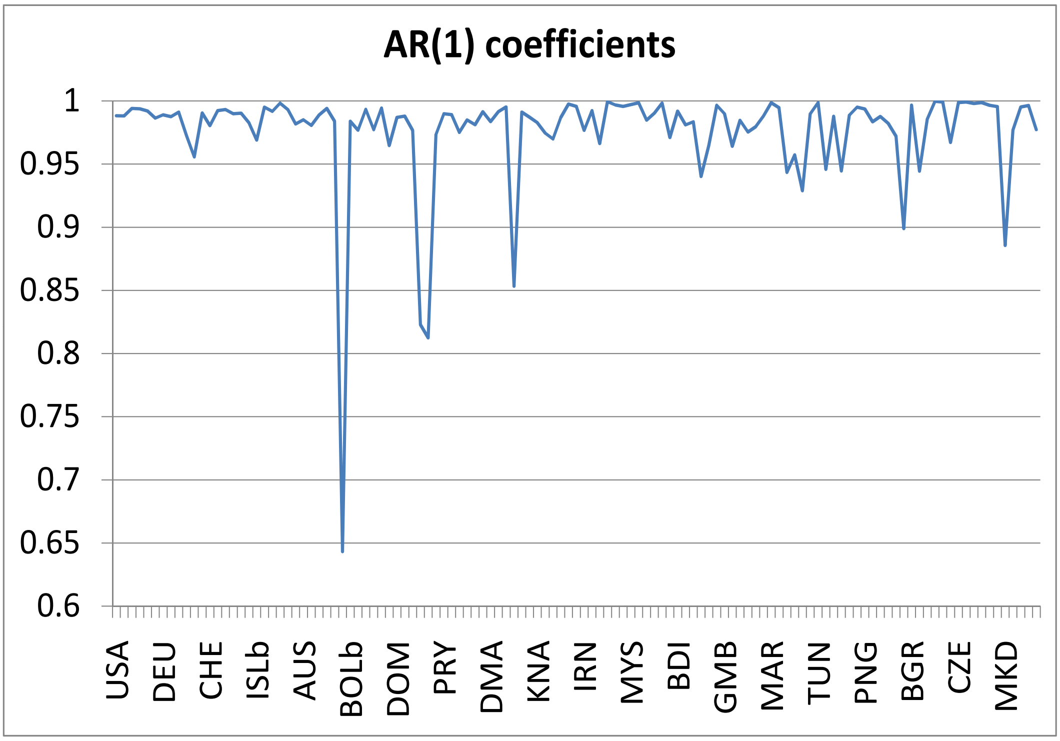

Figure 7.6: AR(1) coefficients

The results of the Monte Carlo exercise cannot give us any particular information about each country's characteristics, we consider that the results of the $(1-\hat{\beta}_j)$ coefficients could be analysed in a simple cross-country analysis. In figure 7.6 we observe that the vast majority of countries are close to a value of 0.98 (the average is 0.976). The maximum value is 0.9997, obtained by China. In the case of the minimum, we have that Bolivia gets a value of 0.6432 for its complete sample. However, we must add that this last result is a biased one by the fact that this country experienced a hyperinflation period that affected its currency in 1985.[29]

[29]See, for example, Asilis, Honohan and Mcnelis (1993) and Campbell(1995).

As we mention before, there are countries that have outliers due to specific events, currency crises in several cases, suffered by these economies. These episodes are the ones affecting our AR(1) estimations. The case of Bolivia is just an example that reflects quite well the situation.[30] If we remove these observations and reduce the sample in the case of Bolivia, we have that the coefficient $(1-\hat{\beta}_j)$ increases from 0.6432 to 0.9838. The results for $(1-\hat{\beta}_j)$ are very homogeneous in general terms, even more when we only consider results of countries with clean samples, excluding outliers from our estimations. There are just a few countries that obtain a value below 0.90, six cases to be precise.[31]

If we now look the results of the point estimates of σ_{ϵ_j} (standard deviation of innovation term in our AR(1) process) we find that the value for this parameter increases considerably in estimations using data of middle and low income countries. Latin American and African countries are the economies with high values of sigma. As we expect, the countries that have outliers in their samples report higher values for $\hat{\sigma}_\epsilon$: Bolivia (77.47), Nicaragua (451435), Guyana (21.67), Iran (49.97), Ghana (232.16), Nigeria (18.90), Sierra Leone (20.57), Uganda (101.40) and Poland (31.62). In all these cases after reducing the sample and estimating an AR(1) without outliers we have that the fitted value for sigma is now a single digit number. So we get that the presence of outliers in our estimations affect the estimates of $(1-\beta_j)$ and σ_{ϵ_j} in different ways. For the former we have an increase in the mean value as for the latter we find the opposite result.

Despite removing outliers for some series, we have that there is higher dispersion in the coefficients of $\hat{\sigma}_{\epsilon_j}$ than in the ones for $(1-\hat{\beta}_j)$. As we mention before, the great majority of $(1-\beta_j)$ estimates are above 0.95, but none reaches the value of 1.[32] On the other hand, we have that even though we try to reduce the sample of some countries in order to eliminate episodes of distress on irregular situations, we still encounter high values of $\hat{\sigma}_{\epsilon_j}$ for some countries (mainly less developed and transition economies).

The following table contains the descriptive statistics of the coefficients obtained in our AR(1) estimations. We report two set of statistics. In the first one, the statistics are calculated using the whole set of countries, including cases with outliers; while in the second

[30] The list of countries with outliers include: Iceland, Argentina, Bolivia, Chile, Nicaragua, Guyana, Iran, Algeria, Ghana, Nigeria, Sierra Leone, Uganda, Macedonia and Poland.

[31] Although from these six cases, two of those are for Nicaragua.

[32] As a matter of fact, if a value of 1 is calculated by any statistical software, the estimation is not ended due to problems of invertibility of the matrix.

the same statistics are calculated, but now the number of cases is reduced as we remove the ones that include outliers in their sample.[33]

Table 7.7: Descriptive Statistics - AR(1) results

	I	II
A) Complete set of countries	$(1-\hat{\beta}_j)$	$\hat{\sigma}_{\epsilon_j}$
Maximum	0.999671	451,435.2
Minimum	0.643214	0.676133
Mean	0.975947	3801.299
Standard deviation	0.043216	41,382.29
	I	II
B) Removing cases with outliers	$(1-\hat{\beta}_j)$	$\hat{\sigma}_{\epsilon_j}$
Maximum	0.999671	23.85337
Minimum	0.85329	0.676133
Mean	0.982467	3.040421
Standard deviation	0.020501	2.82207

The first column is a set of statistics for the value of $(1-\hat{\beta}_j)$ (our fitted value for the AR(1) coefficient); while the second includes the same set of statistics for our estimated value of σ_{ϵ_j} (innovation process' standard deviation). The maximum value for $(1-\hat{\beta}_j)$ in both parts is the same (0.999), the minimum does change from a 0.643 (including countries with more than one case) to 0.8533 (removing cases with outliers for several countries). The result of this change is an increase in the average value of AR(1) to be 0.9825 when we remove countries with outliers.

The second column is even more insightful since we observe an impressive reduction in the maximum and average value of $\hat{\sigma}_{\epsilon_j}$, going from an extremely high number to 23.85 in the first category and from 3,801 to 3.040 in the average row. These differences make easier to realize the importance of removing some crisis periods for some countries.

We conclude that the results for the $(1-\hat{\beta}_j)$ coefficient are very similar among all the countries and in some cases very close to the unity. The closer this coefficient is to one, the greater the value of the theoretical standard is obtained.[34] In the case of $\hat{\sigma}_{\epsilon_j}$, we observe more differences since there are considerable variations from one country's result to the other. The presence of outliers in some transition and developing economies is the main

[33] In both sets we consider countries with subsamples, that is shorter samples that do not include outliers.

[34] In the case of unit root process, we have that the value of this coefficient is 1 and the variance of the process is infinite.

reason behind these results. When outliers are no longer part of the sample, the differences in the estimations are reduced but these are still present in a lower magnitude. With the estimation of these two parameters, we now can generate the artificial series that resemble the real exchange rate of all the countries in our sample.

7.7.2 Designing a Monte Carlo Simulation

Our main exercise is to generate artificial data using a similar "loop"' programme to the one implemented in the past sections based on the parameters of an ARIMA(2,0,1). In this case the parameters come from an AR(1) and the actual model in GAUSS software is also an AR(1) (equation 7.35) and not the one in equations (7.4) and (7.5). The procedure is the following one. The parameters obtained from the AR(1) estimations are used to generate data that resemble the country these parameters are taken from. In this case we just need two parameters: (1-$\hat{\beta}_j$) and $\hat{\sigma}^2_{\epsilon_j}$, the autoregressive coefficient and the standard deviation of the error term in the model.

The next step is to create a new matrix that includes a random number generated from a normal distribution with mean equal to zero and variance equal to the squared innovation term's estimate in the AR(1) estimations, or $\hat{\sigma}^2_{\epsilon_j}$. This is our initial observation, the rest of the time series are generated by an AR(1) process written in GAUSS that uses as the AR(1) coefficient the value of (1-$\hat{\beta}_j$). After all the series are generated for all the countries, we have one replication completed and then the standard deviation for the times series generated for each country is calculated and stored. Then, the programme starts all over again to do the same until all the replications specified are done.

Once this part is finished, we have as many standard deviations for each country as number of replications. The final step to obtain our volatility measures is to calculate the mean of these standard deviations and also its dispersion for each country's series. The number of replications is fixed at 100,000 as we did with the case of data generated using the original model.

The size of the sample is the one that could vary from 100 to 100,000 "observations", considering specific cases and not all the possible combinations. These cases are: 100, 500, 1,000, 5,000, 10,000, 50,000 or 100,000 "observations". The measures obtained come from different sample size cases. This is done with the series in levels and these measures are the ones we compare with the result of the standard deviation of the AR(1) process of each country. In the case of first differences, the process is rather similar with one difference: the standard deviations is not calculated from the series in levels but in first differences. That is, rather than calculating standard deviation from our original artificial data generated, we calculate first differences (subtracting $x_{j,t-1}$ from $x_{j,t}$) and then we obtain the volatility measures that we compare with the reference value of the AR(1) process for $\Delta X_{j,t}$.

7.7.3 Results from simulations

As we have mentioned previously, we generate time series with artificial data from an AR(1) model that uses as its first observation a random number generated from a normal distribution with mean zero and standard deviation equal to the estimated value of σ_{ϵ_j} for each country. Then, the simulation is run to complete the number of replications set at the beginning of the exercise. After each simulation, we calculate the average value of the standard deviation of each series generated for each country. That is, in the case of having 500 observations with 100,000 replications, we obtain one hundred thousand standard deviations, all taken from samples with 500 observations. Then, the average value is calculated from this vector with 100,000 entries. We also get the dispersion of this vector by taking the standard deviation of the same vector. As mentioned before, this is done for each country. At the end of a Monte Carlo simulation, we have a vector with the mean value of the standard deviation of each exercise for each economy (in some cases we have more than one entry per country).

All the previous calculations are done for the series in levels. We then take the first difference from each series of artificial data, and do the same calculations as for the series in levels: calculate the mean of the standard deviation taken from each vector that contains our volatility measures of all the replications for each country now in first differences. To complete our results, we also calculate the dispersion of this vector with standard deviations of the series in first differences.

7.7.3.1 General Results

The first thing that should be mentioned is that reporting all the series generated and all the measures of volatility obtained could become confusing and hard to follow in order to formulate conclusions from them. For this reason, we start by reporting comparative statistics taken from the volatility measures of all countries. We repeat the procedure for the different sample sizes of the data generated in our Monte Carlo experiment.

Table 7.8: Comparative statistics for results in Levels - AR(1) model

	Mean	Std Dev	Max	Min
Complete Samples				
Volatility Reference Value (levels)	6716.48	72,831.81	794,540.65	4.283
Standard dev. of art. sample (100)	6256.14	68,017.95	742,008.89	2.317
Dispersion	979.80	10,620.88	115,866.17	0.802
Standard dev. of art. sample (5,000)	6704.52	72,724.72	793,370.31	4.255
Dispersion	155.74	1658.24	18092.81	0.146
Standard dev. of art. sample (100,000)	6715.80	72,825.87	794,475.63	4.282
Dispersion	34.77	368.23	4017.85	0.033
Without outliers				
Volatility Reference Value (levels)	20.670	16.279	118.775	4.283
Standard dev. of art. sample (100)	9.082	6.978	56.282	2.317
Dispersion	2.907	1.906	13.767	0.802
Standard dev. of art. sample (5,000)	18.928	12.446	69.657	4.255
Dispersion	2.291	2.837	20.673	0.146
Standard dev. of art. sample (100,000)	20.547	15.895	113.543	4.282
Dispersion	0.692	1.500	13.698	0.033

Notes: Dispersion is measured by taking the standard deviation of the vector that contains the volatility measures calculated for the artificial series. (n.o) represents a country's series without outliers.

Table 7.8 contains two parts. In the top part of the table, we report the results for our artificial data in levels and we include the results for countries with outliers. The bottom part reports the same statistics but this time we remove the results of countries with outliers. As it is evident in the table, we can have a better interpretation of the results when the outliers results are not part of the analysis. The row labeled "Volatility Reference Value" contains the statistics of the reference standard deviation value taken for all countries.

In both cases (complete samples and without outliers), as the number of observations increases, the values of the standard deviations from the artificial data get closer to the ones of the reference value of volatility. However, the results are biased towards the right (the outliers are high positive values). Hence, it is no surprise to find it easier to analyse the results from the series that do not include them. The results from the last sample size are very close to the numbers we have in the row of the theoretical value of the standard deviation. If we also take a look at the standard deviation row (dispersion of our volatility measures) of the last case, we have that these values are less than half of what we get in the previous case.

In the case of the results taken from series in first differences, table 7.9, we observe a similar pattern for the whole set. We have again that as the number of observations increase the results get closer to the values of the theoretical standard deviation for the series in first differences. The deviations of these measures taken from artificial data in first differences with respect to the reference value are considerably smaller, and if we take a look at the row of the standard deviations we report low numbers for the dispersion of the results, we could say that the distribution of our volatility measures degenerates to an specific value (which in this case is the reference standard deviation of the series in first differences) as we increase the number of observations generated in the Monte Carlo exercise. In short, these are more accurate results.

Table 7.9: Comparative statistics for results in First differences - AR(1) model

	Mean	Std Dev	Max	Min
Complete Samples				
Volatility Reference Value of $\Delta X_{j,t}$	3981.43	43345.81	472854.76	0.67715
Standard dev. of art. sample (100)	3986.65	43402.82	473476.76	0.67614
Dispersion	290.05	3157.86	34448.71	0.04823
Standard dev. of art. sample (5,000)	3981.61	43347.84	472876.98	0.67714
Dispersion	40.72	443.35	4836.50	0.00678
Standard dev. of art. sample (100,000)	3981.27	43344.09	472836.02	0.67712
Dispersion	9.09	98.95	1079.48	0.00151
Without outliers				
Volatility Reference Value of $\Delta X_{j,t}$	3.05996	2.86143	24.21849	0.67715
Standard dev. of art. sample (100)	3.05901	2.86436	24.24924	0.67614
Dispersion	0.21902	0.20550	1.74012	0.04823
Standard dev. of art. sample (5,000)	3.05992	2.86144	24.21877	0.67714
Dispersion	0.03069	0.02878	0.24360	0.00678
Standard dev. of art. sample (100,000)	3.05984	2.86133	24.21759	0.67712
Dispersion	0.00682	0.00641	0.05429	0.00151

Notes: Dispersion is measured by taking the standard deviation of the vector that contains the volatility measures calculated for the artificial series. (n.o) represents a country's series without outliers.

If we now take a look at the complete set of results we can say that one of the features we observe in all of them is, as expected, an approximation of the volatility's mean value to the population's standard deviation as we increase sample size in both cases, using artificial data in levels and in first differences. The results of the volatility measures in levels for our simulation using a sample size of 100 are not that encouraging since less than half of the countries obtain a volatility measure similar to the reference value.[35] These numbers improve and the differences are reduced when we increase the number of observations. Figures 7.7 to 7.9 present the results for all the countries using different sample sizes for the series in levels. The reference volatility is also included and we confirm that as the sample size gets bigger, the volatility measure of the artificial data gets closer to the reference one.

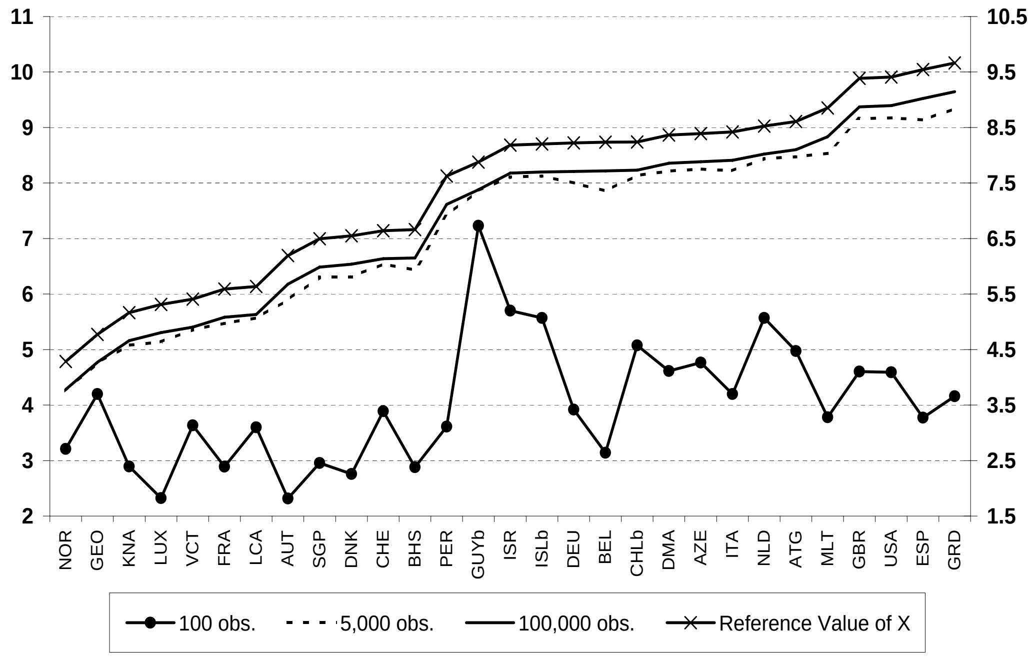

Figure 7.7: Comparison of AR1 Volatility Measures in Levels against reference value (I)

[35]There are interesting cases that should be mentioned: Guyana, the value of its standard deviation is very close to the theoretical value of the process' variance.

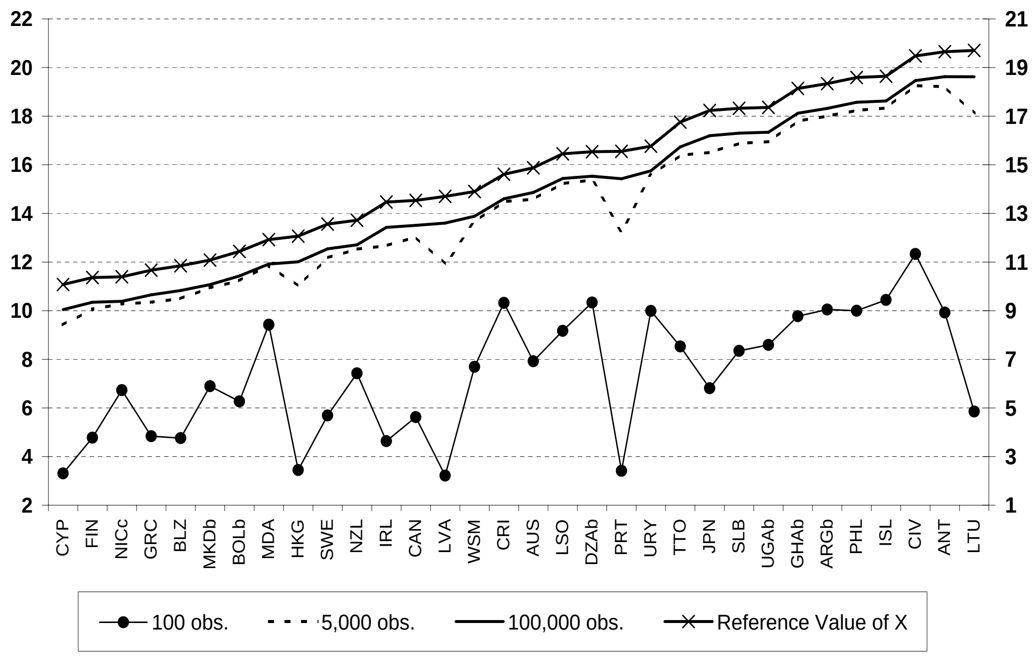

Figure 7.8: Comparison of AR1 Volatility Measures in Levels against reference value (II)

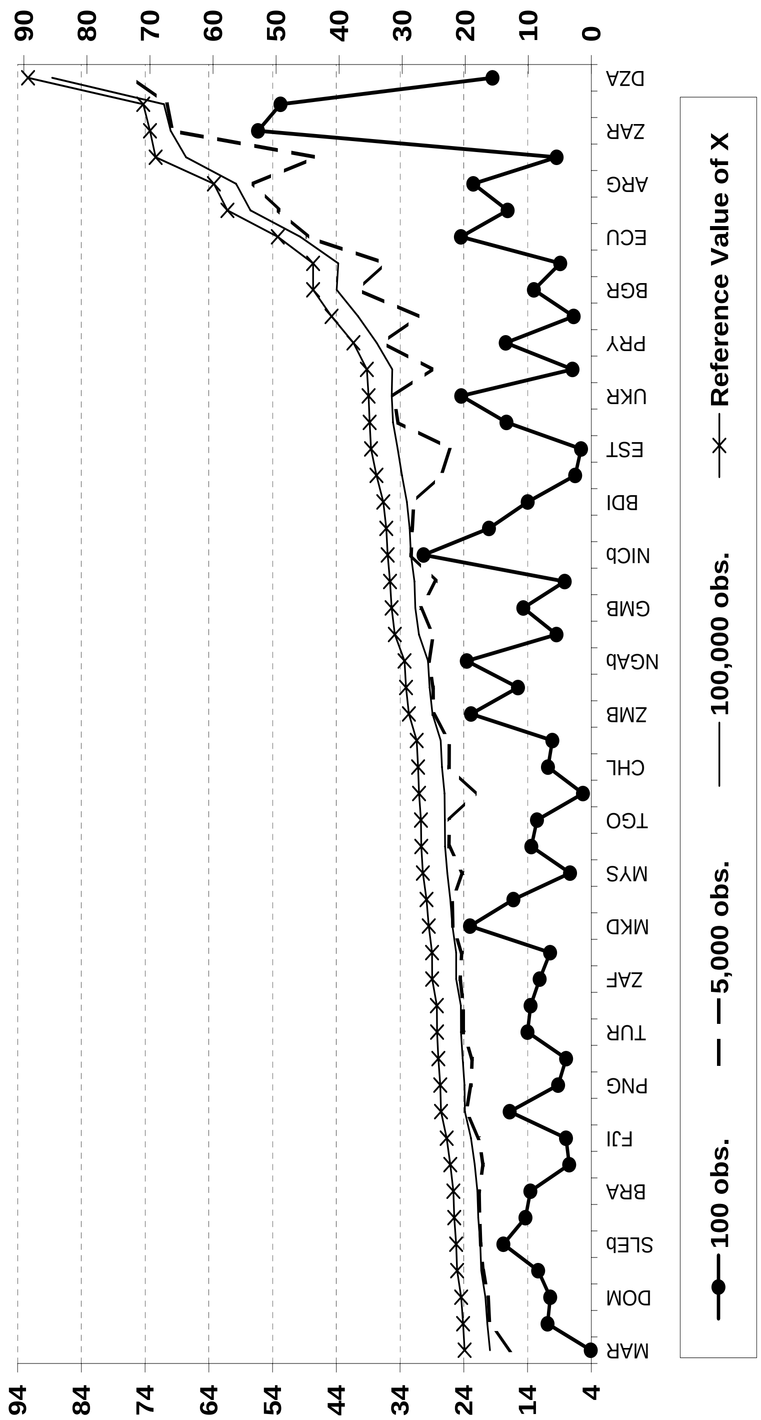

Figure 7.9: Comparison of AR1 Volatility Measures in Levels against reference value (III)

As in the case of our ARIMA(2,0,1) results, the new set of graphs use the right axis as the one for the reference volatility line; The other three lines use the left one. We do this in order to shift upwards the axis and also the reference volatility line and observe the differences between this graph and the volatility measures taken from artificial data.

From our results we have two countries with different behaviour: Georgia and Guyana. The results from these two are very close to the reference standard deviation obtained from an AR(1) process disregarding the sample size. If we take a closer look to the parameters in these particular cases, we observe that the value of $(1 - \hat{\beta}_j)$ of each country is below 0.90. These two series are the most "stationary" of all countries.[36]

If we turn our attention to first difference series' results, we have that the standard deviation obtained in each simulation is very close to the theoretical value.[37] Even in the first exercise, sample with 100 "observations", the standard deviation of each simulation is about a 99% similar to the theoretical reference value we want to reach. The variability of the standard deviation of the artificial series in first differences is rather small, and becomes smaller as the sample of the data generated increases, in particular for developed economies parameters. The reduction is observed in all countries but at a lower rate for developing, transition and less developed countries. Figure 7.10 presents this results.

These results seem to establish a clear picture in our real exchange rate series: the closer each series resembles a random walk, the more observations are needed in order to obtain a measure of variance that is closer to the theoretical value of the process in levels. We encounter a different story for our volatility measures taken from our series in first differences: we do not require a big sample to obtain results that are very close to our reference value for this type of data. This is not surprising since the series in first differences are more stationary.

The results from our volatility measures, as we continue analysing first differences cases, show that standard deviation's average values of each simulation are very close to standard

[36]These are the characteristics that we get from our results of the simulation, not only in the value of the mean of the standard deviation, but also in the dispersion of these results.

[37]This variance is different to the one from the process in levels. The value is very close to the one from the error term but also different. These two values could be the same in case of having unit root process. If that is the situation, all the innovations in the error term are captured by the AR(1). These changes become permanent.

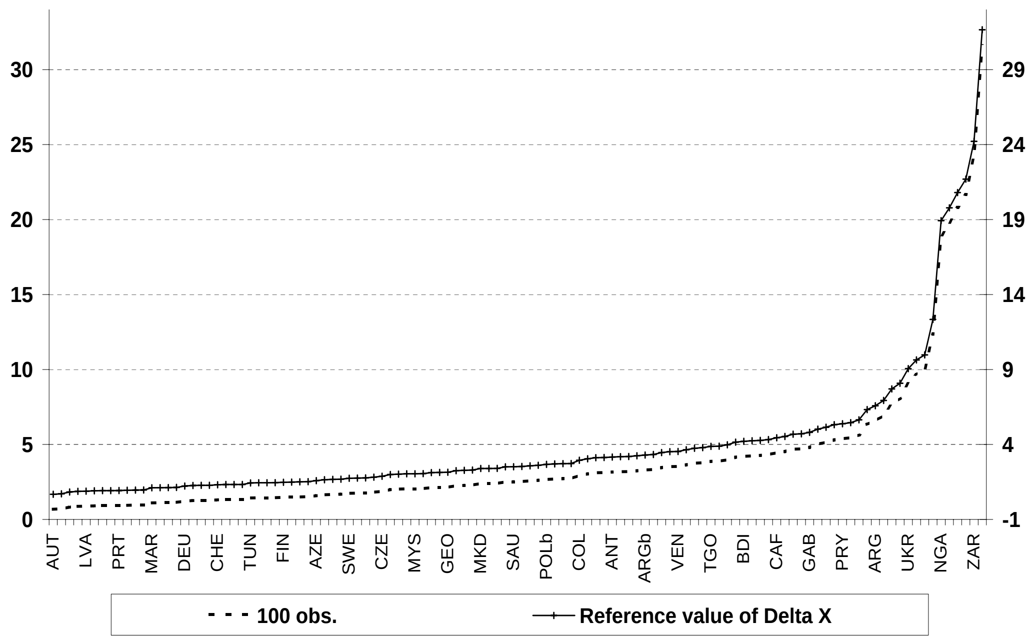

Figure 7.10: Comparison AR1 Volatility Measures in 1st. Diff. against reference value.

deviation's value of the innovation term in our AR(1) model. Once again we should remark that the value of the variance of the data generated in first differences is not the same as the one from the error term of the $X_{j,t}$ process, $\sigma^2_{\epsilon_j}$.[38] Despite all, we can say that we get close results to the reference volatility of the series in first differences (standard deviation of the $\Delta X_{j,t}$). Even in the small sample exercise, 100 "observations", we obtain positive results.

In our simplified model, using an AR(1), we have that for real exchange rates it seems as a better measure of volatility the standard deviation of the monthly change, or series in first differences. We base this claim on the results of our simulations using a small number of observations (e.g. 100, 1,000, 5,000). The results for series in levels are not satisfactory for our small samples. The results improved as we increase sample size. However, we cannot say that it is correct to use proxies in first differences when we are interested in data in levels because there are considerable differences between the theoretical standard deviation series in levels and the sample standard deviation of $\Delta X_{j,t}$; and we have to remark the fact that for big samples, we obtain very similar volatility measures between the standard deviation of $X_{j,t}$ and the sample standard deviation of the artificial data in levels.

If we sort our results taking as a reference the value of (1-$\hat{\beta}_j$), we have that as this parameter gets closer to 1, the value of the standard deviation from the artificial data's volatility using a small number of observations is considerably different from the volatility of the AR(1) process of $X_{j,t}$. Actually, the value of the standard deviation taken from the artificial data does not get closer to the reference one unless we run our exercise with a large number of observations. In the top part of table 7.10 we present the first ten countries with the lowest value of this coefficient. If we go back to the estimation of the parameters, we have that the countries with a value of (1-$\hat{\beta}_j$) closer to 1 are economies with a small number of observations, mainly transition ones, and China. It is possible that the lack of observations affects their results. The bottom part of table 7.10 shows the last ten countries with the lowest value in (1-$\hat{\beta}_j$), or in other words, first ten countries with the highest value in that coefficient. We observe that the volatility measure for the 5,000 "observations" case is considerably close to the reference one of $X_{j,t}$.

Taking a look at the dispersion of the volatility calculated from the artificial data, we have

[38]The only way to obtain the same value between the variance of the error term and the one from the process in first differences is when we have a Martingale process.

Table 7.10: Data in Levels - Results sorted by value of $(1-\hat{\beta}_j)$.

		Reference Value		Std. Dev. - Artificial data		
	$(1-\hat{\beta}_j)$	$X_{j,t}$	$\Delta X_{j,t}$	100	5000	100000
First Ten countries						
BOL	0.6432	101.1898	85.4782	98.399	101.137	101.185
Dispersion				10.684	1.565	0.347
NIC - n.o. I	0.8125	32.3071	19.7827	30.304	32.264	32.305
Dispersion				4.590	0.714	0.158
GUY - n.o.	0.8533	7.8783	4.2676	7.229	7.864	7.878
Dispersion				1.233	0.199	0.044
MKD	0.8855	25.7845	12.3383	23.022	25.723	25.781
Dispersion				4.396	0.739	0.165
GEO	0.8989	4.7719	2.1455	4.198	4.760	4.771
Dispersion				0.846	0.146	0.033
SLE - n.o.	0.9289	21.4336	8.0847	17.795	21.349	21.429
Dispersion				4.114	0.784	0.176
ZAR	0.9402	70.0004	24.2185	56.282	69.657	69.981
Dispersion				13.767	2.801	0.629
NGA - n.o.	0.9433	29.6295	9.9762	23.530	29.477	29.621
Dispersion				5.857	1.220	0.274
MDA	0.9444	11.9229	3.9759	9.422	11.861	11.919
Dispersion				2.361	0.494	0.111
ZMB	0.9445	28.9308	9.6399	22.862	28.787	28.922
Dispersion				5.737	1.200	0.270
NOR	0.9556	4.2833	1.2764	3.209	4.255	4.282
Dispersion				0.855	0.199	0.045
Last Ten countries						
PRT	0.9982	15.5554	0.9305	3.413	13.256	15.426
Dispersion				1.336	2.848	0.811
DZA	0.9982	89.3340	5.3206	19.503	75.965	88.581
Dispersion				7.639	16.397	4.675
MAR	0.9985	20.0966	1.1085	4.086	16.672	19.900
Dispersion				1.603	3.803	1.135
PAK	0.9985	44.1353	2.4023	8.863	36.437	43.690
Dispersion				3.490	8.425	2.521
CZE	0.9986	35.6077	1.8796	6.942	29.064	35.227
Dispersion				2.743	6.807	2.097
TUN	0.9986	27.3228	1.4363	5.304	22.278	27.027
Dispersion				2.092	5.224	1.616
HUN	0.9987	34.0736	1.7690	6.530	27.637	33.697
Dispersion				2.573	6.576	2.040
SVK	0.9990	41.2077	1.8160	6.769	31.180	40.577
Dispersion				2.693	8.160	2.890
EST	0.9991	34.9383	1.5047	5.611	26.119	34.376
Dispersion				2.238	6.907	2.505
SAU	0.9993	69.1118	2.5165	9.443	47.283	67.569
Dispersion				3.779	13.532	5.808

that for some countries the dispersion increases in the first cases (small samples) and it does not decrease unless we obtain the volatility measure from a sample with more than 1,000 observations. Despite these results, we can find series with better behaviour that are generated from countries with a close to zero (1-$\hat{\beta}_j$) parameter. These do not report an increase in the dispersion of the volatility. We repeat once more that these remarks are only observed for the results in levels. In the case of first differences, we have that none of the previous features are observed in those results.

The reason for the difference in the results from the artificial data in levels and the ones taken from the first differences series is related to stationarity once again. As we mention above in the case of the series in levels, countries with lower values of (1-$\hat{\beta}_j$) generate series that give results closer to the AR(1) DGP standard deviation values without the need for a big sample size. If we analyse even more stationary series like $\Delta X_{j,t}$, we expect and obtain more stable and closer results to the standard deviation of the process $\Delta X_{j,t}$. As a final remark, we have to add that the dispersion in the results of series in first differences is always decreasing as the number of observations increase. The results for these series sorted by the value of (1-$\hat{\beta}_j$) can be found in table 7.11.

If we now sort our results with respect to the value of $\hat{\sigma}_{\epsilon_j}$, we find an interesting feature in the data generated in first differences. By doing this we sort at the same time our results with respect to the value of the standard deviation calculated for the artificial data. The relationship between $\hat{\sigma}_{\epsilon_j}$ and our results in first differences is very strong, however, we must repeat once more that this does not mean that the value of the former is the best proxy that we could use in order to get a measure of real exchange rate volatility.

It is clear that the results for volatility measures in first differences are closer to their respective theoretical value even when we use a small sample size. We also observe that dispersion for these results is also lower. These findings do not mean that our results from the measures taken of series in levels are incorrect. We observe a convergence to the theoretical value, although in some cases it is necessary to use a great number of observations.

The relevant point here is that using the standard deviation of the series in first differences is a more reliable volatility measure for the DGP in first differences without the need of

Table 7.11: Data in First Differences - Results sorted by value of $(1-\hat{\beta}_j)$.

		Reference Value		Std. Dev. - Artificial data		
	$(1-\hat{\beta}_j)$	$X_{j,t}$	$\Delta X_{j,t}$	100	5000	100000
First Ten countries						
BOL	0.6432	101.1898	85.4782	85.564	85.477	85.475
Dispersion				6.409	0.899	0.201
NIC - n.o. I	0.8125	32.3071	19.7827	19.807	19.781	19.782
Dispersion				1.446	0.203	0.045
GUY - n.o.	0.8533	7.8783	4.2676	4.272	4.268	4.267
Dispersion				0.310	0.043	0.010
MKD	0.8855	25.7845	12.3383	12.350	12.339	12.338
Dispersion				0.891	0.125	0.028
GEO	0.8989	4.7719	2.1455	2.148	2.145	2.145
Dispersion				0.155	0.022	0.005
SLE - n.o.	0.9289	21.4336	8.0847	8.090	8.084	8.084
Dispersion				0.581	0.082	0.018
ZAR	0.9402	70.0004	24.2185	24.249	24.219	24.218
Dispersion				1.740	0.244	0.054
NGA - n.o.	0.9433	29.6295	9.9762	9.984	9.976	9.976
Dispersion				0.718	0.100	0.022
MDA	0.9444	11.9229	3.9759	3.980	3.976	3.976
Dispersion				0.286	0.040	0.009
ZMB	0.9445	28.9308	9.6399	9.650	9.640	9.640
Dispersion				0.692	0.097	0.022
NOR	0.9556	4.2833	1.2764	1.278	1.276	1.276
Dispersion				0.092	0.013	0.003
Last Ten countries						
PRT	0.9982	15.5554	0.9305	0.928	0.930	0.930
Dispersion				0.066	0.009	0.002
DZA	0.9982	89.3340	5.3206	5.310	5.321	5.320
Dispersion				0.380	0.053	0.012
MAR	0.9985	20.0966	1.1085	1.106	1.108	1.108
Dispersion				0.079	0.011	0.002
PAK	0.9985	44.1353	2.4023	2.396	2.402	2.402
Dispersion				0.172	0.024	0.005
CZE	0.9986	35.6077	1.8796	1.875	1.879	1.880
Dispersion				0.134	0.019	0.004
TUN	0.9986	27.3228	1.4363	1.433	1.436	1.436
Dispersion				0.102	0.014	0.003
HUN	0.9987	34.0736	1.7690	1.765	1.769	1.769
Dispersion				0.126	0.018	0.004
SVK	0.9990	41.2077	1.8160	1.812	1.816	1.816
Dispersion				0.129	0.018	0.004
EST	0.9991	34.9383	1.5047	1.501	1.505	1.505
Dispersion				0.108	0.015	0.003
SAU	0.9993	69.1118	2.5165	2.510	2.517	2.516
Dispersion				0.179	0.025	0.006

having a big sample size. This is not the case when we want to have an accurate measure of volatility for real exchange rates in levels and the number of observations is very limited. However, it is not correct to use the standard deviation of the series in first differences in order to capture the volatility of the real exchange rate (in levels). As we have seen already, there are considerable differences between both volatility values. Our finding relies on the fact that the AR(1) is the actual DGP of the real exchange rate.

7.8 Cross-country analysis: Evidence from correlations

So far we have generated a considerable amount of data from our Monte Carlo exercise based on an AR(1) model. All these exercises are based on a univariate time series analysis. That is, the volatility measures obtained are calculated using individual artificial time series calibrated with the help of parameters estimated for each economy. We now calculate statistics using as our input the volatility measures from the artificial series that resemble the countries in our observed dataset. We finish our empirical analysis with a report of correlations between the sample standard deviation of the observed data, the one from the artificial series and the reference value of the volatility of an AR(1) process. Each exercise is done using the series in levels and in first differences.

7.8.1 Cross-country correlations

We now try to obtain a link between the different measures of volatility for the series in levels and first differences; but, before analysing the correlations using our results from the Monte Carlo exercise, it would be interesting to take a look to the correlations we have between the values of our parameters ($(1-\hat{\beta}_j)$ and $\hat{\sigma}_{\epsilon_j}$), our sample standard deviations from actual real exchange rate series and the ones calculated using the AR(1) DGP.

We get a good relationship between the sample standard deviation of the observed data and the value of $X_{j,t}$ following an AR(1) using now a cross-country sample. The rest of the values are below 0.7 in absolute value. More impressive is the correlation between the theoretical value of the $\Delta X_{j,t}$ process and the sample standard deviation of the observed data in first differences and also between the former and the estimated value $\hat{\sigma}_{\epsilon_j}$. In both

Table 7.12: Cross-country correlations

	Reference Volatility		Observed Sample Std. Dev.			
	$X_{j,t}$	$\Delta X_{j,t}$	$X_{j,t}$	$\Delta X_{j,t}$	$\hat{\sigma}_{\epsilon_j}$	$\hat{\beta}_j$
Reference Volatility $X_{j,t}$	1.0					
Reference Volatility $\Delta X_{j,t}$	0.486	1.0				
Obsed. Smpl. Std. Dev. $X_{j,t}$	0.916	0.682	1.0			
Obsed. Smpl. Std. Dev. $\Delta X_{j,t}$	0.484	1.0	0.681	1.0		
$\hat{\sigma}_{\epsilon_j}$	0.489	1.0	0.685	1.0	1.0	
$(1 - \hat{\beta}_j)$	0.159	-0.413	0.063	-0.415	-0.408	1.0

cases we obtain a correlation of 1. Once again, we observe the influence of high values of $(1 - \hat{\beta}_j)$ that just reflects the fact of having a high persistence in the original process $X_{j,t}$. The standard deviation of $\Delta X_{j,t}$ is very similar to the standard deviation of the innovation process we estimate via an AR(1).

The following tables include the correlations between the reference volatility of the DGP process in levels and in first differences and the results from our simulations. We focus our attention on the correlations between the statistic taken from artificial data and one of the reference measures (theoretical standard deviation of an AR(1)) and not between two statistics of artificial series since these do not tell us anything. For the other cases that we report, we expect results close to the unit.

Table 7.13: Cross-country correlations for artificial data results

Artificial data in Levels	Reference Volatility	
	$X_{j,t}$	$\Delta X_{j,t}$
Reference Volatility $X_{j,t}$	1.000	0.486
Reference Volatility $\Delta X_{j,t}$	0.486	1.000
Std. Dev. (artificial sample) 100 Obs.	0.589	0.980
Std. Dev. (artificial sample) 500 Obs.	0.735	0.896
Std. Dev. (artificial sample) 1,000 Obs.	0.814	0.831
Std. Dev. (artificial sample) 5,000 Obs.	0.952	0.655
Std. Dev. (artificial sample) 10,000 Obs.	0.981	0.592
Std. Dev. (artificial sample) 50,000 Obs.	0.999	0.511
Std. Dev. (artificial sample) 100,000 Obs.	1.000	0.499

Table 7.13 shows the correlation between the mean standard deviation of the artificial series in levels we obtain for each country and the reference value of the volatility we want to reach with the data generated. In this case we have that the row (or column) for our

reference volatility value of the $X_{j,t}$ process in levels is labeled "Reference Volatility $X_{j,t}$ " and "Reference Volatility $\Delta X_{j,t}$ " corresponds to the one for the reference value of the $\Delta X_{j,t}$ process. The first column shows a correlation value that increases as the number of observations also gets bigger. In the second column we find that the correlations have the opposite behaviour, they become lower as the number of observations is greater.

We can say that when the number of observations is small (first case), the variance of the series in levels is closer to the value of the volatility of the $\Delta X_{j,t}$ process, but this changes as N or T increases: the value of the variance of the series gets closer and closer to the theoretical standard deviation in levels. When the standard deviation is taken from artificial series with five thousand observations we have a inflection point and the volatility taken from artificial data is now closer to the theoretical standard deviation in levels (higher correlation). We then have similar results in the cross-country correlation results as in the time series standard deviations: it is necessary to have a considerable amount of observations to get a high correlation between the theoretical standard deviation and the volatility measure taken from the artificial data in levels.

The second table includes our results for the artificial data in first differences. The results are expected to differ from the ones above in table 7.13 since we now focus our attention to the reference volatility value of the process in first differences and not in levels.

Table 7.14: Cross-country correlations for artificial data results

Artificial data in First Differences	Reference Volatility	
	$\Delta X_{j,t}$	$X_{j,t}$
Reference Volatility $\Delta X_{j,t}$	1.000	0.486
Reference Volatility $X_{j,t}$	0.486	1.000
Std. Dev. (artificial sample) 100 Obs.	1.000	0.486
Std. Dev. (artificial sample) 500 Obs.	1.000	0.486
Std. Dev. (artificial sample) 1,000 Obs.	1.000	0.486
Std. Dev. (artificial sample) 5,000 Obs.	1.000	0.486
Std. Dev. (artificial sample) 10,000 Obs.	1.000	0.486
Std. Dev. (artificial sample) 50,000 Obs.	1.000	0.486
Std. Dev. (artificial sample) 100,000 Obs.	1.000	0.486

The first thing to notice in table 7.14 is that even from our first case, the one with 100 observations, we have a high correlation between the standard deviations of the countries in first differences and the theoretical value for the series also in first differences. There is a 100 percent correlation between the data from all the countries generated by us with the parameters obtained from an AR(1) model. The same value is obtained for the rest of the cases (increasing the number of observations). Columns two includes correlations between the volatility of artificial data in first differences and the reference value of the standard deviation for the AR(1) process in levels. The highest correlation is 0.486 and we obtain this value even with 100 observations. As a final comment, we must say that this number, 0.486, is the correlation that we get between the theoretical standard deviation in levels and the one in first differences.

7.9 Conclusions

This work represents an attempt to fill a void in the literature to discuss if there exist considerable differences between real exchange rate volatility measures taken from series in levels and the ones obtained from first differences. Most of the empirical works investigating the RER volatility do not consider the previous point and use volatility measures taken from series in first differences. Our work makes use of artificial data generated via Monte Carlo simulations that resemble the real exchange rate series observed in real life. The use of artificial data (generated via a Monte Carlo exercise) becomes a relevant part of our work as we need to use long time series with more observations than the ones we can obtain by using real data on real exchange rates.

This last point is important and relevant to our results as we find that a good volatility measure in levels depends on how stationary the series is or in the amount of observations available to carry out the empirical work (the more observations we can obtain, the more accurate our measure is). Our most important result is the fact that the real exchange rate series of some countries (assuming an specific DGP for the RER) is considerably stationary to use volatility measures calculated from series in levels rather than using first differences as proxy in empirical works.

The next thing we have to remark in detail from all our exercises is the fact that volatility in levels, taken from any sample or reference, is almost always different to the one calculated in first differences, and in some cases the differences are quite big. We find that the artificial data generated using parameters of a few countries could give us similar measures of volatility of the series in levels and in first differences. It is inappropriate to use one measure taken from a sample in first differences to investigate the one in levels. By doing this we are closer to obtain more information from the innovation term (error term) of the DGP than from the actual real exchange rate behaviour.

Our results show that we need to have stationary series in order to obtain more reliable measures of volatility. The measures taken from series in levels are not as close to the reference value as the ones in first differences when we calculate these from small samples. As the sample increases there is an important improvement in the ones from series in levels. This is not an issue for the series in first differences. The volatility measure is very close to the reference value of the process in first differences.

It is also quite important to mention that the selection of which DGP we choose to model real exchange rate series is very relevant. We find that our first model gives good results for the volatility measures in levels and it is not necessary to have a big sample in order to obtain a measure that resembles the reference one as when we use a more basic set-up (AR(1) model). Despite the differences between our two chosen models, we find the same pattern in both: the measures in first differences are more precise than the ones in levels when these are taken using small sample sizes. The measures in levels perform better as the sample size increases and also if the series behave less as a unit root and more as a stationary process.

The importance of stationarity is also observed in the relevance of the autoregresive coefficient. As the coefficient gets closer to one (closer to a unit root process), the less accurate the measure is. At the same time, if the autoregressive coefficient is far from the value of one the volatility measure is closer to the reference value without the need of a big sample. Despite its relevance for the measures in levels, this coefficient is not important for the measures in first differences.

We have found and highlighted the differences between volatility measures taken from series in levels and first differences. The latter are more accurate in any case, but this could represent loss of information in our results. In order to avoid this, it is important to do a preliminary analysis to our data in levels and first differences and corroborate that real exchange rates (or any macroeconomic time-series) are stationary enough to obtain satisfactory results using series in levels. It is possible that the loss in accuracy of using levels can be compensated by obtaining more detailed results and getting a better understanding of real exchange rates and not of their changes. However, using series in first differences when we face real exchange rates that are close to a unit root process could be the only way to accomplish this.

In our analysis using the artificial series as proxies for the countries' real exchange rate behaviour we confirm the previous, a strong relationship of the autoregressive coefficient with the volatility measure in levels, which fades away as the sample size increases, and also a more relevant role of the variance of the stochastic part for the measures in first differences.

Chapter 8

Conclusions and Future Work

8.1 A brief summary of our findings

This research consists of five empirical chapters of which three are devoted to the study of real exchange rate volatility. The other two are a "by-product" of our real exchange rate volatility analysis. These are focused on the estimation of an openness equation. The exposition of our topics and their results is the following: we started by doing a variance decomposition of the real exchange rate. In this part we assumed a representation for the real exchange rate in which this variable can be split into two type of prices. One is the price of non-traded goods and the second one is for traded goods. The division is a straightforward one but it also represents a good introduction to the relevance of trade flows and openness for the real exchange rate volatility.

Our results showed that the importance of non-traded goods is far from being negligible as some authors have claimed. These findings could also be interpreted as a "vindication" of a PPP (for traded goods) that holds in the long run as the impact of traded goods in the real exchange rate volatility diminishes across time. In a seminal paper published more than ten years ago, Engel (1999) claimed that almost all the volatility of the RER is generated by the traded goods component of the real exchange rate. His paper could be interpreted as follows: having more traded goods in the economy implies a higher volatility with a diminishing role for non-traded goods; and more important, this result contradicts the empirical results of other authors in which they show a negative relationship between trade openness and the real exchange rate's volatility.[1] After finding in our chapter results that rejected the hypothesis of a RER volatility generated exclusively by traded goods, we moved to actually testing empirically the impact of several exogenous variables on the levels of real exchange rate volatility.

In the second empirical chapter we combined and explored in more detail the main findings of two relevant papers that investigate the determinants of the real exchange rate volatility. The first paper shows the importance of trade openness for the levels of real exchange rate volatility. In the second paper this relationship is also observed but the impact of openness is reduced if some other variables are considered; in particular variables that capture the effects of barriers to trade. We decided to test the relationship between real exchange rate volatility and openness and also to replicate the results of estimations that consider as exogenous variables barriers to trade (imposed and natural ones). At the same time, our goal is to include some ideas of our own as new features in our work. To be more specific, we used some of the results of the second paper as motivation for our research in order to control for imposed barriers to trade. We were able to replicate the main findings of these two works.

Additionally, we incorporated new variables to obtain more detailed results in line with previous research. In particular, we disaggregated further the natural barriers to trade variables to control for more effects in our results. Apart from replicating previous findings with our estimations and obtaining more detailed results, we were able to generate a new result. Our contribution to the literature is the inclusion of a variable that represents an important link between real exchange rate volatility and other types of volatility that the economy might suffer. We included in the RER volatility specification as an extra regressor inflation volatility, with significant results that help us in the search for a better explanation not only for its own relationship with the real exchange rate. At the same time, we observed that this result affects differently high income countries and the rest of the economies included in our sample. This variable captures in a simple way the idea of an asymmetric impact of shocks in the real exchange rate suffered by developing and developed economies. It also illustrates that periods of higher real exchange volatility of the last three

[1] Examples of the previous include Asea and Mendoza (1994), Brock (1994), Brock and Turnovsky (1994), Samuelson (1994) and Obstfeld and Rogoff (1996).

decades are also related to severe economic imbalances that several developing countries have experienced.

Chapters Three and Four represented a deeper exploration into the role of openness on the real exchange rate. In this case, we decided to search for and to establish a relationship between a small set of variables that mainly control for trade barriers (imposed and non-imposed ones), which become the regressors in our main specification of these two chapters, and openness (playing the role of dependent variable) in an econometric analysis. The main objective of the chapters was to place the issue of an econometric model of openness under the spotlight to show that this equation can help us not only to explain the immediate goal of the establishment of an openness equation, but also to enhance its role as an auxiliary regression in the estimation of other dependent variables. In the first chapter devoted to investigating openness we decided to establish the existence of a simple and parsimonious econometric relationship between trade flows and trade barriers (imposed and natural ones) by using cross-country characteristics (mainly geographic ones). The results were favourable for the openness specification and we also obtained evidence for the existence of differentiated impact of some variables on the dependent variable. The differences in the effects of some of our regressors were connected to differences in income levels of the economies.

In the second chapter devoted to an openness specification, we took a step further and estimated a regression using panel data econometric techniques. The results of this chapter corroborated the ones from the previous analysis and also showed changes in the effects of some of our independent variables across time. We were able to apply a new and interesting econometric technique first developed by Plümper and Troeger in which we are able to use (almost) time-invariant variables in a Fixed-Effects estimation framework. With the help of this new technique, named Fixed-Effects Vector Decomposition (FEVD), we could rely on the results of a fixed-effects estimation that includes (almost) time-invariant variables. In some other works the use of Hausman-Taylor estimation techniques is recommended, but this type of framework is too restrictive for our purposes and in some cases biased and less consistent that the FEVD framework.[2] We found evidence that supports the idea of increases in trade levels that economies have experienced in the past decades. We also

[2]In order to use a Hausman-Taylor estimation framework it is required that the actual Hausman tests signals for the use of Random- and not Fixed-effects estimations techniques, which we do not obtain in our results; and also balanced panel data, which we also do not have in our work. For more details on Hausman-Taylor estimation techniques see Hausman and Taylor (1981).

found evidence of changes across time in the impact of key variables that affect openness, in particular the role of remoteness (a proxy for trade costs).

The final chapter took us back to a study focused on real exchange volatility. In this case we analysed the problem of what measure represents better the volatility observed in real exchange rate series. To be more specific, we constructed measures of real exchange rate volatility taken from RER data in levels and in first differences. Our objective was to show that from an economic point of view it makes more sense to use volatility measures taken from series in levels, whilst several empirical works use, without significant discussion, measures taken from series in first differences. In our results we showed that there exist differences between the two types of measures and that series in first differences are closer to our reference values calculated for the analysis. However, our results revealed a more complex situation because the measures taken from series in first differences were not very similar to the ones taken from the levels. We also found that in some cases the measures from series in levels are also close to the reference value. The key factors in obtaining this particular finding were two: The first one is related to the size of the sample; as sample size gets bigger, the results from the measures in levels are closer to the reference value. And secondly, which could also help with the first one, is related to how stationary the real exchange rate series are. The more stationary, the better the series behave and the more accurate our measures of volatility in levels are.

These five chapters were an effort to obtain a better explanation of certain characteristics observed in the real exchange rate of different economies, and to get more robust answers for the behaviour this variable has experienced in recent decades. As it has been found in the literature and in our results, the role of openness is important in the variation of the real exchange rate. This is our motivation to model an empirical equation for openness in order to get a more detailed relationship between this variable and other economic factors; and, at the same time, to enlarge the scope of the literature related to trade flows.

8.2 Traded and Non-traded goods and the difficulties to validate empirically the PPP

The results of the variance decomposition chapter revealed to us the importance of non-traded goods as a source of fluctuations of the real exchange rate. It could be argued that the study is based on three countries only. However, two of those three are part of one of the most important trade agreements the United States has signed. The bilateral exchange rates employed in the chapter are calculated using as reference value the cost of the representative basket of goods of the US economy. Despite a first set of results taken from simple statistics showing a low contribution of non-traded goods prices, we were able to get results that show how the role of traded goods loses importance across time. This was observed with more clarity in the case of Canada.

We were not only able to indirectly test the (long-term) PPP hypothesis empirically, with results that do not reject it completely in the long-run, we also tried two different measures of the real exchange rate using different proxies for non-traded and traded goods prices. The results of both measures were consistent with each other. However, the findings from measures that are constructed with general price indices (considering a greater amount of goods instead of using an index that includes just one type of good) are more supportive of PPP.

This first set of results were just a preview of what we consider a more insightful analysis of the role of both type of goods in real exchange rate volatility. With the help of three types of VAR systems for each country and for each RER constructed by us, we obtained more evidence in favour of the hypothesis that the contribution of non-traded goods prices to real exchange rate volatility is far from negligible. Using a forecast error variance decomposition, we obtained more evidence of this.

In a more detailed analysis based on the VECM results for Mexico, we observed that the relevance of non-traded goods is rather small in the short run, but that situation is reversed as we consider further horizons to end up with a high contribution of this component in the long run. It is also possible to observe, in the Mexican case again, the impact of nominal shocks to the real exchange rate volatility via movements in the nominal exchange rate. The variations in this nominal variable are totally absorbed in the medium run for developed economies, but in the case of Mexico it is necessary to consider a longer horizon to actually observe a complete erosion of this shock in the real exchange rate. All this means that volatility in the nominal exchange rate is translated into variations of the real exchange rate. It also represents a different behaviour in the developing country that can explain the observed differences in the levels of volatility of the real exchange rate between high income nations and the rest of countries. As a matter of fact, several authors have claimed that one of the explanations for the different levels of real exchange rate volatility between developing and industrialized economies is the persistence of shocks.

Finally, the results obtained with the use of Mexican data allowed us to observe different behaviour of the real exchange rate under fixed and flexible exchange rate regimes (with the help of results obtained from two different subsamples). It is claimed by several authors that the switch from a fixed to a flexible exchange rate regime generates an increase in the volatility of the real exchange rate. We got this effect in our results for Mexico. This claim could be directly related to the impact of the nominal exchange rate in our results for both subsamples of the Mexican case. Our results support the hypothesis of observing more volatile real exchange rates during flexible exchange rate regimes for the Mexican case.

8.3 The RER Estimation

We established an econometric specification for real exchange rate volatility that allowed us to replicate the findings of other seminal works. At the same time we were able to include new relevant variables in our RER volatility specification. These new variables helped us refine the role of trade openness in real exchange rate volatility by including more specific country characteristics that can be regarded as natural barriers to trade. The other new regressors considered in our specification helped us control for the impact of other types of volatility that affect the economy (which can also be interpreted as the role of shocks that affect the economy); and, as our results show, the fluctuations of the real exchange rate.

In terms of the basic results, we confirmed that the findings are robust as we solve some issues observed in previous studies. Our results also confirmed a more discreet role of openness as main determinant of real exchange rate volatility. This is a direct consequence of including new variables in the analysis that control for trade barriers effects. In our specifications we were able to include further variables to capture the effect of these in real exchange rate volatility. We found that the role of natural trade barriers in the levels of real exchange rate volatility should not be minimized.

Despite a reduction in the impact of openness, our results did not suggest for its elimination from the RER volatility specification, but better ways to include this regressor in these estimations. A possibility we can think of is to estimate an openness equation and include this specification as a first stage regression in an IV estimation framework (or any other procedure involving two stage regressions). Other authors have done this, but without a proper analysis of the openness estimation they use. It is also possible that a new framework as the one just described could give us a reduced role for openness but with more detailed, specific, and robust results in our real exchange rate volatility estimation.

As a third relevant finding observed in the results of this chapter, we have that the behaviour of other macroeconomic indicators can affect real exchange rate volatility. We are referring to the positive relationship we find in our results between the volatility of the real exchange rate and inflation volatility. If we consider that a non-zero real exchange rate volatility can be interpreted as departures of this variable from an "equilibrium" level at which the economy is at internal and external balance (or perhaps a situation out of this equilibrium that is sustainable in the long run), we can interpret the inflation volatility as the existence of an unbalanced position for the economy that at some point is reflected in the real exchange rate volatility. We could also consider the scenario depicted by Gonzaga and Terra (1997) in which they interpret this inflation volatility as an extra factor of uncertainty in the economy. This uncertainty could introduce unbalances to the economy that is a source of variations to the real exchange rate.

It is also true that the inclusion of this variable in the model responds more to an *ad-hoc* representation than one derived from a proper theoretical model, nevertheless the estimation results are robust and it could be considered an important extension of this work to validate the link found in our results via a theoretical model.

Our real exchange rate volatility specification and its results represent important refinements to the empirical literature that tries to obtain a more detailed answer to the variations that the real exchange rate suffers and also to the different levels of volatility this variable reports for different type of economies. The next goal is to make a sensible attempt to establish an identity among the variables considered in the chapter and not only a relationship.

A final comment must be made in relation to the fact that developing countries experience higher real exchange rate volatility levels than the observed ones for industrialized economies. Our results reflected the existence of these differences, we just need to observe the result for the income level proxy variable (real GDP per capita and the dummy variable that indicates if a country is a high income level one or not); and at the same time we had that the impact of the inflation volatility variable is higher for developing and less developed countries. However, by controlling for the impact of these variables on the real exchange rate volatility we were not able to obtain a complete answer of why we observe different levels of real exchange rate volatility in different type of economies. This means that our results should be considered as an intermediate step in the search for an answer that explains the previous puzzle. Future work should build upon our results to obtain not only an accurate and valid but also quite robust explanation.

8.4 Openness, a diversion that might help us to get a better solution (explanation)

Most of the literature related to the topic of trade flows is focused on the estimation of a gravity equation, which is a model with very good empirical results, but it only studies bilateral trade flows. The number of empirical works that consider trade openness as their main research topic are rare, but that does not mean this variable is not important. Several authors consider trade openness an important indicator of the economy to the point of being part of economic growth or other macroeconomic empirical estimations, and in several cases openness is being instrumented in order to have more robust results. However, these works do not include a relevant discussion of which variables could be the most significant ones to be included in a second stage regression for openness. It is possible that the lack of works on the topic forces researchers to consider openness as a first stage regression only in a instrumental variables approach and not as the main topic of research.

In our case, we started the analysis of an openness equation because of its relationship with real exchange rate volatility. The impact of the former on the latter varies in a systematic way when other specific variables are considered in a real exchange rate volatility estimation model. For this reason we decided to explore further the issue. We were able to find a good specification for openness that explains in a simple way the impact of imposed and natural trade barriers. Our results were in line with the findings of other authors. As a matter of fact, we were not only able to replicate these, but we also obtained more detailed conclusions, since we detect a structural break in our specification with respect to income level of the countries. We explored the topic even further with an extensive analysis for middle and low income countries, with encouraging positive results for regressions that were run using only a subsample of our complete set of countries. As a matter of fact most of the effects found in our complete sample case hold when we estimate the openness equation only using developing and less-developed countries.

The next step was to estimate panel data regressions in which we included the most relevant variables of our cross-section specification. The building block of our estimations was not only a simple fixed-effects framework. We included a new type of estimation because several of our variables do not change considerably through time. For this reason we employed a new estimation technique developed by Plümper and Troeger called Fixed-Effects Vector Decomposition. The results we obtained with this estimation technique were in line with the ones from our cross-country counterpart. This particular result could be regarded as a robustness check on both of our exercises. We also observed how trade openness has increased across time in the economies that are part of our sample. As a matter of fact, the Fixed-Effects Vector Decomposition approach we employed not only captures the dynamic impact of each variable for each country, but the obtained coefficients can also incorporate cross-country effects.

We were able to obtain significant results for interactive regressors included in our openness specification. In particular, we observed changes in time of the impact of relevant variables on openness. We found, for most of our interactive variables, a decline in the impact of the regressor across time. The most interesting case is observed in our proxy for distance, our remoteness variable. In other words, we could establish a lower role of transport costs (distance) effect on the levels of openness of an economy. However, we still observed a negative and very significant effect of these in the trade flows and we could not conclude, as some other authors have claimed, that distance is no longer an important factor to consider in the decision to engage in trade with another nation.

The work on the determination of an openness equation is far from being concluded, even if we consider the lack of a theoretical model to help us back up our findings in the empirical field (a similar situation to the one in the gravity equation model). Nevertheless, the results presented here and their robustness should make us consider the importance of this topic and the need to explore it further. We can reach important conclusions by doing so, not only for the understanding of trade openness, but also to use this variable indirectly in other econometric estimations.

8.5 Long and Homogeneous Time Series

In the final chapter of this thesis we tackled in a different way the topic related to the stationarity of the real exchange rate time series. In our approach we discussed whether it is a reliable choice to use real exchange rate volatility measures taken from series in levels, or if we should only consider the ones generated from the series in first differences. As we found in our study, a very important fact that should be considered is the stationarity of the series in order to carry out empirical work on the RER volatility. Our main objective was to show that both measures are rather different and in some cases not similar at all. We also acknowledged, after observing our results, that in some cases the most viable way to analyse real exchange rate volatility is through the employment of series in first differences, assuming that some information is lost in the transformation which may make difficult to study some aspects of this variable. In the chapter we set up a model that represents a possible data generating process (DGP) for real exchange rate series; and we then generated artificial data to calculate measures taken from the series in levels and in first differences. We compared the volatility measures generated from artificial data series with reference values calculated using the DGP process assumed and the parameters estimated in the first part of the analysis.

It is also important to highlight the relevance of using Monte Carlo simulation techniques because it is not possible to obtain data for more than a 100 countries that represents more than 200 years of daily observations. We needed long time series because we mainly tested long-run properties of the real exchange rate.

A first and simple result taken from our exercise was to observe the actual differences between the variance and standard deviation of the series in levels and in first differences. It is easy to conclude that one measure cannot replace the other. What we tried to do here is to figure out which measure is closer to the reference values calculated. In all our exercises we were able to obtain very good results for the series in first differences. Things are different for the measures taken from series in levels; in this case we observed more deviations from the reference values for samples with a small amount of observations. The results improved considerably when we allowed for a greater number of observations. We obtained good results for our measures in levels when we analysed artificial data that resemble stationary countries' series of the real exchange rate. The less stationary the series behave, the more differences we found between the volatility measure taken from series in levels and its respective reference value. There are cases in which we obtained favourable results for volatility measures in levels, and the key factor for this was the stationarity of the country's real exchange rate. At the same time, the need for bigger samples to obtain a good measure of volatility is reduced. In our results we observed that with a considerably great amount of observations the stationarity condition became less necessary as we could rely more on the law of large numbers to obtain results that are close to the reference value.

An important feature of our analysis was the elimination of outliers from the series employed to carry out our empirical work. This is relevant as our results were not biased due to their presence. However, the outliers represent specific events in real exchange rate series. As a matter of fact, these represent periods of high volatility for several of the countries that are part of our sample. Our goal was to decide which volatility measure works better for real exchange rate series, but in order to have a better understanding of the real exchange rate of a country it is important to consider in future analyses these outliers as relevant and particular episodes in the real exchange rate time-series of each economy.

We conclude that the chapter not only let us realize the importance of the decision regarding how to construct our volatility measure for our research, it also makes us think about the importance of developing better tests that can signal more efficiently for the existence of unit roots in our real exchange rate series. The debate in the literature regarding the persistence of this series is huge. It is very likely that we cannot obtain a definitive answer until more reliable tests are available to us. A different option we could consider is to wait for new data of our relevant series to be generated and published so we can depend more on their asymptotic properties.

8.6 Future Work and Extensions

Despite our findings and conclusions reported in our chapters, the complete work presented here is subject to improvement. Our framework could be regarded as the benchmark of future studies in order to obtain even more robust and/or more specific results. As is always the case in empirical works, the research can simply continue by employing greater samples that consider the publication of new data observed in real life. Besides this trivial improvement of our estimations, we consider more complex extensions that could enrich the analysis reported here.

We start with potential extensions to our initial chapter, variance decomposition of the real exchange rate. The natural extension to the work presented is to consider a larger number of countries in the analysis. With this extension we have the possibility to get a more detailed analysis, including other currencies and more representative economies of other regions (for instance Germany, England and Japan in the case of industrialized countries and economies from the South-Asia region and transition ones for the rest of the economies) to enhance our findings. Another possible extension that could enrich the analysis presented here is the use of different price indices as new proxies for traded and non-traded goods prices. A final refinement is to consider exogenous variables to be included inside the VAR system in order to control for more specific perturbations affecting real exchange rates and let us capture in a "cleaner" way the impact of traded and non-traded goods (for example, we could include oil prices in our VAR systems).

If we now move towards the following chapters (estimation of real exchange rate volatility), we can mention an interesting extension that links the results of two of our chapters (our specifications for real exchange rate volatility and the one for openness). The potential analysis we are considering is an IV estimation of the real exchange rate volatility equation in which we instrument openness and at the same time implement a Fixed-Effects Vector Decomposition technique. We decided not to carry such research in here because the implications of this research work are quite extensive and there are other more basic issues that are explained throughly in the five chapters included in this thesis. The results of these chapters by themselves can be regarded as contributions to the literature by establishing robust and basic linkages. At the same time these serve as a good benchmark for future investigations. It is necessary to consider all the points highlighted in all the chapters. From the use of long samples in order to avoid problems of time series that might not be very stationary to the use of a more powerful estimation techniques, as we mention above.

The use of an openness equation as a first-stage regression in a instrumental variables approach is nothing new as previous works use this particular estimation to support the robustness of their final econometric model. The drawback of this approach is the lack of a clear explanation of what variables should be included in the openness estimation, or the way these are expected to affect the dependent variable. An empirical work using the elements described previously would represent the encapsulation of all our findings and perhaps a more complete or extensive explanation for the behaviour of real exchange rate volatility, and of course the role of trade openness.

Our final chapter in which we compare two volatility measures of the real exchange rate constructed by us represents a first attempt to analyse the very basic features of different volatility measures. It is important to have a clear understanding of the limitations and differences that these two have. As a second step we can now expand our study to include more complex dispersion measures that can be calculated using artificial data generated by Monte Carlo simulations. Another possibility to enhance this work is to consider different data generating processes that could proxy more accurately the real exchange rate time-series. In a more ambitious scope of a future work, we could consider different DGP representations for different types of economies. Finally, the work can be extended by considering different estimation techniques to obtain the parameters that feed the Monte Carlo exercise; to be more precise, we can switch to a Kalman-Filter estimation framework in order to estimate our original mean reversion model presented in the chapter.

So far we have discussed possible extensions to research topics presented in this thesis. However, there are different lines of research not considered here due to space and time limitations. In this last section of our work we mention research topics that are not developed in this work, but we still consider quite relevant to obtain a more complete understanding of real exchange rates in general.

Among the topics not covered here, we can mention the importance of capital flows in the determination and movements of real exchange rates. The importance of capital flows is not covered in our approach, but we consider these relevant to depict certain characteristics of the RER. Our real exchange rate volatility model could be enhanced by the inclusion of a variable that captures the effect of capital flows. Additionally, we can also control for capital restrictions and how these affect our variable of interest. In just a few words, this econometric model would take into account financial restrictions imposed in the economy. In a related matter, it is possible to link real exchange rate volatility to the Dutch Disease phenomena (Saborowski (2009)), and also to the experiences of different regions of the world in terms of capital flows shocks and disruptions -sudden stops- (Edwards (1998); Athukorala and Rajapatirana (2003), for example); we also can mention the topic of switching exchange rate regimes and the impact on real exchange rate volatility (see Baldi and Mulder (2004) and Dibooglu and Koray (2001)).

Economies face an important decision when they consider opening their country to international markets, and decide what to liberalize first, either their goods markets or their capital ones. As a matter of fact Cerda (2002) attempts to link trade and capital openness with movements in the real exchange rate. The literature on the topic of real exchange volatility and capital openness is extensive, however there are issues that can be explored in more detail. In short, we could combine international finance and international macroeconomics to explore further the topic of real exchange rate volatility.

An important component of recent literature in international macroeconomics not explored in this work is the one related to the refinement of recent theoretical models. In this sense we consider that the theoretical model named New Open Economy Macroeconomics (NOEM) is a relevant effort to explain in a better way the dynamics of the real exchange rate, its volatility and repercussions in an open economy. The NOEM literature represents an effort to develop a new "workhorse" model for open-economy macroeconomic analysis with an interesting characteristic, which is the introduction of nominal rigidities and market imperfections into a dynamic general equilibrium model with well-specified micro-foundations.[3]

[3]See Lane(1999) for a complete and extensive survey in the topic.

The literature on NOEM models has been growing considerably in recent years. But the need for such models has been noticed in the past; for example, Dornbusch (1987) highlighted years ago the need of a model like the one previously described by recognizing firms are price setters, and how their economic decisions relate to current disturbances that could translate into innovations in exchange rates. Several authors have claimed that by using this theory models, it is possible to have a good representation of real exchange rates, in particular it is possible to generate a highly persistent real exchange rate as it is observed in real life. The work of Sellin (2007) is a clear example of the previous as he uses a NOEM framework not only to model but also to forecast real exchange rates. As a matter of fact, NOEM-based models make it possible to investigate in detail the potential connection between the issue of incomplete full pass-through of the nominal exchange rate to traded goods prices, which at the same time can be linked to the stylized fact of observing very close movements of the nominal and real exchange rate.

Appendix A

Appendix of Chapter 3

A.1 VAR and VECM construction

All VARs and VECMs are estimated using J-MulTi software developed initially by Alexander Benkwitz and improved by Markus Krätzig. In the following table we describe the details of the specifications estimated for each country.

A.2 MEI Impulse Response graphs

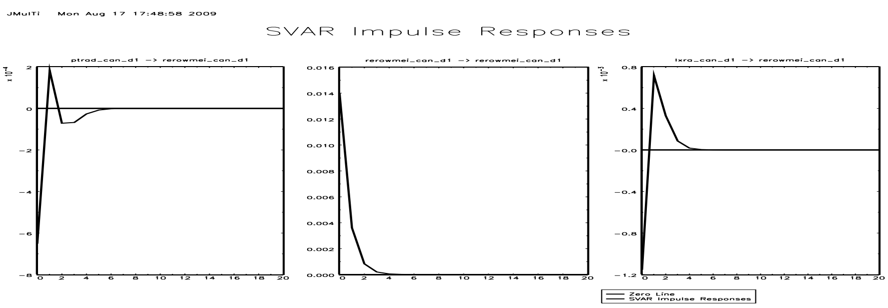

Figure A.1: Impulse-Response: CAN, VAR: s+q+z

Table A.1: VARS specifications

VAR	MEI		IFS	
	Optimal lags	Constant	Optimal lags	Constant
Can. (q+s)	1		1	
Can. (q+s+z)	1		1	
Can. (q+s+y)	1		1	
Nor. (q+s)	1		1	
Nor. (q+s+z)	1		1	
Nor. (q+s+y)	1		1	
Mex. (q+s; Complete)	2	✓	1	
Mex. (q+s+z; Complete)	2		1	
Mex. (q+s+y; Complete)	2		1	
Mex. (q+s; I period)	1		1	
Mex. (q+s+z; I period)	1	✓	1	
Mex. (q+s+y; I period)	1	✓	1	
Mex. (q+s; II period)	3		3	
Mex. (q+s+z; II period)	1		1	
Mex. (q+s+y; II period)	1		1	

Table A.2: VECMs specifications

VECM	MEI			IFS	
	Optimal lags	Constant	Trend	Optimal lags	Constant
Mex. (q+s+z; Complete)	3	✓		2	✓
Mex. (q+s+z; I period)	2	✓	✓		
Mex. (q+s+z; II period)	2	✓			
Mex. (q+s+y; Complete)	3	✓		2	✓
Mex. (q+s+y; I period)	2	✓	✓		
Mex. (q+s+y; II period)	2	✓			

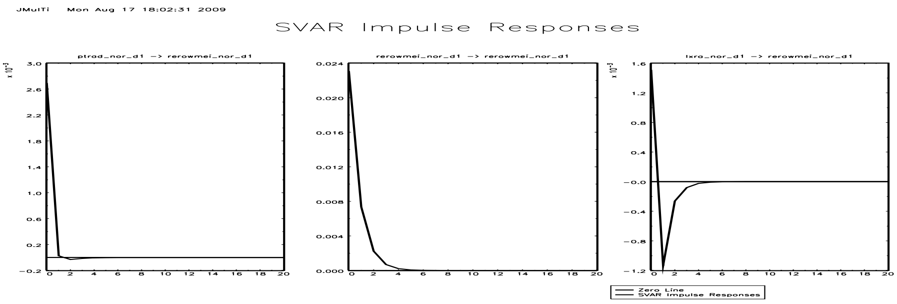

Figure A.2: Impulse-Response: NOR, VAR: s+q+z

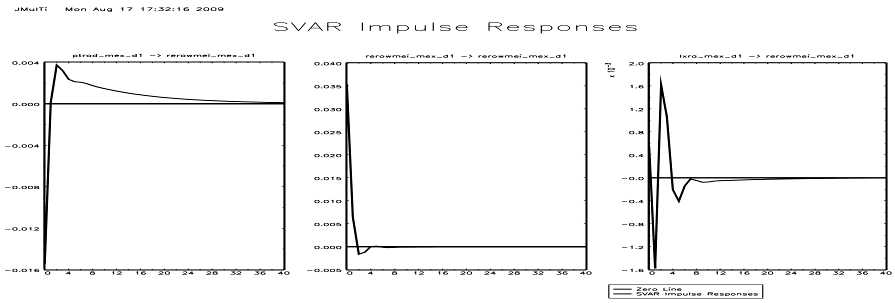

Figure A.3: Impulse-Response: MEX, VAR: s+q+z. Complete Sample

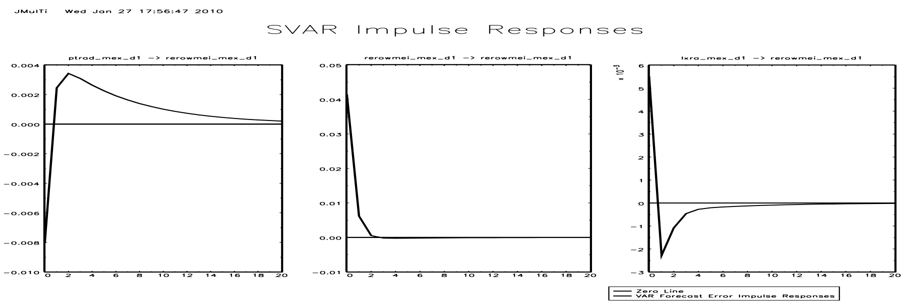

Figure A.4: Impulse-Response: MEX, VAR: s+q+z. 1st sub-sample

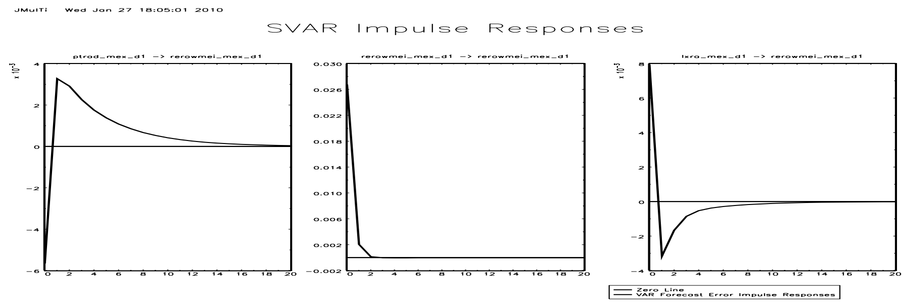

Figure A.5: Impulse-Response: MEX, VAR: s+q+z. 2nd sub-sample

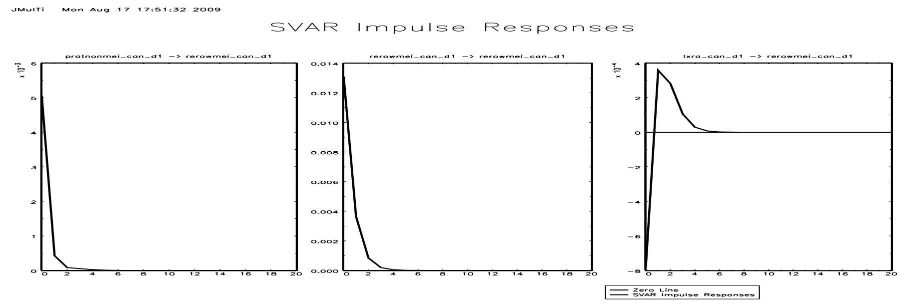

Figure A.6: Impulse-Response: CAN, VAR: s+q+y

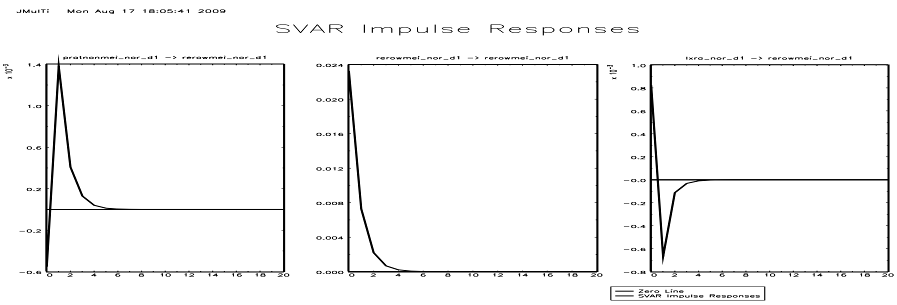

Figure A.7: Impulse-Response: NOR, VAR: s+q+y

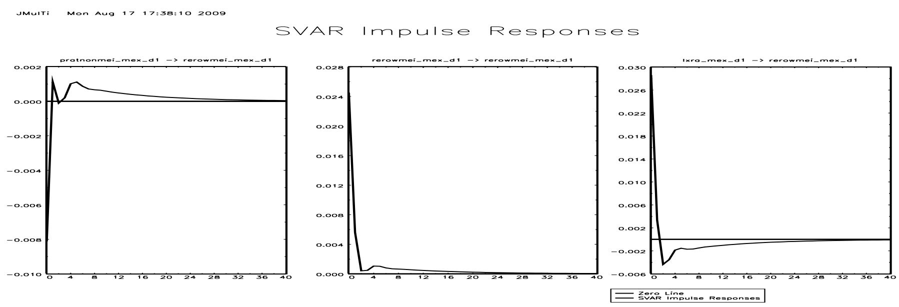

Figure A.8: Impulse-Response: MEX, VAR: s+q+y. Complete Sample

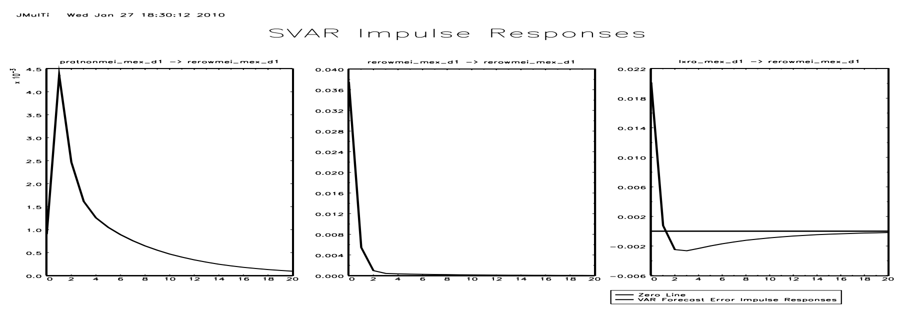

Figure A.9: Impulse-Response: MEX, VAR: s+q+y. 1st sub-sample

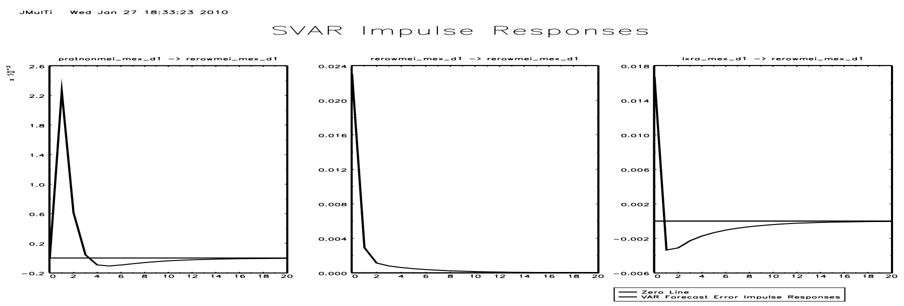

Figure A.10: Impulse-Response: MEX, VAR: s+q+y. 2nd sub-sample

A.3 IFS Impulse Response graphs

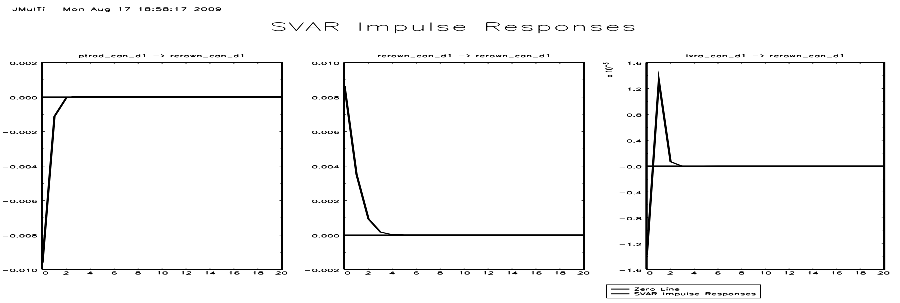

Figure A.11: Impulse-Response: CAN, VAR: s+q+z

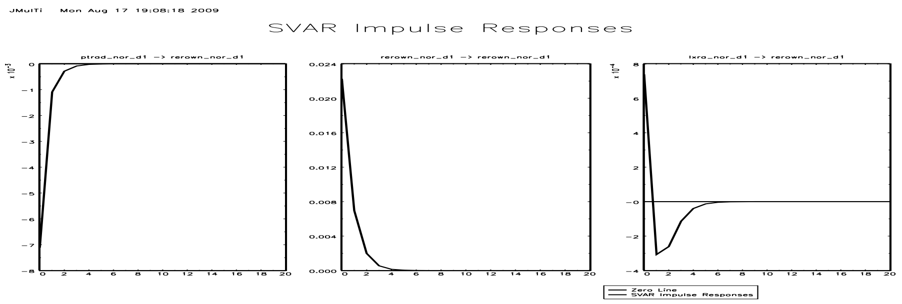

Figure A.12: Impulse-Response: NOR, VAR: s+q+z

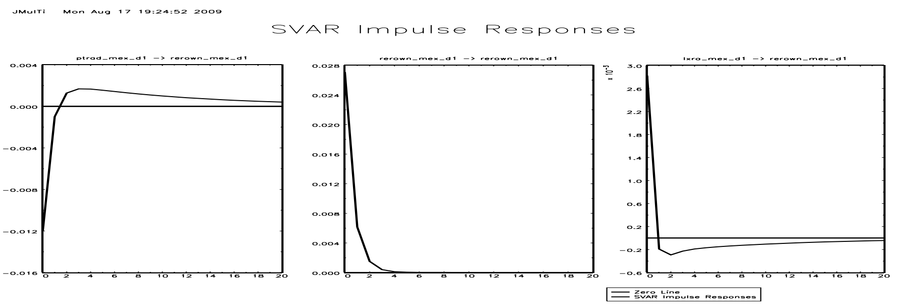

Figure A.13: Impulse-Response: MEX, VAR: s+q+z. Complete Sample

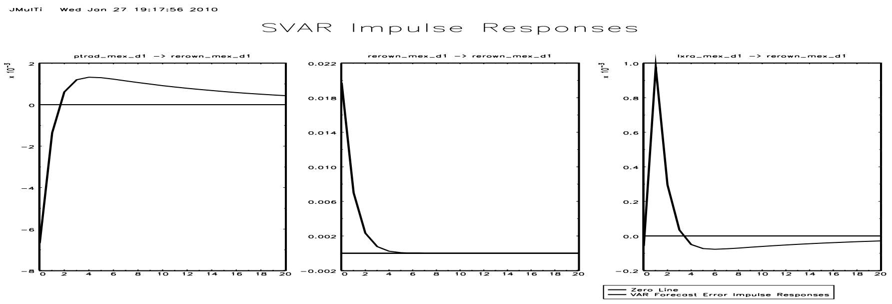

Figure A.14: Impulse-Response: MEX, VAR: s+q+z. 1st sub-sample

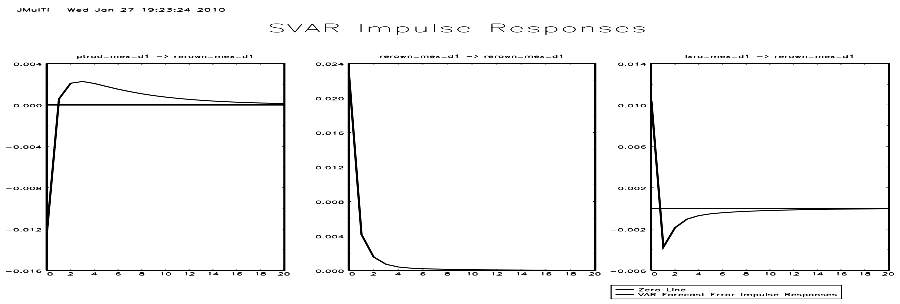

Figure A.15: Impulse-Response: MEX, VAR: s+q+z. 2nd sub-sample

A.4 Impulse-Response graphs, VECMs

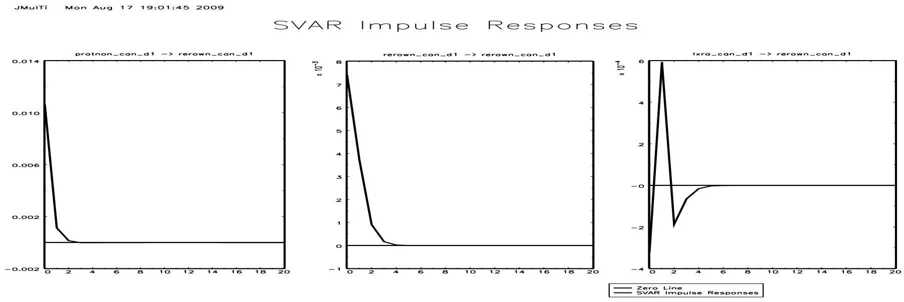

Figure A.16: Impulse-Response: CAN, VAR: s+q+y

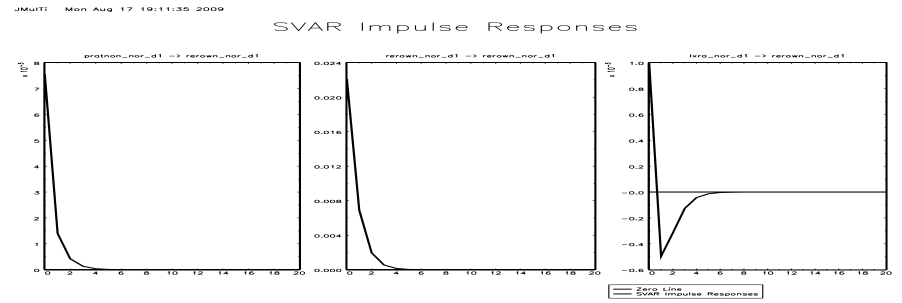

Figure A.17: Impulse-Response: NOR, VAR: s+q+y

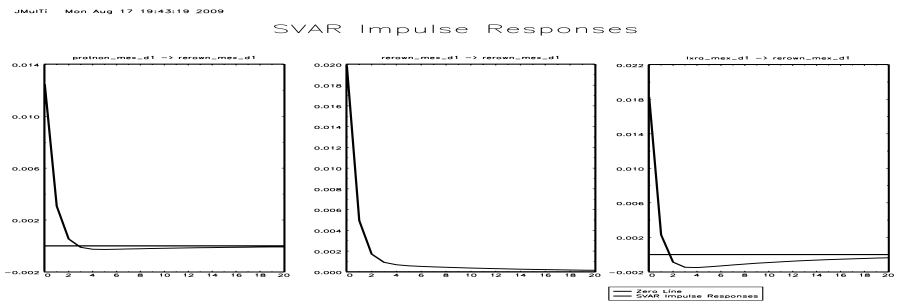

Figure A.18: Impulse-Response: MEX, VAR: s+q+y. Complete Sample

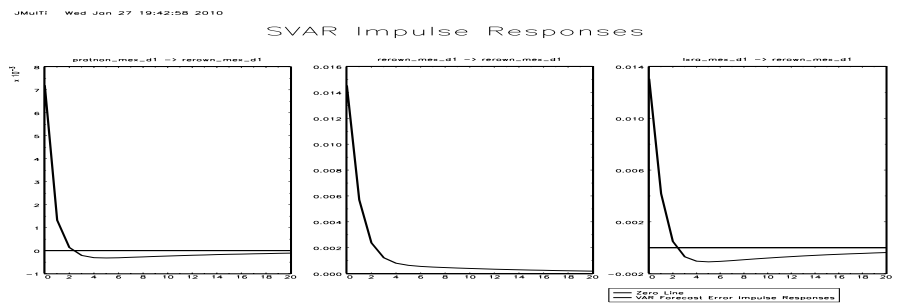

Figure A.19: Impulse-Response: MEX, VAR: s+q+y. 1st sub-sample

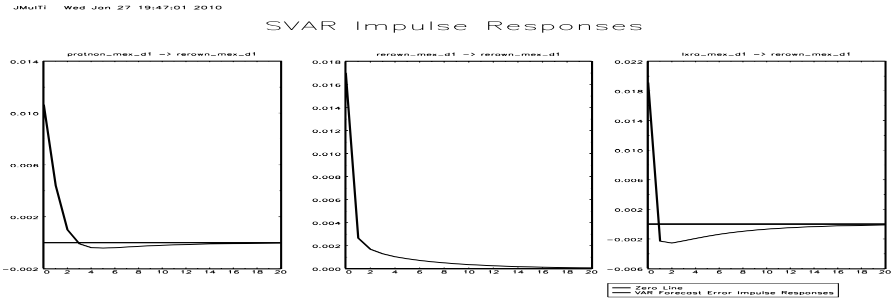

Figure A.20: Impulse-Response: MEX, VAR: s+q+y. 2nd sub-sample

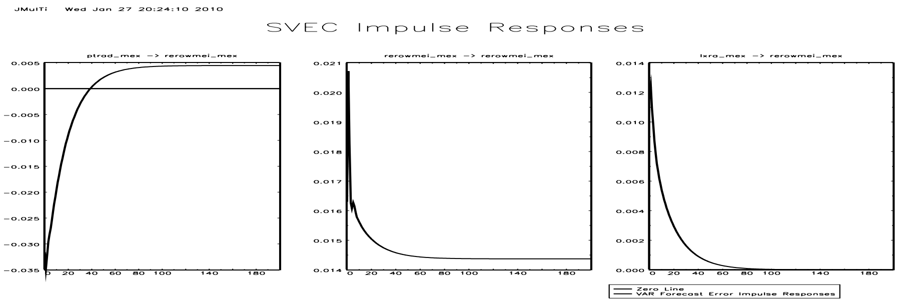

Figure A.21: MEI dataset. Impulse-Response: MEX, VECM: s+q+z. Complete sample

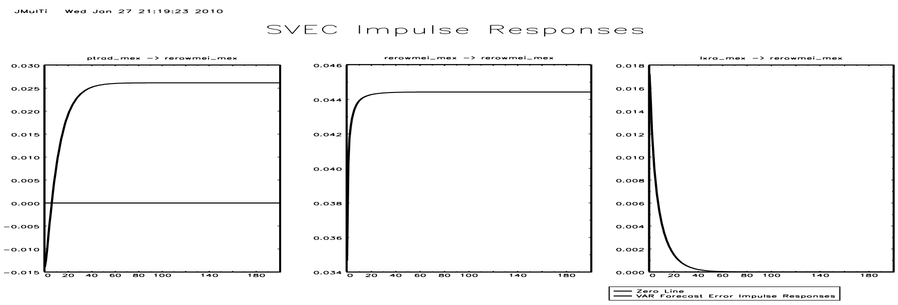

Figure A.22: MEI dataset. Impulse-Response: MEX, VECM: s+q+z. 1st sub-sample

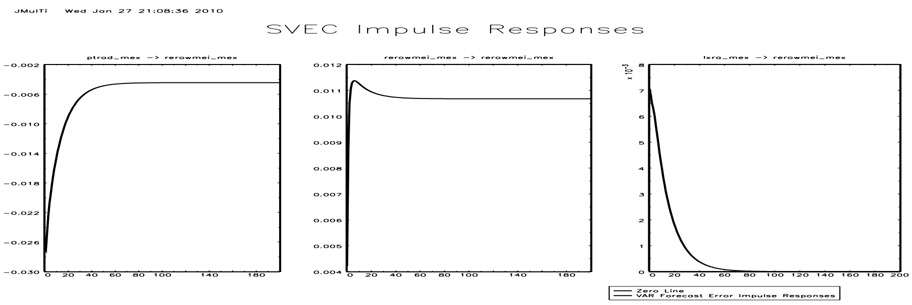

Figure A.23: MEI dataset. Impulse-Response: MEX, VECM: s+q+z. 2nd sub-sample

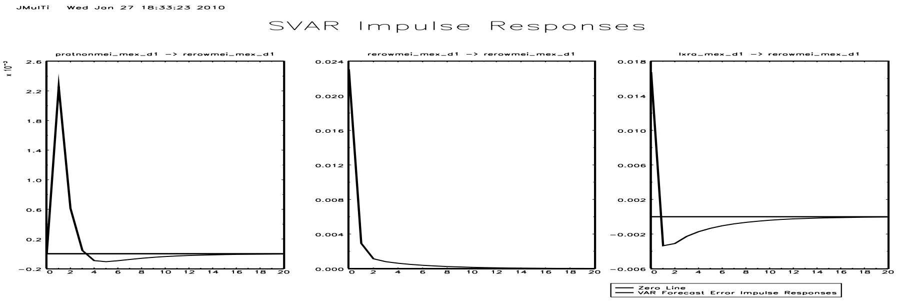

Figure A.24: MEI dataset. Impulse-Response: MEX, VECM: s+q+y. Complete sample

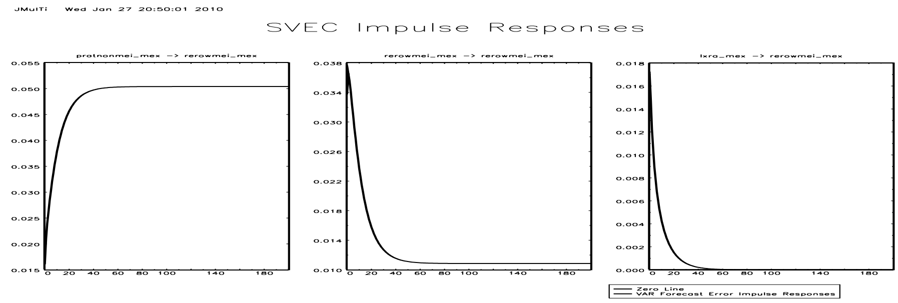

Figure A.25: MEI dataset. Impulse-Response: MEX, VECM: s+q+y. 1st sub-sample

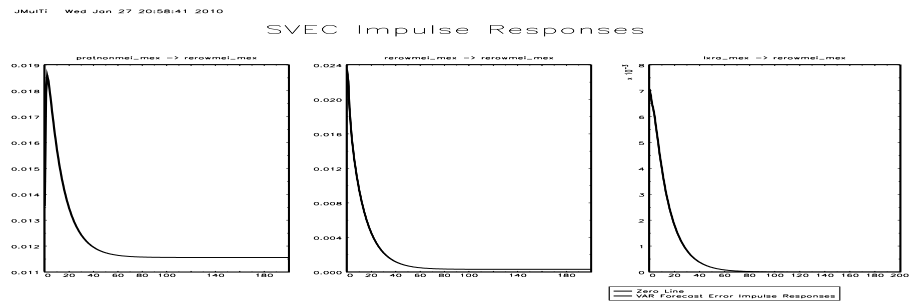

Figure A.26: MEI dataset. Impulse-Response: MEX, VECM: s+q+y. 2nd sub-sample

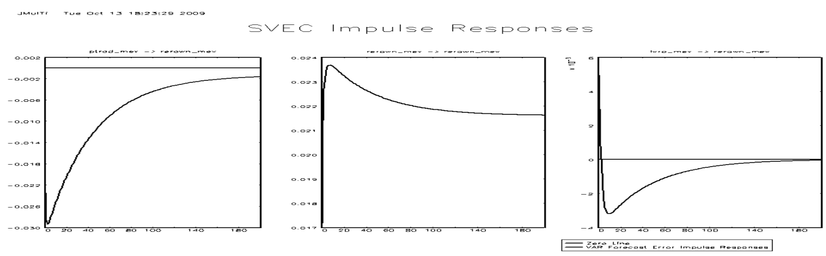

Figure A.27: IFS dataset. Impulse-Response: MEX, VECM: s+q+z. Complete sample

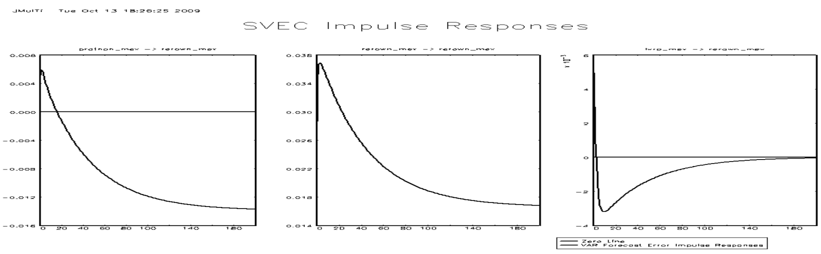

Figure A.28: IFS dataset. Impulse-Response: MEX, VECM: s+q+y. Complete sample

Appendix B

Appendix of Chapter 4

B.1 Extra Regressions

Table B.1: Results for Panel Data with Interaction terms

	Dependent variable: RER volatility		
Variable	(1)	(2)	(1)+interaction
Remote	1.19**	1.28**	1.32**
	(0.53)	(0.51)	(0.55)
Area	0.07***	0.09***	0.07***
	(0.01)	(0.02)	0.02
Inf	0.25***	0.25***	0.40
	(0.04)	(0.05)	(0.40)
GDP pc	-0.21***	-0.21***	-0.18*
	(0.05)	(0.05)	(0.10)
Pop_den		0.05*	
		(0.03)	
*Inf*GDP pc*			-0.02
			(0.05)
Dum. Decade	-0.15*	-0.16*	-0.17*
	(0.09)	(0.09)	(0.09)
Constant	-4.27***	-4.90***	-4.80***
	(1.21)	(1.18)	(1.66)
Observations	135	135	135
R^2	0.63	0.64	0.64
RMSE	0.47	0.47	0.47

Notes: *,**,*** denote significance at the 10%, 5%, and 1% level, respectively. Standard Errors in parentheses.

Table B.2: Interaction terms Results for Panel Data

	Dependent variable: RER volatility	
Variable	(1)	(2)
Remote	1.37**	1.52***
	(0.53)	(0.55)
Open	-0.37***	-0.35***
	(0.08)	(0.09)
Inf	0.24***	0.42
	(0.04)	(0.36)
GDP pc	-0.20***	0.16*
	(0.05)	(0.09)
*Infl*GDP pc*		-0.02
		(0.04)
Dum. Decade	-0.14*	-0.16*
	(0.08)	(0.09)
Constant	-2.37*	-3.08
	(1.43)	(1.89)
Observations	131	131
R^2	0.64	0.65
RMSE	0.47	0.47

Notes: *,**,*** denote significance at the 10%, 5%, and 1% level, respectively. Standard Errors in parentheses.

Table B.3: Trade Variables Added - Panel

	Dependent variable: RER volatility			
Variable	GDP 1	GDP 2	Dummy 1	Dummy 2
Remote	1.32*	1.10	0.94	0.90
	(0.77)	(0.77)	(1.00)	(1.08)
Open	-0.34***		-0.38***	
	(0.11)		(0.11)	
Area		0.06***		0.07***
		(0.02)		(0.02)
Infl	0.24***	0.24***	0.24***	0.24***
	(0.04)	(0.04)	(0.04)	(0.04)
GDP pc	-0.09	-0.12		
	(0.08)	(0.08)		
Trade Policy	-0.08**	-0.07**	-0.07*	-0.07*
	(0.04)	(0.04)	(0.04)	(0.04)
Dum. Industrial			-0.25	-0.19
			(0.19)	(0.21)
Dum. Low Income			0.13	0.20
			(0.13)	(0.14)
Dum. Decade	-0.02	-0.06	-0.04	-0.07
	(0.10)	(0.10)	(0.10)	(0.10)
Constant	-2.87	-4.44***	-2.77	-5.10***
	(1.86)	(1.86)	(2.20)	(2.18)
Observations	114	116	114	116
R^2	0.65	0.64	0.66	0.64
RMSE	0.48	0.49	0.48	0.49

Notes: *,**,*** denote significance at the 10%, 5%, and 1% level, respectively. Standard Errors in parentheses.

Table B.4: Cross Section Results w/Avg. Inflation

	Dependent variable: RER volatility					
Variable	Decade 1	Decade 2	Decade 1	Decade 2	Decade 1	Decade 2
Remote	2.06***	2.17***	1.40**	1.84***	1.58***	1.67***
	(0.60)	(0.57)	(0.61)	(0.64)	(0.54)	(0.61)
Open	-0.19	-0.31***	0.04	-0.16		
	(0.13)	(0.10)	(0.18)	(0.16)		
Area			0.08**	0.04	0.07***	0.07***
			(0.03)	(0.03)	(0.02)	(0.02)
Infl	0.21***	0.19***	0.21***	0.19***	0.21***	0.20***
	(0.05)	(0.04)	(0.05)	(0.04)	(0.05)	(0.04)
GDP pc	-0.28***	-0.28***	-0.30***	-0.29	-0.29***	-0.29***
	(0.06)	(0.05)	(0.06)	(0.05)	(0.06)	(0.05)
Constant	-2.93*	-2.61*	-3.22*	-3.02**	-3.42***	-3.65**
	(1.68)	(1.51)	(1.65)	(1.51)	(1.13)	(1.45)
Observations	67	68	66	68	68	71
R^2	0.66	0.74	0.69	0.75	0.69	0.74
RMSE	0.44	0.38	0.43	0.38	0.42	0.38

Notes: *,**,*** denote significance at the 10%, 5%, and 1% level, respectively. Standard Errors in parentheses.

Table B.5: Panel Data Results w/Avg. Inflation

	Dependent variable: RER volatility		
Variable	(1)	(2)	(3)
Remote	1.06**	0.96*	1.05**
	(0.52)	(0.56)	(0.52)
Open	-0.34***	-0.29**	
	(0.09)	(0.13)	
Area		0.02	0.06***
		(0.02)	(0.02)
Infl	0.25***	0.25***	0.25***
	(0.04)	(0.04)	(0.04)
GDP pc	-0.25***	-0.25***	-0.25***
	(0.05)	(0.05)	(0.05)
Dum. Dec	-0.09	-0.09	-0.11
	(0.09)	(0.09)	(0.09)
Constant	-0.48	-0.62	-2.51**
	(1.40)	(1.39)	(1.21)
Observations	130	129	134
R^2	0.62	0.62	0.61
RMSE	0.48	0.49	0.49

Notes: *,**,*** denote significance at the 10%, 5%, and 1% level, respectively. Standard Errors in parentheses.

Table B.6: Correlation table

Variables	$GDP\ pc$	Dummy var. High inc.	Low inc.	$Infl_a$	$Infl_b$	(1)*(4)	(1)*(5)	(2)*(4)	(3)*(4)	(2)*(5)	(3)*(5)
$GDP\ pc$ (1)	1										
Dum. Industrial (2)	0.692	1									
Dum. Low Income (3)	-0.776	-0.312	1								
$Infl_a$ (4)	-0.461	-0.362	0.268	1							
$Infl_b$ (5)	-0.477	-0.385	0.300	0.928	1						
$Infl_a$*L(GDP pc)	-0.298	-0.317	0.144	0.974	0.824	1					
$Infl_b$*L(GDP pc)	-0.334	-0.355	0.175	0.810	0.977	0.833	1				
$Infl_a$*industrial	0.575	0.870	-0.262	-0.239	-0.276	-0.150	-0.223	1			
$Infl_a$*low income	-0.711	-0.244	0.812	0.531	0.493	0.368	0.315	-0.213	1		
$Infl_b$*industrial	0.448	0.725	-0.227	-0.183	-0.137	-0.114	-0.053	0.844	-0.185	1	
$Infl_b$*low income	-0.725	-0.257	0.823	0.507	0.532	0.314	0.351	-0.226	0.954	-0.187	1

Notes: Subindex a and b represents variables for our cross-section and panel data samples respectively. All series are in logs.

Appendix C

Appendix of Chapter 5

C.1 Extra specifications for High Income Countries

Despite the fact the number of observations is rather small, we estimate our baseline specifications for the subsample of high-income countries. The results, as expected, are not quite satisfactory. Only the area of a country and its population density are significant in the tables reported here. In the case of the results for the IV approach, we also find *Lrgdpch* to be significant at the 10% level. We report these regressions with the only objective to complete the set of results for the two subsamples.

To conclude this section, we just add some comments on the results of area and population density, which are the only variables with significant results in almost all the specifications. These are in line with our estimations using the complete sample and the subsample using non-industrialized countries. An extra remark that we should make is the fact that the coefficient of the proxy for income levels obtains a negative sign (non-significant result). This result is also observed in the complete sample case, but not in the subsample of developing and less developed countries.

Table C.1: Baseline Results, High Income subsample

	Dependent variable: Openness			
Variable	I	II	III	IV
Lremote	-15.23	-12.33	-0.84	1.11
	(11.58)	(11.79)	(10.88)	(10.15)
Larea	-6.95***	-5.25**	-10.52***	-8.87***
	(1.80)	(2.06)	(2.08)	(1.75)
Lpop den	-4.50*	-4.75*	-6.58**	-6.61**
	(2.43)	(2.38)	(2.69)	(2.66)
landlock	-2.55	-27.95	-5.88	-26.64
	(4.01)	(21.63)	(5.70)	(18.69)
Lcoast		-3.29		-2.73
		(2.58)		(2.17)
Lrgpdc	-1.75	0.08	-2.48	-0.67
	(3.52)	(3.60)	(3.26)	(3.37)
freetrad			4.30	3.78
			(3.19)	(2.94)
Constant	298.06**	263.79**	202.36*	175.32*
	(117.40)	(114.22)	(109.80)	(101.77)
Observations	28	28	27	27
R^2	0.54	0.57	0.70	0.72
RMSE	12.70	12.53	10.59	10.44

Notes: *,**,*** denote significance at the 10%, 5%, and 1% level, respectively. Standard Errors in parentheses.

Table C.2: Infrastructure results, High Income subsample

	Dependent variable: Openness			
Variable	I	II	III	IV
Lremote	-17.78	-14.69	-3.87	-1.94
	(11.38)	(11.22)	(9.64)	(9.75)
Larea	-6.35***	-5.02**	-10.23***	-9.06***
	(1.59)	(1.99)	(1.88)	(1.66)
Lpop den	-4.6*	-4.75*	-6.96**	-6.97**
	(2.41)	(2.31)	(2.66)	(2.62)
landlock	-1.57	-22.73	-5.46	-21.49
	(3.39)	(20.72)	(5.38)	(18.49)
Lcoast		-2.75		-2.11
		(2.53)		(2.14)
Linfr	-3.95	-1.98	-5.33*	-3.71
	(2.72)	(3.04)	(3.01)	(3.15)
freetrad			4.54	4.24
			(2.71)	(2.58)
Constant	318.89***	288.51***	231.46**	211.45**
	(105.26)	(101.34)	(96.78)	(96.02)
Observations	29	29	27	27
R^2	0.55	0.57	0.72	0.73
RMSE	12.36	12.33	10.23	10.25

Notes: *,**,*** denote significance at the 10%, 5%, and 1% level, respectively. Standard Errors in parentheses.

Table C.3: Instrumental Variables, High Income subsample

	Dependent variable: Openness					
Variable	I	II	III	IV	V	VI
Lrgdpch	-6.63	-6.33	-5.10*	-4.76*	-2.31	-2.31
	(4.17)	(4.26)	(2.66)	(2.57)	(1.87)	(1.69)
Lremote	-4.60	-4.80	-18.33*	-16.50*	-4.80	-4.84
	(8.94)	(9.12)	(9.57)	(9.50)	(6.22)	(6.13)
Larea	-9.89***	-9.53***	-6.47***	-6.38***	-7.64***	-7.64***
	(1.55)	(1.45)	(1.34)	(1.37)	(0.98)	(0.90)
Lpop den	-6.99***	-7.26***	-4.98***	-5.20**	-4.81**	-4.85**
	(2.20)	(2.30)	(2.01)	(2.08)	(2.00)	(1.93)
freetrad	4.41	3.65				
	(2.92)	(2.61)				
Constant	266.56***	268.46***	352.27***	333.62***	224.19***	224.83***
	(99.45)	(103.01)	(98.99)	(97.10)	(74.32)	(72.71)
Obs	27	27	28	28	27	27
R^2	0.67	0.67	0.52	0.52	0.64	0.64
RMSE	9.50	9.56	11.45	11.46	10.00	10.00
Hansen test	0.95	1.58	0.16	1.39	3.30	3.27
P-value	0.33	0.45	0.69	0.50	0.19	0.35
Instruments	landlock	landlock	landlock	landlock	landlock	landlock
	Linfr	Linfr	Linfr	Linfr	Linfr	Linfr
		lcoast		lcoast		lcoast
					freetrad	freetrad

Notes: *,**,*** denote significance at the 10%, 5%, and 1% level, respectively. Standard Errors in parentheses.

C.2 Extra Figures to observe differences in the impact of GDP per capita according to countries' income levels

These two graphs (figure C.1 and C.2) include the effect of *Lrgdpch* on openness considering the coefficient for this variable obtained from the estimations using the three different samples (complete sample, subsample of high income countries and the subsample of the rest of economies). In both cases, the plot in the middle is the one taken from the complete sample case; the one on top is the result of using developing and less developed countries sample, and the one at the bottom is the one we obtain using high income countries only in our estimation. The only difference between these plots is the slope of the complete sample case: If we consider our baseline model that also includes the variable $freetrad$, we obtain a negative coefficient for *Lgdpch*. If $freetrad$ is not part of the estimated model, then the slope becomes positive but very close to zero.

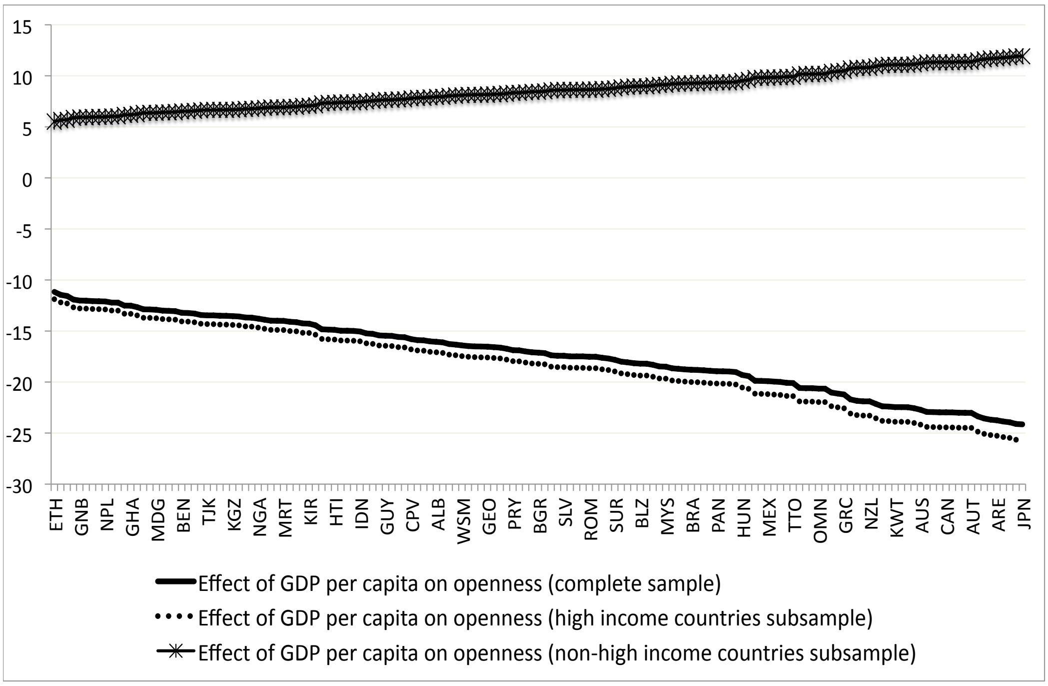

Figure C.1: Structural break between High-income countries and the rest of the Economies. Elasticities obtained from Baseline Model+$freetrad$.

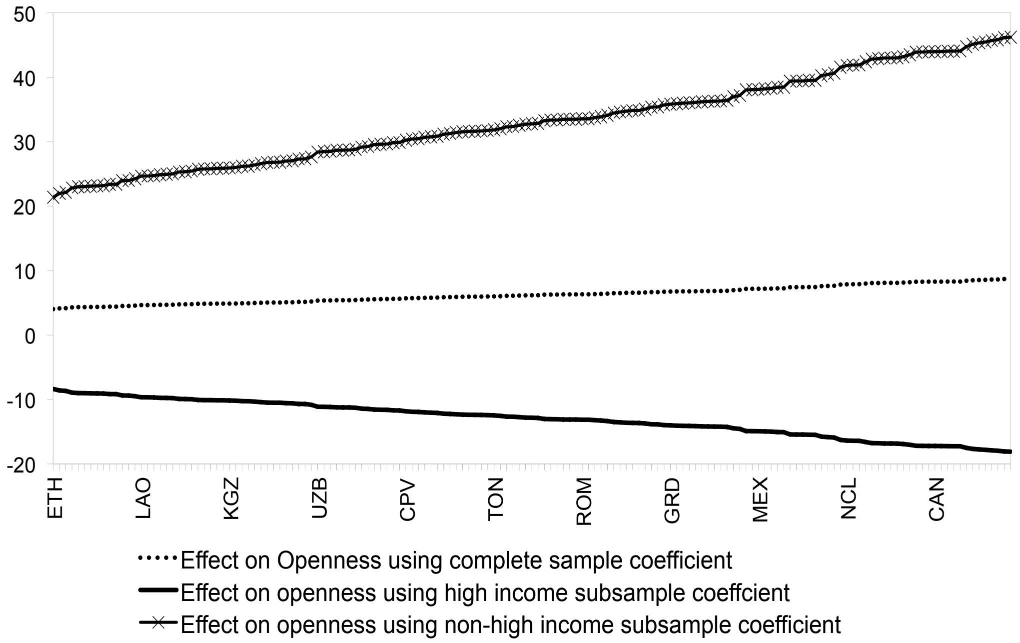

Figure C.2: Structural break between High-income countries and the rest of the Economies. Elasticities obtained from Baseline Model.

Appendix D

Appendix of Chapter 6

D.1 Government Expenditure

The idea of controlling for government spending is originated by analyzing the works of Rodrik (1996) and Alsina and Wacziarg (1998). In these, we find an explicit relationship between the size of the government and how much a country trades. However, if we take a closer look to their works, we notice that the relationship between these two variables is the inverse one: trade flows affect the size of the government. Epifani and Gancia (2009) also show that openness can increase government's size. Once more causality is on the opposite direction to what we want to explore in this section. They find that the main driver in this dynamic is terms of trade. In Epifani and Gancia's words "terms of trade considerations are a driving force behind the growth of the public sector may appear surprising at first."

Nevertheless, we try these new variable in some specifications of openness. The new series ($Government/GDP$) is the government expenditure as percentage of GDP taken from the WDI database, World Bank. Three specifications are estimated in the first one we just include the results of Fixed- and Random-effects regressions techniques (table D.1. The second one (table D.2 shows the results of a FEVD estimation controlling for government expenditure.

We have that the coefficient for government expenditure's sign is positive, which means that

Table D.1: Fixed and Random Effects including Government Expenditure

Dependent variable: Log(Openness)				
Estimation Method	FE	RE	FE	RE
ToT	2.723***	2.814***	2.989***	3.105***
se	(0.626)	(0.623)	(0.624)	(0.622)
$Time$	0.363***	0.375***	0.416***	0.417***
se	(0.029)	(0.028)	(0.026)	(0.026)
$Investment/GDP$	0.496***	0.512***	0.531***	0.545***
se	(0.039)	(0.038)	(0.038)	(0.037)
$rGDPpc$	3.584***	3.177***		
se	(0.947)	(0.732)		
$Freedom$	0.310**	0.300***	0.280**	0.313**
se	(0.141)	(0.140)	(0.141)	(0.140)
$Government/GDP$	0.099*	0.120***	0.109*	0.141**
se	(0.057)	(0.056)	(0.057)	(0.056)
Constant	-11.604	-5.966	12.697***	14.714***
se	(7.340)	(6.208)	(3.566)	(3.988)
Obs	2228	2228	2228	2228
Countries	121	121	121	121
F/Wald	105.23	660.40	122.64	636.28
Prob>F	0.00	0.00	0.00	0.00
Hausman Test				
Statistic		17.57		23.93
P-value		0.01		0.00

Notes: *,**,*** denote significance at the 10%, 5%, and 1% level, respectively. Standard Errors in parentheses.

a bigger government (in terms of how much it spends) increases the amount of trade the economy registers. In terms of which estimation technique is better to do the regressions, Hausman tests signal for the use of fixed effects as in all our previous estimations.

The FEVD results show that the impact of government is reinforced in the second stage regression of the procedure. We obtain a higher coefficient for this variable. The rest of the variables once more report similar results to what we observe in previous estimations. It is clear that government size and openness are positively related. In our last exercise in this section we find that in recent years the impact of government has been reduced as we register a negative sign in the interaction term.

D.2 Extra regressions

The results in table D.3 can be divided into two sets. The first one (first two columns) include the estimation of a model similar to the one in our baseline specification, in the case of FEVD, we have two more variables that can be part of the estimation now, *Area* and *Landlocked*. The FEVD results are the ones in the second column. If we compare the first and second columns, we observe that the coefficient of the terms of trade index and the time trend are the same ones (the only difference are the standard errors, which are below the coefficient and in parenthesis). The coefficient of the FEVD estimation is just the fixed-effects one if the variable is not included in the second stage regression.[1] The investment variable, our income proxy variable (real GDP per capita) and the trade policy one are included in both first and second stage regressions. In the case of investment and the trade policy variables we have that the magnitude of the fixed-effects estimation is reinforced by the estimation on the second stage. This is not the case for real GDP per capita. We have that the coefficient changes signs and it is not significant anymore. The explanation for the sign reversal could be the fact of including the income level variable in the second stage of the FEVD procedure. Exploring the effects of income levels on openness Guttmann and Richards (2006) find a negative relation; in our case it is probable that the effects of the cross-section estimation are more relevant than the ones from a panel estimation.

[1] We are referring to the regression of individual-effects on time invariant and almost time-invariant variables as the second stage regression. Please see the content of the chapter for more details.

Table D.2: FEVD estimation with Government Expenditure through time

Dependent variable: Log(Openness)			
Estimation Method	FE	FEVD	FEVD
ToT	2.813***	2.813***	3.067***
se	(0.626)	(0.418)	(0.410)
$Time$	0.523***	0.523***	1.134***
se	(0.053)	(0.022)	(0.057)
$Investment/GDP$	0.497***	0.832***	0.803***
se	(0.039)	(0.021)	(0.021)
$rGDPpc$	2.094**	-1.877***	-1.487***
se	(1.036)	(0.146)	(0.146)
$Pop.\_density$	-7.909***	-6.016***	-5.991***
se	(2.169)	(0.142)	(0.139)
$Remote$	-0.009	-6.241***	-6.296***
se	(2.626)	(0.585)	(0.574)
$Freedom$	0.370***	1.360***	1.062***
se	(0.143)	(0.101)	(0.101)
$Area$		-8.307***	-8.256***
se		(0.093)	(0.091)
$Landlocked$		-6.723***	-6.322***
se		(0.422)	(0.415)
$Government/GDP$	0.074	0.432***	1.254***
se	(0.057)	(0.031)	(0.082)
$(Government/GDP) * Time$			-0.036***
se			(0.003)
Unexplained Fixed-effects		1.000***	1.000***
se		(0.011)	(0.011)
Constant	26.540	189.208***	172.885***
se	(26.664)	(6.359)	(6.386)
Obs	2228	2228	2228
Groups	121		
F/Wald	81.02		1816.87
Prob>F	0.00		0.00
R^2		0.909	0.910
Adjusted R^2		0.903	0.910
RMSE		6.322	6.19

Notes: *,**,*** denote significance at the 10%, 5%, and 1% level, respectively. Standard Errors in parentheses.

Table D.3: Fixed-Effects Vector Decomposition

Dependent variable: Openness				
	FE	FEVD	FE	FEVD
	I	II	III	IV
ToT	2.605***	2.605***	2.850***	2.850***
	(0.615)	(0.406)	(0.614)	(0.406)
Time	0.359***	0.359***	0.411***	0.411***
	(0.029)	(0.021)	(0.026)	(0.021)
Investment/GDP	0.494***	0.836***	0.529****	0.841***
	(0.039)	(0.021)	(0.038)	(0.021)
rGDPpc	3.609***	-0.085		
	(0.947)	(0.136)		
Freedom	0.310**	1.351***	0.279**	1.232***
	(0.141)	(0.100)	(0.141)	(0.073)
Area		-5.991***		-5.983***
		(0.073)		(0.073)
Landlocked		-1.297***		-1.289***
		(0.406)		(0.379)
Unexplained Fixed-effects		1.000***		1.000***
		(0.010)		(0.010)
Constant	-9.575	79.775***	15.192***	77.268***
	(7.248)	(2.390)	(3.221)	(2.294)
Obs	2231	2231	2231	2231
Groups	121		121	
F/Wald	126.39	2593.323	153.37	
Prob>F	0.00	0.00	0.00	
R^2		0.908		0.907
Adjusted R^2		0.902		0.902
RMSE		6.353		6.375

Notes: *,**,*** denote significance at the 10%, 5%, and 1% level, respectively. Standard Errors in parentheses.

Area and the landlocked dummy variable are now part of the set of results and both obtain the expected sign, negative one. *Area* is the variable with the greatest impact, in absolute value, in all our results. In the second set of regressions(last two columns) we remove real GDP per capita and the results remain very similar to the ones where this variable is part of the regressors. If we compare this table with our very first estimation of the model in table 6.1, we observe only one notable difference and that is once more the results for our income proxy variable; in our baseline model we get a positive and very significant coefficient, while in the most recent exercise we have a negative and not significant one.

Appendix E

Appendix of Chapter 7

E.1 Standard deviation comparison tables

Table E.1: Comparing AR(1), ARMA(2,1) and observed data Std. Dev. I

	Volatility measures taken from series in Levels		
Type of Data	Observed	Estimated Parameters	
		AR(1)	ARMA(2,1)
	I	II	III
Algeria (DZA)	95.831	89.334	79.732
" (1991.02-2007.12)	15.722	15.540	13.444
Antigua and Barbuda (ATG)	7.918	8.608	9.556
Armenia (ARM)	20.623	26.976	14.974
Australia (AUS)	15.219	14.877	11.724
Austria (AUT)	6.225	6.194	5.063
The Bahamas (BHS)	4.957	6.662	4.849
Bahrain (BHR)	29.393	31.931	-
Belgium (BEL)	6.452	8.238	7.086
Belize (BLZ)	8.300	10.848	7.463
Bolivia (BOL)	101.533	101.190	506.661
" (1985.12-2007.12)	11.688	11.437	2.028
Bulgaria (BGR)	24.299	44.135	36.292
Burundi (BDI)	32.931	32.999	46.622
Cameroon (CMR)	22.253	21.294	22.573
Canada (CAN)	13.209	13.535	11.157
Central African Republic (CAF)	24.598	24.493	21.126
Chile (CHL)	27.358	27.484	25.392
" (1985.07-2007.12)	8.585	8.239	6.625
China (CHN)	61.370	118.775	-
Colombia (COL)	27.380	27.701	28.541
Congo Dem. Rep. of (ZAR)	65.213	70.000	345.719
Costa Rica (CRI)	12.069	14.609	-
Cote d'Ivoire (CIV)	19.252	19.478	23.577
Croatia (HRV)	11.084	22.364	17.966
Cyprus (CYP)	6.773	10.078	8.253
Czech (CZE))	21.885	35.608	-
Denmark (DNK)	6.459	6.549	5.274
Dominica (DMA)	7.003	8.364	6.698
Dominican Republic (DOM)	18.553	20.642	16.427
Ecuador (ECU)	48.179	49.725	34.432
Equatorial Guinea (GNQ)	21.844	23.849	-
Fiji (FJI)	23.195	22.952	25.712
Finland (FIN)	11.408	10.363	9.053
France (FRA)	4.813	5.590	3.235

Table E.2: Comparing AR(1), ARMA(2,1) and observed data Std. Dev. II

	Volatility measures taken from series in Levels		
Type of Data	Observed	Estimated Parameters	
		AR(1)	ARMA(2,1)
	I	II	III
Gabon (GAB)	47.648	57.721	59.152
The Gambia (GMB)	29.005	31.669	21.972
Germany (DEU)	6.288	8.222	9.164
Ghana (GHA)	905.407	874.062	677.174
" (1994.01-2007.12)	20.730	18.140	12.515
Greece (GRC)	9.827	10.669	9.593
Grenada (GRD)	6.821	9.664	7.156
Guyana (GUY)	231.609	220.218	179.323
" (1989.04-2007.12)	7.977	7.878	7.660
Hungary (HUN)	20.795	34.074	-
Iceland (ISL)	15.906	18.643	16.058
" (1983.01-2007.12)	7.569	8.203	5.738
Iran (IRN)	243.909	232.877	-
" (1992.04-2007.12)	22.078	25.255	18.709
Ireland (IRL)	7.987	13.467	5.320
Israel (ISR)	7.844	8.182	21.336
Italy (ITA)	8.641	8.421	6.666
Japan (JPN)	14.882	17.234	13.080
Lesotho (LSO)	16.278	15.451	18.499
Luxembourg (LUX)	5.112	5.313	-
Macedonia (MKD)	17.675	25.785	22.644
" (1993.06-2007.12)	11.613	11.080	10.145
Malawi (MWI)	31.419	35.157	24.356
Malaysia (MYS)	25.133	26.726	23.075
Malta (MLT)	8.572	8.851	6.615
Moldova (MDA)	10.913	11.923	8.564
Morocco (MAR)	9.226	20.097	14.963
Netherlands (NLD)	8.963	8.526	13.179
Netherlands Antilles (ANT)	19.179	19.650	19.379
New Zealand (NZL)	12.043	12.719	9.276
Nicaragua (NIC)	800575	794541	-
" (1988.01-2007.12)	32.370	32.307	27.418
" (1991.03-2007.12)	10.487	10.392	7.681
Nigeria (NGA)	200.670	181.218	-
" (1986.10-2007.12)	31.028	29.630	27.407
Norway (NOR)	4.017	4.283	3.695
Pakistan (PAK)	37.236	44.135	32.917
Papa New Guinea (PNG)	22.215	23.959	18.990
Paraguay (PRY)	32.718	37.735	32.441
Philippines (PHL)	18.089	18.592	15.342
Poland (POL)	350.154	324.636	283.798
" (1988.01-2007.12)	22.105	31.163	21.252

Table E.3: Comparing AR(1), ARMA(2,1) and observed data Std. Dev. III

Type of Data	Volatility measures taken from series in Levels		
	Observed	Estimated Parameters	
		AR(1)	ARMA(2,1)
	I	II	III
Portugal (PRT)	11.645	15.555	12.168
Romania (ROM)	34.061	32.520	-
Russia (RUS)	25.568	29.398	21.969
Samoa (WSM)	14.344	13.898	19.116
Saudi Arabia (SAU)	39.698	69.112	50.144
Sierra Leone (SLE)	72.627	71.074	-
” (1987.06-2007.12)	21.586	21.434	-
Singapore (SGP)	7.396	6.495	-
Slovak Republic (SVK)	23.978	41.208	-
Solomon Islands (SLB)	16.590	17.326	23.519
South Africa (ZAF)	25.220	25.246	21.969
Spain (ESP)	9.029	9.543	7.299
St. Kitts and Nevis (KNA)	5.572	5.166	4.604
St. Lucia (LCA)	5.217	5.637	-
St. Vincent and Grenadines (VCT)	5.070	5.408	-
Sweden (SWE)	11.670	12.563	10.092
Switzerland (CHE)	6.895	6.641	5.481
Togo (TGO)	24.141	27.016	37.206
Trinidad and Tobago (TGO)	18.117	16.757	13.122
Tunisia (TUN)	18.858	27.323	22.262
Uganda (UGA)	281.053	312.419	1051.834
” (1990.07-2007.12)	15.928	17.363	13.549
Ukraine (UKR)	23.945	35.334	22.371
United Kingdom (GBR)	9.229	9.384	7.421
United States (USA)	9.133	9.409	7.453
Uruguay (URY)	16.602	15.763	14.227
Venezuela (VEN)	21.448	20.343	16.261
Zambia (ZMB)	28.349	28.931	-
Turkey (TUR)	20.795	24.468	18.772
Argentina (ARG)	54.667	59.872	35.016
(1991.01-2001.12)	12.585	18.340	22.707
Brasil (BRA))	22.365	21.881	16.934
Mexico (MEX)	27.412	26.145	-
India (IND)	23.834	24.264	22.184
Azerbaijan (AZE)	6.026	8.392	7.038
Belarus (BLR)	20.158	21.751	12.179
Estonia (EST)	16.981	34.938	24.731
Georgia (GEO)	4.787	4.772	4.343
Hong Kong (HKG)	9.820	12.064	-
Latvia (LVA)	6.913	13.701	8.727
Lithuania (LTU)	17.976	19.703	15.061
Peru (PER)	6.481	7.627	7.178

Table E.4: Comparing AR(1), ARMA(2,1) and observed data Std. Dev. IV

Type of Data	Volatility measures, series in 1st. Differences		
	Observed	Estimated Parameters	
		AR(1)	ARMA(2,1)
	I	II	III
Algeria (DZA)	5.305	5.321	5.223
" (1991.02-2007.12)	3.753	3.745	3.676
Antigua and Barbuda (ATG)	1.673	1.672	1.772
Armenia (ARM)	4.230	4.246	3.996
Australia (AUS)	2.576	2.573	2.543
Austria (AUT)	0.677	0.677	0.739
The Bahamas (BHS)	0.874	0.873	0.887
Bahrain (BHR)	2.248	2.254	-
Belgium (BEL)	0.922	0.922	1.009
Belize (BLZ)	1.446	1.445	1.368
Bolivia (BOL)	85.683	85.478	102.805
" (1985.12-2007.12)	2.059	2.056	2.805
Bulgaria (BGR)	3.615	3.650	3.590
Burundi (BDI)	4.225	4.210	5.176
Cameroon (CMR)	4.176	4.154	4.446
Canada (CAN)	1.665	1.687	1.648
Central African Republic (CAF)	4.465	4.449	5.000
Chile (CHL)	3.200	3.198	3.483
" (1985.07-2007.12)	1.761	1.757	1.750
China (CHN)	2.992	3.046	-
Colombia (COL)	2.947	2.945	3.059
Congo Dem. Rep. of (ZAR)	24.188	24.218	34.410
Costa Rica (CRI)	3.879	3.887	-
Cote d'Ivoire (CIV)	4.340	4.323	4.687
Croatia (HRV)	2.123	2.137	2.103
Cyprus (CYP)	0.945	0.944	1.014
Czech (CZE)	1.851	1.880	-
Denmark (DNK)	0.831	0.831	0.833
Dominica (DMA)	1.518	1.518	1.674
Dominican Republic (DOM)	3.332	3.331	3.678
Ecuador (ECU)	7.709	7.705	9.508
Equatorial Guinea (GNQ)	6.328	6.326	-
Fiji (FJI)	2.299	2.294	2.443
Finland (FIN)	1.479	1.476	1.441
France (FRA)	0.925	0.924	1.229

Table E.5: Comparing AR(1), ARMA(2,1) and observed data Std. Dev. V

Type of Data	Volatility measures, series in 1st Differences		
	Observed	Artificial	
		AR(1)	ARMA(2,1)
	I	II	III
Gabon (GAB)	4.799	4.809	4.796
The Gambia (GMB)	4.531	4.533	5.177
Germany (DEU)	1.223	1.223	2.076
Ghana (GHA)	234.777	234.275	249.423
" (1994.01-2007.12)	3.198	3.185	2.836
Greece (GRC)	1.490	1.486	1.493
Grenada (GRD)	1.261	1.261	1.368
Guyana (GUY)	21.700	21.695	23.836
" (1989.04-2007.12)	4.281	4.268	4.294
Hungary (HUN)	1.758	1.769	-
Iceland (ISL)	3.458	3.459	3.603
" (1983.01-2007.12)	2.045	2.046	2.575
Iran (IRN)	50.367	50.268	-
" (1992.04-2007.12)	3.125	3.131	3.692
Ireland (IRL)	1.325	1.332	1.305
Israel (ISR)	2.127	2.126	2.753
Italy (ITA)	1.333	1.331	1.462
Japan (JPN)	2.024	2.019	2.064
Lesotho (LSO)	3.107	3.120	3.110
Luxembourg (LUX)	0.709	0.708	-
Macedonia (MKD)	12.102	12.338	12.602
" (1993.06-2007.12)	2.405	2.398	2.387
Malawi (MWI)	5.476	5.454	5.754
Malaysia (MYS)	2.042	2.046	2.069
Malta (MLT)	1.138	1.136	1.326
Moldova (MDA)	3.974	3.976	4.194
Morocco (MAR)	1.106	1.108	1.320
Netherlands (NLD)	2.000	1.993	2.296
Netherlands Antilles (ANT)	3.168	3.161	3.384
New Zealand (NZL)	2.506	2.505	3.046
Nicaragua (NIC)	473959	472855	-
" (1988.01-2007.12)	19.824	19.783	24.613
" (1991.03-2007.12)	2.405	2.399	2.435
Nigeria (NGA)	19.000	18.928	-
" (1986.10-2007.12)	10.042	9.976	11.805
Norway (NOR)	1.276	1.276	1.274
Pakistan (PAK)	2.390	2.402	2.287
Papa New Guinea (PNG)	2.709	2.705	2.969
Paraguay (PRY)	5.402	5.383	5.995
Philippines (PHL)	3.250	3.247	3.405
Poland (POL)	31.716	31.656	32.840
" (1988.01-2007.12)	2.662	2.673	2.657

Table E.6: Comparing AR(1), ARMA(2,1) and observed data Std. Dev. VI

Type of Data	Volatility measures, series in 1st Differences		
	Observed	Artificial	
		AR(1)	ARMA(2,1)
	I	II	III
Portugal (PRT)	0.928	0.931	0.941
Romania (ROM)	6.949	6.935	-
Russia (RUS)	5.014	5.021	5.084
Samoa (WSM)	2.545	2.531	2.820
Saudi Arabia (SAU)	2.491	2.516	3.101
Sierra Leone (SLE)	20.961	20.798	-
" (1987.06-2007.12)	8.169	8.085	-
Singapore (SGP)	0.912	0.908	-
Slovak Republic (SVK)	1.782	1.816	-
Solomon Islands (SLB)	2.621	2.613	3.151
South Africa (ZAF)	3.791	3.788	3.721
Spain (ESP)	1.118	1.117	1.093
St. Kitts and Nevis (KNA)	0.961	0.959	0.945
St. Lucia (LCA)	1.272	1.272	-
St. Vincent and the Grenadines (VCT)	1.329	1.327	-
Sweden (SWE)	1.744	1.744	1.688
Switzerland (CHE)	1.317	1.314	1.406
Togo (TGO)	3.893	3.876	4.223
Trinidad and Tobago (TTO)	2.732	2.726	2.811
Tunisia (TUN)	1.427	1.436	1.450
Uganda (UGA)	102.747	102.800	132.942
" (1990.07-2007.12)	2.722	2.718	3.061
Ukraine (UKR)	9.022	9.056	11.612
United Kingdom (GBR)	1.453	1.451	1.455
United States (USA)	1.448	1.446	1.397
Uruguay (URY)	3.539	3.523	4.050
Venezuela (VEN)	3.557	3.532	3.946
Zambia (ZMB)	9.647	9.640	-
Turkey (TUR)	4.687	4.686	4.545
Argentina (ARG)	6.580	6.583	6.374
(1991.01-2001.12)	3.278	3.295	3.275
Brasil (BRA)	4.719	4.710	4.623
Mexico (MEX)	5.653	5.641	-
India (IND)	2.273	2.273	2.250
Azerbaijan (AZE)	1.511	1.589	1.671
Belarus (BLR)	5.147	5.148	4.449
Estonia (EST)	1.461	1.505	1.396
Georgia (GEO)	2.152	2.145	2.134
Hong Kong (HKG)	0.960	0.965	-
Latvia (LVA)	0.862	0.884	0.804
Lithuania (LTU)	1.635	1.647	1.771
Peru (PER)	1.120	1.123	1.208

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