Three Essays on Heterogeneity in Macroeconomics

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Abstract

This doctoral thesis emphasizes the role of *Heterogeneity* in modern Macroeconomics. First, it provides a new determinant to heterogeneity in firms' price setting, namely the degree of returns to scale. It provides theoretical and empirical evidence that price rigidity and returns to scale are positively associated. Heterogeneity in price rigidity and returns to scale are then linked. Further, this thesis introduces both dimensions of heterogeneity into an otherwise standard Keynesian model and simulate the real effects of monetary policy shock on output. This thesis also provides evidence that the amplification initially implied by heterogeneity in price rigidity is mitigated when heterogeneity in returns to scale is added. Finally, this thesis explores the heterogeneous effects of macroprudential policy on bank profitability across different income levels. There is evidence that a tightening of macroprudential policy tends to decrease bank profitability in countries where the financial sector is less developed, which is the case for emerging countries.

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Contents

List of Tables

List of Figures

Chapter 1

Introduction

Macroeconomics is the field of Economics that deals with the behavior of economic aggregates, such as Gross Domestic Product, Consumption, Inflation, Unemployment, or Public deficits. Until the 1970s, the Keynesian model was the workhorse of macroeconomics. In that economic theory, aggregate demand, that could be influenced by monetary and fiscal policies, played a crucial role in explaining economic fluctuations. For example, in the case where the demand falls, policymakers could stimulate the aggregate demand thanks to monetary or fiscal expansion, that could increase output but also prices. Therefore, policymakers were only facing the inflation-unemployment trade-off when setting their policies. However, two elements actively challenged that paradigm. On the one hand, the 1970s stagflation episodes that saw many countries experienced high levels of unemployment and inflation. On the other hand, the Lucas critique (Lucas (1976)) argues that the optimal reactions of individuals are likely to vary with any change in the structure of the economy. Thus, these two elements highlight the essential role of real shocks and microeconomic foundations in our understanding of the macroeconomy. Since then, Macroeconomics has treated economic aggregates as the sum of outcomes of many individuals and agents that form their decisions rationally (Plosser (1989)). This approach gave birth to the Real Business Cycle Models (that explains economic fluctuations thanks to real technology and productions shocks) and the New Keynesian Models (characterized by imperfect competition and nominal rigidities). Until relatively recently, most of these models were based on the representative-agent assumption that suggests that agents are identical. While this assumption allows models to be straightforward, it omits heterogeneity among different agents, which has proved to be essential in our understanding of recent economic events such as the Great Financial Crisis (GFC).

What is *heterogeneity*? In Economics, heterogeneity refers to the aspects according to which economic agents differ from each other. Agents can differ in some intrinsic characteristics or the ways they respond to some given shocks. For examples, the concept of heterogeneity captures the differences in terms of income or wealth held by individuals or households, the differences in terms of productivity and difference in terms of shocks individuals are facing. Economists have primarily modeled heterogeneity according to two broad methods. On the one hand, heterogeneity has been mainly studied through a normative way. One particular example is the heterogeneity in household income or wealth, commonly labeled as inequality. This topic is highlighted in numerous studies on income or wealth inequality and the distributional impact of public policies such as tax or insurance reforms. The issue of inequality is still debated extensively (Piketty, 2016). On the other hand, for the last decade, Heterogeneity has proved to be essential for the positive analysis of macroeconomics shocks (Ragot (2018)). Indeed, recent heterogenous agents based models tend to deliver different outcomes compared to a representative agent model. The reasons behind this is that, not only different agents tend to respond differently to shocks but they also develop interactions that make a mere aggregation not sufficient to capture the overall effect. The latest example of this new approach is the development of the Heterogeneous Agent New Keneysian (HANK) model (Kaplan et al. (2018)).

As foreseen, there are numerous possible aspects of heterogeneity. However, the recent positive approach to heterogeneity in Macroeconomics emphasizes two types of heterogeneity, namely the heterogeneity in household financial constraint and heterogeneity in firms price setting. On the one hand, heterogeneity in the households' participation in financial market gains momentum following the Great Financial Crisis (GFC). Indeed, the GFC has highlighted the importance of heterogeneity, especially the difference between borrowers and savers and its implication for the macroeconomy. Bernanke et al. (1999) and Kiyotaki and Moore (1997) pioneered this line of research, followed by Iacoviello (2005) and more recently Kaplan et al. (2018), among numerous others. On the other hand, heterogeneity in price setting behaviour of firms also happens to be crucial for the overall economy. For example, a crucial question in Macroeconomics is the issue of monetary non-neutrality, namely the fact that a nominal monetary shock has real effects on both output and inflation. The standard New Keynesian model (that assumes nominal price rigidity and homogeneous agents) manages to produce some monetary non-neutrality but fails to replicate the amplitude of the effects of monetary policy on real output (Golosov and Lucas (2007)). Several economists then introduce heterogeneity in price setting behaviour of firms in an attempt to deliver more substantial and more persistent effects of monetary shock (Carvalho (2006), Nakamura and Steinsson (2010), Dixon and Kara (2011)). This thesis primarily deals with the issue of heterogeneity in price setting behaviour of firms.

Heterogeneity in Macroeconomics is the central theme of this thesis that includes three self-contained chapters. The second chapter deals with heterogeneity in price setting across sectors. This chapter takes the approach of examining the determinants of heterogeneity in price setting behaviour across sectors and proposes the degree of returns to scale as a critical determinant. Heterogeneity in price stickiness and heterogeneity in returns to scale are therefore related. Following this second chapter, the closely related third chapter explores if the amplification effects implied by the heterogeneity in price rigidity still holds when accounting for heterogeneity in returns to scale simultaneously. There is evidence that the introduction of the second dimension of heterogeneity tends to dampen the initial amplification effects. The third chapter that is more empirical explores the effects of macroprudential policies on bank profitability. Chapter 4 provides evidence of heterogeneous effects of macroprudential policy on bank profitability, depending on the country's income level. In what follows, I summarise the three chapters concisely.

Chapter 2 proposes a new key determinant to the sectoral heterogeneity in price rigidity across sectors. Indeed, previous research on price-setting has shown that the degree of nominal price rigidity differs substantially across sectors[1], i.e., firms in some sectors adjust their prices more or less often than firms in other sectors. This chapter proposes returns to scale as a key determinant of this sectoral heterogeneity in price rigidity. The following two observations motivate the investigation on returns to scale as a possible determinant of sectoral heterogeneity in price rigidity. First, previous economic theory suggests that in the presence of menu costs (menu-cost refers to the generic costs that a firm must incur in order to change its price), returns to scale affect the degree of price rigidity. Burstein and Hellwig (2007) show that decreasing returns to scale make a firm's profit function more concave, and is then expected to affect its

[1]Sectoral heterogeneity in price stickiness is an established result, both for consumer and producer prices. See, for example, Carlton (1986), Bils and Klenow (2004), Klenow and Kryvtsov (2008), Nakamura and Steinsson (2008), Klenow and Malin (2011), and Vermeulen et al. (2012).

incentive to adjust its price and thus the frequency of price changes. Second, previous empirical evidence indicates that returns to scale are different across sectors. For example, Burnside (1996) highlights that for the US manufacturing sector, the equality in returns to scale across its 20 sub-sectors is strongly rejected[2].The above two observations, taken together, suggest that with menu costs present sectoral heterogeneity in returns to scale may contribute to heterogeneity in price rigidity. Chapter 2 proposes theoretical, numerical and empirical evidence of the relationship between returns to scale and price rigidity. Theoretically, this chapter develops a multi-sector menu-cost model with heterogeneity in returns to scale and idiosyncratic sectoral shocks and show that a sector with higher returns to scale is associated with larger price rigidity. The existence of a menu cost makes it suboptimal for a firm to change its price at any single time. Then, the firm's optimal pricing decision consists of a threshold in term of price misalignment (the difference between the firm's current price and its optimal price in the absence of menu cost). Whenever the price misalignment hits that threshold, it triggers a price change. The key element in this theoretical model is to show that this threshold is an increasing function of the firm returns to scale. Thus a firm with higher returns to scale has a larger threshold in term of price misalignment (i.e., displays a larger tolerance to price misalignment), and therefore adjust its price less often. Following the theoretical model, numerical experiments using US manufacturing data suggest that the effect of returns to scale is quantitatively large. I also provide empirical evidence consistent with the theoretical prediction. The empirical section provides evidence of a positive and significant association between returns to scale and price rigidity, and that positive association remains significant even after controlling for other determinants of heterogeneity in price rigidity.

After highlighting the relationship between price rigidity and returns to scale in Chapter 2, Chapter 3 tests if the amplification effect suggested by the presence of heterogeneity in price rigidity is robust when considering returns to scale as an additional dimension of heterogeneity. Indeed, previous research indicates that sectoral heterogeneity in nominal price rigidities increases the size and persistence of the real effects of monetary shocks (Carvalho (2006), Nakamura and Steinsson (2010), Dixon and Kara (2011)). This chapter provides theoretical foundations that this finding is sensitive to the consideration of the *multi-dimensionality*

[2] Also, Basu and Fernald (1997), based on 34 US industries for the 1959-89 period, show that within manufacturing, durables show higher returns to scale than non-durables. In the Japanese context, Beason and Weinstein (1996) and Diewert et al. (2011) also find the heterogeneity in returns to scale across sectors.

of sectoral heterogeneity. This chapter proceeds in two steps. First, I examine the implication of introducing only heterogeneity in returns to scale in an otherwise standard New Keynesian model. I found evidence that heterogeneity in returns to scale, when considered alone, dampens monetary non-neutrality thanks to a lower degree of aggregate strategic complementarities. Strategic complementarities refer to how sensitive the reset price[3] is to the aggregate price index. Thus, a lower level of strategic complementaries entails that firms set their new price away from the aggregate price, and that generates faster price level dynamics and a lower real effect on output. Second, chapter 3 associates the heterogeneity in returns to scale to the established heterogeneity in price rigidity in a NK model. Thus, after highlighting returns to scale as an additional dimension of sectoral heterogeneity, I show that the amplification effect attributed to heterogeneity in price rigidities is likely to be weakened. That happens through two primary channels. On the one hand, heterogeneity in returns to scale, when considered solely, as a dampening effect on monetary non-neutrality by rendering the Phillips curse steeper, thanks to a lower level of aggregate strategic complementarity. On the other hand, the weakening effect may also come from the interaction between those two dimensions. Indeed as the amplification effect of heterogeneity in price rigidities is mainly driven by the sectors with high nominal price rigidity, the positive correlation between price rigidities and returns to scale is likely to dampen the contribution of these sectors. Indeed the sectors with the high price rigidity tend to be the one with high returns to scale and therefore with lower strategic complementarities. The interaction between these two dimensions of heterogeneity matters through the slope of the Phillips curve. The quantitative importance of these interactions is examined using sub-sectoral data in the US manufacturing sector and simulating the impulse response function of the real output following interest rate shocks.

Chapter 4 aims to investigate the effects of macroprudential policies on the banking sector profitability. Since the Great Financial Crisis (GFC), many countries have put a significant emphasis on macroprudential policies in an attempt to enhance financial stability. Thus, more and more countries, both advanced and emerging, have been implementing various instruments of macroprudential policies such as capital requirements, reserve requirements, and loan-to-value ratios to promote financial stability (Cerutti, Correa, Fiorentino and Segalla (2017)). In line with many authors (Freixas and Rochet (2008), Admati and Hellwig (2014)), this chapter con-

[3]the new price set by the firms that change their price

siders prolonged low bank profitability as a threat to financial stability. Indeed low profitability banks are not able to generate capital - either by attracting capital or thanks to retained earnings - and to build up reserves against unexpected losses. Thus, Chapter 4 aims to provide evidence of the effect of change in macroprudential policies on bank profitability, measured by the return-on-assets and the return-on-equity. To do so, I use quarterly data for both bank and macroprudential policy changes variables for 24 countries over the period going from 2005 to 2014. Moreover, the database on macroprudential policies change allows distinguishing between a tightening and a loosening of a country's macroprudential framework. The results and contributions of this chapter are twofold. First, it provides evidence of a negative and significant impact of a tightening of macroprudential policies on bank profitability. The results suggest that a one-point increase in the macroprudential policy index leads to a decrease in return-on-assets (resp. return-on-equity) by an average of 2.75 percentage points (resp.22.6 percentage points). Also, when splitting the sample between emerging and advanced countries, I find evidence that the emerging countries are the ones driving this adverse effect. Second, Chapter 4 further explores the heterogeneous effects using an interaction model between Macroprudential policies and income level/financial development degree. Indeed, GDP per capita and the degree of development of the financial sector are two critical criteria to distinguish emerging and advanced countries. Again, I find that the adverse effect of a tightening of macroprudential policy on bank profitability get smaller when the GDP per capita increases and the financial sector becomes more developed (the adverse effect even becomes insignificant for large enough GDP per capita and sufficiently developed financial industry). Finally, using another interaction model (interaction model between Macroprudential policies index, income level dummy, and financial development), I found that the degree of financial sector development plays a more prominent role when it comes to assessing the effect of macroprudential policy on bank profitability.

The rest of this doctoral thesis is organized as follows. Chapter 2 investigates the association between heterogeneity in price rigidities and heterogeneity in returns to scale. Further, Chapter 3 develops a New-Keynesian model with two dimensions of heterogeneities and explores the real effects of monetary policy. Chapter 4 analyses the heterogeneous effects of macroprudential policies on bank profitability. Last, chapter 5 provides concluding remarks for the thesis, policy implications and opens doors for future research.

Chapter 2

Sectoral Heterogeneities in Price Rigidity and Returns to Scale

2.1 Introduction

What explains the significant amount of heterogeneity in nominal price rigidity across sectors?[1] This chapter considers this question using a multi-sector menu cost model where the degree of price rigidity is endogenized. Our main conclusion is that cross-sectoral differences in returns to scale are an important factor which shapes heterogeneity in price rigidity.

The following two observations motivate my investigation on returns to scale as a possible determinant of sectoral heterogeneity in price rigidity. First, the theory suggests that in the presence of menu costs (generic costs associated with nominal price adjustments), *returns to scale affect the degree of price rigidity.* To explain, Ball et al. (1988) highlight that when a firm's profit function is more concave, and then more sensitive to the deviation of its price from the optimum, a firm has a larger incentive to pay menu costs and reset its price. Then, given that decreasing returns to scale make a profit function more concave than constant returns (Burstein and Hellwig (2007)), the degree of returns, in general, is expected to affect its incentive to adjust a price and thus the frequency of price changes.

Second, previous empirical evidence indicates that *returns to scale are different across sectors.* For example, Burnside (1996) shows that for the US manufacturing sector, the equality in

[1] Sectoral heterogeneity in price stickiness is an established fact, both for consumer and producer prices. See, for example, Carlton (1986), Bils and Klenow (2004), Klenow and Kryvtsov (2008), Nakamura and Steinsson (2008), Klenow and Malin (2011), and Vermeulen et al. (2012).

returns to scale across its 20 sub-sectors is firmly rejected.[2] In line with this finding, Diewert et al. (2011) show that in Japan over 1964-88, the electrical machinery industry shows increasing returns to scale for most of the sample period, while the textiles industry tends to show decreasing returns to scale.[3] Thus, the above two observations, taken together, suggest that in the presence of menu costs, sectoral heterogeneity in returns to scale may contribute to the observed heterogeneity in price rigidity.

To explore this possibility formally, I first develop a multi-sector menu cost model where sectors differ in returns to scale. Each sector consists of a large number of monopolistic firms. Firms in each sector are subject to an *ongoing* sector-specific productivity shock, and every period, after the shock is realized, a firm has an opportunity to adjust its price. When menu costs are absent, a firm *always* adjusts its price to the profit-maximizing price, which varies according to the realized value of the productivity shock. The price is fully flexible in this case. However, with menu costs present, a firm chooses *when* it pays menu costs and *what* new price to set, to maximize the present value of future profits net of menu costs. This means that not adjusting a price, i.e., inaction, can be an optimal decision. I aim to characterize how returns to scale, which differ across sectors, affect the optimal frequency of price changes.

To solve a monopolistic firm's problem with menu costs and ongoing shocks, I follow the approach of Alvarez and Lippi (2014), and map our optimisation problem onto an *impulse control* problem analyzed by Dixit (1991*a*). The solution of this problem consists of a *range* of the deviation of an actual price from the optimal price set in a flexible-price equilibrium (which follows a stochastic process): within this range a firm keeps its price, but when it deviates from the optimal price beyond the range, a firm pays menu costs and resets its price to the flexible-price optimum. Thus, the larger the range is, the less frequently the price adjustment occurs. The central analytical insight of our model is that the length of this range of inaction is *increasing* in returns to scale, implying that a firm in a sector with *higher* returns to scale changes its price *less* often. The intuition is that consistent with Burstein and Hellwig (2007), the profit function of a firm with higher returns to scale is less concave, making the firm less sensitive to mispricing. This way, theory predicts that there is a *positive* association between price rigidity and returns to scale across sectors.

[2] Also, Basu and Fernald (1997), based on 34 US industries for the 1959-89 period, show that within manufacturing, durables show higher returns to scale than non-durables.

[3] In the Japanese context, Nakamura (1992) and Beason and Weinstein (1996) also find the heterogeneity in returns to scale across sectors.

Once I obtain the analytical results, I conduct numerical experiments to shed light on the quantitative importance of returns to scale as a determinant of sectoral heterogeneity in price rigidity. For this purpose, using the NBER-CES manufacturing industry database (Bartelsman and Gray (1996)), and the multifactor productivity data from US Bureau of Labor Statistics (BLS), I first estimate returns to scale for each of the 447 6-digit US manufacturing sectors (according to North American Industry Classification System, NAICS) over the period of 1987-2011. Our reference estimate indicates that the average of returns to scale is 1.12 with the standard deviation of 0.25, suggesting that returns to scale are indeed heterogeneous across sectors. Then, using the calibrated theoretical model, I show that the contribution of cross-sectoral differences in returns to scale to sectoral heterogeneity in price rigidity is sizable. To illustrate, for the reference case considered, an increase in sectoral returns to scale from 0.87 (the estimated mean minus one standard deviation) to 1.12 (the mean) leads to a rise in the price rigidity measure (100 minus the monthly frequency of price changes, in percent) by 7 percentage points from 73% to 80%.

Last, I provide empirical evidence consistent with the theoretical prediction that there is a positive correlation between returns to scale and price rigidity across sectors. To do this, I first match the estimated returns to scale at the 6-digit manufacturing sector level with the frequency of changes in producer prices at the product category level estimated by Nakamura and Steinsson (2008). To highlight the association between returns to scale and price rigidity, I control for various factors which are known to contribute to the sectoral difference in price rigidity. Specifically, following the comprehensive study of Vermeulen et al. (2012) on the determinants of producer price rigidity at a sector level in the Euro area, I take account of sectoral differences in 1) labor and intermediate cost shares in production, 2) industry concentration ratio, and 3) sector-level average inflation rates. Using data on 200 6-digit manufacturing sectors matched with 275 product categories, I show that even after controlling for these factors, price rigidity and returns to scale are positively associated.

Several papers have explored the question of what shapes the sectoral heterogeneity in nominal rigidities. For example, Peneva (2011) shows that labor cost share in production is positively related to price rigidity across sectors, possibly due to the predetermined nature of nominal wages. Also, earlier works of Carlton (1986) and Caucutt et al. (1999) show that the degree of industry concentration is positively associated with price rigidity, though Eckard (1982) finds that the association has the opposite sign. Vermeulen et al. (2012) show that in addition to factors such as the input cost structure and industry concentration, the level of sectoral inflation is also relevant.[4] This chapter adds to this strand of the literature on nominal rigidities by proposing a new determinant of their sectoral heterogeneity in the shape of returns to scale.

This chapter is also related to works which examine the macroeconomic outcomes of sectoral heterogeneity in nominal rigidities. For instance, Carvalho (2006), extending the time-dependent model of Calvo (1983), shows theoretically that the presence of sectoral heterogeneity in nominal price stickiness makes the size and persistence of the real effects of monetary shocks larger. Nakamura and Steinsson (2010) and Dixon and Kara (2011) also highlight the relevance of the sectoral heterogeneity in the investigation of monetary non-neutrality, by generalizing the state-dependent model of Golosov and Lucas (2007) and the time-dependent model of Taylor (1980), respectively.[5] The general message is thus that sectoral heterogeneity in nominal rigidities has an important implication on the non-neutrality of money. This chapter complements these works by investigating the source of heterogeneity in price rigidity, rather than its outcome.

The rest of this chapter is organized as follows. Section 2 presents the theoretical model, and Section 3 derives an analytical solution. Section 4 estimates the returns to scale for US manufacturing sub-sectors, and conducts a calibration exercise. Section 5 offers empirical evidence in support of the theory. Section 6 gives concluding remarks.

2.2 The model

2.2.1 Households

The preference of the representative household is given as

$$\int_0^\infty e^{-\rho t}\left[\log C_t + \kappa \log \frac{M_t}{P_t} - \alpha \int_0^1 f(k) \int_0^1 \frac{L_{kj,t}^{\gamma}}{\gamma} dj dk\right] dt. \tag{2.1}$$

The economy is divided into numerous sectors, and each sector is populated with a large number of firms. Sectors are indexed by $k \in [0;1]$, with a density function $f(k)$ summarizing the

[4]Regarding other possible determinants, Caucutt et al. (1999) show that goods durability is positively related to rigidity. Further, Bils and Klenow (2004) and Klenow and Malin (2011) highlight that raw goods exhibit higher price flexibility since they are more prone to volatile cost shocks.

[5]Further, Bouakez et al. (2009) show that the interaction between sectoral heterogeneities in price stickiness and input-output structure plays an important role in the monetary transmission mechanism. They model nominal rigidity using the price adjustment costs of Rotemberg (1982).

distribution of sectors, and within sector k, firms are indexed by $j \in [0;1]$. The representative household consumes the composite of differentiated goods produced by all the firms in the economy. Within the instantaneous utility function, C_t is the composite consumption at time t. Money enters the model through the money-in-utility approach: utility increases in transaction services brought by real money balances, M_t/P_t. The household supplies labor to all the firms, reducing utility due to the loss of leisure time: $L_{kj,t}$ is labor supply to firm j in sector k, and γ equals $1+\frac{1}{\nu}$, where ν is the Frisch elasticity of labor supply. ρ is the discount rate. This utility function is similar to Carvalho (2006), who studies the role of sectoral heterogeneity in price rigidity in the output effects of money supply.[6]

Assuming a constant elasticity of substitution, ε, C_t is given as

$$C_t = \left[\int_0^1 f(k)^{1/\varepsilon} A_{k,t}^{1/\varepsilon} C_{k,t}^{(\varepsilon-1)/\varepsilon} dk\right]^{\varepsilon/(\varepsilon-1)}, \tag{2.2}$$

where $C_{k,t} = f(k)\left[\int_0^1 C_{kj,t}^{(\varepsilon-1)/\varepsilon} dj\right]^{\varepsilon/(\varepsilon-1)}$. $C_{k,t}$ is the sector-level composite consumption, and $C_{kj,t}$ is the consumption of a differentiated good produced by firm j in sector k (firm kj in short). $A_{k,t}$ is a sector-specific preference shock. At each (infinitesimally short) period t, households solve an intra-temporal problem where they maximize C_t for a given level of income. The solution yields the downward-sloping demand curve for a good produced by firm kj:

$$C_{kj,t} = A_{k,t}\left(\frac{P_{kj,t}}{P_t}\right)^{-\varepsilon} C_t.^{7} \tag{2.3}$$

$P_{kj,t}$ is the price of good j in sector k, and aggregate price index, P_t is defined as

$$P_t = \left[\int_0^1 A_{k,t} f(k) P_{k,t}^{1-\varepsilon} dk\right]^{\frac{1}{1-\varepsilon}}, \tag{2.4}$$

where $P_{k,t} = \left[\int_0^1 P_{kj,t}^{1-\varepsilon} dj\right]^{\frac{1}{1-\varepsilon}}$. P_t ($P_{k,t}$) is interpretable as the minimum expenditure necessary to obtain one unit of composite consumption, C_t (sectoral composite consumption, $C_{k,t}$).

Turning to the inter-temporal problem, the household maximizes the utility subject to the

[6] The differences from Carvalho (2006) are that in our model, 1) the time is continuous (instead of discrete), 2) the consumption component takes a log (instead of constant-relative-risk-aversion) form, and 3) real money balances enter the utility function (instead of assuming a cashless economy).

[7] This can be obtained by dividing the intra-temporal problem into the two stages: one is to maximize $C_{k,t}$ by allocating given income among $C_{kj,t}$, and another is to maximize C_t by allocating given income among $C_{k,t}$. Solving the former yields $C_{kj,t} = f(k)^{-1}(P_{kj,t}/P_{k,t})^{-\varepsilon} C_{k,t}$, and solving the latter gives $C_{k,t} = f(k)A_{k,t}(P_{k,t}/P_t)^{-\varepsilon} C_t$. Combining these leads to Eq.2.3.

following budget constraint:

$$P_tC_t + \dot{M}_t + \dot{B}_t = i_tB_t + \int_0^1 f(k)\int_0^1 W_{kj,t}L_{kj,t}djdk + \Pi_t, \tag{2.5}$$

which says that the sum of nominal consumption, P_tC_t, a rise in money holding, $\dot{M}_t$, and a rise in nominal bond holdings, $\dot{B}_t$ is financed by the sum of nominal net earning from holding bond, i_tB_t (i_t is the nominal net interest rate), the integral of nominal wage, $W_{kj,t}$ paid by firm kj, and nominal profit, Π_t from being a shareholder of monopolistic firms. The first order conditions yield the Euler equation of allocation of consumption over time (Eq.2.6), money demand function representing the equality between nominal interest rate and the marginal rate of substitution (MRS) between consumption and real money balances. (Eq.2.7), and the labor supply function (Eq.2.8) indicating the equality between the real wage and the MRS between consumption and leisure:

$$\frac{\dot{C}_t}{C_t} = i_t - \frac{\dot{P}_t}{P_t} - \rho \tag{2.6}$$

$$\frac{M_t}{P_t} = \kappa\frac{C_t}{i_t} \tag{2.7}$$

$$\frac{W_{kj,t}}{P_t} = \alpha C_t L_{kj,t}^{\gamma-1} \tag{2.8}$$

2.2.2 Firms

Each firm is a monopolistic competitor, facing the downward sloping demand curve (Eq. 2.3). To produce a differentiated good, firm kj (firm j in sector k) uses labor as a sole input. Returns to scale differ across sectors, with the distribution characterized by the density function $f(k)$. Firms in each sector k are subject to sector-specific productivity shocks, $Z_{k,t}$ which follow the exponential of independent Brownian motions. This way of modeling idiosyncratic shocks is similar to Alvarez and Lippi (2014).[8] Formally, the production function of firm kj is given as:

$$Y_{kj,t} = Z_{k,t}L_{kj,t}^{\psi_k}, \tag{2.9}$$

where ψ_k is the degree of returns to scale in sector k, and $Z_{k,t}$ is modeled as:

$$Z_{k,t} = e^{\sigma x_{k,t}}, \tag{2.10}$$

[8]The difference is that they model idiosyncratic shocks across firms and products (they model a multi-product firm), whereas I model idiosyncratic shocks across sectors (firms within the same sector are subject to the same shocks).

where $x_{k,t}(k \in [0,1])$ follows standard Brownian motion, so that σ reflects the size of volatility of the sector-specific shock.[9]

Every period, after sector-specific shocks are realized, a firm chooses whether or not to change its nominal price. However, changing the price requires the firm to pay menu costs, generic costs associated with nominal price adjustments.[10] In what follows, I consider two alternative ways of modeling menu costs paid by firm kj in period t, $F_{kj,t}$. The first is to assume that $F_{kj,t}$ equals the fixed fraction, φ of the firm's real revenue in the flexible-price equilibrium (i.e., equilibrium in the absence of menu costs), $r^*_{kj,t}$:

$$F_{kj,t} = \varphi \, r^*_{kj,t}. \tag{2.11}$$

The second is to assume that menu costs are a fixed fraction ζ of real profits in the flexible-price equilibrium: $F_{kj,t} = \zeta \, \pi^*_{kj,t}$. While both approaches are used in the literature, because a number of empirical studies on menu costs (e.g., Levy et al. (1997), Zbaracki et al. (2004) and Stella (2014)) estimate the magnitude of menu cost as a fraction of the revenue, I prefer the first approach in the light of subsequent calibration of the model.[11]

2.3 Analysis

2.3.1 Pricing decisions without menu costs

I first examine a firm's pricing behavior when menu costs are zero ($\varphi = 0$). In this case, every period, after sector-specific shocks are realized, firm kj resets its price to maximize its real profits in period t, $\pi_{kj,t}$:

$$\pi_{kj,t} = \frac{P_{kj,t}}{P_t} Y_{kj,t} - \frac{W_{kj,t}}{P_t} L_{kj,t}. \tag{2.12}$$

[9] Standard Brownian motion is a stochastic process $W = (W_t, t \in [0, \infty))$ characterized by the following conditions (Mikosch (1998)): (1) It starts at zero: $W_0 = 0$; (2) It has stationary, independent increments. (Stationary increments means that $W_t - W_s$ and $W_{t+h} - W_{s+h}$ have the same distribution; Independent increments means that for every choice of t_i with $t_1 < ... < t_n$ and $n \geq 1$, $W_{t_2} - W_{t_1}$, ..., $W_{t_n} - W_{t_{n-1}}$ are independent random variables.); (3) For every $t > 0$, W_t has a normal N(0, t) distribution; (4) It has continuous sample paths: no jumps.

[10] As often indicated, the term "menu costs" may be misleading, in that the material costs of printing menus and catalogs do not appear to be the most important barrier to price flexibility. What could be more important include, for example, wages to hire employees to change the price tags (Levy et al. (1997)) and the cost of computing the nominal price changes corresponding to desired, ideal real price changes (Ball et al. (1988)).

[11] For instance, Midrigan (2011) models menu costs as a fraction of (steady-state) revenue, while Alvarez and Lippi (2014) models as a fraction of profit.

Incorporating resource constraint, $Y_{kj,t} = C_{kj,t}$, demand function (Eq.2.3), labor supply function (Eq.2.8) and production function (Eq.2.9), I rewrite $\pi_{kj,t}$ as a function of $P_{kj,t}$:

$$\pi_{kj,t} = A_{k,t}\left(\frac{P_{kj,t}}{P_t}\right)^{1-\varepsilon} C_t - \alpha(A_{k,t}Z_{k,t}^{-1})^{\frac{\gamma}{\psi_k}}\left(\frac{P_{kj,t}}{P_t}\right)^{-\frac{\varepsilon\gamma}{\psi_k}} C_t^{1+\frac{\gamma}{\psi_k}}, \tag{2.13}$$

where $A_{k,t}$ and $Z_{k,t}$ are sectoral shocks, and a firm takes the aggregate variables, P_t and C_t as given. To ensure that this profit function remains concave, I introduce the following upper bound to the degree of return to scale (see Appendix 2.7.1 for derivation):

$$\psi^{max} = \frac{\varepsilon\gamma}{\varepsilon - 1}.^{12} \tag{2.14}$$

Note also that setting this upper bound ensures that profit is positive: $\pi_{kj,t} > 0$.[13]

Following Alvarez and Lippi (2014), I assume that the sectoral preference shock, $A_{k,t}$ and productivity shock, $Z_{k,t}$ are negatively related: $A_{k,t}Z_{k,t}^{\varepsilon-1} = 1$. This assumption is necessary to solve the model analytically in the presence of menu costs.[14] Differentiating Eq.2.13 with respect to $P_{kj,t}$ then yields the following optimal relative price:

$$\frac{P_{kj,t}^*}{P_t} = \frac{1}{Z_{k,t}}\left[\frac{\alpha\gamma}{\psi_k}\frac{\varepsilon}{\varepsilon - 1}C_t^{\frac{\gamma}{\psi_k}}\right]^{\frac{1}{1-\varepsilon+\frac{\varepsilon\gamma}{\psi_k}}}. \tag{2.15}$$

Firm kj sets its real price as the markup, $\varepsilon/(\varepsilon - 1)$ over real marginal costs.[15] Notice that the optimal price depends not only on aggregate consumption, C_t, but also on the sector-specific shock, $Z_{k,t}$, which follows a stochastic process in the form of the exponential of Brownian motion (Eq.2.10).

[12] This theoretical upper bound is not so restrictive in the light of an empirical estimate of returns to scale. For example, when $\varepsilon = 4$ and $\nu = 3$ (reasonable values for the elasticity of substitution and Frisch elasticity of labor supply), $\psi^{max} = 1.78$, which is above the value of returns to scale estimated below (Table 4.1).

[13] This is seen as follows. First, it can be shown that (average cost)/(marginal cost) = ψ_k/γ. Next, positive profit requires price being larger than average cost, which means that $(\varepsilon/(\varepsilon-1))$*(marginal cost)>(average cost). Combining the two observations, I know that profits are positive when $\psi_k < \psi^{max}$.

[14] As explained below, this assumption ensures that the stock variable of price gap, defined as the deviation of current price from the optimal price in the flexible price equilibrium, follows a Brownian motion. Although this assumption is for simplification, it can still be justified as follows. Suppose that there is a *rise* in preference term, $A_{k,t}$. What this does is to shift the demand curve to the right (see Eq.2.3) for sector k, which, in turn, tends to push up the optimal price for a given level of production in this sector. Meanwhile, a *fall* in productivity term, $Z_{k,t}$ makes production in sector k less efficient for a given input (Eq.2.9), which in turn tends to push up marginal costs and thus the optimal price for this sector. Thus, in essence, a rise in $A_{k,t}$ and a fall of $Z_{k,t}$ have a similar effect on firm's pricing behavior, justifying the negative association between these two sector-specific shocks.

[15] For example, in the case where production exhibits constant returns to scale in sector k ($\psi_k = 1$), and labor supply affects utility linearly ($\gamma = 1$), Eq.2.15 reduces to $P_{kj,t}^*/P_t = (\varepsilon/(\varepsilon-1))(\alpha C_t/Z_{k,t})$, where $\alpha C_t/Z_{k,t}$ is real marginal cost, given as real wage divided by sectoral productivity.

In Eq.2.15, aggregate consumption, C_t can be tied down by using the price index, P_t (Eq.2.4):

$$\int_0^1 f(k)\left[\frac{\alpha\gamma}{\psi_k}\frac{\varepsilon}{\varepsilon-1}(C_t^*)^{\frac{\gamma}{\psi_k}}\right]^{\frac{1-\varepsilon}{1-\varepsilon+\frac{\varepsilon\gamma}{\psi_k}}} dk = 1, \tag{2.16}$$

where C_t^* denotes aggregate consumption in the flexible-price equilibrium. Notice that this is time-invariant: $C_t^* = \bar{C}$, where $\bar{C}$ indicates the steady-state value.[16] In general, there is no closed-form solution for $\bar{C}$. However, to illustrate, when sectoral heterogeneity in returns to scale is absent (i.e., $\psi_k = \psi$), Eq.2.16 yields:

$$\bar{C} = \left[\frac{\psi}{\alpha\gamma}\frac{\varepsilon-1}{\varepsilon}\right]^{\frac{\psi}{\gamma}}.\text{[17]} \tag{2.17}$$

For later reference, I show that in the flexible-price equilibrium, firm kj's real revenue, $r_{kj,t}^*(= P_{kj,t}^* Y_{kj,t}^*/P_t^*)$ is time-invariant: $r_{kj,t}^* = \bar{r}_{kj}$. This, in turn, means that when menu costs are modeled as a fraction of real revenue (Eq.2.11), menu costs paid by the firm, $F_{kj,t}$ are also time-invariant:

$$F_{kj,t} = \varphi\,\bar{r}_{kj}, \tag{2.18}$$

where

$$\bar{r}_{kj} = \left[\frac{\alpha\varepsilon\gamma}{\psi_k(\varepsilon-1)}\right]^{\frac{\psi_k(1-\varepsilon)}{\psi_k(1-\varepsilon)+\varepsilon\gamma}} \bar{C}^{\frac{(1-\varepsilon)\psi_k+\gamma}{\psi_k(1-\varepsilon)+\varepsilon\gamma}}.$$

Likewise, real profits are time-invariant in the flexible-price equilibrium, so that even when menu costs are modeled as a fraction of real profits, they are constant: $F_{kj,t} = \zeta\,\bar{\pi}_{kj}$.

2.3.2 Introducing menu costs

When menu costs are present, inaction (not adjusting a price) can be optimal. Specifically, to maximize the present value of future profits net of menu costs, a firm chooses *when* it pays menu costs and *what* new price to set, rather than adjusting its price every period.

To formalize this optimization problem, I follow the approach of Alvarez and Lippi (2014), who develop a menu cost model to examine the pricing decision of a multi-product firm.[18] The approach constitutes the two main steps: 1) expressing firm's profits as a function of the

[16] The resource constraint ($Y_t = C_t$) indicates that flexible-price equilibrium aggregate output is also constant: $Y_t^* = \bar{Y}$.

[17] This says that aggregate consumption (and output) increases in returns to scale, ψ, the elasticity of substitution, ε, and labor supply elasticity, ν ($\gamma = 1 + 1/\nu$), and decreases in the weight on leisure in the utility function, α.

[18] Unlike Alvarez and Lippi (2014), our focus is the pricing decision of a single-product firm, with the innovation of heterogeneity in returns to scale across sectors.

deviation of actual price from the optimal price set under flexible-price equilibrium, called a price gap, and 2) applying a second-order Taylor approximation to a profit function to simplify it to a symmetric, quadratic function. The essential advantage of taking this approach is that once acknowledging that a price gap follows a Brownian motion, the problem maps onto a type of impulse control problem which is solved *analytically* by Dixit (1991*a*).[19] This analytical solution gives us a clear understanding of the role of returns to scale as a determinant of price rigidity.

The first step is to obtain firm kj's real profits, $\pi_{kj,t}$ as a function of a price gap, $\hat{p}_{kj,t}$, defined as the log deviation of its current price, $P_{kj,t}$ from the optimal price, $P^*_{kj,t}$:

$$\hat{p}_{kj,t} = log(P_{kj,t}) - log(P^*_{kj,t}).$$

Substituting Eq.2.15 into Eq.2.13 (and using $P_{kj,t}/P_t = (P_{kj,t}/P^*_{kj,t})(P^*_{kj,t}/P_t)$) yields $\pi_{kj,t} = \pi(\hat{p}_{kj,t}, C_t)$.[20] Then, the time 0 problem of firm kj that starts with a price gap, $\hat{p}_{kj,0} = \hat{p}_{kj}$ is to choose $\{\boldsymbol{\tau}, \triangle\boldsymbol{\hat{p}_{kj}}\} \equiv \{\tau_i, \triangle\hat{p}_{kj}(\tau_i)\}_{i=1}^{\infty}$, where $(\tau_i)_{i\in 1,2,...}$ is a set of periods when the firm incurs menu costs, and $\triangle\hat{p}_{kj}(\tau_i)$ is a change made to the price gap at time τ_i. Formally, the firm's problem is written as:

$$V(\hat{p}_{kj}) = \max_{\boldsymbol{\tau}, \triangle\boldsymbol{\hat{p}_{kj}}} \boldsymbol{E}\left[\int_0^{\infty} e^{-\rho t}\pi(\hat{p}_{kj,t}, C_t)dt - \sum_{i=1}^{\infty} e^{-\rho\tau_i} F_{kj,\tau_i} \;\mid\; \hat{p}_{kj,0} = \hat{p}_{kj}\right], \tag{2.19}$$

where the first term in the objective function is the present value of real profits, and the second term is the present value of menu costs in real terms. Notice that considering the case where menu costs are a fraction of flexible-price equilibrium revenue, and realizing that menu costs are time-invariant (Eq.2.18), $\bar{r}_{kj}$ can be factored out from the objective function of Eq.2.19, yielding:

$$V(\hat{p}_{kj}) = \bar{r}_{kj} \max_{\boldsymbol{\tau}, \triangle\boldsymbol{\hat{p}_{kj}}} \boldsymbol{E}\left[\int_0^{\infty} e^{-\rho t} g(\hat{p}_{kj,t}, C_t)dt - \sum_{i=1}^{\infty} \varphi\, e^{-\rho\tau_i} \;\mid\; \hat{p}_{kj,0} = \hat{p}_{kj}\right], \tag{2.20}$$

where $g(\hat{p}_{kj,t}, C_t)(= \pi(\hat{p}_{kj,t}, C_t)/\bar{r}_{kj})$ is firm kj's profits scaled by the flexible-price equilibrium

[19] As explained by Dixit (1991*b*), an impulse control problem is characterized by 1) the state variable following a Brownian motion and 2) a lump-sum payment needed to move the state variable. In our context, the state variable is a price gap, and menu costs are the lump-sum payment. In general, solving this problem corresponds to finding the optimal range of (s, r) and interior points of S and R, whereby once the state variable hits the boundaries of s and r, it is moved to S and R with costs, respectively. However, as seen below, once the above approach is taken, solving the problem for a firm in sector k reduces to finding the optimal range of (h_k, $-h_k$), with the interior point of zero: there is only one value, h_k to tie down.

[20] The exact expression of $\pi(\hat{p}_{kj,t}, C_t)$ is shown in Appendix 2.7.2.

revenue.

The second step is to apply a second-order Taylor approximation to the scaled profit function, $g(\hat{p}_{kj,t}, C_t)$. Approximating it around the flexible-price equilibrium of $g(0, \bar{C})$ gives the following *minimization* problem (see Appendix 2.7.2 for derivation):

$$V(\hat{p}_{kj}) = \min_{\boldsymbol{\tau}, \triangle \hat{\boldsymbol{p}}_{\boldsymbol{kj}}} \mathbf{E}\left[\int_0^\infty S_k \, \hat{p}_{kj,t}^2 \, e^{-\rho t} dt + \sum_{i=1}^{\infty} \varphi \, e^{-\rho \tau_i} \;\mid\; \hat{p}_{kj,0} = \hat{p}_{kj} \right], \tag{2.21}$$

where

$$S_k = \frac{1}{2}(\varepsilon - 1)(1 - \varepsilon + \frac{\varepsilon \gamma}{\psi_k}) > 0. \tag{2.22}$$

The coefficient on the price gap squared, S_k is always positive (due to the existence of the upper-bound threshold ψ^{max}, Eq.2.14), and captures how firm kj's profit loss is sensitive to the deviation of an actual price from the optimal price. The key insight here is that S_k is decreasing in return to scale, ψ_k:

$$\frac{\partial S_k}{\partial \psi_k} < 0. \tag{2.23}$$

This indicates that in a sector with *higher* returns to scale, firm's profits are *less sensitive* to a price misalignment, measured by the gap between its current and optimal prices. In other words, a profit function is less concave at the top when returns to scale are higher. To report, even when menu costs are modeled as a fraction of flexible-price equilibrium profits (instead of revenue), the insight remains the same.[21]

To solve Eq.2.21, observe that under the assumption that money supply is constant ($M_t = \bar{M}$), a price gap follows a Brownian motion: $d\hat{p}_{kj,t} = \sigma \, dx_{k,t}$, where $x_{k,t}$ is standard Brownian motion (see Appendix 2.7.3 for the proof).[22] Intuitively, a price gap inherits Brownian motion from the idiosyncratic productivity shock, $Z_{k,t}$, through its effect on the optimal price, $P^*_{kj,t}$ (Eq.2.15). It is thus the case that Eq.2.21 is an impulse control problem, characterized by 1) a price gap (state variable) following Brownian motion, 2) a time-invariant cost needed to move a price gap, and 3) the quadratic loss function being symmetric. This problem directly maps onto a type of impulse control problem solved *analytically* by Dixit (1991*a*) in the context of a menu costs model.[23] The key difference, however, is that since our model is micro-founded (unlike

[21]When $F_{kj,t} = \zeta \, \bar{\pi}_{kj}$, the only difference made to Eq.2.21 is that S_k equals $(1/2)(\varepsilon - 1)(\varepsilon\gamma/\psi_k)$, and ζ replaces φ.

[22]This is where the negative association between the preference shock and productivity shock, $A_{k,t} Z_{k,t}^{\varepsilon-1} = 1$ plays a key role. Without this assumption, a price gap does *not* follow Brownian motion, which in turn indicates that a firm's optimization problem is not solvable analytically.

[23]Compare Eq.2.21 with Eq.3 on page 142 of his paper.

his model), the curvature of the profit function is affected by a composite of micro parameters, including returns to scale.[24]

2.3.3 Analytical results

As explained by Dixit (1991*a*), solving this problem corresponds to determining the range of a price gap in which no action, i.e., keeping the current price, is optimal. In particular, because in Eq.2.21 the loss function is symmetric with the central value of zero (corresponding to the price gap of zero), the solution to the problem consists of a range of price gap $(h_k, -h_k)$ within which a firm in sector k does not to change its price: only when the stochastic process of a price gap hits the boundaries of either h_k and $-h_k$, a firm kj pays menu costs and reset its price gap to zero. Acknowledging this, the value of this threshold value, h_k can be tied town analytically, by taking account of the following two conditions: the Value Matching Condition $(V(h_k) - V(0) = \varphi)$ and the Smooth Pasting Condition $(V^{'}(h_k) = 0)$.[25] These conditions lead to the following proposition regarding the determinants of the threshold value h_k.

Proposition 1. *A firm in sector k chooses to adjust its price to the optimal, frictionless price $P^*_{kj,t}$ whenever the absolute value of the price gap, $|\hat{p}_{kj,t}|$ reaches h_k:*

$$h_k = \left(\frac{6\sigma^2\varphi}{S_k}\right)^{1/4}.^{26} \tag{2.24}$$

With menu costs present $(\varphi > 0)$, the range of inaction exists (i.e., $h_k > 0$). This implies that a firm may not reset its price every period, because a price gap (which follows a Brownian motion) may not hit the boundaries of h_k or $-h_k$ for some periods. Importantly, the range of inaction is an *increasing* function of the returns to scale, i.e., $\partial h_k/\partial\psi_k > 0$ (due to Eq.2.23: $\partial S_k/\partial\psi_k < 0$). This means that a firm belonging to a sector characterized by higher returns to scale chooses to reset its current price *only when* it deviates from the optimal price by a *larger* margin.

The next proposition highlights the role of returns to scale in the expected duration of

[24] Dixit (1991*a*) directly postulates a loss function without modeling a firm's problem explicitly.

[25] Details of the solution of this impulse control problem is found in Dixit (1991*a*).

[26] To be exact, the analytical expression of h_k is based on an approximation. Following Eq.9 and Eq.12 in Dixit (1991*a*), this approximation is valid if $\delta_k = (2\rho/\sigma^2)^{1/2}h_k$ is sufficiently small so that $\delta_k^5/120$ $(\delta_k^6/720)$ is negligible compared to $\delta_k^3/6$ $(\delta_k^4/24)$. Using the estimated and calibrated values considered in the subsequent numerical experiments, I report that these conditions are satisfied. Specifically, the highest value of δ_k is 0.44, corresponding to the highest estimated value of returns to scale below, $\psi_k = 1.76$, combined with the following set of parameters: $\sigma = 0.03$, $\varepsilon = 4$, $\gamma = 4/3$, and $\rho = 0.0025$. In this case, $\delta_k^5/120 = 0.00014$ $(\delta_k^6/720 = 0.00001)$ being negligible compared to $\delta^3/6 = 0.0143$ $(\delta_k^4/24 = 0.00157)$.

inaction, i.e., the duration for which a firm chooses to keep the current price (see Appendix 2.7.4 for proof).

Proposition 2. *The expected duration of inaction of a firm in sector k, D_k is given as:*

$$D_k = \frac{h_k^2}{\sigma^2} = \left(\frac{6\varphi}{\sigma^2 S_k}\right)^{1/2}, \tag{2.25}$$

so that D_k is an increasing function of sectoral returns to scale ψ_k: $\partial D_k/\partial \psi_k > 0$.

This result is explained by the observation that higher returns to scale make a profit function less concave. Intuitively, when firms characterized by higher returns to scale are less sensitive to price misalignments, they reset prices less frequently. Also, it is worth noting that as the menu cost parameter, φ rises or the volatility of sector-specific shocks, σ falls, the expected duration of inaction becomes longer.

For completeness, the next corollary gives the conversion of the expected duration of inaction, D_k into the per-period probability of a firm in sector k keeping the same price, i.e., a direct measure of price stickiness.

Corollary 1. *The per-period probability of a firm in sector k keeping the same price, the measure of price rigidity, χ_k is given as:*

$$\chi_k = e^{-\frac{1}{D_k}}, \tag{2.26}$$

so that χ_k is an increasing function of ψ_k: $\partial \chi_k/\partial \psi_k > 0$.

Thus, the key prediction of the model is that returns to scale and price rigidity are positively correlated across sectors. As pointed out, this is primarily because higher returns to scale make firms less sensitive to price misalignments. Incidentally, larger price stickiness is associated with higher menu costs and lower volatility of sectoral shocks.

2.4 Numerical Experiments

2.4.1 Estimation of returns to scale

Having formalized how sectoral heterogeneity in returns to scale may contribute to the heterogeneity in nominal price rigidity, I now aim to shed light on its quantitative relevance. For this purpose, this section first estimates returns to scale across US manufacturing sectors. However, at the outset, I admit that it is not our intention to claim that our estimates are without issues.

This is because as noted by Diewert et al. (2011), there are in general different possible sources of erroneous estimates of returns to scale, and it is difficult to address them. For example, Basu and Fernald (1997) show that the estimates of returns to scale are likely to be upward biased when data is aggregated over firms[27]. Although I use data on highly disaggregated (6-digit) sectors, this issue is likely to remain. Further, as previous papers indicate (e.g., Basu and Fernald (1997) and Diewert and Fox (2008)), instruments commonly used in the estimation of returns to scale, such as government defense spending and world oil prices, tend to be weak, which I confirm in the context of our estimations.[28]

With the above caveats, our estimation methodology follows the one initiated by Hall (1990) and extended by Basu and Fernald (1997), who propose to estimate returns to scale following a cost minimization problem in the presence of non-constant returns to scale and imperfect competition. The methodology involves regressing sector by sector the output growth on the cost share-weighted average of inputs growth. Formally, the regression equation is given as:

$$\Delta Y_{k,t} = \alpha_k + \psi_k \Delta X_{k,t} + \varepsilon_{k,t}, \tag{2.27}$$

where k and t denote sector and time. The dependent variable, $\Delta Y_{k,t}$ is the growth rate of real gross output, and the independent variable, $\Delta X_{k,t}$ is the average of growth rates of different inputs, weighted by the shares of those input costs in the total cost, and $\varepsilon_{k,t}$ is the error term. The coefficient, ψ_k represents the returns to scale of sector k.

As for data, I use the NBER-CES manufacturing industry database (Bartelsman and Gray (1996)), which gathers information on output and various inputs for 473 manufacturing sectors defined at the 6-digit level of North American Industry Classification System (NAICS) codes, at annual frequency over the 1958-2011 period.[29,30] The database covers capital, labor and intermediate inputs in real terms for each of the 473 sectors.[31] Because it does not provide

[27]This is what they called the aggregation bias, namely the fact that the higher is the aggregation level, the more upward biased the estimates are likely to be. A natural way to dampen this bias is, therefore, to use the lowest aggregation level possible (in our case the 6-digit manufacturing level).

[28]Ideally, to solve the endogeneity issue, I would want to have instrument sets with sector-specific components, but when considering highly disaggregated sectors, finding such instruments appears to be particularly difficult.

[29]The dataset is available at http://www.nber.org/nberces/. Most of the variables covered by this dataset are taken from the ASM (Annual Survey of Manufacturing), which in turn gathers more than 50,000 firms selected from the 350,000 firms from the CMF (Census of Manufacturing). This database follows the 1997 NAICS. (The classification system has been updated every five years since the introduction in NAICS in 1997. For more details, visit https://www.census.gov/eos/www/naics/.)

[30]Many of the previous empirical works on returns to scale (including Basu and Fernald (1997) and Diewert and Fox (2008)) use less disaggregated, two-digit level of Standard Industrial Classification (SIC) codes. (NAICS was established in 1997 to replace the SIC system which has not been updated since 1987.)

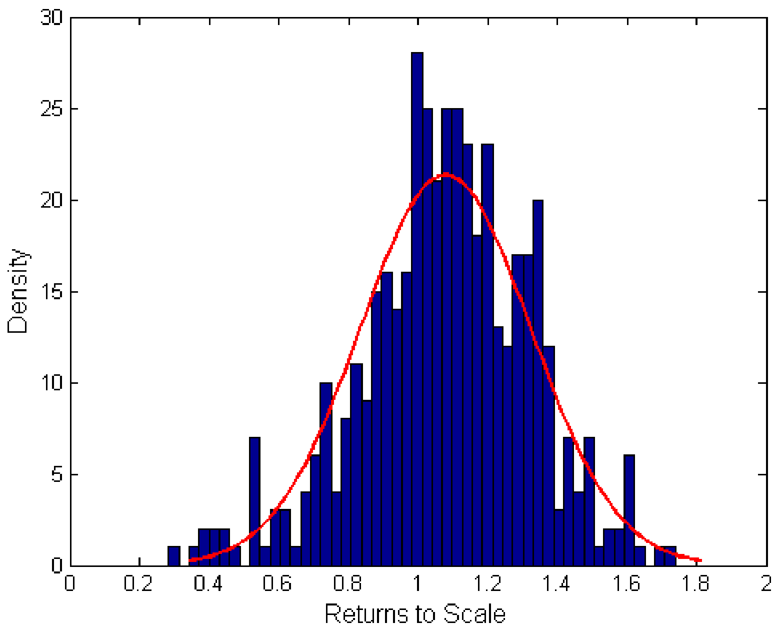
[31]Intermediate input is a composite of materials, energy and purchases services.

data on the cost share of each input in the total cost, I merge it with the data on multifactor productivity provided by the US Bureau of Labor Statistics (BLS).[32] Subsequently, the weighted average of input growth, $\Delta X_{k,t}$ in Eq.2.27 becomes:

$$\Delta X_{k,t} = c^K_{k,t}\Delta K_{k,t} + c^L_{k,t}\Delta L_{i,t} + c^M_{k,t}\Delta M_{i,t} \quad \text{with} \quad c^K_{k,t} + c^L_{k,t} + c^M_{k,t} = 1, \tag{2.28}$$

where $\Delta K_{k,t}$ ($\Delta L_{k,t}$, $\Delta M_{k,t}$) and $c^K_{k,t}$ ($c^L_{k,t}$, $c^M_{k,t}$) are the growth rates and cost share of capital (labor and intermediate inputs) in sector k in year t. After the two databases are merged, the sample period becomes 1987-2011, still covering 473 sectors.

Figure 2.1: Distribution of returns to scale across 6-digits sectors



Notes: Histogram of returns to scale across 6-digit US manufacturing sub-sectors (2 outliers are excluded). A normal distribution is fitted to the histogram. Source: Authors' calculation using NBER-CES Manufacturing Industry and BLS Multifactor Productivity databases

I estimate Eq.2.27 sector by sector, using Ordinary Least Squares (OLS). Figure 2.1 presents the distribution of returns to scale across 447 out of the 473 sectors, for which ψ_k is positive and significant at the 5 percent level.[33] The average is 1.12 and the standard deviation is 0.25, with the maximum (minimum) of 1.76 (0.27).[34] The distribution is approximately bell-shaped,

[32] Specifically, the data on the multifactor productivity (which contains data on the cost structure) are assembled by the Division of Industry Productivity Studies (DIPS) in the office of Productivity and Technology at BLS. The data is available at https://www.bls.gov/mfp/#data. When data on the cost structure for 6-digit sectors are not available, I use data at the corresponding 5-, or 4-digit level (with the preference given to the former).

[33] The figure excludes 2 clear outliers, which are $\psi_k = 2.83$ and $\psi_k = 5.26$.

[34] The maximum point estimate of 1.76 is observed for "electronic coil, transformer, and other inductor manu-

as indicated by a normal distribution fitted to the histogram. Out of the 447 sectors, 112 (20) sectors exhibit increasing (decreasing) returns to scale, with ψ_k significantly larger (smaller) than 1 at the 5 percent level: the remaining 315 sectors show constant returns to scale.

To report, in the view of possible endogeneity issues, I also estimated using instrumental variables (IV) estimator. In particular, following papers such as Hall (1990) and Basu and Fernald (1997), I used military spending (relative to GDP), world oil prices, and the political party of the president as possible instruments. However, I found that for the majority of the sectors, these instruments are weak, not having a strong correlation with the regressor. Therefore, because the use of a weak instrumental variable can lead to substantial bias, the following analysis uses the OLS estimates. Basu and Fernald (1997) and Diewert and Fox (2008) also prefer OLS estimates of returns to scale to IV estimates, on the basis of weak instruments.

2.4.2 Numerical results

Having estimated returns to scale at the sectoral level, I present numerical results using the theoretical model. As for the proportion of menu costs in firm's revenue (Eq.2.11), I use $\varphi = 0.01$ as a reference parameter value. This choice is based on the estimates of menu costs in previous empirical studies, which range from 0.22% to 1.22% of firm's revenue (cf. Levy et al. (1997), Zbaracki et al. (2004) and Stella (2014)).[35] Regarding the volatility parameter of firm's productivity shock, σ (Eq.2.10), I follow Dixit (1991*b*) and Alvarez and Lippi (2014), whose models also entail stock variables which follow Brownian motion. They use the volatility parameter of $\sigma = 0.1$ assuming that the unit of time is a year. Reassuringly, I estimate this parameter (see Appendix 2.7.5), and obtain a very similar value of $\sigma = 0.105$. Since in what follows I assume that the time unit is a month (to be in line with the subsequent empirical analysis where I use the monthly frequency of price change estimated by Nakamura and Steinsson (2008)), I use the monthly equivalent of $\sigma = 0.03$ (instead of $\sigma = 0.1$).[36] The remaining parameters of the model follow values commonly used in the literature: elasticity of demand, $\varepsilon = 4$ (e.g., Nakamura and Steinsson (2010)); Frisch elasticity of labor supply, $\nu = 3$ (e.g., Peterman (2016)), corresponding

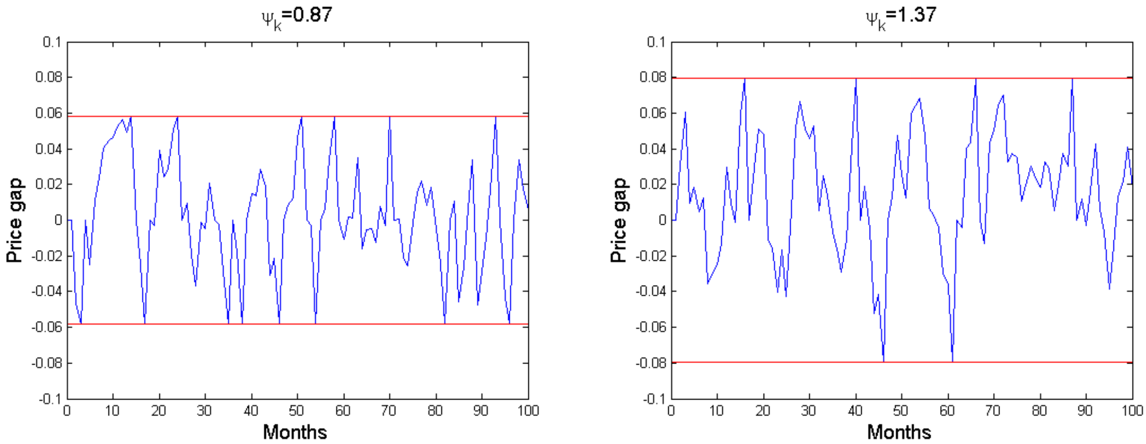
facturing (NAICS code, 334416)", while the minimum estimate of 0.27 is observed for "flour milling (311211)".

[35]In this numerical experiment, I focus on the case where menu costs are modeled as a proportion of a firm's revenue (rather than profits).

[36]To explain, in case time is measured in months, the variance of the exponential of Brownian motion (with no drift term as in the theory model) after one year (12 months) is equal to $e^{\sigma_m^2 * 12}(e^{\sigma_m^2 * 12} - 1)$, where σ_m is the variance parameter relevant for a month after the start of the shock. This variance should be equal to $e^{\sigma_y^2 * 1}(e^{\sigma_y^2 * 1} - 1)$, where σ_y is a yearly counterpart. Thus, when $\sigma_y = 0.1$, I have $\sigma_m = 0.03$.

to $\gamma = 1.33$.

Figure 2.2: Price gap and the range of inaction for different returns to scale

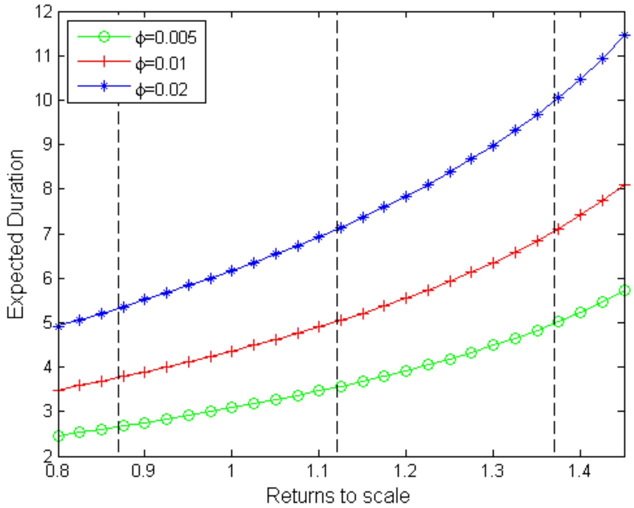


Notes: Sample paths of price gap following a Brownian motion with $\sigma = 0.03$ for $\psi_k = 0.87$ and $\psi_k = 1.37$. The former (latter) value of ψ_k is the mean minus (plus) one standard deviation. Horizontal lines are the boundaries of h_k and $-h_k$ (see Eq.2.24). Parameter values are as explained in the text. Source: Authors' calculation

Evolution of price gaps Figure 2.2 shows a sample path of firm's price gap for two different values of returns to scale, $\psi_k = 0.87$ and $\psi_k = 1.37$, which correspond to the mean of returns to scale estimated above (1.12) plus and minus one standard deviation (0.25). The other parameter values are as explained above. With these values, sectoral price gap threshold h_k is 0.058 for $\psi_k = 0.87$, while 0.080 for $\psi_k = 1.37$ (see Eq.2.24). That is, whenever its current price deviates from the optimal flexible equilibrium price by 5.8% (8.0%) in the absolute value, a profit-optimizing firm in a sector with the returns to scale of 0.87 (1.37) pays menu costs and adjusts its price to the optimal price, corresponding to the price gap of zero. Under the low returns to scale (the left sub-figure), price gap hits boundaries 14 times over the course of 100 months, while under the high returns to scale (right sub-figure), it hits the boundaries only 6 times, implying that higher returns to scale match a longer expected duration of inaction.

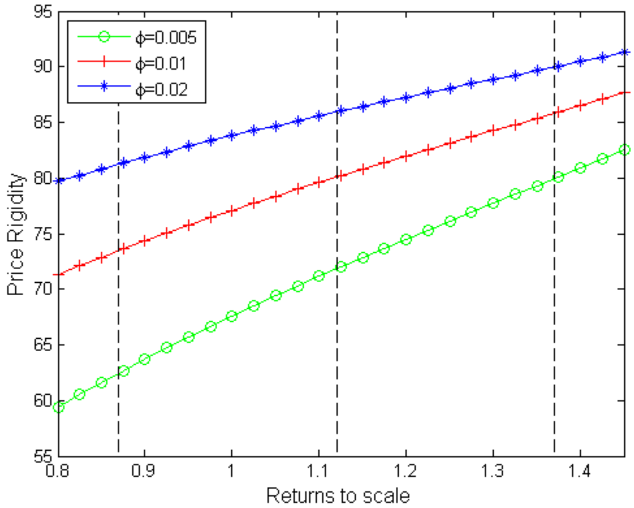
Expected duration of inaction and price rigidity Next, Figure 2.3 shows the expected duration of inaction, D_k as a function of returns to scale ψ_k (Eq.2.25). The duration of inaction is defined in months. The left (middle; right) vertical dashed lines correspond to the sample mean of returns to scale (1.12) minus one standard deviation (0.25), 0.87 (the mean; the mean plus one standard deviation, 1.37). The relation between D_k and ψ_k are plotted for different values of menu costs around the reference value of $\varphi = 0.01$: 0.005 and 0.02. Fig-

Figure 2.3: Expected duration and returns to scale for different menu costs



Note: Expected durations are defined in months. The left (middle, right) vertical dashed lines correspond to the sample mean of returns to scale (1.12) minus one standard deviation (0.25) (the mean, the mean plus one standard deviation). Source: Authors' calculation

Figure 2.4: Price rigidity and returns to scale for different menu costs



Note: Price rigidity is defined as the probability (in percent) of keeping the current price fixed in a given month, calculated as "100−100*(1/expected duration of inaction in months)", where the expected duration is as calculated in Figure 2.3. The three dashed lines are as defined in Figure 2.3. Source: Authors' calculation

ure 2.4 presents corresponding figures, showing instead the measure of price rigidity defined as "100−100*(1/expected duration of inaction in months)".[37] For the reference case of $\varphi = 0.01$, for example, returns to scale of 0.87, 1.12, and 1.37 are associated with the price rigidity of

[37]This way of converting from expected duration to price rigidity is different from Eq.2.26. This is because I now conduct numerical experiments in a discrete time framework.

73%, 80%, and 85%. Judging from the fact that empirical estimates of price rigidity used below (Table 4.1) yield the standard deviation of 22% with the mean of 85%, the effect of returns to scale on price rigidity appears quantitatively sizable. Incidentally, for a given value of returns to scale (1.12), a rise in the menu cost parameter from 0.01 to 0.02, for example, correspond to a rise in price rigidity from 80% to 86%, which also appears non-trivial.

2.5 Empirical evidence

2.5.1 Matching with data on price rigidity

To see if the theoretical prediction is supported empirically, this section examines the correlation between returns to scale and price rigidity across US manufacturing sectors. For this purpose, I first match returns to scale estimated above for 6-digit manufacturing sectors with the monthly frequency of change in producer prices at the product level estimated by Nakamura and Steinsson (2008).[38,39] Using the survey of firms conducted by BLS, they estimate the monthly frequency of producer price change of identical products (as well as the frequency of price change including changes associated with product substitutions) for 348 categories of product over the 1998-2005 period. To illustrate how matching is done, product categories such as "butter" and "natural and processed cheese" are matched with 6-digit sub-sectors of "creamery butter manufacturing (NAICS code: 311512)" and "cheese manufacturing (311513)", and product categories such as "cigarettes" and "cigars" with "cigarette manufacturing (312221)" and "other tobacco product manufacturing (312229)".[40] Overall, I managed to match 277 (out of 348) categories of products with 202 NAICS 6-digit manufacturing sectors, for which returns to scale are estimated.[41] Appendix 2.7.6 lists product categories together with corresponding 6-digit NAICS manufacturing sectors.

Figure 2.5 plots returns to scale against the measure of price rigidity, calculated as 100 minus

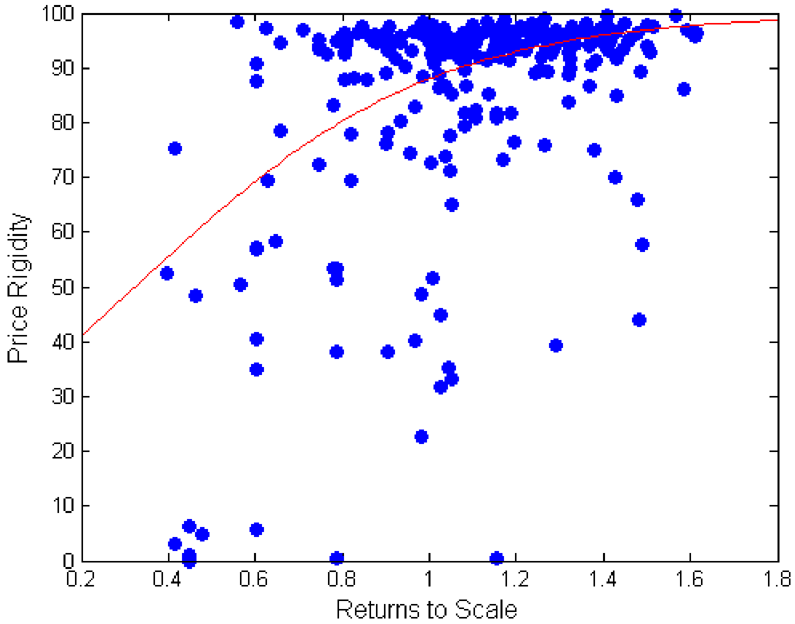
[38]The estimates are available in Table 23 of their online appendix.

[39]The reason why I choose producer prices rather than consumer prices is twofold. First, in our view, using producer prices is more relevant to test our theoretical prediction, which is about producer's pricing behavior. Second, from a practical perspective, it has turned out that a large proportion of sectors for which I estimated returns to scale cannot be matched with the frequency of consumer prices at a product level estimated by Nakamura and Steinsson (2008), reducing the sample size dramatically. The same happened even when I used the frequency of consumer prices estimated by Klenow and Kryvtsov (2008) instead.

[40]Regarding "creamery butter manufacturing (NAICS 311512)", for example, the NAICS manual says that "this U.S. industry comprises establishments primarily engaged in manufacturing creamery butter from milk and/or processed milk products".

[41]Some products are not possible to match. For example, products for which Nakamura and Steinsson (2008) estimate the frequency of price changes include agricultural products such as fresh foods, and these products are produced outside manufacturing sectors.

Figure 2.5: Returns to scale and price rigidity



Note: 277 product categories matched with 202 6-digit manufacturing sectors (according to NAICS) are considered. Price rigidity is calculated as "100 − the monthly frequency of producer price change of identical products (in percent, from Nakamura and Steinsson (2008))". Returns to scale are as estimated above (cf. Eq.2.27). The fitted line is based on the regression line for the relation between the logit transformation of price rigidity and returns to scale. Source: Authors' calculation.

the monthly frequency of price changes of identical products in percent. Since the frequency at which price is kept unchanged is bounded in the 0 to 100 range by definition, the fitted line in Figure 2.5 is based on the regression line for the association between the logit transformation of price rigidity and returns to scale, which is positive and significant at the 1 percent level.[42] The indication is thus that products made in sectors characterized by higher returns to scale exhibit larger price stickiness. This association holds even when I use the frequency including price changes associated with product substitutions. In what follows, I conduct a regression analysis, to examine if the positive correlation between returns to scale and price rigidity still holds even when other determinants of price rigidity highlighted in the previous empirical literature are controlled for.

[42]See Baum (2008) for the use of logit transformation to model proportions.

2.5.2 Regression results

Based on Vermeulen et al. (2012)'s comprehensive study of sectoral heterogeneity in producer price setting in the Euro area, the following regression analysis takes account of 1) the cost structure of production, highlighting labor and intermediate cost shares, 2) the degree of market concentration, and 3) the inflation rate at the sector level, as possible determinants of the heterogeneity in producer price rigidity. I run a cross-sectional regression to examine the relation between returns to scale and producer price rigidity, controlling for an average of these determinants over the sample period of 1987-2011 at the sector level.

Table 2.1: Summary statistics

Variable	Mean	Std. dev.	Min.	Max.
Price rigidity	84.82	21.93	0	99.60
Returns to scale	1.08	0.26	0.4	1.61
Labor cost share	22.93	7.93	3.56	42.47
Intermediate cost share	57.43	9.42	37.08	82.16
Concentration ratio	697.38	594.11	2.67	2707.2
Average inflation	2.14	3.28	-13.38	15.77

Notes: Based on 275 product categories matched with 200 6-digit manufacturing sectors according to NAICS. Source: Authors' calculation using data from NBER-CES Manufacturing Industry database, US Census Bureau, BLS databases, and Nakamura and Steinsson (2008).

Table 4.1 describes the data used for the analysis. Focusing on the case where all the control variables are available, the statistics are based on 275 observations from 200 US 6-digit manufacturing sectors. Regarding the determinants controlled for, labor cost and intermediate cost shares in production (from BLS) are calculated as the average over the 1987-2011 period.[43] On average, labor and intermediate cost shares account for 22.9 % and 57.4 %, respectively. Labor share is expected to show a positive association with price rigidity, while intermediate share shows a negative association (Peneva (2011), Vermeulen et al. (2012)). Next, concentration ratio (from US Census Bureau) is the Herfindahl-Hirschman index (HHI) for 50 largest companies at each of the 6-digit NAICS sector, averaged over 1997, 2002, and 2007.[44] In the most (least) concentrated sector, the index takes 2707.2 (2.67), with the average of 697.4.[45] Since previous works reach different conclusions (e.g., Carlton (1986) and Eckard (1982)), there is no clear conjecture about the sign of the association with price rigidity. Last, inflation rates at the

[43] As explained above, data on the cost structure for 6-digit sectors are not always available. When not available, corresponding data at the 5- or 4-digit level are used.

[44] The data are available only at those three data points.

[45] HHI takes a maximum of 10,000 when one firm has a 100% market share, and it takes close to zero at a minimum when each of many firms has nearly 0% share.

6-digit sector level are obtained from BLS as an average of as much data as available over the 1987-2011 period. In line with Vermeulen et al. (2012), I expect that this variable is negatively related to price rigidity.

Formally, regression equation is described as:

$$rigid_i = \alpha + \beta\, rts_i + \sum_{j=1}^{n} \delta_j\, \mathbf{z}_{i,j} + \epsilon_i, \tag{2.29}$$

where i denotes a product category. The dependent variable, $rigid_i$ is the logit transformation of the price rigidity measure, "100 minus the monthly frequency of price changes of identical products in percent". Our main independent variable, rts_i is the returns to scale estimate for product category i, matched with the 6-digit sector k (cf. Eq.2.27). Next, $\mathbf{z}_{i,j}$ is a vector of additional controls as explained above (i.e., labor cost share, the intermediate cost share, concentration ratio, and sectoral inflation rate) relevant for product category i. I estimate Eq.2.29 using OLS. Because different product categories sometimes belong to the same 6-digit sector, clustered standard errors are used to adjust for correlation of error terms within a sector.

Table 2.2: Returns to scale and price rigidity

Dependent variable: price rigidity (transformed using logit function)

Regressors	(1)	(2)	(3)	(4)	(5)
Returns to scale	2.936***	1.252***	2.954***	2.288***	0.976**
	(3.853)	(2.721)	(3.875)	(3.848)	(2.332)
Labor cost share		0.0748***			0.0567***
		(4.085)			(3.492)
Intermediate cost share		-0.0321**			-0.0345***
		(-2.212)			(-2.733)
Concentration ratio			-0.000419**		-0.000349**
			(-2.136)		(-2.038)
Inflation rate				-0.143***	-0.117***
				(-3.000)	(-3.465)
Constant	-0.937	1.011	-0.651	0.0688	2.366***
	(-1.027)	(0.955)	(-0.708)	(0.0980)	(2.626)
Observations	277	277	275	277	275
Adj R-squared	0.209	0.373	0.237	0.273	0.425

Notes: OLS estimations. In Column (5), for example, 275 product categories are matched with 200 6-digit manufacturing sectors according to NAICS. t-statistics using robust standard errors that adjust for correlation within 6-digit NAICS are in parentheses.*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 2.2 summarizes the results. Column (1) is without any additional controls, corresponding to the positive regression line in Figure 2.5. The positive and significant coefficient

2.936 can be interpreted using odds ratio[46]. For example, an increase in returns to scale by 0.1 is associated with a rise in the odds ratio by 34% ($e^{0.1*2.936} - 1 = 0.34$). Thus, if the initial price rigidity is 84.82% (sample mean, see Table 4.1), a rise in returns to scale by 0.1 corresponds to the increase in price rigidity by 3.4 percentage points, which appears substantial.[47] While Columns (2) to (4) control for cost shares, concentration ratio, and inflation rate, respectively, the association between returns to scale and price rigidity remains positive and significant at the 1 percent level. As expected, the coefficients on labor and intermediate cost shares are significantly positive and negative. In line with Eckard (1982), the concentration ratio is negatively associated with price rigidity. The negative and significant coefficient on inflation rate means that under high inflation, producer price changes more frequently.

Last, Column (5) shows that even when all the variables are controlled for simultaneously, the positive correlation between returns to scale and price rigidity still holds, albeit the coefficient on returns to scale is smaller (0.976). To interpret as above, a rise in returns to scale by 0.1 at the mean price rigidity of 84.82% is associated with a rise in the price rigidity by 1.22 percentage points. Given that one standard deviation change (= 0.26) corresponds to 3.17 percentage points change, the effect does appear to matter quantitatively. To report, the results are robust to the use of the frequency of price changes including changes associated with product substitutions. Interestingly, the quantitative effect is somewhat close to the result from the calibration exercise above: there, a one standard deviation increase in returns to scale at the reference point (where the price rigidity measure takes 80 percent) causes a rise in price rigidity by 5 percentage points.

2.5.3 Robustness

The above regressions are based on the point estimates of returns to scale. However, as mentioned, estimating returns to scale is inherently difficult due to different sources of erroneous estimates. Acknowledging this, instead of exploiting the variations of the point estimates of returns to scale as in Table 2.2, I here use the variations among the three categories: increasing, constant, and decreasing returns to scale.

[46]The Odds ratio is the ratio between the probability that an event occurs and the probability that it does not. In our case, the event is defined as inaction, i.e., *not* changing the current price.

[47]With the price rigidity of 84.82%, the odds ratio is $84.82/(100 - 84.82)(=5.588)$. When the odds ratio rises by 34%, the new ratio is 7.487. Then, the price rigidity corresponding to the new ratio is tied down as 88.22%, an increase of 3.4 percentage points from the initial rigidity.

Specifically, I consider the following model:

$$rigid_i = \alpha + \beta IRS_i + \gamma DRS_i + \sum_{j=1}^{n} \delta_j \mathbf{z}_{i,j} + \epsilon_i, \tag{2.30}$$

where the only difference from Eq.2.29 is that instead of using rts_i, a point estimate of returns to scale of product category i, I use IRS_i, a dummy variable which takes the value of 1 if product category i is matched with a sector characterized by IRS technology, 0 otherwise (i.e., if it is matched with a sector with CRS or DRS technology). Likewise, DRS_i is a dummy which takes the value of 1 if product category i is associate with a sector characterized by DRS technology, 0 otherwise. When returns to scale are larger (smaller) than the value of 1 at the 5 percent level, a sector is considered to exhibit increasing (decreasing) returns to scale. A CRS dummy is omitted, to avoid perfect multicollinearity. Our interests in Eq.2.30 are the signs of coefficients, β and γ, which, to the extent that the above results in Table 2.2 prevails, should be positive and negative, respectively.

Table 2.3: Returns to scale and price rigidity: dummy variable approach

Dependent variable: price rigidity (transformed using logit function)

Regressors	(1)	(2)	(3)	(4)	(5)
IRS	0.592***	0.303**	0.572***	0.392**	0.199
	(3.231)	(2.005)	(3.232)	(2.345)	(1.292)
DRS	-3.155***	-1.571*	-3.173***	-2.691***	-1.494*
	(-2.809)	(-1.660)	(-2.813)	(-2.939)	(-1.784)
Labor cost share		0.0761***			0.0561***
		(4.097)			(3.734)
Intermediate cost share		-0.0280**			-0.0285**
		(-2.257)			(-2.461)
Concentration ratio			-0.000487*		-0.000378**
			(-1.931)		(-1.973)
Inflation rate				-0.156***	-0.122***
				(-4.065)	(-3.943)
Constant	2.287***	2.120**	2.640***	2.640***	3.164***
	(15.69)	(2.193)	(14.75)	(18.25)	(3.646)
Wald IRS_DRS, p-value	0.000971	0.0457	0.00103	0.000733	0.0407
Observations	277	277	275	277	275
Adj R-squared	0.220	0.385	0.249	0.303	0.442

Notes: OLS estimations. In Column (5), for example, 275 product categories are matched with 200 6-digit manufacturing sectors according to NAICS. IRS (DRS) is a dummy variable, taking the value of one if product category i belongs to a sector characterized by increasing (decreasing) returns to scale, and the value of zero otherwise. Wald IRS_DRS tests the equality of coefficients on IRS and DRS. t-statistics using robust standard errors that adjust for correlation within 6-digit NAICS are in parentheses.*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 2.3 summarizes the results. The structure is the same as Table 2.2, except that the dummy variables of returns to scale are used instead of the point estimates. Among 277 observations for Column (1), for example, 67 (195, 15) product categories are matched with industries which exhibit increasing (constant, decreasing) returns to scale. As expected, coefficients on IRS is always positive, and ones on DRS is always negative. While those coefficients are mostly significant, in Column (5) the coefficient on IRS is not significant. However, it can be confirmed that it is significantly different from the coefficient on DRS. This is based on the observation that the Wald test rejects the equality of coefficients on IRS and DRS for all the columns, including Column (5). It is thus the case that even when I do not exploit the variations of point estimates, the price of a product category from a sector characterized by IRS changes less frequently than the price of a product from a DRS sector. Coefficients on all the additional controls are in line with the ones in Table 2.2, both in terms of the sign and significance.

2.6 Concluding remarks

This chapter proposes returns to scale as a possible explanatory factor behind sectoral heterogeneity in nominal price stickiness. I first built a dynamic multi-sector menu-cost model to show analytically that there is a positive association between returns to scale and price rigidity across sectors. This happens because higher returns to scale make firms less sensitive to price misalignment, prompting them to adjust prices less often in the presence of menu costs. I then estimated returns to scale using data on 6-digit US manufacturing sectors. A calibration exercise using the returns to scale estimates suggests that returns to scale are a quantitatively important factor behind sectoral heterogeneity in price stickiness. Last, I provided evidence in support of our main theoretical prediction. The positive correlation between returns to scale and producer price rigidity still stands even after controlling for some of the key determinants of price rigidity highlighted in the literature.

One reason why the previous literature emphasizes the relevance of heterogeneity in price rigidity is that this heterogeneity is expected to amplify the real effect of monetary policy. The next chapter of this thesis will test if this result is robust when an additional heterogeneity, namely the heterogeneity in returns to scale, is also considered.

2.7 Appendix 1

2.7.1 Upper-bound of returns to scale, ψ^{max}

Firm kj's real profit in time t is given as (Eq.2.13):

$$\pi_{kj,t} = A_{k,t} p_{kj,t}^{1-\varepsilon} C_t - \alpha (A_{k,t} Z_{k,t}^{-1})^{\frac{\gamma}{\psi_k}} p_{kj,t}^{-\frac{\varepsilon\gamma}{\psi_k}} C_t^{1+\frac{\gamma}{\psi_k}},$$

where $p_{kj,t} = \frac{P_{kj,t}}{P_t}$. Firm kj maximizes its profits by choosing an optimal relative price $p^*_{kj,t} = \frac{P^*_{kj,t}}{P_t}$. I first obtain the stationary point, $p^s_{kj,t}$ that satisfy $\frac{\partial \pi_{kj,t}}{\partial p_{kj,t}}(p^s_{kj,t}) = 0$, and then check if $\frac{\partial^2 \pi_{kj,t}}{\partial p^2_{kj,t}}(p^s_{kj,t}) < 0$ to ensure that the stationary point corresponds to a maximum.

The stationary point $p^s_{kj,t}$ is obtained as:

$$(p^s_{kj,t})^{1-\varepsilon+\frac{\varepsilon\gamma}{\psi_k}} = \frac{\alpha\gamma}{\psi_k}\frac{\varepsilon}{\varepsilon-1} A_{k,t}^{\frac{\gamma}{\psi_k}-1} Z_{k,t}^{-\frac{\gamma}{\psi_k}} C_t^{\frac{\gamma}{\psi_k}}$$

Then, the second derivative at the stationary point is:

$$\frac{\partial^2 \pi_{kj,t}}{\partial p^2_{kj,t}}(p^s_{kj,t}) = (\varepsilon - 1)\left[\varepsilon - (\frac{\varepsilon\gamma}{\psi_k} + 1)\right] A_{k,t} C_t (p^s_{kj,t})^{-\varepsilon-1}.$$

With $\varepsilon - 1 > 0$, $A_{k,t}$ and C_t being positive, and $p^s_{kj,t} > 0$, the second derivative of the profit function at the stationary point is negative if and only if:

$$\left[\varepsilon - (\frac{\varepsilon\gamma}{\psi_k} + 1)\right] < 0 \quad \Leftrightarrow \quad \psi_k < \frac{\varepsilon\gamma}{\varepsilon - 1} = \psi^{max}$$

As long as returns to scale are below ψ^{max}, the profit function remains concave.

2.7.2 Approximation of scaled profit, g

Substituting Eq.2.15 into Eq.2.13 (and using $P_{kj,t}/P_t = (P_{kj,t}/P^*_{kj,t})(P^*_{kj,t}/P_t)$) yields

$$\pi(\hat{p}_{kj,t}, C_t) = \alpha \left[\frac{\alpha\varepsilon\gamma}{\psi_k(\varepsilon-1)}\right]^{\frac{-\varepsilon\gamma}{\psi_k(1-\varepsilon)+\varepsilon\gamma}} C_t^{\frac{(1-\varepsilon)\psi_k+\gamma}{\psi_k(1-\varepsilon)+\varepsilon\gamma}} \; e^{-\frac{\varepsilon\gamma}{\psi_k}\hat{p}_{kj,t}} \left[\frac{\varepsilon\gamma}{\psi_k(\varepsilon-1)} e^{(1-\varepsilon+\frac{\varepsilon\gamma}{\psi_k})\hat{p}_{kj,t}} - 1\right].$$

In turn, $g(\hat{p}_{kj,t}, C_t)(= \pi(\hat{p}_{kj,t}, C_t)/\bar{r}_{kj})$ is given as:

$$g(\hat{p}_{kj,t}, C_t) = \frac{\psi_k(\varepsilon-1)}{\varepsilon\gamma}\left[\frac{C_t}{\bar{C}}\right]^{\frac{(1-\varepsilon)\psi_k+\gamma}{\psi_k(1-\varepsilon)+\varepsilon\gamma}} \; e^{-\frac{\varepsilon\gamma}{\psi_k}\hat{p}_{kj,t}} \left[\frac{\varepsilon\gamma}{\psi_k(\varepsilon-1)} e^{(1-\varepsilon+\frac{\varepsilon\gamma}{\psi_k})\hat{p}_{kj,t}} - 1\right].$$

I approximate the function g around the flexible-price equilibrium where $C_t = \bar{C}$ and $\hat{p}_{kj,t} = 0$. As in Alvarez and Lippi (2014), I use the second-order Taylor approximation:

$$\begin{aligned}
g(\hat{p}_{kj,t}, C_t) =& g(\bar{C}, 0) + \frac{\partial g}{\partial \hat{p}}(\bar{C}, 0)\hat{p}_{kj,t} + \frac{\partial g}{\partial C}(\bar{C}, 0)(C_t - \bar{C}) \\
&+ \frac{1}{2}\left[\frac{\partial^2 g}{\partial \hat{p}\partial \hat{p}}(\bar{C}, 0)\hat{p}^2_{kj,t} + \frac{\partial^2 g}{\partial C \partial C}(\bar{C}, 0)(C_t - \bar{C})^2\right] \\
&+ \frac{\partial^2 g}{\partial \hat{p}\partial C}(C_t, 0)\hat{p}_{kj,t}(C_t - \bar{C}) + o(||\hat{p}^2_{kj,t}, C_t - \bar{C}||^2) \\
=& 1 + \frac{(1-\varepsilon)\psi_k + \gamma}{\varepsilon\gamma}\frac{C_t - \bar{C}}{\bar{C}} + \frac{1}{2}(1-\varepsilon)\left[1 - \varepsilon + \frac{\varepsilon\gamma}{\psi_k}\right]\hat{p}^2_{kj,t} \\
&+ \frac{1}{2}\frac{(1-\varepsilon)\psi_k + \gamma}{\varepsilon\gamma}\left[\frac{(1-\varepsilon)\psi_k + \gamma}{\psi_k(1-\varepsilon) + \varepsilon\gamma} - 1\right]\left[\frac{C_t - \bar{C}}{\bar{C}}\right]^2 + o(||\hat{p}^2_{kj,t}, C_t - \bar{C}||^2).
\end{aligned}$$

Denoting $\chi = \frac{\psi_k(1-\varepsilon)+\varepsilon\gamma}{\varepsilon\gamma}$ and $\delta = \frac{(1-\varepsilon)\psi_k+\gamma}{\psi_k(1-\varepsilon)+\varepsilon\gamma}$, and plugging the above into Eq.2.20, the firm's problem can be written as the following minimization problem:

$$\begin{aligned}
\min_{\boldsymbol{\tau}, \triangle\hat{\boldsymbol{p}}_{\boldsymbol{kj}}} \ \bar{r}_{kj} \ \mathbf{E}\Big[&\int_0^\infty \frac{1}{2}(\varepsilon - 1)(1 - \varepsilon + \frac{\varepsilon\gamma}{\psi_k})\hat{p}^2_{kj,t}e^{-\rho t}dt + \sum_{i=1}^{\infty} e^{-\rho\tau_i}\varphi \\
&- \int_0^\infty \big[\chi\frac{C_t - \bar{C}}{\bar{C}} + \frac{1}{2}\chi(\delta - 1)(\frac{C_t - \bar{C}}{\bar{C}})^2\big]e^{-\rho t}dt \\
&+ \int_0^\infty o(||\hat{p}^2_{kj,t}, C_t - \bar{C}||^2)e^{-\rho t}dt \mid \hat{p}_{kj,0} = \hat{p}_{kj}\Big].
\end{aligned} \tag{2.31}$$

In Eq.2.31, only the first line of the problem depends on firm kj's choice of the pricing policy $(\boldsymbol{\tau}, \triangle\hat{\boldsymbol{p}}_{\boldsymbol{kj}})$ Thus, the firm's problem simply becomes:

$$\min_{\boldsymbol{\tau}, \triangle\hat{\boldsymbol{p}}_{\boldsymbol{kj}}} \ \mathbf{E}\Big[\int_0^\infty \frac{1}{2}(\varepsilon - 1)(1 - \varepsilon + \frac{\varepsilon\gamma}{\psi_k})\hat{p}^2_{kj,t}e^{-\rho t}dt + \sum_{i=1}^{\infty} e^{-\rho\tau_i}\varphi \mid \hat{p}_{kj,0} = \hat{p}_{kj}\Big]. \tag{2.32}$$

2.7.3 Price gap following Browning motion

Assuming that money supply is constant over time, i.e., $M_t = \bar{M}$, Eqs.2.6, 2.7, and 2.16 indicate that in the flexible price equilibrium, aggregate price is also constant at:

$$\bar{P} = \frac{\rho\bar{M}}{\kappa\bar{C}}.$$

Then, in the flexible-price equilibrium, a nominal price set by firm kj, $P^*_{kj,t}$ is given as (cf. Eq.2.15):

$$P^*_{kj,t} = \frac{1}{Z_{k,t}}\left[\frac{\alpha\gamma}{\psi_k}\frac{\varepsilon}{\varepsilon - 1}\bar{C}^{\frac{\gamma}{\psi_k}}\right]^{\frac{1}{1-\varepsilon+\frac{\varepsilon\gamma}{\psi_k}}}\frac{\rho\bar{M}}{\kappa\bar{C}}.$$

Taking the log of this equation and differentiating it (with respect to time) yields $\text{dlog}P^*_{kj} = -\text{dlog}Z_k$. Further, taking the log of Eq.2.10 and differentiating it gives $\text{dlog}Z_k = \sigma \text{d}x_k$, where x_k follows standard Brownian motion. I thus have

$$\text{dlog}P^*_{kj} = -\sigma \text{d}x_k. \tag{2.33}$$

Next, given that a price gap, $\hat{p}_{kj,t} = \log(\frac{P_{kj,t}}{P^*_{kj,t}})$, I have $\text{d}\hat{p}_{kj} = \text{dlog}P_{kj} - \text{dlog}P^*_{kj}$. Since price $P_{kj,t}$ is constant between two consecutive price changes *by definition*, $\text{dlog}P_{kj} = 0$ between those changes. This means that:

$$\text{d}\hat{p}_{kj} = -\text{dlog}P^*_{kj}. \tag{2.34}$$

Last, combining Eqs.2.33 and 2.34 yields:

$$\text{d}\hat{p}_{kj} = \sigma \text{d}x_k.$$

A price gap $\hat{p}_{kj,t}$ follows a Brownian motion with the volatility parameter of σ.

2.7.4 Derivation of the expected duration of inaction

Denote $q_t = \hat{p}^2_{kj,t}$, and $\bar{q} = h^2_k$. Proposition 1 shows that a firm changes its price whenever q_t reaches $\bar{q}$. For a starting price gap $\hat{p}_{kj}$, and $q = \hat{p}^2_{kj}$, I define $T(q)$ as the expected time required for q_t to reach $\bar{q}$ when starting from q. The function T satisfies the following Bellman equation:

$$T(q) = dt + \mathbf{E}[T(q + dq)] \Rightarrow 0 = dt + \mathbf{E}[dT(q)] \tag{2.35}$$

Given that a price gap $\hat{p}_{kj,t}$ follows a Brownian motion (i.e. $\text{d}\hat{p}_{kj} = \sigma \text{d}x_k$ where x_k is standard Brownian motion), and using Ito's Lemma, it is straightforward to prove that $dq = \sigma^2 dt + 2\sigma\sqrt{q}dx_k$. Similarly, using Ito's lemma on function $T(q)$, I have:

$$dT(q) = (T^{'}(q)\sigma^2 + 2\sigma^2 qT^{''}(q))dt + (2\sigma\sqrt{q}T^{'}(q))dx_k \tag{2.36}$$

Plugging Eq.2.36 into Eq.2.35, and using the fact that $\mathbf{E}[dx_k] = 0$, I derive:

$$0 = dt + (T^{'}(q)\sigma^2 + 2\sigma^2 qT^{''}(q))dt$$

Dividing this by dt gives an Ordinary Differential Equation (ODE):

$$0 = 1 + T^{'}(q)\sigma^2 + 2\sigma^2 q T^{''}(q) \tag{2.37}$$

Using the boundary condition $T(\bar{q}) = 0$, the solution for the ODE in Eq.2.37 is $T(q) = \frac{\bar{q}-q}{\sigma^2}$. Thus, the expected duration of inaction of a firm in sector k, D_k is equal to:

$$D_k = T(0) = \frac{\bar{q}}{\sigma^2} = \frac{h_k^2}{\sigma^2}$$

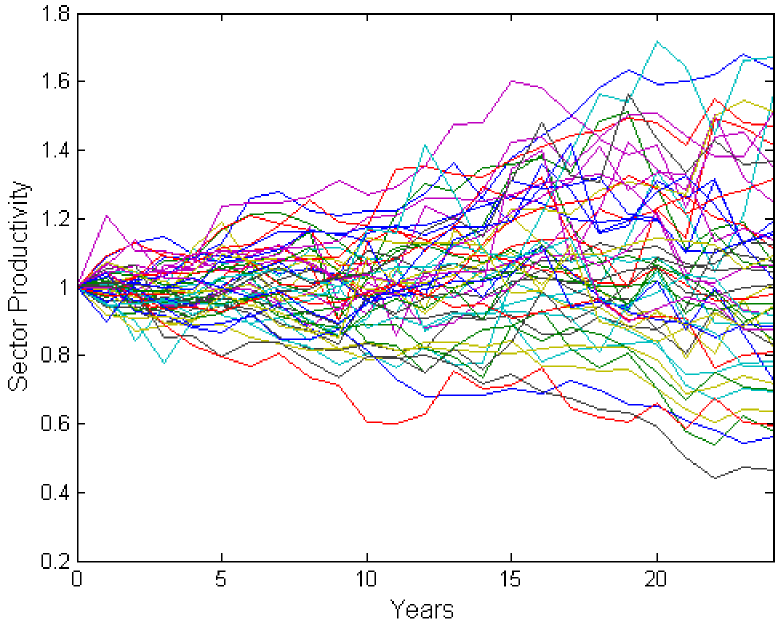
2.7.5 Estimation of the volatility parameter, σ

Here, I estimate the volatility parameter σ of sectoral productivity shocks, modeled as the exponential of Brownian motion, i.e., geometric Brownian motion. First, in line with the estimation of returns to scale (Eqs.2.27 and 2.28), I assume that the production function of firms in sector k is given as:

$$Y_{k,t} = Z_{k,t}(L_{k,t}^{cL_{k,t}} K_{k,t}^{cK_{k,t}} M_{k,t}^{cM_{k,t}})^{\psi_k},$$

where $Y_{k,t}$ is gross output (in sector k in year t); $Z_{k,t}$ is total factor productivity; $L_{k,t}$, $K_{k,t}$, and $M_{k,t}$ are labor, capital, and intermediate inputs; $cL_{k,t}$, $cK_{k,t}$, and $cM_{k,t}$ are the cost shares of respective inputs; ψ_k is returns to scale. Then, using the data from NBER-CES manufacturing industry and BLS multifactor productivity databases, and our estimates for returns to scale (see Figure 2.1), I compute $Z_{k,t}$ for each year from 1987 to 2011 for the 447 sectors. To normalize the initial value of geometric Brownian motion to its standard value of 1, I divide $Z_{k,t}$ by $Z_{k,1987}$. Figure 2.6 presents the realized path of $Z_{k,t}$ for 50 (of 447) sectors from $t = 0$ (1987) to $t = 24$ (2011).

Figure 2.6: Sector productivity shocks $Z_{k,t}$



Note: Normalized paths of $Z_{k,t}$ for 50 6-digit US manufacturing sub-sectors. Year $t = 0$ corresponds to year 1987. Sources: Authors' calculation using data from NBER-CES Manufacturing Industry and BLS Multifactor Productivity databases.

I regard these 447 normalized paths of $Z_{k,t}$ as a set of *realizations* of geometric Brownian motion, Z_t. To incorporate the possibility that there is a trend to sectoral total factor productivity in reality, I assume that Z_t is geometric Brownian motion with drift, characterized by a volatility parameter σ and a drift parameter μ. Thus, the mean and variance of this stochastic process at time t are given as:

$$E(Z_t) = e^{(\mu+(1/2)\sigma^2)t} \quad \text{and} \quad Var(Z_t) = e^{(2\mu+\sigma^2)t}(e^{\sigma^2 t} - 1) = E(Z_t)^2(e^{\sigma^2 t} - 1),$$

which, in turn, yields:

$$\frac{Var(Z_t)}{E(Z_t)^2} = e^{\sigma^2 t} - 1.$$

Then, using the 447 realizations of Z_t, I obtain the estimate of the volatility parameter σ for each year t ($t = 1, ..., 24$), and I find that the average of these 24 estimated values is 0.105. This is our estimate for σ (Eq.2.10) for the case where the unit of time is a year. Interestingly, this estimated value of volatility parameter is quite close to the parameter of 0.1 used by Dixit (1991*a*) and Alvarez and Lippi (2014) who assume that the unit of time is a year.

2.7.6 Matching product categories with NAICS 6-digit manufacturing sector

Code	Prod. description	6-digits NAICS description	NAICS
278	Shortening and cooking oil	Fats and Oils Refining and Blending	311225
641	Fats and oils, inedible	Fats and Oils Refining and Blending	311225
255	Confectionery end Prod.s	Confectionery	311330
254	Confectionery materials	Chocolate and Confectionery	311320
253	Refined sugar	Cane Sugar Refining	311312
242	Frozen fruits, juices and ades	Frozen Fruit, Juice, and Vegetable Mfg.	311411
282	Pickles and pickle Prod.s	Fruit and Vegetable Canning	311421
284	Canned specialties	Specialty Canning	311422
281	Jams, jellies, and preserves	Fruit and Vegetable Canning	311421
244	Canned vegetables and juices	Fruit and Vegetable Canning	311421
285	Frozen specialties	Frozen Specialty Food Mfg.	311412
241	Canned fruits and juices	Fruit and Vegetable Canning	311421
245	Frozen vegetables	Frozen Fruit, Juice, and Vegetable Mfg.	311411
235	Condensed and evaporated milk	Dry, Condensed, and Evaporated Dairy	311514
234	Ice cream and frozen desserts	Ice Cream and Frozen Dessert Mfg.	311520
232	Butter	Creamery Butter Mfg.	311512
233	Natural and processed cheese	Cheese Mfg.	311513
221	Meats	Animal (except Poultry) Slaughtering	311611
222	Processed poultry	Poultry Processing	311615
286	Meat sauces	Mayonnaise, Dressing, and Other Sauce	311941
283	Processed eggs	All Other Miscellaneous Food Mfg.	311999
262	Soft drinks	Soft Drink Mfg.	312111
391	Textile fibers, yarns and fabrics, n.e.c.	Yarn Spinning Mills	313111
326	Yarns	Yarn Spinning Mills	313111
327	Threads	Thread Mills	313113
345	Nonwovens and felt goods	Nonwoven Fabric Mills	313230
347	Embroideries and lace goods	Schiffli Machine Embroidery	313222
337	Broadwovens	Broadwoven Fabric Mills	313210
342	Broadwovens	Broadwoven Fabric Mills	313210
339	Other fabrics	Other Knit Fabric and Lace Mills	313249
344	Narrow fabrics	Narrow Fabric Mills	313221
348	Knit fabrics,finished in knitting mills	Weft Knit Fabric Mills	313241
338	Knits	Weft Knit Fabric Mills	313241
346	Coated fabrics, not rubberized	Fabric Coating Mills	313320
393	Other finishing of textiles	Textile and Fabric Finishing Mills	313312
382	Textile housefurnishings	Curtain and Drapery Mills	314121
1214	Bedding	Curtain and Drapery Mills	314121
442	Gloves	Glove and Mitten Mfg.	315992
427	Finished and unfinished leather	Leather and Hide Tanning and Finishing	316110
419	Hides and skins, incl. cattle	Leather and Hide Tanning and Finishing	316110
432	Women's footwear	Women's Footwear (except Athletic) Mfg.	316214
439	All other footwear	Other Footwear Mfg.	316219
431	Men's footwear	Men's Footwear (except Athletic) Mfg.	316213
437	Athletic footwear	Rubber and Plastics Footwear Mfg.	316211
441	Luggage and small leather goods	Women's Handbag and Purse Mfg.	316992
445	Leather/leather-like goods, n.e.c.	All Other Leather Good Mfg.	316999
871	Treated wood and contract wood preserving	Wood Preservation	321114
851	Logs, bolts, timber and pulpwood	Sawmills	321113
849	Other sawmill planing mill Prod.s	Sawmills	321113
832	Hardwood plywood and related Prod.s	Hardwood Veneer and Plywood Mfg.	321211
831	Softwood plywood	Softwood Veneer and Plywood Mfg.	321212
922	Hardboard, particleboard fiberboard prods.	Reconstituted Wood Prod. Mfg.	321219
834	Hardwood plywood veneer	Hardwood Veneer and Plywood Mfg.	321211
833	Softwood plywood veneer	Softwood Veneer and Plywood Mfg.	321212
923	Building board, const. paper felt stock	Reconstituted Wood Prod. Mfg.	321219
1553	Mobile homes, residential, double wide	Manufactured Home (Mobile Home) Mfg.	321991
823	Miscellaneous millwork Prod.s	Other Millwork (including Flooring)	321918
1552	Mobile homes, residential, single wide	Manufactured Home (Mobile Home) Mfg.	321991
842	Boxes	Wood Container and Pallet Mfg.	321920
822	Prefabricated structural members	Prefabricated Wood Building Mfg.	321992
861	Prefabricated wood buildings components	Prefabricated Wood Building Mfg.	321992
812	Hardwood lumber	Cut Stock, Resawing Lumber, and Planing	321912
841	Wood pallets and skids	Wood Container and Pallet Mfg.	321920
821	General millwork	Cut Stock, Resawing Lumber, and Planing	321912
811	Softwood lumber	Cut Stock, Resawing Lumber, and Planing	321912
1556	Mobile homes, nonresidential	Manufactured Home (Mobile Home) Mfg.	321991

911	Woodpulp	Pulp Mills	322110
913	Paper	Paper (except Newsprint) Mills	322121
914	Paperboard	Paperboard Mills	322130
915	Converted paper and paperboard Prod.s	All Other Converted Paper Prod. Mfg.	322299
916	Pressure sensitive Prod.s	Coated and Laminated Paper Mfg.	322222
937	Commercial printing	Commercial Gravure Printing	323111
931	Newspapers	Commercial Gravure Printing	323111
935	Manifold business forms	Manifold Business Forms Printing	323116
934	Book printing	Books Printing	323117
932	Periodicals	Commercial Gravure Printing	323111
938	Blankbooks, binders, and bookbinding work	Tradebinding and Related Work	323121
1361	Prep. asphalt tar roofing siding prod.	Asphalt Shingle and Coating Materials Mfg.	324122
561	Crude petroleum (domestic Prod.ion)	Petroleum Refineries	324110
574	Residual fuels	Petroleum Refineries	324110
1394	Paving mixtures and blocks	Asphalt Paving Mixture and Block Mfg.	324121
571	Gasoline	Petroleum Refineries	324110
581	Petroleum and coal Prod.s, n.e.c.	All Other Petroleum and Coal Prod.s Mfg.	324199
1362	Other asphalt roofing	Asphalt Shingle and Coating Materials Mfg.	324122
573	Light fuel oils	Petroleum Refineries	324110
512	Bituminous coal and Lignite	All Other Petroleum and Coal Prod.s Mfg.	324199
614	Basic organic chemicals	Gum and Wood Chemical Mfg.	325191
551	Residential natural gas	Cyclic Crude and Intermediate Mfg.	325192
532	Liquefied petroleum gas	Industrial Gas Mfg.	325120
613	Basic inorganic chemicals	Alkalies and Chlorine Mfg.	325181
531	Natural gas	Cyclic Crude and Intermediate Mfg.	325192
552	Commercial natural gas	Cyclic Crude and Intermediate Mfg.	325192
553	Industrial natural gas	Cyclic Crude and Intermediate Mfg.	325192
662	Thermoplastic resins	Plastics Material and Resin Mfg.	325211
663	Thermosetting resins	Plastics Material and Resin Mfg.	325211
652	Fertilizer materials	Nitrogenous Fertilizer Mfg.	325311
653	Other agricultural chemicals	Pesticide and Other Agricultural Chemical Mfg.	325320
637	Biological Prod.s	Biological Prod. (except Diagnostic) Mfg.	325414
631	Medicinal and botanical chemicals	Medicinal and Botanical Mfg.	325411
638	Pharmaceutical preparations	Pharmaceutical Preparation Mfg.	325412
634	Preparations, veterinary	Pharmaceutical Preparation Mfg.	325412
622	Paint materials	Paint and Coating Mfg.	325510
623	Allied and miscellaneous paint Prod.s	Paint and Coating Mfg.	325510
621	Prepared paint	Paint and Coating Mfg.	325510
675	Cosmetics and other toilet preparations	Toilet Preparation Mfg.	325620
672	Specialty cleaning, polish. san. prods.	Toilet Preparation Mfg.	325620
679	Misc. chemical prod. and preparations	All Other Miscellaneous Chemical Prod.	325998
723	Laminated plastic sheets, rods, and tubes	Unsupported Plastics Packaging Film.	326112
725	Plastic packaging	Unsupported Plastics Packaging Film	326112
721	Plastic construction Prod.s	All Other Plastics Prod. Mfg.	326199
729	Other plastic Prod.s	All Other Plastics Prod. Mfg.	326199
722	Unsupp. plastic film/sheet/other shapes	Unsupported Plastics Packaging Film	326112
713	Miscellaneous rubber Prod.s	All Other Rubber Prod. Mfg.	326299
711	Crude rubber	Rubber and Plastics Hoses and Belting Mfg.	326220
712	Tires, tubes, tread, repair materials	Tire Mfg. (except Retreading)	326211
1052	Vitreous china fixtures	Vitreous China Plumbing Fixture	327111
1352	Clay refractories	Clay Refractory Mfg.	327124
1345	Structural clay Prod.s, n.e.c.	Other Structural Clay Prod. Mfg.	327123
1342	Brick and structural clay tile	Brick and Structural Clay Tile Mfg.	327121
1353	Refractories, non clay	Nonclay Refractory Mfg.	327125
1261	Tableware, kitchenware and other pottery	Vitreous China and Other Pottery	327112
1313	Other finished glassware	Other Glass and Glassware Mfg.	327212
1265	Mirrors	Glass Prod. Mfg.	327215
1262	Household glassware	Other Glass and Glassware Mfg.	327212
1311	Flat glass	Flat Glass Mfg.	327211
1335	Prestressed concrete Prod.s	Other Concrete Prod. Mfg.	327390
1332	Concrete pipe	Concrete Pipe Mfg.	327332
1333	Ready-mixed concrete	Ready-Mix Concrete Mfg.	327320
1322	Cement	Cement Mfg.	327310
1331	Concrete block and brick	Concrete Block and Brick Mfg.	327331
1334	Precast concrete Prod.s	Other Concrete Prod. Mfg.	327390
1371	Gypsum Prod.s	Gypsum Prod. Mfg.	327420
1395	Cut stone and stone Prod.s	Cut Stone and Stone Prod. Mfg.	327991
1392	Insulation materials	Mineral Wool Mfg.	327993
1136	Abrasive Prod.s	Abrasive Prod. Mfg.	327910
1321	Construction sand, gravel, and crushed stone	All Other NonMt.lic Mineral Mfg.	327999

1399	NonMt.lic minerals and Prod.s, n.e.c.	All Other NonMt.lic Mineral Mfg.	327999
1016	Blast and electric furnace Prod.s	ElectroMt.lurgical Ferroalloy Prod. Mfg.	331112
1012	Iron and steel scrap	Iron and Steel Mills	331111
1017	Steel mill Prod.s	Iron and Steel Mills	331111
1011	Iron ore	Iron and Steel Mills	331111
1022	Primary nonferrous Mt.s	Smelting and Refining of Nonferrous Mt.	331419
1025	Nonferrous mill shapes	Smelting and Refining of Nonferrous Mt.	331419
1026	Nonferrous wire and cable	Smelting and Refining of Copper	331411
1028	Nonferrous foundry shop Prod.s	Smelting and Refining of Nonferrous Mt.	331419
1023	Nonferrous scrap	Smelting and Refining of Nonferrous Mt.	331419
1021	Nonferrous Mt. ores	Smelting and Refining of Nonferrous Mt.	331419
1027	Nonferrous forage shop Prod.s	Smelting and Refining of Nonferrous Mt.	331419
1024	Secondary nonferrous Mt.s	Smelting and Refining of Nonferrous Mt.	331419
1042	Hand and edge tools	Hand and Edge Tool Mfg.	332212
1267	Cutlery, razors and razor blades	Cutlery and Flatware (except Precious) Mfg.	332211
1076	Fabricated steel plate	Plate Work Mfg.	332313
1073	Sheet Mt. Prod.s	Sheet Mt. Work Mfg.	332322
1071	Mt. doors, sash, and trim	Mt. Window and Door Mfg.	332321
1079	Prefabricated Mt. buildings	Prefabricated Mt. Building and Component Mfg.	332311
1072	Mt. tanks	Mt. Tank (Heavy Gauge) Mfg.	332420
1077	Steel power boilers	Power Boiler and Heat Exchanger Mfg.	332410
1032	Barrels, drums, and pails	Other Mt. Container Mfg.	332439
1075	Heat exchanges and condensers	Power Boiler and Heat Exchanger Mfg.	332410
1041	Hardware, n.e.c.	Hardware Mfg.	332510
1088	Fabricated ferrous wire Prod.s	Other Fabricated Wire Prod. Mfg.	332618
1081	Bolts, nuts, screws, rivets, and washers	Bolt, Nut, Screw, Rivet, and Washer Mfg.	332722
1195	Machine shop Prod.s	Machine Shops	332710
1089	Other miscellaneous Mt. Prod.s	All Other Fabricated Mt. Prod. Mfg.	332999
1056	Mt. sanitary ware	All Other Fabricated Mt. Prod. Mfg.	332999
1054	Brass fittings	Plumbing Fixture Fitting and Trim Mfg.	332913
112G	Parts for construction Mch.	Construction Mch. Mfg.	333120
1192	Mining Mch. and Eq.	Mining Mch. and Eq. Mfg.	333131
1191	Oil field and gas field Mch.	Oil and Gas Field Mch. and Eq. Mfg.	333132
1114	Agricultural Mch. and Eq.	Farm Mch. and Eq. Mfg.	333111
1266	Lawn and garden equip., ex. garden tractors	Lawn and Garden Tractor and Eq. Mfg.	333112
112D	Off-highway Eq., excluding parts	Construction Mch. Mfg.	333120
112I	Construction Mch. and Eq. sold	Construction Mch. Mfg.	333120
1164	Paper industries Mch.	All Other Industrial Mch. Mfg.	333298
1166	Other special industry Mch.	All Other Industrial Mch. Mfg.	333298
1162	Textile Mch. and Eq.	Textile Mch. Mfg.	333292
1163	Woodworking Mch. and Eq.	All Other Industrial Mch. Mfg.	333298
1165	Printing trades Mch. and Eq.	Printing Mch. and Eq. Mfg.	333293
1161	Food Prod.s Mch.	Food Prod. Mch. Mfg.	333294
1541	Photographic Eq.	Photographic and Photocopying Eq. Mfg.	333315
1542	Photographic supplies	Photographic and Photocopying Eq. Mfg.	333315
1168	Service industry Mch. and parts	Other Commercial and Service Industry Mch. Mfg.	333319
1186	Optical instruments and lenses	Optical Instrument and Lens Mfg.	333314
1169	Commercial laundry dry cleaning equip.	Other Commercial and Service Industry Mch. Mfg.	333319
1193	Office and store machines and Eq.	Office Mch. Mfg.	333313
1066	Water heaters, domestic	Heating Eq. (except Warm Air Furnaces) Mfg.	333414
1062	Warm air furnaces	Air-Conditioning+Warm Air Heating Equip Mfg.	333415
1064	Domestic heating stoves	Heating Eq. (except Warm Air Furnaces) Mfg.	333414
1148	Air conditioning and refrigeration equip	Air-Conditioning+Industrial Refrigeration Equip Mfg.	333415
1147	Fans and blowers, except portable	Industrial and Commercial Fan and Blower Mfg.	333412
1061	Steam and hot water Eq.	Heating Eq. (except Warm Air Furnaces) Mfg.	333414
1063	Conversion burners	Air-Conditioning+Warm Air Heating Equip Mfg.	333415
1135	Cutting tools and accessories	Cutting Tool and Machine Tool Accessory Mfg.	333515
113A	Mt.working Mch. n. e. c.	Other Mt.working Mch. Mfg.	333518
1139	Tools, dies, jigs, fixtures ind. molds	Industrial Mold Mfg.	333511
1138	Mt. forming machine tools	Cutting Tool and Machine Tool Accessory Mfg.	333515
1137	Mt. cutting machine tools	Cutting Tool and Machine Tool Accessory Mfg.	333515
1194	Internal combustion engines	Turbine and Turbine Generator Set Units Mfg.	333611
1196	Steam, gas, hydraulic turbines parts	Turbine and Turbine Generator Set Units Mfg.	333611
1145	Mechanical power transmission Eq.	Mechanical Power Transmission Eq. Mfg.	333613
1197	Turbine generator sets and parts	Turbine and Turbine Generator Set Units Mfg.	333611
1141	Pumps, compressors, and Eq.	Pump and Pumping Eq. Mfg.	333911
1132	Power driven hand tools	Power-Driven Handtool Mfg.	333991
112A	Tractors and attachments, excluding parts	Industrial Truck, Tractor Mch. Mfg.	333924
1133	Welding machines and Eq.	Welding and Soldering Eq. Mfg.	333992
112B	Power cranes, excavators and Eq.	Overhead Traveling Crane, Hoist Mfg.	333923

1142	Elevators, escalators, and other lifts	Elevator and Moving Stairway Mfg.	333921
1144	Industrial material handling Eq.	Conveyor and Conveying Eq. Mfg.	333922
1149	Miscellaneous general purpose Eq.	All Other Miscellaneous General Purpose Mch. Mfg.	333999
1167	Packing and packaging Mch.	Packaging Mch. Mfg.	333993
1146	Scales and balances	Scale and Balance (except Laboratory) Mfg.	333997
1143	Fluid power Eq.	Fluid Power Cylinder and Actuator Mfg.	333995
1134	Industrial process furnaces and ovens	Industrial Process Furnace and Oven Mfg.	333994
1152	Computer storage devices	Computer Storage Device Mfg.	334112
1153	Computer terminals and parts	Computer Terminal Mfg.	334113
1154	Computer peripheral Eq. and parts	Other Computer Peripheral Eq. Mfg.	334119
1151	Electronic computers	Electronic Computer Mfg.	334111
1176	Communication and related Eq.	Other Communications Eq. Mfg.	334290
1252	Television receivers	Radio and Television Eq. Mfg.	334220
1257	Speakers and commercial sound Eq.	Audio and Video Eq. Mfg.	334310
1178	Electronic components and accessories	Other Electronic Component Mfg.	334419
1181	Environmental controls	Automatic Environmental Control Mfg.	334512
1172	Integrating and measuring instruments	Instruments+Related Measuring Mfg	334513
1184	Fluid meters and counting devices	Totalizing Fluid Meter and Counting Device Mfg.	334514
1182	Process control instruments	Instruments Controlling Industrial Process Variables	334513
1189	Measuring and controlling devices, n.e.c.	Other Measuring and Controlling Device Mfg.	334519
1185	Engineering and scientific instruments	Analytical Laboratory Instrument Mfg.	334516
159C	Precorded cd/tape/record producing	Prerecorded Compact Disc	334612
1245	Electric lamps	Electric Lamp Bulb and Part Mfg.	335110
1177	Electric lamps/bulbs and parts	Electric Lamp Bulb and Part Mfg.	335110
1083	Lighting fixtures	Residential Electric Lighting Fixture Mfg.	335121
1243	Household vacuum cleaners, parts, attach.	Household Vacuum Cleaner Mfg.	335212
1258	Other home electronic Eq.	Electric Housewares and Household Fan Mfg.	335211
1244	Electric housewares and fans	Electric Housewares and Household Fan Mfg.	335211
1241	Major appliances	Household Cooking Appliance Mfg.	335221
1175	Switchgear, switchboard, etc. Eq.	Switchgear and Switchboard Apparatus Mfg.	335313
1174	Transformers and power regulators	Power, Distribution, and Specialty Transformer Mfg.	335311
1173	Motors, generators, motor generator sets	Motor and Generator Mfg.	335312
1171	Wiring devices	Current-Carrying Wiring Device Mfg.	335931
1416	Travel trailers and campers	Travel Trailer and Camper Mfg.	336214
1413	Truck and bus bodies	Motor Vehicle Body Mfg.	336211
1414	Truck trailers	Truck Trailer Mfg.	336212
1411	Motor vehicles	Motor Vehicle Body Mfg.	336211
1412	Motor vehicle parts	All Other Motor Vehicle Parts Mfg.	336399
1421	Aircraft	Aircraft Mfg.	336411
1423	Aircraft engines and engine parts	Aircraft Engine and Engine Parts Mfg.	336412
1425	Aircraft parts and auxiliary Eq., nec	Other Aircraft Parts and Auxiliary Eq. Mfg.	336413
1442	Railroad cars and car parts	Railroad Rolling Stock Mfg.	336510
1441	Locomotives and parts	Railroad Rolling Stock Mfg.	336510
1431	Ships	Ship Building and Repairing	336611
1432	Boats	Boat Building	336612
1491	Transportation Eq., n.e.c.	All Other Transportation Eq. Mfg.	336999
1212	Wood household furniture	Nonupholstered Wood Household Furniture Mfg.	337122
1213	Upholstered household furniture	Upholstered Household Furniture Mfg.	337121
1216	Household furniture, n.e.c.	Household Furniture (except Wood and Mt.) Mfg.	337125
1211	Mt. household furniture	Mt. Household Furniture Mfg.	337124
1223	Public building furniture	Institutional Furniture Mfg.	337127
1215	Porch and lawn furniture	Upholstered Household Furniture Mfg.	337121
1222	Mt. office furniture and store fixtures	Office Furniture (except Wood) Mfg.	337214
1221	Wood office furniture and store fixtures	Wood Office Furniture Mfg.	337211
1564	Ophthalmic goods	Ophthalmic Goods Mfg.	339115
1571	Industrial safety Eq.	Surgical Appliance and Supplies Mfg.	339113
1565	Dental Eq. and supplies	Dental Eq. and Supplies Mfg.	339114
1563	Surgical appliances and supplies	Surgical Appliance and Supplies Mfg.	339113
1562	Medical instruments and Eq.	Surgical and Medical Instrument Mfg.	339112
1594	Jewelry and jewelry Prod.s	Jewelry (except Costume) Mfg.	339911
1264	Household flatware	Silverware and Hollowware Mfg.	339912
1593	Musical instruments	Musical Instrument Mfg.	339992
1398	Gaskets, packing, and sealing devices	Gasket, Packing, and Sealing Device Mfg.	339991
1512	Sporting and athletic goods	Sporting and Athletic Goods Mfg.	339920
1595	Pens, pencils, and marking devices	Marking Device Mfg.	339943
1532	Needles, pins, and fasteners	Fastener, Button, Needle, and Pin Mfg.	339993
1531	Buttons, button blanks, and parts	Fastener, Button, Needle, and Pin Mfg.	339993
1591	Caskets	Burial Casket Mfg.	339995
1597	Brooms and brushes	Broom, Brush, and Mop Mfg.	339994
1511	Toys, games, and children's vehicles	Game, Toy, and Children's Vehicle Mfg.	339932

1263	Hollowware	Silverware and Hollowware Mfg.	339912

Abbreviation: Mfg.=Manufacturing, Prod.=Product, Mch.=Machinery, Eq.=Equipment
Notes: Matching of 277 Product code to 202 6-digits NAICS manufacturing. The description of some NAICS industries have been modified to fit into the table. For the full description of the 6-digits 1997 NAICS, visit http://www.nber.org/nberces/.
Sources: Authors' matching using NBER-CES Manufacturing Industry and Product code from Nakamura and Steinsson (2008).

Chapter 3

Does Heterogeneity in Price Rigidity Really Matter for Monetary non-Neutrality?

3.1 Introduction

Golosov and Lucas (2007) paper challenges the importance of nominal rigidities in generating substantial monetary non-neutrality. In response to Golosov and Lucas (2007), several economists have developed models that extend the standard New Keynesian (NK) model in an attempt to generate larger real effects of monetary shock. For example, many papers extend the standard NK model by introducing heterogeneity in nominal price rigidities[1]. For example, Carvalho (2006), examining the real effects of monetary shocks, find that the size and persistence of the output effects are more substantial in the presence of heterogeneity in nominal price stickiness. Further, Dixon and Kara (2011) develop a sticky price model using a Taylor-type contract with different contract length and show that this feature can significantly increase the persistence in output effects of monetary shocks. Similarly, Nakamura and Steinsson (2010) find that heterogeneity in the frequency of price change amplifies (up to triple) the degree of monetary non-neutrality compare to the non-neutrality generated by a homogenous price stickiness calibrated to the mean frequency of price change.

Acknowledging that the sectoral heterogeneity in price stickiness, on its own, is likely to have a

[1]Indeed, a critical empirical feature of nominal price rigidity is the presence of sectoral heterogeneity. Bils and Klenow (2004) report that while the average monthly frequency of price change is about 26% in the US, at one extreme, taxi fares exhibit a frequency of about 5%, and at the other, regular unleaded gasoline displays a frequency of 78%

significant impact on the effects of monetary policy shocks, this chapter sheds further light on the conditions under which this result holds. Specifically, this chapter examines if the result is sensitive to the consideration of the multi-dimensionality of sectoral heterogeneity. The basic idea is that heterogeneity in price stickiness is likely to be associated with another dimension of heterogeneity (e.g., returns to scale, as evidenced in Chapter 2). Then, to the extent that this is true, possible interactions of different sources of heterogeneity may have a significant impact on the monetary transmission mechanism. Some authors have already associated heterogeneity in price rigidities to other dimensions of heterogeneity. Peneva (2011) presents empirical evidence that sectors which differ regarding price stickiness also differ in term of labor intensity. Specifically, she finds a positive relationship between the degree of price stickiness and the sectoral labor intensity. Imbs et al. (2011), deriving sectoral Phillips curves for the French economy where sectors differ both regarding price stickiness and labor intensity, simulate aggregate inflation to match actual data. Combining heterogeneity in price stickiness to additional heterogeneities such as production technologies and combination of inputs, Bouakez et al. (2009) find evidence of amplified transmission mechanism in response to monetary shock in the case of the heterogeneous model.

In this chapter after highlighting returns to scale as an additional dimension of sectoral heterogeneity, I show that the amplification effect attributed to heterogeneity in price rigidities is likely to be weakened. That happens through two primary channels. On the one hand, heterogeneity in returns to scale, when considered solely, has a dampening effect on monetary non-neutrality by rendering the Phillips curve steeper. This is due to a lower level of aggregate strategic complementarity. On the other hand, the weakening effect may also come from the interaction between those two dimensions. Indeed as the amplification effect of heterogeneity in price rigidities is mainly driven by the sectors with high price rigidities, the positive association between price rigidities and returns to scale is likely to dampen the contribution of these sectors.

My interest and choice of returns to scale as an additional dimension of heterogeneity is motivated by several factors. In a broader macroeconomic context, the presence of non-constant returns to scale (especially increasing returns to scale) is thought to be playing a larger role than expected in the explanation of economic growth. For example, several papers argue that increasing returns to scale play a large role in the explanation of US economic growth. These papers include Romer (1996), Devereux et al. (1996), Basu and Fernald (1997), Jones (2004) and Diewert and Fox (2008). They also bring evidence of substantial heterogeneity in the degree of returns to scale[2]. Second, in the narrower monetary economics literature, increasing returns to scale has primarily been investigated through the lens of indeterminacy issues and in an attempt to better matches business cycles (Benhabib and Farmer (1994), Farmer and Guo (1994) and Wu and Zhang (2000)). Little attention has been paid to its implication in term of monetary non-neutrality. Finally, following the Chapter 2 of this thesis that evidenced a positive association between returns to scale and price rigidity [3], heterogeneity in returns to scale appears to be a sensible choice for an additional dimension of heterogeneity.

In this chapter, after presenting some stylised facts about heterogeneity in returns to scale in the US economy, I first introduce this dimension of heterogeneity in an otherwise standard New Keynesian (NK) model. The purpose of this is to analyze the impact of heterogeneity in returns to scale (when considering alone) on monetary non-neutrality, before coupling it with the established heterogeneity in price rigidities. Thus, considering an economy where sectors solely differ in term of returns to scale, I find that the sectoral degree of strategic price setting (enabling strategic complementarities or substitutability) is an increasing and convex function of the sectoral returns to scale. That pattern leads to an aggregate level of strategic price setting which is higher in the heterogeneous model, compared to the homogeneous model of returns to scale across sectors. When considering alone, heterogeneity in returns to scale changes the output gap coefficient in the New Keynesian Philips Curve (NKPC). This factor becomes higher in the case of heterogeneity in returns of scale, leading to a weaker and less persistent impact on real output. I call this effect the *dispersion effect* of heterogeneity in returns to scale as it varies with the variance of the distribution of returns to scale increases.

After assessing the impact of heterogeneity in returns to scale on monetary non-neutrality, I combine this new dimension of heterogeneity to the well-established heterogeneity in price rigidity. Thus, in Section 3, I present an NK model with two dimensions of sectoral heterogeneity: price stickiness and returns to scale. This new framework strongly affects the NKPC curve as the new generalized NKPC I derived exhibits an output gap term but also an endogenous shift term (similar to Carvalho (2006)). The computation of the real cumulated effect reveals that besides the dispersion effect previously stated, the presence of two dimensions of heterogeneity is translated into a *two dimensions (2D) interaction effect.* The intuition behind the latter effect

[2]For example, Diewert and Fox (2008) show that over the period from 1950 to 2000, the furniture and fixture industry displayed a return to scale of 1.214, while the chemicals and allied industry showed a return to scale of 2.174.

[3]The economic intuition behind this result is that firms exhibiting higher returns to scale are less sensitive to price misalignment and therefore less prompt to reset their prices.

can be interpreted as follows. While heterogeneity in price rigidities affect affects the "speed" of sectoral reaction to a shock, heterogeneity in returns to scale impacts the "amplitude" of these reactions. The overall impact of these two dimensions of heterogeneity on the monetary non-neutrality will then depend on the dispersion effect and the 2D interaction effect. With this latter effect being sensitive to the relationship between the returns to scale and price rigidity. I argue that sectors with high returns to scale are likely to change their prices less often, i.e., a higher degree of price rigidities. The intuition behind is that higher returns to scale make firms' profit function less concave and therefore less sensitive to possible price misalignment. This lower sensitivity prompt less frequent price reset. A positive correlation between price stickiness and returns to scale is likely to a lower level of monetary neutrality. Indeed, the amplification effect heterogeneity in price is primarily due to the disproportionate effects of the sectors with high price rigidity. A positive correlation entails that those industries are the ones exhibiting higher returns to scale, i.e., lower strategic complementarities (or in some case strategic substitutability). The disproportionate effect of higher rigidities sectors is therefore dampened.

In Section 4, I calibrate the two dimensions of heterogeneity model using data from the US manufacturing sector. I present impulse response functions of output gap following a contractionary interest rate shock, for three different cases. The first case corresponds to a model with homogeneous price stickiness and returns to scale. The second case characterizes a model with heterogeneous price stickiness and homogeneous returns to scale. Finally, the third case describes a model with both heterogeneous price stickiness and returns to scale. The IRF suggest quantitative evidence that the amplified monetary non-neutrality attributed to heterogeneity in price rigidity is sharply reduced when introducing another dimension of heterogeneity.

This chapter adds to the economic literature of the NK model in two primary ways. First, I introduced heterogeneity in returns to scale and show that this heterogeneity, when considered solely, results in a weaker and less persistent effect of monetary shock on the output gap. I also show that this decline in persistence is likely to be more significant while the variance of the distribution of the returns to scale increases. This finding opens comparisons between different countries by the distribution of their respective sectoral returns to scale. The second main contribution is to combine this latter heterogeneity to the widely used heterogeneity in price stickiness. Indeed, besides heterogeneity in price stickiness, some papers have argued that sectors could differ in other aspects. Considering an additional dimension of heterogeneity (namely the returns to scale), this chapter shows that the stronger effect initially implied by heterogeneous price stickiness can be cast doubt by this additional heterogeneity. That suggests that heterogeneity in price candidate may not be the perfect candidate to explain strong and resilient monetary non-neutrality.

The rest of this chapter is organized as follows. In section 2, after presenting some stylised facts, I develop a baseline NK model with heterogeneity in returns to scale and evaluate its impact on monetary non-neutrality. Then in section 3, I set up an NK model where the economy is divided into sectors displaying two dimensions of heterogeneity, namely distinct sectoral returns to scale and price rigidities. Section 4 derives impulse response functions of output gaps using on US manufacturing sub-sectoral data with different stages of heterogeneity. Section 5 concludes.

3.2 Heterogeneity in Returns to scale

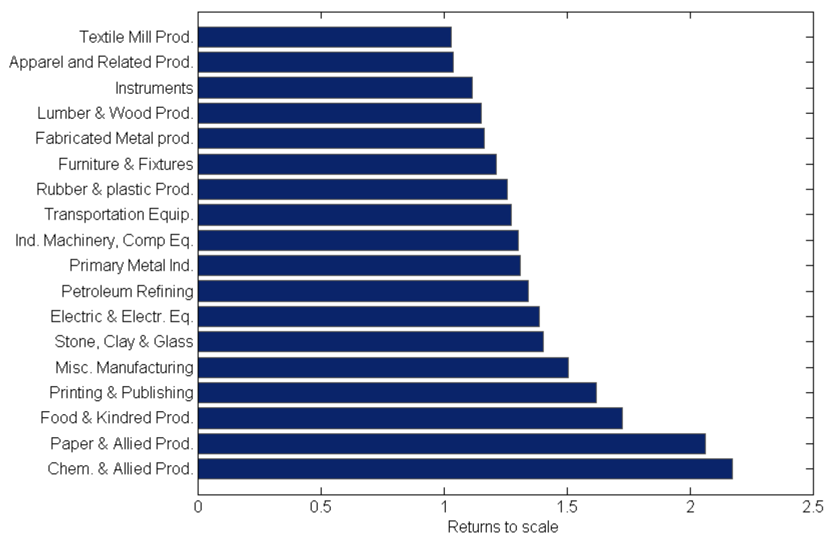
3.2.1 Some Facts about Returns to scale

The presence of increasing returns to scale has major implications for macroeconomic models. While it may help explain the procyclicality nature of productivity (Hall (1990), Basu and Fernald (1997)), increasing returns to scale is also found to play a significant role in explaining economic growth, especially in the US (Romer (1996), Devereux et al. (1996), Basu and Fernald (1997), Jones (2004)). Increasing returns to scale require a certain degree of market power, therefore an imperfect competition set up. Indeed, some extend to market power allows the firms to make a profit and payback for inputs. However, the literature on increasing returns to scale lack a consensus on empirical estimates.
Early attempts to estimate the levels of returns to scale come from influential papers of Hall (1990) and Basu and Fernald (1997). Relaxing to perfect competition framework, Basu and Fernald (1997) rely on a cost minimization solving to derive the degree of returns to scale (this involves regressing the output growth on cost share-weighted average of inputs growth). Conscious of endogeneity issues, Basu and Fernald (1997), however, argue that the use of a weak instrumental variable may lead to substantial bias, especially in a context of small sample[4]. While not finding evidence of a significant level of increasing returns to scale (conversely to Hall (1990), who finds large and sometimes irrealistic levels of returns to scale), Basu and Fernald (1997) bring evidence of substantial heterogeneity in returns to scale, for instance

[4]The set of likely instrumental variables includes military spending, world oil prices or political party of the president. Recently Nekarda and Ramey (2011) use government spending as an instrument for their estimation of industry returns to scales and suggest presences of increasing returns to scale in the US manufacturing sector

between durable and non-durable goods. Diewert and Fox (2008) also provide a framework to estimate the degree of returns to scale for multiple outputs and inputs sectors based on monopolistic competition. Their structure leads to an estimation methodology relying on a Törnqvist combined index of inputs or outputs[5]. Using manufacturing US data from 1950 to 2000, Diewert and Fox (2008) find evidence of significant increasing returns to scale in the manufacturing sector (the aggregate sector displays a returns to scale level of 1.522) while suggesting a difference in returns to scale between durables goods (1.686) and non-durables goods (1.383). They also find evidence of net heterogeneity in the level of these sub-sectoral returns to scale. Indeed the returns to scale computed in that paper range from 1.02 in the textile sector to nearly 2.2 in the chemical products sector. Figure 3.1 presents a bar chart of estimates of sectoral returns to scale in the US manufacturing sectors in Diewert and Fox (2008).[6]. Since monopolistic competition is a fundamental assumption of the New Keynesian model, I will calibrate and simulate my models using the empirical estimates from Diewert and Fox (2008).

Figure 3.1: Estimates of returns to scale in the US manufacturing sector



Source: Diewert and Fox (2008)

[5]The Törnqvist index is a geometric average index weighted by the average expenditure shares in two periods (the current and previous period). For the inputs, the Tornqvist inputs index is computed using KLEMS (Kapital, Labour, Energy, Materials, and Services)

[6]Using 6-digits manufacturing sectors, Chapter 2 of this thesis provides evidence of heterogeneity in sectoral returns to scale, see Figure 2.1

3.2.2 The NKPC with heterogeneity in returns to scale

I consider an economy which is divided into a continuum of sectors indexed by $k \in [0, 1]$. Firm $j \in [0, 1]$ in sector k is indexed by kj. The sectors differ in term of returns to scale which is denoted ψ_k. For simplicity I will suppose that all firms in a given sector k display the same production function with the same return to scale. The production function of firm kj is then[7]:

$$Y_{kj,t} = {L_{kj,t}}^{\psi_k} \tag{3.1}$$

where $L_{kj,t}$ is the labour supplied to firm kj by the representative household and ψ_k denotes the returns to scale of sector k. The representative household derives utiliy from a Dixit-Stiglitz composite of differentiated consumption goods and supplies firm-sepecific labour to monopolistically competitive firms. The distribution of firms across sectors is represented by a density function $f(k)$. Following Carvalho (2006) and Carvalho and Schwartzman (2015)[8], I assume that the representative household solves the following problem:

$$\max_{C_t, L_{kj,t}} \; E_0 \sum_{t=0}^{\infty} \beta^t [\log(C_t) - \int_0^1 f(k) \int_0^1 \frac{L_{kj,t}^{\gamma}}{\gamma} dj dk] \tag{3.2}$$

$$\text{s.t} \;\; P_t C_t = \int_0^1 f(k) \int_0^1 L_{kj,t} W_{kj,t} dj dk + T_t + I_{t-1} B_{t-1} - B_t \tag{3.3}$$

where E_0 denotes the expectation conditional on time 0, β is the discount factor, C_t the consumption of the composite good, P_t the price index of the composite good, , $W_{kj,t}$ the nominal wage of firm kj, T_t denotes lump-sum dividend received from the ownership of intermediate good firms, and B_t the nominal bond associated with interest rate I_t. Let note ε the elasticity of substitution between different varieties of goods. $1/(\gamma - 1) = \varphi$ represents the Frisch elasticity of labour supply. The composite consumption goods (aggregate and sectoral) are defined by:

$$C_t = [\int_0^1 f(k) C_{k,t}^{\frac{\varepsilon-1}{\varepsilon}} dk]^{\frac{\varepsilon}{\varepsilon-1}} \;\; \text{where} \;\; C_{k,t} = [\int_0^1 C_{kj,t}^{\frac{\varepsilon-1}{\varepsilon}} dj]^{\frac{\varepsilon}{\varepsilon-1}}$$

[7]A production function using only labour and displaying increasing returns to scale may seem a bit unusual, all the more that NK model is a short term model, and firms often display constant returns to scale in a short term. I use this production function for a matter a simplification. A more general production function will be for instance $Y_t = (L^{\alpha} K^{1-\alpha})^{\psi}$, with a constant level of capital in a short term. The output elasticity to labour will then be $\alpha\psi$, and be raised by the presence of increasing returns to scale. The qualitative implication of increasing returns to scale would not be changed by the latter production function.

[8]I assume that the intertemporal elasticity of substitution in consumption is equal to 1.

The representative household's intra-temporal cost minimization problem leads to the following downward sloping demand curve:

$$C_{kj,t} = f(k)(\frac{P_{kj,t}}{P_t})^{-\varepsilon} C_t \tag{3.4}$$

$$\text{where} \;\; P_t = [\int_0^1 f(k) P_{k,t}^{1-\varepsilon} dk]^{\frac{1}{1-\varepsilon}} \;\; \text{and} \;\; P_{k,t} = [\int_0^1 P_{kj,t}^{1-\varepsilon} dj]^{\frac{1}{1-\varepsilon}} \tag{3.5}$$

Solving for the inter-temporal representative consumer optimisation problem, I derive the following first order conditions (The Euler Equation and the Labour supply equation):

$$E_t[(\frac{C_{t+1}}{C_t})^{-1} \frac{P_t}{P_{t+1}} I_t] = \frac{1}{\beta} \;\; \text{and} \;\; \frac{W_{kj,t}}{P_t} = L_{kj,t}^{1/\varphi} C_t \tag{3.6}$$

In this first specficiation, I consider that within each sector, all firms set their prices thanks to a time dependent process *a la Calvo* (Calvo (1983)). Thus at each period, firm kj can change its price with a fixed probability λ. For now, λ is the *same* for all sectors. When firm kj has the chance to change its price, it will choose its new price $P^*_{kj,t}$ to maximise its future discounted profit subject to the downwards sloping demand curve. Using with the market clearing condition in the goods market $C_{kj,t} = Y_{kj,t}$, the firm's reset price solves:

$$\max_{P^*_{kj,t}} E_t \sum_{s=0}^{\infty} \beta^s (1-\lambda)^s \Lambda_{t,t+s} [P^*_{kj,t} Y_{kj,t+s} - W_{kj,t+s} L_{kj,t+s}] \;\; \text{s.t} \;\; Y_{kj,t+s} = f(k)(\frac{P^*_{kj,t}}{P_{t+s}})^{-\varepsilon} Y_{t+s} \tag{3.7}$$

$\Lambda_{t,t+s}$ represents the stochastic nominal discount factor between periods t and $t+s$. Introducing increasing returns to scale into the production function of the monopolistically competitive firms, implies an upper bound for those returns to scale in order to maintain concavity of the profit function. This was mentioned in Chapter 2 and proved in Appendix 2.7.1. The upper bound is equal to $\psi^* = \frac{\varepsilon\gamma}{\varepsilon - 1}$. For a sectoral returns to scale below this threshold[9] ψ^*, I derive an expression for the optimal reset price of firm kj:

$$(P^*_{kj,t})^{1-\varepsilon+\frac{\varepsilon\gamma}{\psi_k}} = \frac{\varepsilon}{\psi_k(\varepsilon-1)} \frac{E_t \sum_{s=0}^{\infty} (1-\lambda)^s \Lambda_{t,t+s} Y_{t+s}^{1+\gamma/\psi_k} P_{t+s}^{1+\varepsilon\gamma/\psi_k}}{E_t \sum_{s=0}^{\infty} (1-\lambda)^s \Lambda_{t,t+s} Y_{t+s} P_{t+s}^{\varepsilon}} \tag{3.8}$$

$P^*_{kj,t}$ is the same for all firms in sector k that change their price, so that I can just note it $P^*_{k,t}$.

[9] For $\varepsilon = 5$ and $\gamma = 2$, two commnonly accepted values in the literature, $\psi^* = 2.5$ which is above most returns to scale derived in empirical studies. This threshold is then relatively innocuous.

Thus the sectoral price index becomes:

$$P_{k,t} = [\lambda(P^*_{k,t})^{1-\varepsilon} + (1-\lambda)P^{1-\varepsilon}_{k,t-1}]^{\frac{1}{1-\varepsilon}} \tag{3.9}$$

I then derive the log-deviation around the steady state of the optimal sectoral reset price:

$$p^*_{k,t} = (1-\beta(1-\lambda))\sum_{s=0}^{\infty}\beta^s(1-\lambda)^s[p_{t+s} + h(\psi_k)y_{t+s}] \tag{3.10}$$

$$\text{where} \quad h(\psi_k) = \frac{1+\varphi}{\varepsilon+\varepsilon\varphi+(\varphi-\varepsilon\varphi)\psi_k} = \frac{1}{\varepsilon}\,\frac{\psi^*}{\psi^*-\psi_k} \tag{3.11}$$

For each sector k, $h(\psi_k)$ represents the degree of strategic price setting[10] i.e. how a firm' s price will change if the aggregate price index increases. This coefficient characterises sectoral strategic complementarities ($h(\psi_k) < 1$)[11] or strategic substitutability ($h(\psi_k) > 1$) [12]. In this NK model with sectoral heterogeneity in returns to scale, the sectoral coefficients $h(\psi_k)$ can be higher than 1, in which case the sector displays strategic substitutability in price setting. Following Proposition 1, I only pay attention to the case where the returns to scale are lower than the cut-off ψ^*. Sectors for which returns to scale belong to the interval $]\psi_1;\psi^*[$ (with $\psi_1 = 1 + \frac{1}{\varphi}$) display strategic substitutability in price setting. Those sectors' firms are likely to decrease their price if aggregate price index increases. Figure 3.2 presents the function h of the degree of strategic price setting (solid line). h is a positive, increasing and convex function of the returns to scale ψ. The red dashed horizontal line (when the "yaxis" is equal to 1) represents the limit between strategic complementarities ($h(\psi) < 1$ i.e., when returns to scale belongs to the interval $[0,\psi_1]$) and strategic substitutabilities ($h(\psi) > 1$ i.e., when returns to scale belongs to the interval $]\psi_1;\psi^*[$). For Figure 3.2, $\psi_1 = 1.5$ and $\psi^* = 2$[13].

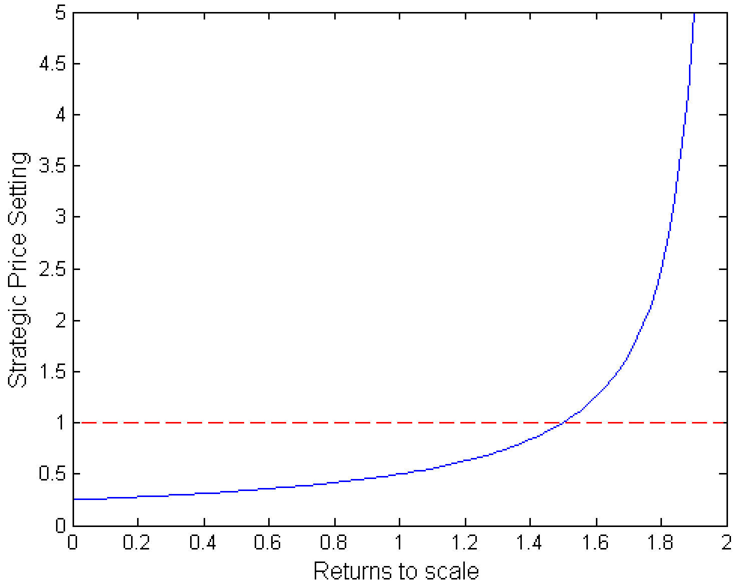
[10] See Woodford (2003), chapter 3, for more details.

[11] In a case of strategic complementarities, there is lower strategic complementarities as the degree of strategic price setting gets closer to 1.

[12] In the standard NK model with homogeneous and linear production function, the degree is strategic price setting is equal to $h(1) = \frac{1+\varphi}{\varepsilon+\varphi}$. Since $h(1) \leq 1$ with equality only in the extreme case where $\varphi = \infty$ (labour supply is infinitely elastic), the standard NK model tends to exibit strategic complementarities in price setting.

[13] This corresponds to $\varepsilon = 4$ and $\gamma = 1.5$, $\varphi = 2$.

Figure 3.2: Degree of strategic price setting and returns to scale



I also derive log-linearized equations of sectoral price index, aggregate price index and downwards sloping demand curve:

$$p_{k,t} = \lambda p^*_{k,t} + (1-\lambda)p_{k-1,t} \quad ; \quad p_t = \int_0^1 f(k)p_{k,t}dk \quad ; \quad y_{k,t} = y_t - \varepsilon(p_{k,t} - p_t) \tag{3.12}$$

Using Equations 3.10 to 3.12, I obtain the New Keynesian Phillips Curve (NKPC) in the case of heterogeneity of returns to scale:

$$\pi_t = \beta E_t \pi_{t+1} + g(\lambda)\Omega(f)\, y_t \text{ with } g(\lambda) = \frac{\lambda(1-(1-\lambda)\beta)}{(1-\lambda)} \text{ and } \Omega(f) = \int_0^1 f(k)h(\psi_k)dk \tag{3.13}$$

The above NKPC differs from the standard NKPC via the coefficient of output gap. Heterogeneity in returns to scale affects the response of inflation to output gap deviation from steady state. $\Omega(f)$ can be seen as is the *degree of aggregate strategic price setting.* When $\Omega(f) < 1$ (*resp.* $\Omega(f) > 1$), this coefficient describes aggregate strategic complementarities (*resp.* aggregate strategic substitutability). In the standard model with homogeneous degree of price flexibility of λ and homogeneous returns to scale $\bar{\psi}$ (usually equal to 1), the coefficient of the output gap is $g(\lambda)h(\bar{\psi})$. Since the function h is convex, using the Jensen's Inequality, one note that:

$$\Omega(f) = \int_0^1 f(k)h(\psi_k)dk > h(\bar{\psi})$$

This means that, for the same frequency of price change λ, the coefficient of the output gap in the heterogeneous returns to scale model will be *higher* than the one associated with the model of homogeneous returns to scale (calibrated at the mean)[14]. Thus, everything else equal, heterogeneity in returns to scale reduces the monetary non-neutrality by making the short-run philips curve *steeper*. The higher $\Omega(f)$ is, the weaker the effect of monetary shocks on real output will be. $\Omega(f)$ itself will depend on the distribution f of returns to scale.

3.2.3 The cases of Uniform and Beta distributions

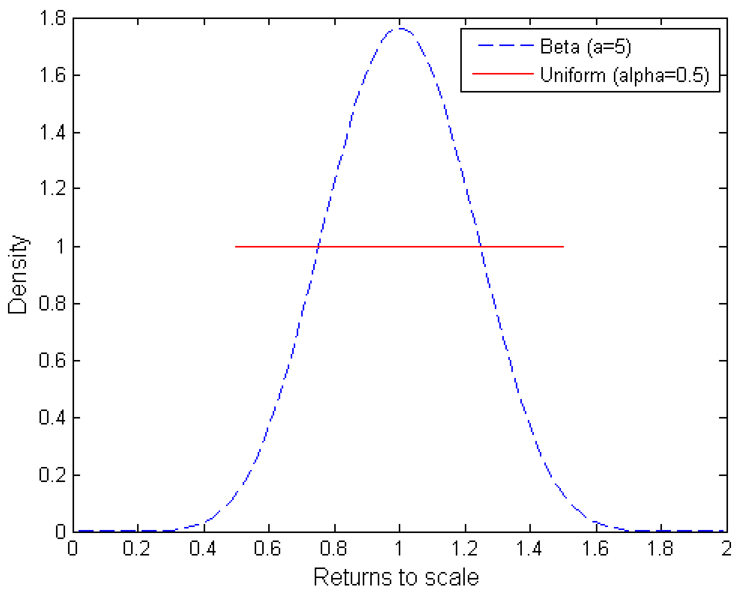
There are various evidence of heterogeneity in sectoral returns to scale. However, the distribution function of these returns to scale is hard to assess. In this section, I consider two types of distribution functions, center around the standard value of constant returns to scale 1. I consider uniform and beta types of distributions whose specification are given below. Both distributions are parametrized, respectively, with parameters α and a.

$$\text{Uniform: } f_\alpha(\psi) = \frac{1}{2\alpha}, \quad \text{for } \psi \in [1-\alpha; 1+\alpha]; \quad \text{var}(f_\alpha) = \frac{\alpha^2}{3}; \quad \alpha \in]0;1]$$

$$\text{Beta: } d_a(\psi) = \frac{\psi^{a-1}(\psi^* - \psi)^{a-1}}{B(a,a)\psi^{*2a-1}} \quad \text{for } \psi \in [0;2]; \quad \text{var}(d_a) = \frac{1}{4(2a+1)}; \quad a > 1$$

Figure 3.3 represents two distribution functions (uniform and beta) centered around 1.

Figure 3.3: Beta and uniform distributions of returns to scale



[14]The interesting feature about the aggregate strategic price setting is that, assuming an homogeneous returns to scale $\bar{\psi}$ usually leads to strategic complementarities (i.e., $h(\bar{\psi}) < 1$) while the assumption of heterogeneity in returns to scale can lead to aggregate strategic substitutability (i.e., $\Omega(f) > 1$). This pattern has strong qualitative and quantitative implications as I will in the model with two dimensions of heterogeneity.

From the previous section, one already knows that $\Omega(f_\alpha)$ and $\Omega(d_a)$ are both higher that $h(1)$, which corresponds to the case of homogeneous linear production function. For uniform distribution the variance of the distribution gets larger as α increases, while for the beta distributions the variance increases as the parameter a ($a > 1$) gets closer to 1. In the next proposition, I derive how $\Omega(f_\alpha)$ and $\Omega(d_a)$ evolve with the variance of the distribution, which is directly related to the parameters α and a:

Proposition 3. *$\Omega(f_\alpha)$ (resp. $\Omega(d_a)$) is an increasing (resp. decreasing) function of α (resp. a).*

In order to prove Proposition 2, one just need to derive Ω_{f_α} and Ω_{d_a} as follows:

$$\Omega(f_\alpha) = \frac{\psi^*}{2\alpha\varepsilon} ln(\frac{(1-\alpha) - \psi^*}{(1+\alpha) - \psi^*})$$

$$\Omega(d_a) = \int_0^{\psi^*} \frac{1}{\varepsilon} \frac{\psi^*}{\psi^* - \psi} \frac{\psi^{a-1}(\psi^* - \psi)^{a-1}}{B(a,a)\psi^{*2a-1}} d\psi = \frac{1}{\varepsilon} \frac{B(a,a-1)}{B(a,a)} = \frac{1}{\varepsilon} \frac{2a-1}{a-1}$$

A straightforward corrolary of the previous proposition is that, for uniform or beta distributions of returns to scale centered around 1 (or another mean value), a larger variance of the returns to scale distribution will lead to a steeper NKPC (everything else equal). Thus, a larger variance of the distribution of the returns to scale results in a weaker effect of monetary shocks on real output. The degree of the real output response to monetary shock can be measured through the persistence and real cumulative effect.

3.2.4 Persistence and Cumulative real effect

In this section, I derive the persistence and cumulative real effect on real output as a function of the variance of a beta distribution of returns to scale centered around the standard value 1[15]. The persistence measures to what extend the effect on real output fades away, while the cumulative real output measures the overall effect on real output. Following Woodford (2003), I consider a permanent increase in nominal aggregate demand[16], noted $D_t = P_t Y_t$, where P_t is the price level and Y_t is the output level. That unexpected disturbance permanently increases $\log(D_t)$ by one unit at time $t = 0$ i.e. $E_0(\log(D_t)) = 1$ for $t \geqslant 0$. I also assume that before the shock ($t < 0$), $P_t = Y_t = D_t = 1$.

[15]In Chapter 2, Figure 2.1 presents evidence of a distribution of returns to scale that is bell-shaped and roughly centered around 1.

[16]In Appendix 3.6.1, I show that the results remain the same when assuming a AR(1) process on aggregate demand instead of a permanent increase.

Concerning the returns to scale, they are symetrically beta distributed over the interval $[0; 2]$ with a mean of 1 ($\psi^* = 2$). The extreme case of $a = \infty$ (*resp.* $a = 1$) correponds to the case where the variance is equal to 0 (*resp.* 1/12) i.e. the homogenous case where all sectors display the same returns to scale of 1 (*resp.* an uniform distribution over the interval $[0; 2]$). A nonzerol variance of the distribution is synonymous of heterogeneity in returns to scale. For a given beta distribution of returns to scale d_a, the NKPC is given by:

$$\pi_t = \beta E_t \pi_{t+1} + g(\lambda)\Omega(d_a)\ y_t$$

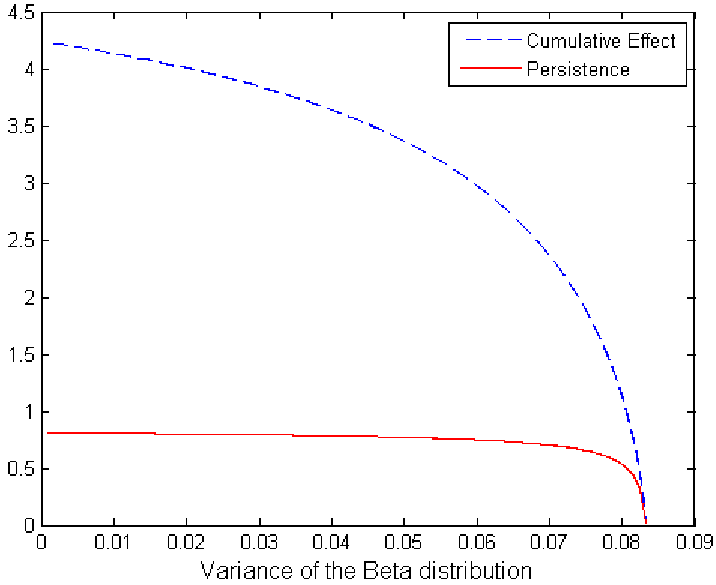
where $\pi_t = p_t - p_{t-1}$. The lowercase variable p_t and y_t denote the *log* of capital variable and also in this case the log-deviation to the steady state. Woodford (2003) shows that for $t \geqslant 0$, $y_t = \delta_a^{t+1}$, where δ_a is the smallest root of the second order degree polynomial:

$$\beta X^2 - (1 + \beta + g(\lambda)\Omega(d_a))X + 1 = 0.$$

The persistence of the real output is then given by δ_a, while the cumulative real effect ($\sum_0^\infty y_t$) is given by $\frac{\delta_a}{1-\delta_a}$. For a fixed value of frequency of price change $\lambda = 0.26$[17], Figure 3.4 present the persistence and cumulative real effect (CRE) of the output gap as a function of the variance of the beta distribution. One can notice that the impact of the variance of the beta distribution is more pronounced on the cumulative real effect than on the persistence. Also, a higher dispersion or variance of the distribution of the returns to scale (a lower a) leads to a lower persistence and weaker effect of the monetary shock on the output gap. I called this effect the *dispersion effect* of heterogeneity in returns to scale.

[17]Bils and Klenow (2004) derive an average frequency of price change of 26% for the US.

Figure 3.4: Cumulative effect and persistence



3.3 The model with two dimensions of heterogeneity

3.3.1 A generalized NKPC

I now consider the case where the economy displays two dimensions of heterogeneity. Indeed the economy is now divided into various sectors k that differ both in terms of returns to scale ψ_k and the degree of price stickiness λ_k. I consider the same framework as in the model with heterogeneity in returns to scale but add the sector-specific frequency of price change λ_k. The results are similar up to firm kj optimal reset price. In this new set-up, when firm kj has the chance to set its price, it will choose a new price $P^*_{kj,t}$ to solve:

$$\max_{P_{kj,t}} E_t \sum_{s=0}^{\infty} (1-\lambda_k)^s \Lambda_{t,t+s} [P_{kj,t} Y_{kj,t+s} - W_{kj,t+s} L_{kj,t+s}]$$

$$\text{s.t} \quad Y_{kj,t+s} = (\frac{P_{kj,t}}{P_{t+s}})^{-\varepsilon} Y_{t+s}$$

Similarly, using the market clearing condition in the goods markets, the production function and the downward sloping demand curve, I derive an expression for the optimal reset price:

$$(P^*_{kj,t})^{1-\varepsilon+\frac{\varepsilon\gamma}{\psi_k}} = \frac{\varepsilon\gamma}{\psi_k(\varepsilon-1)} \frac{E_t \sum_{s=0}^{\infty} (1-\lambda_k)^s \Lambda_{t,t+s} Y_{t+s}^{1+\gamma/\psi_k} P_{t+s}^{1+\varepsilon\gamma/\psi_k}}{E_t \sum_{s=0}^{\infty} (1-\lambda_k)^s \Lambda_{t,t+s} Y_{t+s} P_{t+s}^{\varepsilon}}$$

The firms in sector k that change their prices choose the same reset price $P^*_{k,t}$ so that the sectoral price index is simply:

$$P_{k,t} = [\lambda_k (P^*_{k,t})^{1-\varepsilon} + (1-\lambda_k) P_{k,t-1}^{1-\varepsilon}]^{\frac{1}{1-\varepsilon}}$$

Then I derive the log deviation around the steady state of the optimal sectoral reset price and sectoral price index:

$$p^*_{k,t} = (1-\beta(1-\lambda_k)) \sum_{s=0}^{\infty} \beta^s (1-\lambda_k)^s [p_{t+s} + h(\psi_k) y_{t+s}] \tag{3.14}$$

$$p_{k,t} = \lambda_k p^*_{k,t} + (1-\lambda_k) p_{k,t-1} \tag{3.15}$$

Using equations 3.12, 3.14 and 3.15, I obtain the following New Keynesian Phillips Curve relative to the two dimensions of heterogeneity:

$$\pi_t = \beta E_t(\pi_{t+1}) + \frac{1}{\varepsilon}[\int_0^1 f(k)g(\lambda_k)y_{k,t}dk] + [\int_0^1 f(k)(h(\psi_k) - \frac{1}{\varepsilon})g(\lambda_k)dk]y_t \tag{3.16}$$

$$\text{with} \;\; g(\lambda_k) = \frac{\lambda_k(1-(1-\lambda_k)\beta)}{(1-\lambda_k)} \;\; \text{and} \;\; h(\psi_k) = \frac{1}{\varepsilon}\,\frac{\psi^*}{\psi^* - \psi_k}$$

Let note $\tilde{h}$ the following function:

$$\tilde{h}(\psi_k) = h(\psi_k) - \frac{1}{\varepsilon} = \frac{1}{\varepsilon}(\frac{\psi^*}{\psi^* - \psi_k} - 1)$$

So I can rewrite the generalized New Keynesian Philips Curve as :

$$\pi_t = \beta E_t(\pi_{t+1}) + \left(\int_0^1 f(k)\tilde{h}(\psi_k)g(\lambda_k)dk\right)y_t + \frac{1}{\varepsilon}\left(\int_0^1 f(k)g(\lambda_k)y_{k,t}dk\right) \tag{3.17}$$

This generalized NKPC includes two output gap related terms. There is one aggregate output gap term (global effect) and one endogenous output gaps term (sectoral effect). This generalized NKPC form is similar to the one derived in Carvalho (2006) in the case of heterogeneity in price stickiness. In the case of sole heterogeneity in price stickiness (and linear production function), the coefficient of the output gap in the generalized NKPC is

$$(h(1) - \frac{1}{\varepsilon})\int_0^1 f(k)g(\lambda_k)dk \tag{3.18}$$

Once more, introducing heterogeneity in returns to scale affects the coefficient of the output gap in the generalized NKPC. The coefficient of the output gap will depend on the interaction between the sectoral returns to scale ψ_k, and the sectoral degree of price change λ_k. The presence of the additional heterogeneity in sectoral return to scale affects the dynamics in two ways. On the one hand, it modifies the coefficient of the output gap in the generalized NKPC. On the other hand, it also affects the dynamic of the sectoral output gap since sectors with different returns to scale also display different degrees of strategic complementarities.

3.3.2 Cumulative real effects with two dimensions of heterogeneity

I now discuss the implication of the presence of two dimensions of heterogeneity on the cumulative real effect. Facing an unexpected shock (for example, an unexpected increase in aggregate demand), the cumulated real effect on output gap is derived as (see Appendix 3.6.2):

$$CRE(y_t) = \sum_{t=0}^{\infty} y_t = \frac{\int_0^1 \frac{1}{g(\lambda_k)}(\beta(p_{k,0} - 1) + 1)f(k)dk}{\int_0^1 h(\psi_k)f(k)dk} \tag{3.19}$$

The real cumulative effect of the output gap displays two main effects. First, the denominator of the above equation reflects the dispersion effect characterized in the previous section of this chapter. That happens through the aggregate degree of strategic price setting. Thus a wider dispersion of the returns to scale tends to weaken the impact on the real output. However, the overall effect will also depend on the numerator that I describe as being the *2 dimensions (2D) interaction effect*. Indeed, $p_{k,0}$ will depend on both the fraction of firms that can change their prices λ_k and on the strategic price setting $h(\psi_k)$ which depends on of the returns to scale ψ_k. Intuitively speaking, heterogeneity in price stickiness can be seen as affecting the speed of reaction across sectors while heterogeneity in returns to scale impacts the amplitude of reaction across sectors. This determines the 2D interaction effect that depends on the relationship between the two dimensions of heterogeneity.

Chapter 2 of this thesis uncovers the relationship between returns to scale and price rigidity. It provides theoretical and empirical evidence that returns to scale and price rigidities are positively associated, i.e., firms with higher returns to scale are likely to change their goods price less often. The intuition behind this result is that high returns to scale makes the profit function less concave and therefore less sensitive to price misalignment.

As price stickiness and returns to scale are positively correlated, the 2D interaction effect will tend to diminish the effect on the output gap. Indeed, the amplification effect attributed to heterogeneity in price stickiness is mainly driven by the sectors with low price flexibility. In the case where those sectors are also the ones with high returns to scale (low degree of strategic complementarities), their amplification role may then be dampened. Overall (i.e., also considering the dispersion effect), the introduction of returns to scale tends to argue that the stronger effect attributed to heterogeneity in price stickiness is mitigated.

3.4 A quantitative analysis

3.4.1 Data for US manufacturing subsectors

I now calibrate the previous model using data on US manufacturing sector. In section 3.2.1, I present the degrees of returns to scale for about 18 2-digit SIC industries in the manufacturing US sector estimated by Diewert and Fox (2008). Concerning specific industries frequencies of prices of price change, Peneva (2011) derives the frequencies of price change of 29 SIC industries accounting for about 69% of the US Consumer expenditure survey (CEX). Those frequencies are computed using Bils and Klenow (2004) comprehensive dataset. She also provides the weight of each of these industries in the consumer basket. Merging these two sources of information, I derive next Table 3.1 which presents the degree returns to scale, the frequencies of price changes and the weight for 17 manufacturing industries[18]. These information represent ψ_k, λ_k and $f(k)$ in the previous model setting. The industries share $f(k)$ are computed as follows $f(k) = \frac{w_{C,k}}{\sum_{k=1}^{17} w_{C,k}}$, where $w_{C,k}$ is the weight of industry k in the Consumer expenditures survey CEX. The 17 industries account for $\sum_{k=1}^{17} w_{C,k} = 27\%$ of the CEX. The average frequency of price change is equal to 30.8%, while the average returns to scale equals to 1.51[19].

Table 3.1: Returns to scale and frequency of price change by industry

Sector Code	Sector name	Returns to scale	Price change (%)	Weight (%)
22	Textile mills	1.029	14.97	0.74
23	Apparel and allied products	1.038	33.47	15.26
38	Instruments	1.114	10.85	2.02
24	Wood products	1.153	21.6	0.04
34	Fabricated metals	1.163	12.38	0.44
25	Furniture and related products	1.214	23.01	4.38
30	Plastics and rubber products	1.258	29.91	1.10
37	Transportation equipments	1.274	18.96	1.03
35	Machinery	1.304	29.72	3.09
29	Petroleum	1.344	72.18	12.80
36	Electrical equipments	1.389	26.26	4.93
32	Stone, Clay and Glass	1.404	16.16	0.51
39	Miscellaneous manufacturing	1.508	17.38	6.44
27	Printing and related activities	1.621	8.28	2.68
20	Food and kindred products	1.724	31.53	34.65
26	Paper products	2.062	17.64	1.58
28	Chemical products	2.174	15.05	8.31
	US Manufacturing sector	1.51	30.8	100

Source: Diewert and Fox (2008) , Peneva (2011)

[18]There is no data for frequency of price change for the Primary metal industry.
[19]The overall aggregate manufacturing returns to scale is about 1.51.

3.4.2 An interest rate shock

The previous sections provide theoretical evidence that adding heterogeneity in returns to scale to a model with heterogeneous price stickiness may cast doubt on the amplification mechanism initially suggested by the latter compared to the homogeneous model. To quantitatively test this result, I simulate the impulse response function (IRF) of output gap to a contractionary interest rate[20] shock in three different cases, calibrated using Table 1. The first case corresponds to a standard model of homogenous price flexibility $\bar{\lambda} = 32.3\%$ and homogenous constant returns to scale $\psi = 1$. The second case corresponds to the setting of heterogeneous frequencies of price change, explored by previous literature. In the second case, the returns to scale are still homogeneous $\psi = 1$ while while price flexibility λ_k differ across sector k weighted by $f(k)$. According to previous literature, the cumulated real effect on the output gap is expected to be larger in the second case compared to the first case. Finally, the third case corresponds to the case where sectors k, weighted by $f(k)$, differs both in term of price flexibility λ_k and returns to scale ψ_k. My main interest is to compare the IRF from the third case to the previous two cases, i.e. to see how introduction of this valid (because there is substantial heterogeneity in sectoral returns to scale in the economy) and sensible (because returns to scale is likely to be related to price flexibility) additional dimension of heterogeneity in returns to scale affects the amplification effects suggested by heterogeneity in price stickiness.

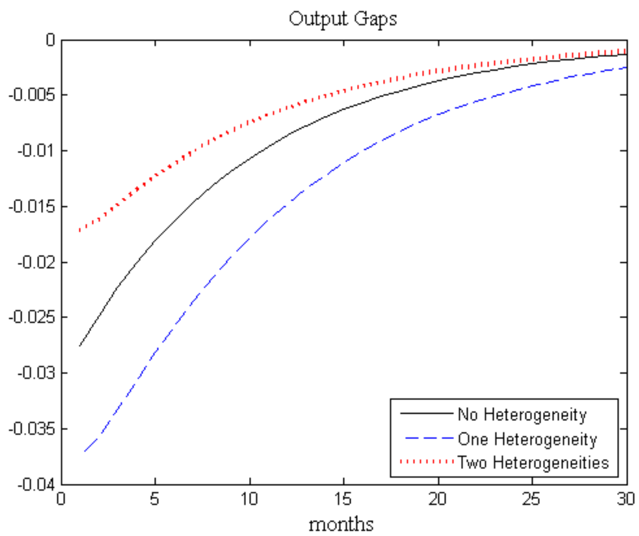
Figure 3.5 presents the IRF of the output gap to a contractionary interest rate shock in the three cases described above. The solid line IRF presents the first case (homogeneous case). The dashed line presents the second case (one heterogeneity) while the dotted line IRF characterizes the third case (two heterogeneities). As expected by the previous literature, the real effect on output gap is larger in presence heterogeneity in price stickiness (second case) compared to the homogeneous price stickiness (first case) in the presence of homogenous constant returns to scale. This amplification can be measured by the ratio of the real cumulative effect. This ratio is equal to 1.62 which means that the real effect on output in the case of heterogeneity in price rigidity is 62% larger than the one in the case of homogenous price rigidity. However, when I consider an additional dimension of heterogeneity (third case), one notice that the amplification effects are sharply reduced, since the overall effect on output gap in the third case is even smaller than the one in the first case (30% weaker than the homogeneous case). This supports the theoretical findings that the amplification effects suggested by heterogeneity in returns to scale are sensitive to consideration of other dimensions of heterogeneity.

[20] The interest rate follows a usual Taylor rule. See Appendix 3.6.3 for details on the chosen parameters.

Figure 3.6 presents the same framework as previously with the exception that the homogeneous returns to scale for the case 1 and 2 is no longer equal to 1 but calibrated at the mean of return to scale $\bar{\psi} = 1.51$. Then, now, the first case is characterized by homogenous price flexibility $\bar{\lambda}$ and returns to scale $\bar{\psi}$. The second case corresponds to the sole heterogeneity in price flexibility but homogenous and returns to scale $\bar{\psi}$, while the third case, as previously, corresponds to both heterogeneities in price rigidity and returns to scale. One notice that Figure 3.6 displays the same pattern with Figure 3.5. The amplification effect of heterogeneity in price stickiness is about 76% compared to the homogeneous case. However, adding heterogeneity in returns to scale clear this previous effect. The CRE in the first and third case are about the same. Both Figure 3.5 and Figure 3.6 suggest that this additional dimension of heterogeneity in returns to scale tends to sharply dampen the amplification effect initially implied by heterogeneity in price stickiness.

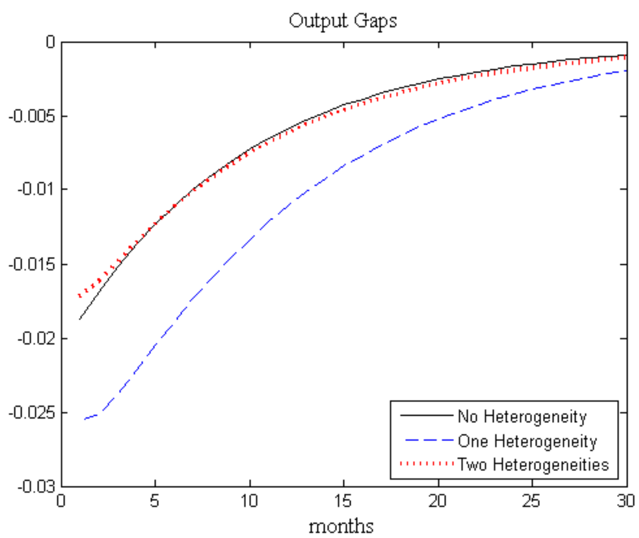
The IRF presented in Figure 3.5 and 3.6 are derived using the following parameters: $\beta = 0.9975$ (with corresponds to a 3% per year), $\varepsilon = 4$ and $\varphi = 1.5$. ε and φ are chosen so that the returns to scale threshold ψ_* is higher than the maximum returns to scale in Table 1, 2.174. Robustness checks presented in Appendix 3.6.4 confirm similar results with another set of parameters: $\beta = 0.9975$, $\varepsilon = 6$ and $\varphi = 1.2$.

Figure 3.5: Output gaps impulse response function to a contractionary interest rate shock with the homogenous returns to scale equals to 1



Notes: This figure presents the different impulse response functions for the output gap after a contractionary interest rate shock. The dark line correspnds to the case where both the price rigidity and returns to scale ($\psi = 1$) are the same for all sectors. The dash blue line corresponds to the case where the returns the scale is still homogenous (equal to 1), but with heterogeneity in price rigidity. The dotted red line corresponds to the case with heterogeneity in returns to scale and price rigidity, calibrated by Table 3.1. Source: Author' simulation

Figure 3.6: Output gaps impulse response function to a contractionary interest rate shock with the homogenous returns to scale equals to 1.51



Notes: This figure presents the different impulse response functions for the output gap after a contractionary interest rate shock. The dark line correspnds to the case where both the price rigidity and returns to scale ($\psi = 1.51$) are the same for all sectors. The dash blue line corresponds to the case where the returns the scale is still homogenous (equal to 1), but with heterogeneity in price rigidity. The dotted red line corresponds to the case with heterogeneity in returns to scale and price rigidity, calibrated by Table 3.1. Source: Author' simulation

3.5 Conclusion

In this chapter, I introduced two dimensions of heterogeneity, namely the degree of price stickiness and the returns to scale, in an otherwise standard New Keynesian model. Heterogeneity in price stickiness has been widely explored in new extensions of the NK model. This heterogeneity is expected to deliver a more persistent effect of a monetary shock in the presence of strategic complementarities. Based on the recent empirical literature, I argued that sectors that differ in term of price stickiness are likely to vary in term of returns to scale. Combining these two dimensions of heterogeneity, I can cast doubt on the amplification previously implied by the heterogeneity in price stickiness. The overall impact is disaggregated into two main effects: the dispersion effect and the interaction effect. This finding emphasizes the importance of multidimensionality of heterogeneity in the assessment of the real effects of monetary shock.

3.6 Appendix 2

3.6.1 An AR(1) process on aggregate demand

$D(t) = P(t)Y(t)$ is the aggregate nominal demand. The logarithm of aggregate demand is then $d_t = p_t + y_t$. Again, the lowercase variable denote the log of the capital variables. I now consider that the growth rate of the aggregate nominal demand $\Delta d(t)$ follows an AR(1) process, so that $\Delta d_t = \rho \Delta d_{t-1} + \epsilon_t$. Following Woodford (2003) specification, I consider an initial shock at time $t = 0$ and size $\epsilon_0 = 1 - \rho$ with $0 < \rho < 1$. Before the shock, I assume $P_t = Y_t = D_t = 1$ so that $p_t = y_t = d_t = 0$ for $t < 0$. This specification of the growth rate of the aggregate nominal demand leads to $d(t) = 1 - \rho^{t+1}$ for $t \geqslant 0$. Using the NK Phillips Curve, I can derive the law of motion of the price index and subsequently the one for real output. With a beta distribution d_a of returns to scale around 1, the NKPC can be then written as:

$$p_t - p_{t-1} = \beta E_t(p_{t+1} - p_t) + g(\lambda)\Omega(d_a)(d_t - p_t) \tag{3.20}$$

Denoting $\tilde{p}_t = E_0(p_t) - 1$, one can derive the following equation:

$$\beta\tilde{p}_{t+1} - (1 + \beta + g(\lambda)\Omega(d_a))\tilde{p}_t + \tilde{p}_{t-1} = g(\lambda)\Omega(d_a)\rho^{t+1} \tag{3.21}$$

Let note κ the lowest root of the following second order polynomial:

$$\beta X^2 - (1 + \beta + g(\lambda)\Omega(d_a))X + 1 = 0 \tag{3.22}$$

κ is a decreasing function of $\Omega(d_a)$. Thus, solving differential Equation 3.21, I found that:

$$\tilde{p}_t = \kappa\tilde{p}_{t-1} - \frac{g(\lambda)\Omega(d_a)}{\kappa^{-1} - \beta\rho}\rho^{t+1} = -\kappa^{t+1} - \frac{g(\lambda)\Omega(d_a)}{\kappa^{-1} - \beta\rho}(\sum_{s=1}^{t+1}\kappa^{t+1-s}\rho^s) \tag{3.23}$$

So writting

$$E_0(y_t) = -\tilde{p}_t - \rho^{t+1} = \kappa^{t+1} + \frac{g(\lambda)\Omega(d_a)}{\kappa^{-1} - \beta\rho}(\sum_{s=1}^{t+1}\kappa^{t+1-s}\rho^s) - \rho^{t+1} \tag{3.24}$$

The persistence of the real effects will depend on the size of the root κ which itseld depend of the term $g(\lambda)\Omega(d_a)$. The cumulative real effect (CRE) on the output is defined as:

$$CRE(y) = E_0(\sum_{t=0}^{\infty} y_t)$$

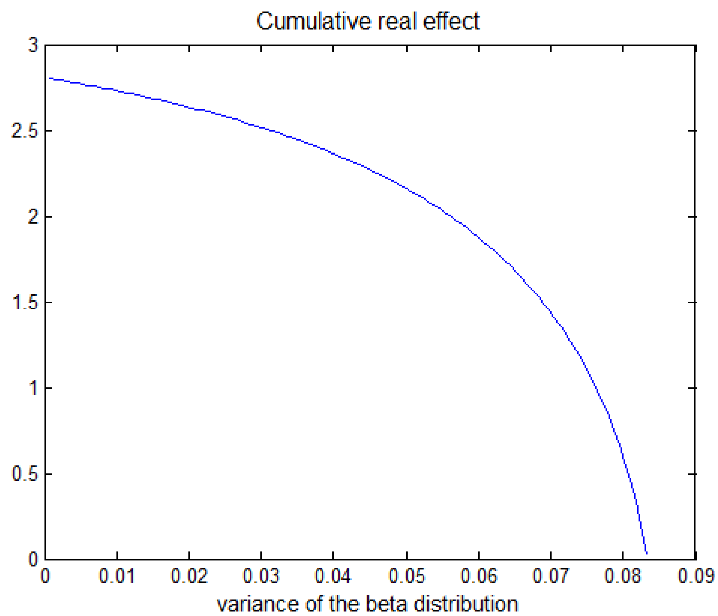
Using Equation 3.24, the cumulative real effects can be expressed as:

$$CRE(y) = \frac{\kappa}{1-\kappa} - \frac{\rho}{1-\rho} + \frac{g(\lambda)\Omega(d_a)}{\kappa^{-1} - \beta\rho} \frac{1}{1-\kappa} \frac{\rho}{1-\rho} \tag{3.25}$$

$$CRE(y) = \frac{\kappa}{1-\kappa}(1 + \frac{g(\lambda)\Omega(d_a)}{1-\beta\rho\kappa}) - \frac{\rho}{1-\rho} \tag{3.26}$$

Again I compute the CRE on real output for different variance of the beta distribution of returns to scale. Similarly to the case of permanent increase in aggregate demand, Figure 3.7 shows that the CRE is a decreasing and concave function of the variance of the beta distribution.

Figure 3.7: Cumulative real effect for a shock on aggregate demand growth AR(1) process



3.6.2 A generalised Cumulative Real Effect

In this section, I derive the cumulative real effect on output in the case of two dimensions of heterogeneity (price stickiness and returns to scale). Using Equations 3.14 and 3.15 of optimal sectoral reset price and sectoral price index, one can obtain the following relationship.

$$-\beta(1-\lambda_k)p_{k,t+1} + (1+\beta(1-\lambda_k)^2)p_{k,t} - (1-\lambda_k)p_{k,t-1} = \lambda_k(1-\beta(1-\lambda_k))(p_t + h(\psi_k)y_t) \tag{3.27}$$

Again, I consider an unexpected permanent increase in nominal aggregate demand $D_t = P_tY_t$ at time $t = 0$. In log deviation, $d_t = p_t + y_t = 1$ for $t \geq 0$. Before the shock $d_t = y_t = p_t = p_{kt} = 0$. I define $\tilde{p}_t = p_t - 1$ and $\tilde{p}_{k,t} = p_{k,t} - 1$. Summing up the previous equation from $t = 0$ to $t = \infty$, one finds:

$$\beta(1-\lambda_k)\tilde{p}_{k,0} - (1-\lambda_k)\tilde{p}_{k,-1} + \lambda_k(1-\beta(1-\lambda_k))\sum_{t=0}^{\infty}\tilde{p}_{k,t} = \lambda_k(1-\beta(1-\lambda_k))(\sum_{t=0}^{\infty}\tilde{p}_t + h(\psi_k)\sum_{t=0}^{\infty}y_t) \tag{3.28}$$

I now multiply the latter equation by density function $f(k)$ and integrate it over the set of different sectors in the economy. Considering that

$$\text{For} \quad t < 0 \quad p_t = p_{k,t} = 0 \quad \text{and} \quad p(t) = \int_0^1 f(k)p_{k,t}dk \tag{3.29}$$

I find that

$$\int_0^1 \frac{(1-\lambda_k)}{\lambda_k(1-\beta(1-\lambda_k))}(\beta\tilde{p}_{k,0} + 1)f(k)dk = (\int_0^1 h(\psi_k)f(k)dk)\sum_{t=0}^{\infty}y_t \tag{3.30}$$

The cumulative real effect on the output gap is then

$$CRE(y_t) = \sum_{t=0}^{\infty}y_t = \frac{\int_0^1 \frac{(1-\lambda_k)}{\lambda_k(1-\beta(1-\lambda_k))}(\beta\tilde{p}_{k,0} + 1)f(k)dk}{\int_0^1 h(\psi_k)f(k)dk} \tag{3.31}$$

Eventually the cumulative real effect on the real output can be written as:

$$CRE(y_t) = \sum_{t=0}^{\infty}y_t = \frac{\int_0^1 \frac{1}{g(\lambda_k)}(\beta\tilde{p}_{k,0} + 1)f(k)dk}{\int_0^1 h(\psi_k)f(k)dk} \tag{3.32}$$

3.6.3 Taylor Rule

Following Carvalho (2006), I consider a Taylor-type interest rate rule given by (in log-deviation):

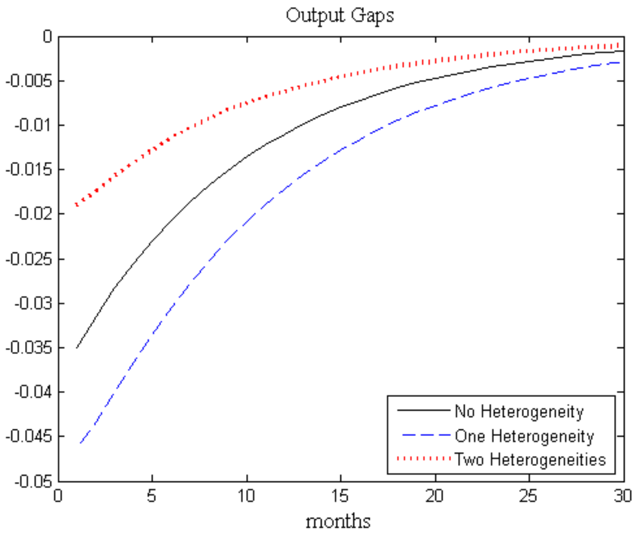
$$i_t = \phi_\pi \pi_t + \psi_y y + \upsilon_t \quad \text{with} \quad \upsilon_t = \rho \upsilon_{t-1} + \epsilon_t$$

where ϵ_t is an i.i.d finite variance and zero mean process. The parameters values are: $\phi_\pi = 1.24$, $\phi_y = 0.33/12$ and $\rho = 0.9$. The variance of ϵ_t is $\sigma_{\epsilon_t} = 0.01$

3.6.4 Alternative IRF

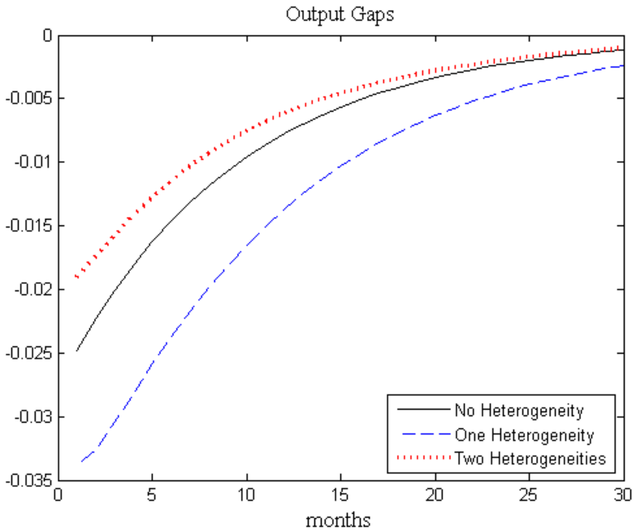
This section presents IRF of output gap using an alternative set of parameters: $\beta = 0.9975$, $\varepsilon = 6$ and $\varphi = 1.2$.

Figure 3.8: Output gaps impulse response function to a contractionary interest rate shock with the homogenous returns to scale equals to 1



Notes: This figure presents the different impulse response functions for the output gap after a contractionary interest rate shock. The dark line correspnds to the case where both the price rigidity and returns to scale ($\psi = 1$) are the same for all sectors. The dash blue line corresponds to the case where the returns the scale is still homogenous (equal to 1), but with heterogeneity in price rigidity. The dotted red line corresponds to the case with heterogeneity in returns to scale and price rigidity, calibrated by Table 3.1. Source: Author' simulation

Figure 3.9: Output gaps impulse response function to a contractionary interest rate shock with the homogenous returns to scale equals to 1.51



Notes: This figure presents the different impulse response functions for the output gap after a contractionary interest rate shock. The dark line correspnds to the case where both the price rigidity and returns to scale ($\psi = 1.51$) are the same for all sectors. The dash blue line corresponds to the case where the returns the scale is still homogenous (equal to 1), but with heterogeneity in price rigidity. The dotted red line corresponds to the case with heterogeneity in returns to scale and price rigidity, calibrated by Table 3.1. Source: Author' simulation

Chapter 4

Macroprudential Policy and Bank Profitability

4.1 Introduction

The Great Financial Crisis (GFC) unveils the crucial linkage between the financial sector and the macroeconomic sector. Since then, many advanced and emerging countries have taken prudential measures to ensure the stability of their financial sectors. These prudential measures are implemented with a macroeconomic perspective (i.e., taking into consideration the effect of the financial industry on the overall economy) instead of a microeconomic view (i.e., only at the individual financial institution level). The widespread use of macroprudential policies raises questions about its effectiveness. Research on its effects on both the financial sector and the macroeconomic framework is still ongoing and faces many challenges (Cerutti, Claessens and Laeven (2017)). One of the main challenges to measure the effectiveness of macroprudential policies comes from the fact that defining financial stability appears to be a tough task. Therefore economists usually consider a wide range of proxies, such as credit growth, asset prices, capital flow or bank risk. Another issue comes from the fact that macroprudential policies usually involve many instruments and objectives, making the estimation of its effects more difficult. Last but not least, there is also an issue related to data availability and coverage because the popularity of macroprudential policies is relatively recent. This chapter contributes to the literature by investigating the effects of macroprudential policies on bank profitability in both advanced and emerging countries, and find evidence of adverse and heterogeneous effects of macroprudential policy tightening on bank profitability, especially in countries with a poorly developed financial sector.

Various factors motivate this interest in bank profitability. First, bank profitability is an essential aspect of the overall condition of the economy. Indeed, as the economic situation worsens, the bank portfolio deteriorates and adversely affects the profitability of the bank. Reversely, weak bank profitability can dampen the banking sector willingness to lend and therefore harm consumption and investment. Recently, the issue of bank profitability gains further attention because banks in several advanced economies have been experiencing weak profitability since the GFC, possibly due to low-interest rates (Alessandri and Nelson (2015), Claessens et al. (2018)). Second, bank profitability is also related to financial system soundness and stability. For example, Demirguc-Kunt and Detragiache (1999) show that bank profitability is a predictor of a financial crisis. Further, in line with many authors (Freixas and Rochet (2008), Admati and Hellwig (2014), Altavilla et al. (2018)), I consider prolonged weak bank profitability as a threat to financial stability. Indeed low profitability banks are not able to generate capital - either by attracting capital or thanks to retained earnings - and to build up reserves against unexpected losses. Thus, low profitability is likely to lead to a less stable financial sector.

This chapter first provides evidence of adverse effects of tightening macroprudential policies on bank profitability, measured by the return-on-assets and the return-on-equity. Second, this chapter suggests evidence of heterogeneous effects relative to the country's income-per-capita level the degree of financial development. Specifically, the less developed is the financial sector (resp., the lower is the income level), the more adverse and significant is the effect of a tightening of macroprudential policy on bank profitability. A fall in Net-interest income drives these adverse effects. The intuition behind this result is that the tightening of macroprudential instruments restrains the bank capability to conduct their activities.

To investigate these effects, I utilize a dataset on macroprudential policy changes. This dataset constructed by Cerutti, Correa, Fiorentino and Segalla (2017) provides quarterly measures of macroprudential policies (classified in four (4) categories and nine (9) different instruments) for 64 countries from 2000Q1 to 2014Q4. This dataset constitutes the primary source of data and captures the intensity and direction of macroprudential policies (i.e., tightening or loosening). For example, tightening (resp. loosening) macroprudential policy consists of increasing (resp. decreasing) the capital or reserve requirements ratio or decreasing (resp. increasing) the loan-to-value ratio. On the other hand, I used the IMF-FSI (International Monetary Fund-Financial Stability Indicator)to extract data on bank profitability, bank-related variables, and macroeconomic variables. I also use the IMF WEO 2014 classification to distinguish between advanced and emerging countries. Concerning the econometric methodology, the fast-growing literature on the effectiveness of macroprudential policies has implemented some estimation methodologies to deal with several challenges. These challenges include the need to control for global and domestic factors, isolating the effects of macroprudential policies from other policies (such as monetary and fiscal) and endogeneity issues (Galati and Moessner (2018)). In this chapter, Following Altavilla et al. (2018), our preferred estimation method is then the dynamic fixed-effect estimator. This specification allows controlling for time and country invariant omitted bias, while the size and quarterly feature of our database dampen potential Nickell bias (Nickell (1981)) and reverse causality.

After implementing this methodology, I find evidence of a negative and significant effect of a tightening macroprudential policy on both return-on-assets and return-on-equity. return-on-assets (roa) and the Return-on-Equity (roe) are bank profitability measures that capture how deposit- takers use their assets and capital efficiently to generate income. The results suggest that a one-time tightening of one the macroprudential instruments leads to a decrease in return-on-assets (resp. return-on-equity) by an average of 2.75 percentage points (resp.22.6 percentage points). Following this baseline results, I use an interaction model to investigate the effects across different income and financial development level. I find evidence of heterogeneous effects across these two dimensions. The adverse effect of a tightening macroprudential policy on bank profitability seems to be mostly driven by Emerging countries. Indeed, this adverse effect tends to get smaller when the GDP per capita increases or the financial sector is more developed (the adverse effect even becomes insignificant for large enough GDP per capita and sufficiently developed financial sector). I then argue that the level of financial sector development plays a more prominent role when it comes to assessing the effect of macroprudential policy on bank profitability.

This chapter is related to the recent and flourishing literature that attempts to document the effects of macroprudential policies on various macroeconomic and banking variables, such as housing price, credit growth or bank risk, using either cross-country panel data or micro-data. This literature includes Tovar et al. (2012), Zhang and Zoli (2014) Vandenbussche et al. (2015),Altunbas et al. (2018), among other. Within that literature, the contribution of this chapter is twofold. First, to the best of my knowledge, this chapter is one of the few studies that investigate the effects of a macroprudential policy instruments index on bank profitability by distinguishing the direction of the macroprudential policy change[1]. Second, the main contribution of this chapter is to document the heterogeneous effect of macroprudential policy on bank profitability across different income level and financial development degree. These considerations need to be taken into account when setting macroprudential policy changes.

The rest of this chapter is organized as follows. The next section presents the data some descriptive statistics. Section 3 shows the results of the baseline model. Section 4 investigates the heterogeneous effects and the crucial role of financial sector development. Section 5 concludes.

[1]Previous papers use datasets that document macroprudential changes as a mere dummy variable, regardless of its directions.

4.2 Data and Descriptive Statistics

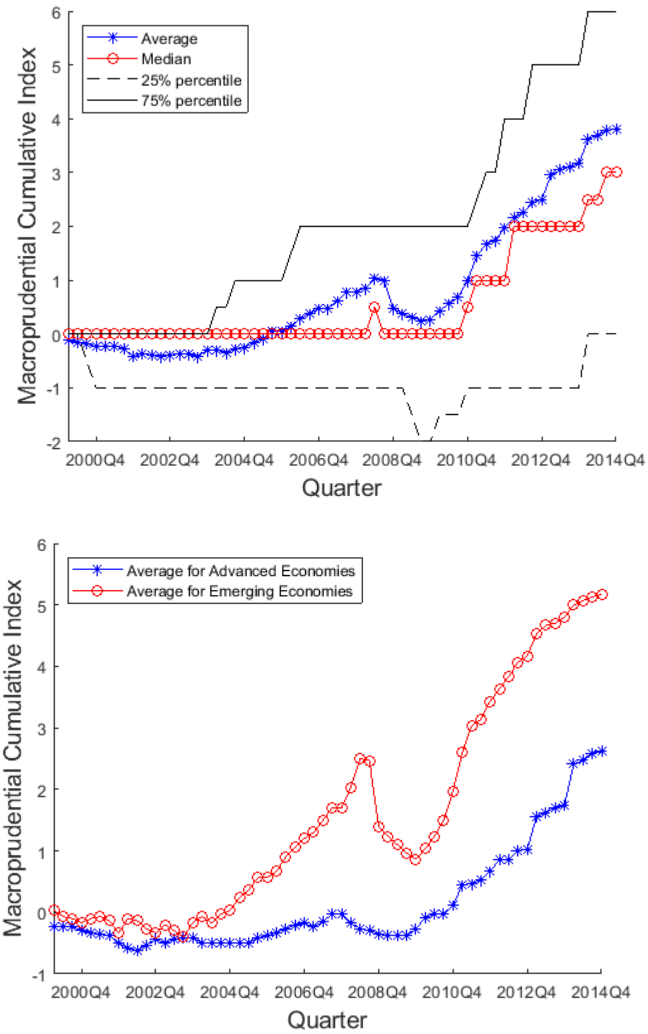
4.2.1 Macroprudential policies

To investigate the relationship between macroprudential policies and bank profitability, I utilize a cross-country database provided by Cerutti, Correa, Fiorentino and Segalla (2017). This new database captures the quarterly changes of nine prudential instruments for sixty-four countries covering the period going from the first quarter of 2000 to the last quarter of 2014. This database provides cumulative prudential measures, measured by summing the individual indexes since the first quarter of 2000. A one (1) point increase (resp. decrease) in this cumulative index means a tightening (resp. loosening) of the macroprudential framework.[2]. Figure 4.1 shows the development of the cumulative macroprudential policies index over the period 2000Q1 to 2014Q4. The top panel presents the evolution of cumulative macroprudential combined index ($Mapp$) for all 64 countries (average, median, $25th$ and the $75th$ percentiles). It shows that while the macroprudential policies were roughly balanced before 2010(average and median that are close or equal to 0), there has been a general tightening of macroprudential policies since then. Indeed, the average cumulative combined index raises from 0.56 in 2010Q2 to 3.81 in 2014Q4. The median of the cumulative combined index also experiences the same increase. This overall tightening of prudential policies comes along with a broader heterogeneity, characterized the expanding difference between the $25th$ and the $75th$ percentiles. Indeed, the gap between $25th$ and the $75th$ percentiles doubles from 2010Q2 to 2015Q4. The bottom panel of Figure 1 presents the evolution of the average cumulative prudential combined index for advanced and emerging countries.[3] It reveals that while advanced and emerging were experiencing the same patterns in the early 2000s, there has been a clear divergence between the two sets of countries. This is because emerging countries use macroprudential policies more often (especially the one related to foreign exchange, Cerutti, Correa, Fiorentino and Segalla (2017)) and tend to tighten these instruments. The divergent pattern between advanced and emerging countries may also explain the broader heterogeneity in the macroprudential indexed noticed in the top panel.

[2]Appendix 4.6.1provides more details about the construction of this cumulative macroprudential index

[3]Using the 2014 IMF World Economic Outlook classification, out of the 64 countries, 34 (resp. 30) are classified as advanced (resp. emerging) economies. The distinction between advanced and emerging economies is made using three criteria: the per-capita income, the export diversification and the degree of integration into the global financial market.

Figure 4.1: Cumulative macroprudential policy indexes



Notes: The top panel presents the average, median and the 25*th* and the 75*th* percentiles of cumulative macroprudential policies. The bottom panel shows the evolution of the average of cumulative macroprudential policies for both advanced and emerging economies. Source: Cerutti, Correa, Fiorentino and Segalla (2017) database and Author' calculation

4.2.2 Bank Profitability

The other main data source for this chapter is the IMF Financial Soundness Indicators (FSI) database. Initiated in 2001 by the IMF, this database provides an insight into countries' financial system soundness. It does so by providing a set of core and encouraged quarterly indicators of the current financial health and soundness of the entire sector of financial institutions in a country, along with the corporate and household sectors[4]. For this chapter, I am interested in the set of core indicators of deposit takers. The two primary measures of bank profitability are

[4]For more details about the FSI database, please visit *https://www.imf.org/external/np/sta/fsi/eng/fsi.htm*

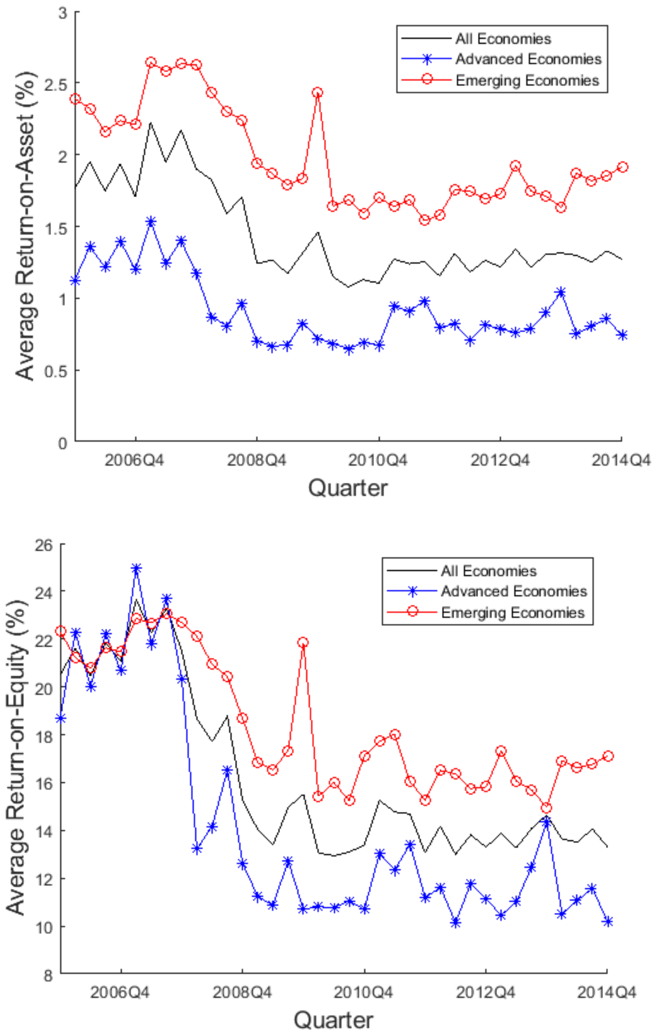
the return-on-assets (ROA) and the Return-on-Equity (ROE) that capture how deposit takers use their assets and capital efficiently to generate income. These are the traditional measures of bank profitability used in the literature. In addition to these measures, bank profitability can also be disaggregated into various components. The three main components of bank profitability are the net-interest income (NII), the non-interest income (NNI), and the loan-loss provision (LLP).[5]

Figure 4.2 presents the evolution of the two main measures of bank profitability (return-on-assets and return-on-equity). The IMF-FSI database provides profitability measures for 52 countries out of the 64 countries from the Cerutti, Correa, Fiorentino and Segalla (2017) database. However, conversely, to the Cerutti, Correa, Fiorentino and Segalla (2017) database, the IMF-FSI is unbalanced with the number of observations per country that ranges from as low as four observations to up to 56. The top panel of Figure 4.2 illustrates the evolution of the average return-on-assets for all countries, and per group (advanced and emerging). To avoid outliers, I only consider the quarters where observations for at least four countries are available. This panel displays decreasing and parallel trends for return-on-assets for both advanced and emerging countries. On the other hand, the bottom panel presents the evolution of the return-on-equity. Similarly to the top panel, the bottom panel shows that the return-on-assets exhibits a decreasing trend for both advanced and emerging countries. However, the advanced countries seem to experience a sharper fall in return to equity from the beginning of 2008, i.e., with the Great Financial Crisis (GFC). In both panels, the return-on-assets and the return-on-equity start falling with the GFC and stabilize after 2010. Until the end of our panel (2014Q4), there is no clear sign of recovery for both return-on-assets and the return-on-equity to their pre-crisis level[6].

[5] Appendix 4.6.2 provides more details about these measures and components of bank profitability.

[6] Using a slightly longer panel and individual bank data, Altavilla et al. (2018) show that the bank profitability start a slow recovery after 2015 thanks to better net-interest income and lower provisions.

Figure 4.2: return-on-assets and Return-on-equity



Notes: The top (resp. bottom) panel presents the average of return-on-assets (resp. return-on-equity) for all countries, advanced and emerging countries. Source: IMF FSI database and Author' calculation

4.2.3 Macro and other banking sector variables

While the macroprudential policies indexes and the bank profitability measures and components are the main variables, I also consider a set of macro and banking sector control variables. On the one hand, I use the following banking sector variables as control variables: the tier 1 capital ratio ($tier1$, computed as the ratio between core capital and total assets), the total asset ($size$, the logarithm of total assets), the liquidity position ($liquid$, the ratio between liquid assets and total assets), the ratio expenditure-income (exp_inc, captures a measure of non-efficiency), and the growth of total loan (gr_loan). These variables belong to the set of bank variables traditionally used in the bank profitability studies and are also provided by the IMF-FSI database. On the other hand, the macroeconomic control variables are the growth rate of real GDP (*gdpgr*), the CPI Inflation ($infla$) and the Central bank policy rate (*cbpr*). The GDP growth rate[7] and the IMF website provides data of the inflation rates, while the Central bank policy rates are collected from the St Louis Federal Reserve website. All but one (*cbpr*) of these variables are available at a quarterly frequency.

4.2.4 Summary Statistics

After collecting and merging the various database, our final dataset is an unbalanced panel that covers 38 countries (20 advanced and 18 emerging) with a total of 1101 observations covering the period going from 2008Q4 to 2014Q4. Table 4.1 below presents the summary statistics for the variables described in the previous sections. Table 4.1 shows that there is a large variation for our main variables (cumulative macroprudential index and return-on-assets and return-on-equity). For example, the cumulative prudential index ranges from -8 to 24, suggesting obvious disparities in the way countries use macroprudential policies (advanced vs. emerging countries) and the tightening trend of macroprudential policy observed after the financial crisis. On the other hand, our main dependent variables, the return-on-assets, and return-on-equity also present evidence of wide variation. They range from about 0 to 9%, and from about 0 to 97% respectively. Other variables (such as components of bank profitability and control variables) also exhibit a large amount of variation.

4.3 The baseline model

4.3.1 Methodology

To investigate the effects of macroprudential policies on bank profitability, I start with the following baseline model specification:

$$Y_{i,t} = \alpha_0 + \alpha_1 Y_{i,t-1} + \alpha_2 Mapp_{i,t} + \alpha_3 X_{i,t} + \alpha_4 Z_{i,t} + \nu_t + \mu_i + \varepsilon_{i,t} \tag{4.1}$$

where Y is either the return-on-assets roa or the return-on-equity roe of banks in country i at quarter t. $Mapp_{i,t}$ is the index of cumulative combined prudential policy in country i at quarter t. $X_{i,t}$ and $Z_{i,t}$ represent the set of control variables associated with the banking sector (Tier 1 capital, total asset, ratio expenditure income, liquidity and growth rate of loans) and the macroeconomy (GDP growth rate, Inflation rate, and Central Bank policy rate), respectively.

[7]For about 8 OECD countries (not available in the IMF-IFS Database), I use the Eurostat website to collect the growth rate of the GDP at quarterly frequency.

Table 4.1: Summary statistics

Variable	Mean	Std. dev.	Min.	Max.	Obs.
Macroprudential Policy					
Prudential	0.10	0.41	-1	1	1101
Cumulative prudential	1.69	4.36	-8	24	1101
Prudential 2	0.10	0.41	-1	1	1101
Cumulative prudential 2	1.63	4.36	-12	24	1101
Bank Profitability					
return-on-assets	1.46	1.08	0.002	9.12	1101
Return-on-Equity	16.12	9.17	0.04	97.61	1101
Net-interest income	1.72	1.61	0.13	9.15	1073
Non-interest income	1.05	0.99	-0.02	10.5	1073
Loan-loss provision	1.68	2.21	-0.32	18.2	995
Banking Variables					
Tier 1 Capital	13.0	3.04	0.93	35.2	1063
Total Assets	14.40	2.49	9.23	21.41	1075
Expenses/Income	56.9	12.93	15.61	171.79	1099
Liquidity	24.22	13.65	4.15	72.41	1040
Loan growth	1.90	9.80	-275	36.8	957
Macroeconomic variables					
Real gdp growth	0.65	1.34	-13.1	9.63	893
CPI inflation	0.84	1.14	-3.43	8.36	1052
Central Bank Policy rate	3.54	3.68	-0.2	28.63	992

Notes: All variables except the macroprudential policy variables, are expressed in percentage. Total Assets are expressed in logarithm. Source: Authors' calculation using data from Cerutti, Correa, Fiorentino and Segalla (2017), IMF-FSI Database and St-Louis Fed Website.

Further, ν_t and μ_i represent the set of quarter and country fixed-effects. I also use the lag of the dependent variable, $Y_{i,t-1}$, on the right-hand side to control for the persistence of bank profitability measure (Berger et al. (2000)). In this first baseline model, the main coefficient of interest is α_2. With the same methodology, one can use the three components of bank profitability as a dependent variable to understand the possible channels through which the bank profitability is affected by macroprudential policies.

Starting from a fixed-effect estimator, it is crucial to identify the potential sources of endogeneity. There are a few possible sources of endogeneity issues in this specification that could lead to bias of the estimate of the coefficient of interest. First, the issue of omitted variables bias. In this specification, I expect the country and time fixed effect to deal with the time and country invariant characteristics that might be correlated with the regressor. Second, there is the issue of the Nickell bias (Nickell (1981)). Indeed, using a fixed-effect with a lag of the dependent variables is likely to lead to a biased estimate. However, the size of that bias is inversely proportional to the sample size ($1/T$). In this study, the average sample size for each country is about 30, so that the Nickell bias is relatively negligible. On the other hand, the additional source of endogeneity is the possible reverse causality between macroprudential policies on bank

profitability. Indeed, monetary and financial authorities may implement prudential policies in response to some changes in important financial variables (Galati and Moessner (2018)), e.g., when they notice weak profitability in the banking sector. In the previous literature, the standard methodology to dampen this endogeneity issue is to introduce the lag of the explanatory variable and to run a GMM (General Methods of Moments) estimation (Claessens et al. (2013), Cerutti, Claessens and Laeven (2017), Altunbas et al. (2018)). The GMM estimator, developed by Arellano and Bover (1995), consists of using the lagged of the dependent and independent variables as possible instruments for the regressors. However, this estimator is more suitable for situations where T is small, to avoid having a relatively large number of instruments (Roodman (2009)). In our case, there are about $N = 28$ countries with an average of $T = 30$ observations. Then, the GMM is likely not appropriate here.
A special feature of our data is its quarterly nature. I argue that a quarter is a too short duration for the macroprudential authority to react to a change in the financial sector, especially if it has only to do with bank profitability. Thus, I expect that the possible reverse causality issue is limited. Following Altavilla et al. (2018), our preferred estimation method is then the fixed-effect estimator.

4.3.2 Baseline Results

Table 4.2 below presents the results from the model specification (4.1) where the dependent variable Y is respectively the return-on-assets, the return-on-equity, the non-interest income, the net interest income, and the loan-loss provision. On the one hand, columns 1 and 2 of Table 4.2 present the results of the baseline specification using return-on-assets and return-on-equity as the dependent variable and show that the effect of tightening the macroprudential policies x on the country's banks profitability. From column 1, an one point increase in the cumulative combined prudential index[8] leads to a decrease in return-on-assets by an average of 2.75 percentage points, which is not trivial (mainly if the macroprudential instrument are used often and tightened as it is the case in Emerging countries and also because I use a quarterly frequency). On the other hand, a similar increase in the cumulative combined prudential index will lead to 22.6 percentage points decrease in the return-on-equity. Both effects correspond to a fall of about 2.5% standard deviation of both return-on-assets and return-on-equity[9].

[8]For example, a one-point increase in the cumulative combined index refers to a situation where only one macroprudential instrument is tightened (e.g., capital ratio), or two instruments are tightened (e.g. capital and reserve ratios) and one another is loosened (e.g. loan-to-value).
[9]See Appendix 4.6.5 for robustness check.

Concerning the banking sector controls, there is evidence that banks tend to get less profitable when they get larger[10]. Also, the ratio between expenditure and income is significantly and negatively associated with bank profitability. Among country macroeconomic control variable, only the central bank policy rate appears to be significantly and positively associated with the return-on-equity. This may be explained by the fact that as central bank raises its interest rate, banks are more eager to adjust the interest rate they retrieve from loan than to raise the one they pay on deposits. Columns 3,4 and 5 use the three components of bank profitability as the dependent variable. In this first specification, the coefficients of the macroprudential index are not significant, therefore not providing channels for the adverse effects of macroprudential policy on bank profitability. However, there are negative and significant effects for control variables such as size, inefficiency ratio and inflation on both non-interest income and net interest income. Concerning inflation, an increase in inflation is indeed likely to lower the real income from both non-interest origins (deposit or transactions fees) and net-interest margin (interest rate margin). Further, for loan-loss provision, the size and inefficiency ratio are positively associated with a higher loan-loss provision ratio which is a sign of lower profitability. The real GDP growth is however not significant in any of the five columns. This may be because banks decisions to lend usually dependent on growth expectations, rather than on current growth[11].

The result suggesting a negative and significant effect of a tightening of macroprudential policies on bank profitability measures is robust to different specifications. As the sample is unbalanced, a first robustness exercise consists of limiting the sample to countries that have at least 20 quarterly observations (five years). This robustness check ensures that a few outliers do not drive the main result. The main result remains robust. As a second robustness check, I use an alternative measure of cumulative macroprudential index collected from the same Cerutti, Correa, Fiorentino and Segalla (2017) dataset. The results from the robustness check are presented in Appendix 4.6.5.

From the descriptive statistics section, there is evidence of different usage of macroprudential policies for both emerging and advanced countries. According to the IMF classification, advanced countries are primarily characterized by the per capita income level and the degree of development of their financial sector. Further, I now use an interaction model to investigate the role of the income level and financial sector development when it comes to assessing the

[10]Economic literature usually distinguishes between two possible and opposite effects of bank size on profitability. On the one hand, a bigger bank can benefit from economies of scale and therefore higher efficiency. On the other hand, however, a smaller bank enjoys a closer relationship with clients and get better information to set more profitable contracts. The latter effect seems to be dominant here.

[11]In their paper, Altavilla et al. (2018) use growth expectations data taken from Consensus Economics database. This database is however restricted.

impact of macroprudential policies on bank profitability.

Table 4.2: Baseline model regressions

VARIABLES	(1) ROA	(2) ROE	(3) NNI	(4) NII	(5) LLP
lag.ROA	0.334**				
	(2.276)				
lag.ROE		0.299**			
		(1.981)			
lag.NNI			0.169**		
			(2.280)		
lag.NII				0.158**	
				(2.534)	
lag.LLP					0.925***
					(26.91)
Mapp	-0.0275***	-0.226**	0.00378	-0.0164	-0.0110
	(-2.946)	(-2.286)	(0.299)	(-0.952)	(-1.504)
Tier 1 Capital	-0.0185	-0.388*	8.40e-05	-0.0309**	-0.00792
	(-1.058)	(-1.733)	(0.00603)	(-2.159)	(-0.871)
Total Assets	-0.249*	-1.723	-0.147**	-0.200**	0.0902***
	(-1.925)	(-1.499)	(-2.030)	(-2.155)	(3.381)
Liquidity	0.00424	0.0505	-0.00576	0.00835	-0.00332
	(0.930)	(0.932)	(-0.959)	(0.827)	(-0.583)
Inefficiency ratio	-0.0128***	-0.184***	-0.0139***	-0.00232	0.00277**
	(-2.615)	(-2.831)	(-5.230)	(-0.700)	(2.381)
Loan growth	-0.0523	-0.567	-0.0115	-0.0279	-0.141*
	(-0.359)	(-0.319)	(-0.117)	(-0.188)	(-1.768)
GDP growth	1.058	16.63	0.831	-0.256	-1.037
	(0.504)	(0.633)	(0.600)	(-0.130)	(-1.203)
Policy Rate	0.0192	0.222*	0.0230	0.0345	0.0109
	(1.614)	(1.778)	(1.586)	(1.598)	(1.498)
Inflation	-0.434	2.314	-5.951***	-6.061*	-0.515
	(-0.231)	(0.106)	(-2.815)	(-1.864)	(-0.305)
Constant	5.273**	49.90**	3.648***	4.642***	-1.040**
	(2.467)	(2.486)	(3.307)	(3.460)	(-2.202)
Countries fixed-effects	Yes	Yes	Yes	Yes	Yes
Quarter dummies	Yes	Yes	Yes	Yes	Yes
Observations	756	756	756	756	756
Number of countries	28	28	28	28	28
Adjusted R-squared	0.800	0.642	0.768	0.887	0.980

Notes: ROA=return-on-assets, ROE=Return-on-Equity, NII=Net-income Income, NNI=Non-interest Income, LLP=Loan-loss provision. *Mapp*=Cumulative macroprudential policy index. Fixed-effect regression with data at quarterly frequency on an unbalanced sample of 28 countries from 2005Q5 to 2014Q4. Robust t-statistics in parentheses. *** p<0.01, ** p<0.05, * p<0.1

4.4 Heterogeneous Effects

4.4.1 Interaction model with income level

To explore the potential role of income level in the effects of macroprudential policies on bank profitability, I introduce the GDP per capita and an interaction term (Prudential index times GDP per capita) in the previous specification model. The econometric model then becomes:

$$Y_{i,t} = \alpha_0 + \alpha_1 Y_{i,t-1} + \alpha_2 Mapp_{i,t} + \alpha_3 lgpc_{i,t} + \alpha_4 (Mapp_{i,t} * lgpc_{i,t}) + \alpha_5 X_{i,t} + \alpha_6 Z_{i,t} + \nu_t + \mu_i + \varepsilon_{i,t} \tag{4.2}$$

where $lgpc_{i,t}$ is the logarithm of the GDP per capita for country i at time t. The GDP per capita variable is collected from the IMF World Economic Outlook 2018 database and measured in thousands of 2005 US dollar constant[12]. Table 4.3 shows the results of the regression model 4.2.

First, consistently with previous regression tables, the coefficients for the macroprudential cumulative index are negative for both column 1 and 2. However, because of the interaction term, these coefficients cannot be directly interpreted as the effect of prudential policies on bank profitability. Concerning the GDP per capita, one notices the positive and significant coefficient of the log of GDP per capita in the first two columns of table 4.3. These coefficients can be interpreted as the effects of the GDP per capita on the bank profitability when the cumulative macroprudential index is equal to 0. In this case, a 1% increase in the GDP per capita leads to a 0.44 (resp. 5.74) percentage point increase in the return-on-assets (resp. return-on-equity). Thus, in the absence of macroprudential policies, banks tend to become more profitable as the GDP per capita rises. Also, in the absence of macroprudential policies, banks tend to collect less non-interest income (e.g., transaction fees) and have less provision for non-performing loans (because of a less risky environment) as the GDP per capita rises.

With this interaction model, the effect of macroprudential policies on bank profitability is not directly captured by the coefficient of the macroprudential index. Instead, the effects depend on the income level. The main interest is the marginal effect of the macroprudential cumulative index on bank profitability. This marginal effect and its standard error are given by:

$$\frac{\partial Y}{\partial Mapp} = \alpha_2 + \alpha_4 lgpc \text{ and } \hat{\sigma}_{\frac{\partial Y}{\partial Mapp}} = \sqrt{var(\hat{\alpha}_2) + (lgpc^2)var(\hat{\alpha}_4) + 2 * lgpc * cov(\hat{\alpha}_2 \hat{\alpha}_4)} \tag{4.3}$$

[12] The mean of *ldpc* is equal to 9.58 with a standard deviation of 1.04. See Appendix 4.6.4 for the histogram.

Table 4.3: Interaction model with log of GDP per capita

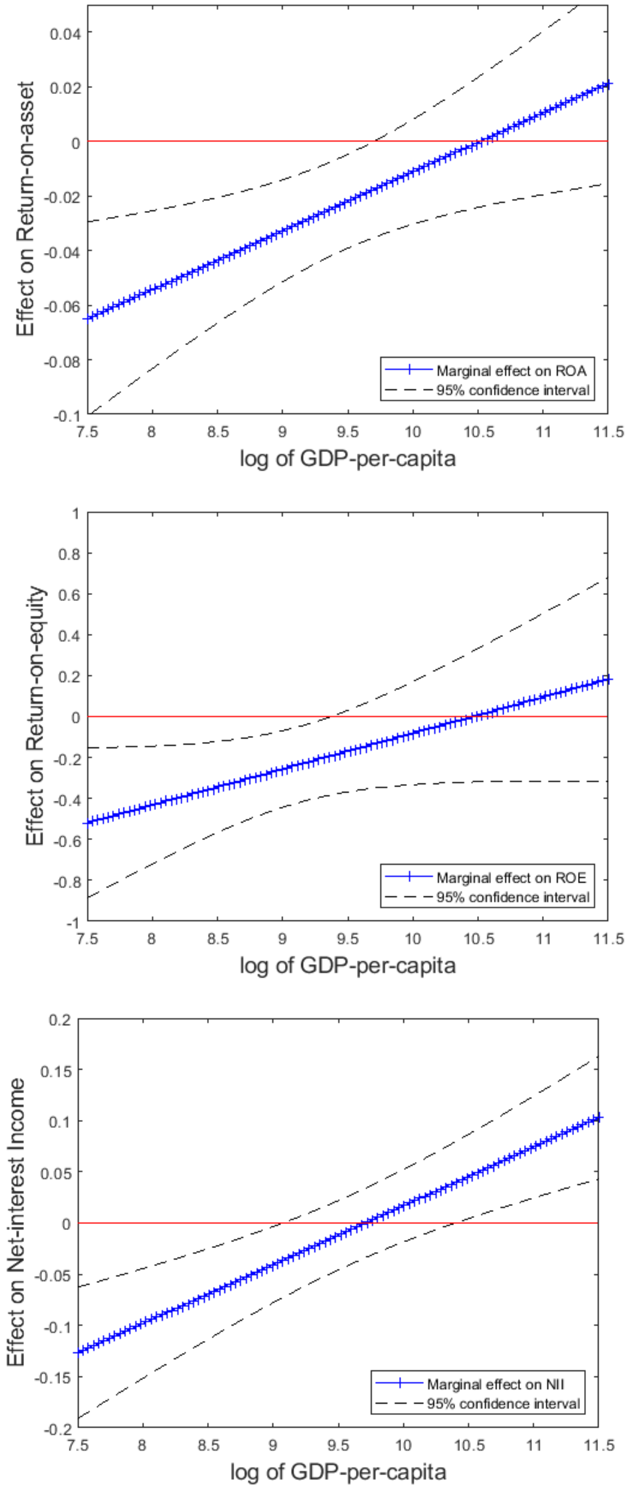
VARIABLES	(1) ROA	(2) ROE	(3) NNI	(4) NII	(5) LLP
Lag.ROA	0.324**				
	(2.252)				
Lag.ROE		0.292*			
		(1.963)			
Lag.NNI			0.159**		
			(2.172)		
Lag.NII				0.119**	
				(1.989)	
Lag.LLP					0.914***
					(25.13)
Mapp	-0.227***	-1.835**	-0.0321	-0.558***	-0.0663*
	(-2.938)	(-2.009)	(-0.408)	(-4.338)	(-1.914)
lgpc	0.445**	5.728**	-0.558**	-0.533	-0.419***
	(2.353)	(2.481)	(-2.427)	(-1.530)	(-2.747)
Mapp*lgpc	0.0216***	0.175*	0.00352	0.0575***	0.00557*
	(2.660)	(1.763)	(0.436)	(4.328)	(1.707)
Countries fixed-effects	Yes	Yes	Yes	Yes	Yes
Quarter dummies	Yes	Yes	Yes	Yes	Yes
Observations	756	756	756	756	756
Number of countries	28	28	28	28	28
Adjusted R-squared	0.802	0.644	0.770	0.890	0.981

Notes: ROA=return-on-assets, ROE=Return-on-Equity, NII=Net-income Income, NNI=Non-interest Income, LLP=Loan-loss provision. *Mapp*=Cumulative macroprudential policy index, *lgpc*=log of GDP per capita in $US. Fixed-effect regression with data at quarterly frequency on an unbalanced sample of 28 countries from 2005Q5 to 2014Q4. For readability, the control variables estimates are not presented here. Robust t-statistics in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Using the results from Table 4.3, one also plot the marginal effect as a function of the log of GDP per capita. Figure 4.3 presents the marginal effects of a one-point tightening of the macroprudential policies index on bank profitability (return on asset and return on equity) as a function of GDP per capita. Figure 4.3 is consistent the estimation on emerging and advanced countries subsamples, that suggests a negative and significant effect of a macroprudential tightening on bank profitability in the case of emerging countries, while the effect was positive but insignificant for advanced economies. Indeed, starting from a negative and significant effect, the marginal effect increases with the level of incomes and even becomes positive but fails to become significant as the log of GDP per capita reaches the second half of the distribution (which roughly characterizes the advanced economies). The first two panels of Figure 4.3 then suggests evidence of negative and heterogeneous effects of prudential policies on bank profitability, and this negative effect tends to fall in magnitude as the income level increases. Concerning the channels through which macroprudential policy affect bank profitability, the last panel provides evidence of the critical role played by the net interest income (NII). Indeed the net-interest income tends to drop following a tightening of macroprudential policies in countries belonging to the lower third of the income distribution (mainly emerging countries). For the countries belonging to the top of the income distribution, the effect is positive and significant.

This section suggests that a tightening of the macroprudential policy framework tend to have a negative and significant effect on bank profitability in emerging countries but not significant in advanced countries. As a robustness check, I run the baseline model (4.1) on the advanced and emerging countries subsamples (the results are presented in Appendix 4.6.6). The subsamples regressions are consistent with the effect displayed in 4.3.

Figure 4.3: Marginal effect of macroprudential policies and GDP per capita



Notes: Marginal effect of a one-point increase in the cumulative macroprudential index on the return-on-assets (top panel), the return-on-equity (middle panel) and the Net-interest income (bottom panel) as a function of the logarithm of GDP per capita. The dash lines represent the 95% confidence intervals. Source: Table 4.3 and Author's Calculation

4.4.2 Interaction model with financial sector development

As mentioned previously, the emerging and advanced countries classification does not only rely on income per capita level. It also relies on the degree of development of the financial sector. Similarly to the previous section, in this section, I utilize an interaction model to explore the role of financial sector development. The model specification then becomes:

$$Y_{i,t} = \alpha_0 + \alpha_1 Y_{i,t-1} + \alpha_2 Mapp_{i,t} + \alpha_3 Fin_{i,t} + \alpha_4 (Mapp_{i,t} * Fin_{i,t}) + \alpha_5 X_{i,t} + \alpha_6 Z_{i,t} + \nu_t + \mu_i + \varepsilon_{i,t} \tag{4.4}$$

where Y is either the return-on-assets or the return-on-equity and Fin captures the level of development of the Financial sector. Cihak et al. (2013) mention that financial development has various dimensions that span from depth, access, efficiency, and stability. In this chapter, I use a measure related to financial depth, namely the ratio of domestic credit to the private sector to the GDP, *dcgdp* [13]. These variables, collected from the World Bank Global Financial Development database.[14] Table 4.4 below presents the results from the regression model (4.4). Interestingly when the macroprudential cumulative index is equal to 0, the domestic credit to GDP ratio is positively and significantly associated with both measures of bank profitability (see columns 3 and 4 of Table 4.4). As in the previous interaction model, Figure 4.4 shows the marginal effect of macroprudential policy on bank profitability as a function of the level of development of the financial sector. Figure 4.4 presents a pattern that is similar to the one depicting the role of GDP per capita in the effects of macroprudential policy on bank profitability. One the reason behind that is the strong correlation between the per capita income and the two measures of financial sector development (See Appendix 4.6.3 for scatter plots). Indeed banks in countries with less developed financial sector tend to see their profitability drop after a tightening of prudential policies. The robustness checks that make use of an alternative measure of financial depth are presented in Appendix 4.6.7.

[13] For robustness check, I utilize an alternative measure of financial depth, namely the ratio of private credit to GDP, *pcgdp*

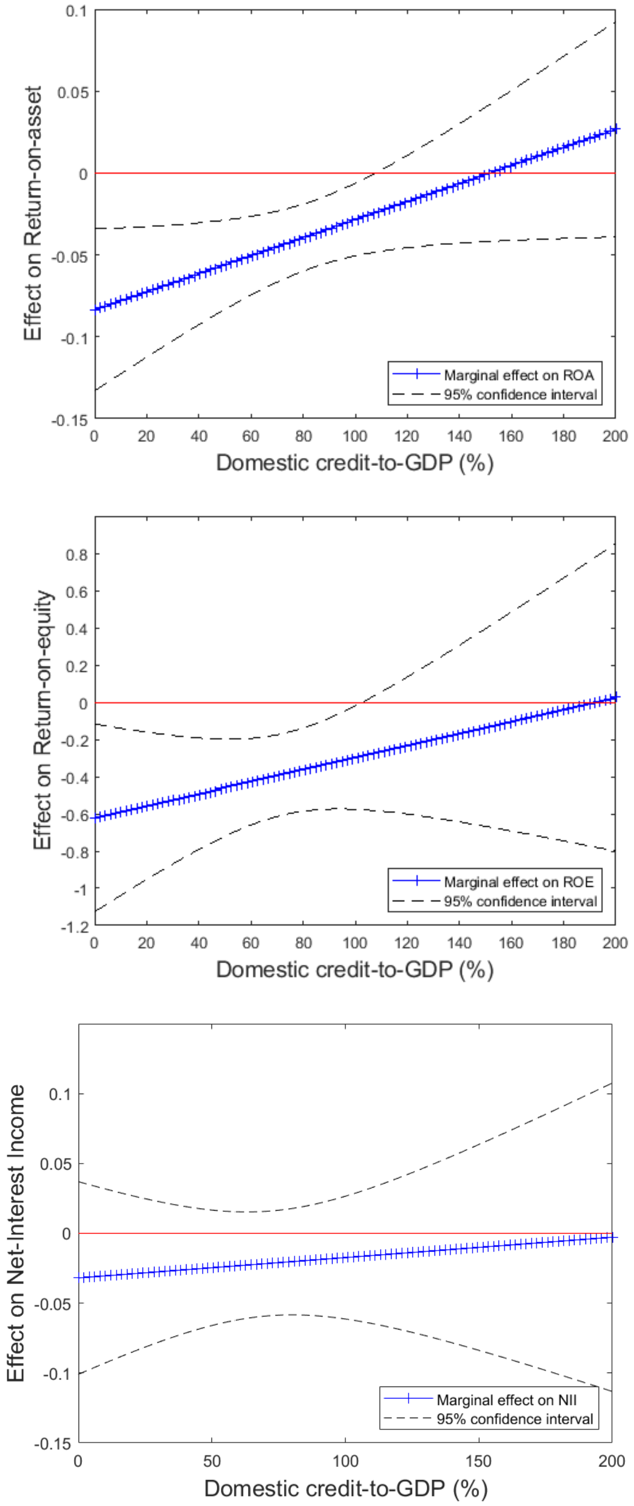
[14] Appendix 4.6.3 and Appendix 4.6.4 present the summary statistics and the histograms of these variables.

Table 4.4: Interaction model with domestic credit to GDP

VARIABLES	(1) roa	(2) roe	(3) nni	(4) nii	(5) llp
L.roa	0.310**				
	(2.225)				
L.roe		0.279*			
		(1.957)			
L.nni			0.174**		
			(2.267)		
L.nii				0.160**	
				(2.530)	
L.llp					0.929***
					(24.71)
Mapp	-0.0829***	-0.586**	-0.0390	-0.0320	-0.0250*
	(-3.299)	(-2.290)	(-1.435)	(-0.909)	(-1.811)
dcpsgdp	0.00626**	0.108***	-0.00169	-0.00174	0.00225
	(2.301)	(2.732)	(-0.805)	(-0.626)	(1.577)
Mapp*dcpsgdp	0.000508*	0.00222	0.000568*	0.000146	0.000151
	(1.826)	(0.678)	(1.935)	(0.354)	(1.127)
Countries fixed-effects	Yes	Yes	Yes	Yes	Yes
Quarter dummies	Yes	Yes	Yes	Yes	Yes
Observations	689	689	689	689	689
Number of countries	24	24	24	24	24
Adjusted R-squared	0.794	0.620	0.762	0.884	0.978

Notes: ROA=return-on-assets, ROE=Return-on-Equity, NII=Net-income Income, NNI=Non-interest Income, LLP=Loan-loss provision. *Mapp*=Cumulative macroprudential policy index, *dcpsgdp*=ratio of domestic credit to private sector to GDP. Fixed-effect regression with data at quarterly frequency on an unbalanced sample of 28 countries from 2005Q5 to 2014Q4. For brevity, the control variables estimates are not presented here. Robust t-statistics in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Figure 4.4: Marginal effect of macroprudential policies and domestic credit to GDP



Notes: Marginal effect of a one-point increase in the cumulative macroprudential index on the return-on-assets (top panel), the return-on-equity (middle panel) and the Net-interest income (bottom panel) as a function of the domestic credit-to-GDP per capita. The dash lines represent the 95% confidence intervals. Source: Table 4.4 and Author's Calculation

4.4.3 Income level or Financial development?

The two previous sections provide evidence that there are heterogeneous effects of macroprudential policy on bank profitability, respective to both income level and financial development. In this section I argue that the heterogenous effects depending on income level primarily reflect difference in terms of financial development, especially related to domestic capacity. To do so, I classify the countries into high and low income level and high and low financial development. This leads to create 4 dummy variables that take value 1 if a country respectively belongs to high income ($high\_inc$), low-income (low_inc), high financial developemt ($high\_fin$), low financial development (low_fin) respectively. I then run the following model:

$$\begin{aligned} Y_{i,t} = \alpha_0 + \alpha_1 Y_{i,t-1} &+ \beta_1 Mapp_{i,t} * high\_inc_i * high\_fin_i + \beta_2 Mapp_{i,t} * low\_inc_i * high\_fin_i \\ &+ \beta_3 Mapp_{i,t} * high\_inc_i * low\_fin_i + \beta_4 Mapp_{i,t} * low\_inc_i * low\_fin_i \\ &+ \alpha_2 X_{i,t} + \alpha_3 Z_{i,t} + \nu_t + \mu_i + \varepsilon_{i,t} \end{aligned}$$

The results from the above model are presented in Table 4.5. The fifth and sixth row of Table 4.5 suggest that for countries with low financial development, a tightening of macroprudential policies has adverse consequences on the bank profitability regardless of the income level[15]. The last two rows of Table 4.5 present the Wald tests that test if the coefficients of macroprudential policies in countries with different income levels but with highly (resp. weakly) developed financial sector, are equal. Practically the ultimate (resp. penultimate) row tests if the coefficients from the fifth and sixth rows (resp. the third and fourth rows) are equal. The Wald test, with a null hypothesis of equality of coefficient, cannot be rejected. This provides evidence that when it comes to the effects of macroprudential policy on bank profitability, the level of financial development plays a more crucial role than the country income level. I suggest that the adverse effect of a tightening of macroprudential policy on bank profitability in emerging countries happens because financial sectors that are already relatively less developed in emerging countries can less easily cope with policies that tighten their activities. The banks in emerging markets are therefore more vulnerable to prudential policies. For example, let imagine a tightening of the macroprudential framework that increases the capital requirement ratio. When facing such conditions, banks in countries with developed financial sectors can still raise capital more efficiently than their counterparts in other countries. This gives them an edge when it comes to coping with a tightening of the macroprudential framework.

[15] Among our 24 countries, 4 of them belong to the high-income group but display a low level of financial development. There are Saudi Arabia, Czech Republic, Croatia, and Slovenia.

Table 4.5: Income level *vs.* Financial development

VARIABLES	(1) ROA	(2) ROE	(3) ROA	(4) ROE
lag.ROA	0.300*		0.311**	
	(1.919)		(1.981)	
lag.ROE		0.265*		0.276*
		(1.669)		(1.699)
Mapp*high_inc*high_fin	0.00325	0.123	0.0268	0.392
	(0.159)	(0.368)	(1.466)	(1.225)
Mapp*low_inc*high_fin	0.0280	0.0343	0.0470**	0.227
	(1.078)	(0.126)	(2.130)	(1.262)
Mapp*high_inc*low_fin	-0.137**	-1.227*	-0.118*	-1.130
	(-2.107)	(-1.711)	(-1.869)	(-1.560)
Mapp*low_inc*low_fin	-0.0476***	-0.347***	-0.0360***	-0.244**
	(-4.095)	(-3.355)	(-3.197)	(-2.476)
Countries fixed-effects	Yes	Yes	Yes	Yes
Quarter dummies	Yes	Yes	No	No
Observations	661	661	661	661
Number of countries	24	24	24	24
Adjusted R-squared	0.803	0.629	0.810	0.639
Walt test,Mapp-highfin	0.36	0.81	0.40	0.63
Walt test,Mapp-lowfin	0.17	0.23	0.20	0.23

Notes: ROA=return-on-assets, ROE=Return-on-Equity. $Mapp$=Cumulative macroprudential policy index. *high_inc* (resp. *low_inc*) is a dummy variable that takes value 1 if country belongs to high income level (resp. low income level), and 0 otherwise. $high\_fin$ (resp. low_fin) is a dummy variable that takes value 1 if country display high (resp. low) degree if financial developemt income level, and 0 otherwise. Columns 1 and 2 use the domestic credit to GDP ratio to consutruct $high\_fin$ (resp. low_fin), while Columns 3 and 4 use the private credit to GDP ratio to consutruct $high\_fin$ (resp. low_fin). Fixed-effect regression with data at quarterly frequency on an unbalanced sample of 24 countries from 2005Q5 to 2014Q4. $Walt\ test, Mapp - highfin$ (resp. $Walt\ test, Mapp - lowfin$) test if the coefficients of macroprudential policy for different income levels are equal in countries with high financial developement (resp. low financial developemt). For brevity, the control variables are not presented here. Robust t-statistics in parentheses. *** p<0.01, ** p<0.05, * p<0.1

4.5 Concluding Remarks

Since the Great Financial Crisis, ensuring a strong and resilient financial sector has become a crucial element of monetary and financial authorities. The economic literature has identified bank profitability as one of the aspects of the soundness of the financial system. This chapter investigates the impact of macroprudential policies on bank profitability. The results suggest evidence of an adverse of a tightening of macroprudential instruments on both primary measures of bank profitability (return-on-assets and return-on-equity). This adverse effect mostly happens through a fall in the Net-interest income. Also, there is evidence of heterogeneous effects depending on the country income level and financial sector development.

This adverse effect of a tightening of prudential policies on bank profitability raises several concerns. One of them is the global trend of tightening of macroprudential policies since the GFC. This trend may have resulted in low bank profitability and possibly a weaker financial system. However, bank profitability is only one aspect of the stability of the financial system. Thus, it is likely that other aspects (liquidity, resilience to shock, propagation risk, soundness to external shock) of the soundness of the financial sector have improved. Therefore, Financial authorities then face some trade-off when implementing macroprudential policy.
Finally, this chapter opens doors for further research. One the one hand, a more detailed analysis requires a better dataset on bank profitability. For example, a bank level database may provide more insight into what happens at the individual bank level when macroprudential policies are implemented. On the other hand, another econometric methodology that emphasizes heterogeneous effects may be useful. An example is the the Pooled Mean Group (PMG) estimator, introduced by Pesaran et al. (1999), that assumes the existence of a common long-run relationship between the variables, but allows for a difference in short-run dynamics.

4.6 Appendix 3

4.6.1 Macroprudential policies dataset

This database captures the quarterly changes of nine prudential instruments for sixty-four countries covering the period going from the first quarter of 2000 to the last quarter of 2014. These nine prudential instruments correspond to five different prudential categories. Table 4.6 below presents the prudential tools along with their corresponding prudential types. The Cerutti, Correa, Fiorentino and Segalla (2017) database is part of the IBRN (International Banking Research Network) initiative that intends to document cross-country changes in prudential policies extensively to help provide a consistent analysis of the effectiveness of prudential policies. The primary source of this database is the GMPI (Global Macroprudential Policy Instruments) survey. The IMF Monetary and Capital Department conducted this survey with the cooperation of countries regulation authorities (Cerutti, Claessens and Laeven (2017)).The Cerutti, Correa, Fiorentino and Segalla (2017) database presents one primary advantage. This database captures not only whether a prudential policy is changed or not, but also the qualitative (tightening or loosening) and quantitative nature of that change. Indeed, unlike previous datasets that use a mere dummy specification depending on whether a prudential policy measure is implemented or not in a given period, Cerutti, Correa, Fiorentino and Segalla (2017) document changes in prudential policy by acknowledging if the policy is tightened or loosened. For instance, increasing (resp. decreasing) the capital ratio requirements corresponds to tightening (resp. loosening) of macroprudential policy and is recorded as 1 (resp. -1)[16]. This allows measuring the qualitative traits of the policies. If a given macroprudential instrument is tightened twice in the same quarter, it will be recorded as 2 (1+1), therefore capturing the quantitative feature of the Prudential policy change. For example in the last quarter of 2002, Brazil's regulation authorities first increased the capital requirements on exchange exposures (prudential instrument Sector-Specific Capital Buffer for other credit) from 50% to 75%, and again from 75% to 100% during the same quarter. Thus $SSCB\_OtherCredit(Brazil, 2002Q4) = 2$. The authors compute a combined prudential index ($pruc$) that sums up the nine instruments in a given quarter and record 1 (resp. -1) if the sum is higher (resp. lower) or equal to 1, and 0 otherwise. Further, to capture the intensity of the prudential index instruments, the database compiles cumulative indexes relative to the first quarter of 2000. These cumulative indexes are computed by summing the individual indexes from the first quarter of 2000 to a given period. A cumulative

[16] Raising the capital ratio requirements corresponds to tightening policy because by doing so, the regulation authority forces the banks to either increase their capital (e.g., through retained earnings) or lower their assets (decreasing the amounts of loan). In both cases, the bank's freedom in running its activities is lessened.

prudential measure *cum_pruc* is also computed for the combined measure of prudential policy *pruc*. *cum_pruc* will serve as our primary measure of prudential policy in this chapter since it captures the qualitative, quantitative and intensity feature of prudential changes. Alternative measures of combined prudential index *pruc*2 and cumulative combined index *cum_pruc*2 are computed when individual instruments are adjusted to have maximum (resp. minimum) of 1 (resp. -1). Also, this database provides a larger coverage thanks to its quarterly specification and spans sixty-four countries from both advanced and emerging countries that allows for income level comparison of macroprudential policy effects.

Table 4.6: Prudential instruments and categories

Prudential Categories	**Prudential Instruments**
Capital Buffer	SSCB Real Estate SSCB Consumer Loans SSCB Other Loans General Capital Requirements
Interbank Exposure	Interbank Exposure Limits
Concentration	Concentration limits
Loan-to-value	Loan-to-value Ratio limits
Reserve Requirements	RR Foreign Currency RR Local Currency

Note: SSCB: Sector-spectific Capital Buffer, RR= Reserve Requirements

4.6.2 Bank profitability data

Table 4.7 below presents the indicators that capture a country' banking sector profitability measures and components and a brief description of these indicator. Unlike other papers that use individual bank data to capture the effects of macroprudential policy on bank characteristics (e.g., Altunbas et al. (2018)), this paper use country-level data on the banking sector. I do so mainly for two reasons. The first one is to maintain consistency with the other primary data source described in the previous sections. Indeed, the FSI database provides country financial health indicators at a quarterly frequency, likewise the Cerutti, Correa, Fiorentino and Segalla (2017) database. The other reason is a matter of availability as a database that would provide a rich set of information about banks balance sheet for such a large number of countries are usually restricted or only available for a small set of countries, e.g., European Countries.

Table 4.7: Bank profitability measures, components and descriptions.

BP	Indicators	Description
BP Measures	return-on-assets *roa*	ratio between net income and average value of total asset. It measures the bank efficiency in using its assets to generate income.
	Return on Equity *roe*	ratio between net income and average value of total capital and reserves. It captures the bank effciency in using its capital and reserves to generate income.
BP Components	Net-Interest-Margin *nii*	Ratio between the net interest income (difference between interest rate charged on loan and that paid on deposits) and average value of total asset.
	Non-interest-Income *nni*	Ratio between non-interest income (income that are not generated from interest rate charge, such as deposit or transaction fees) and average value of total asset.
	Loan-loss provision *llp*	Ratio between loan-loss provision (provision to cover nonperforming loans) and the average value of total asset.

Notes: BP: Bank Profitability

Table 4.8: Correlations

	ROA	ROE	NII	NNI	LLP
ROA	1.000				
ROE	0.892	1.000			
NII	0.270	0.162	1.000		
NNI	0.407	0.293	0.628	1.000	
LLP	0.127	0.095	0.067	0.128	1.000

Notes: ROA=return-on-assets, ROE=Return-on-Equity, NII=Net-income Income, NNI=Non-interest Income, LLP=Loan-loss provision. Cross-correlation between the measures and components of bank profitability.

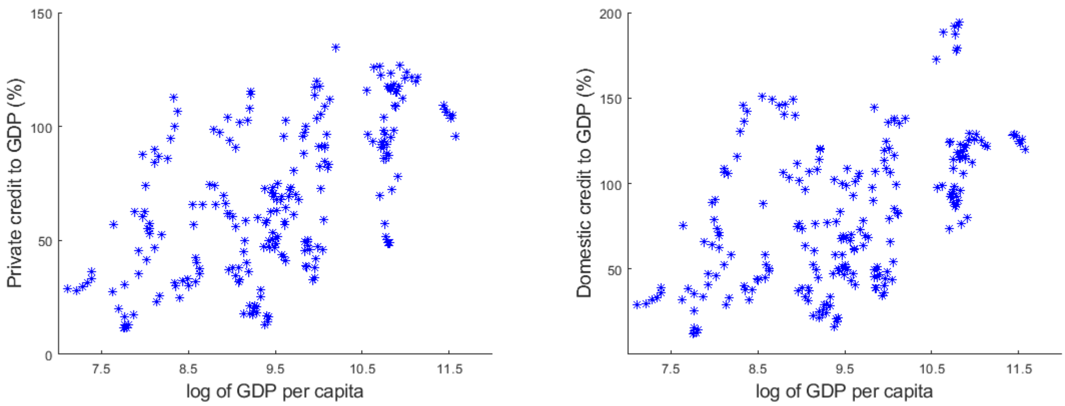
4.6.3 Financial development variables

Table 4.9: Summary statistics of financial development variables

Variable	Mean	Std. dev.	Min.	Max.	Obs.
Financial Development					
Private credit to GDP	68.07	32.62	11.52	134.70	885
Domestic credit to GDP	81.88	42.01	11.79	194.23	889

Notes: Both variables are expressed in percentage. Source: Authors' calculation using data from the World Bank Global Financial Developemnt database.

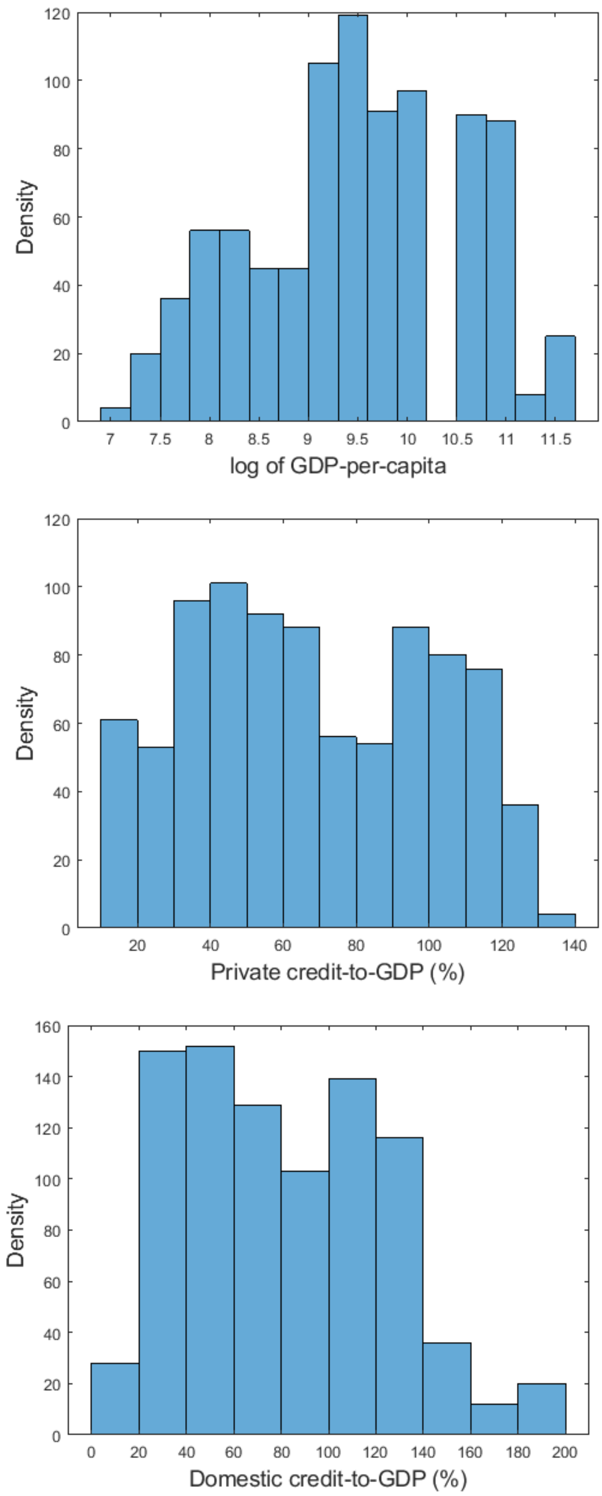
Figure 4.5: GDP per capita and measures of financial development



Notes : Scatter plots. Source: IMF FSI database and Author' calculation

4.6.4 Histograms

Figure 4.6: Histograms of GDP per capita, private credit and domestic credit



Notes: Histogram plots. Source: IMF WEO and FSI database and Author' calculation

4.6.5 Robustness check for baseline model

For robustness check, I run some additional regression models. One the one hand, one run model with only the countries that have at least 20 quaterly observations (i.e., at leat 5 years). This is to ensure that our regression estimates are not driven by any outlier country with very few observations. On the other hand, for robustness check I use the alternative measure of macroprudential policies.

Table 4.10: Baseline model on subsample of countries with at least 20 observations

VARIABLES	(1) ROE	(2) ROE	(3) NNI	(4) NII	(5) LLP
lag.ROA	0.328**				
	(2.237)				
lag.ROE		0.292*			
		(1.946)			
lag.NNI			0.175**		
			(2.307)		
lag.NII				0.164***	
				(2.602)	
lag.LLP					0.922***
					(24.28)
Mapp	-0.0291***	-0.251**	0.00294	-0.0163	-0.0111
	(-3.071)	(-2.499)	(0.230)	(-0.933)	(-1.456)
Countries fixed-effects	Yes	Yes	Yes	Yes	Yes
Quarter dummies	Yes	Yes	Yes	Yes	Yes
Observations	718	718	718	718	718
Number of countries	24	24	24	24	24
Adjusted R-squared	0.792	0.621	0.764	0.885	0.979

Robust t-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Notes: ROA=return-on-assets, ROE=Return-on-Equity, NII=Net-income Income, NNI=Non-interest Income, LLP=Loan-loss provision. *Mapp*=Cumulative macroprudential policy index. Fixed-effect regression with data at quarterly frequency on an unbalanced sample of 24 countries from 2005Q5 to 2014Q4. For readability, the control variables are not presented here. Robust t-statistics in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 4.11: Baseline model with alternative measure of Prudential policies

VARIABLES	(1) ROE	(2) ROE	(3) NNI	(4) NII	(5) LLP
lag.ROA	0.325**				
	(2.233)				
lag.ROE		0.291*			
		(1.949)			
lag.NNI			0.176**		
			(2.313)		
lag.NII				0.167***	
				(2.634)	
lag.LLP					0.922***
					(24.27)
Mapp2	-0.0340***	-0.291***	-0.00510	-0.00658	-0.0120
	(-3.576)	(-2.952)	(-0.377)	(-0.379)	(-1.578)
Countries fixed-effects	Yes	Yes	Yes	Yes	Yes
Quarter dummies	Yes	Yes	Yes	Yes	Yes
Observations	713	713	713	713	713
Number of countries	24	24	24	24	24
Adjusted R-squared	0.792	0.621	0.764	0.885	0.979

Robust t-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Notes: ROA=return-on-assets, ROE=Return-on-Equity, NII=Net-income Income, NNI=Non-interest Income, LLP=Loan-loss provision. $Mapp2$=Alternative measure cumulative macroprudential policy index. Fixed-effect regression with data at quarterly frequency on an unbalanced sample of 24 countries from 2005Q5 to 2014Q4. For readability, the control variables are not presented here. Robust t-statistics in parentheses. *** p<0.01, ** p<0.05, * p<0.1

4.6.6 Baseline Model for emerging and advanced countries

This section presents the results from the regression on the subsamples of advanced and emerging countries. The results suggests that a tightening of the macroprudential framework tend to have a negatie and significant effect on bank profitability measures mainly in emerging countries.

Table 4.12: Baseline model for advanced economies

VARIABLES	(1) ROE	(2) ROE	(3) NNI	(4) NII	(5) LLP
lag.ROA	0.164				
	(1.094)				
lag.ROE		0.215			
		(1.347)			
lag.NNI			-0.0331		
			(-0.454)		
lag.NII				-0.125*	
				(-1.651)	
lag.LLP					0.925***
					(18.18)
cum_pruc	0.0375*	-0.0198	0.0129	0.0160	-0.0139
	(1.774)	(-0.0703)	(0.671)	(1.011)	(-1.124)
Countries fixed-effects	Yes	Yes	Yes	Yes	Yes
Quarter dummies	Yes	Yes	Yes	Yes	Yes
Observations	347	347	347	347	347
Number of countries	15	15	15	15	15
Adjusted R-squared	0.503	0.547	0.739	0.771	0.985

Notes: ROA=return-on-assets, ROE=Return-on-Equity, NII=Net-income Income, NNI=Non-interest Income, LLP=Loan-loss provision. $Mapp$=Cumulative macroprudential policy index. Fixed-effect regression with data at quarterly frequency on an unbalanced sample of 15 countries from 2005Q5 to 2014Q4. For readability, the control variables are not presented here. Robust t-statistics in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 4.13: Baseline model for emerging economies

VARIABLES	(1) ROE	(2) ROE	(3) NNI	(4) NII	(5) LLP
lag.ROA	0.488***				
	(3.457)				
lag.ROE		0.453**			
		(2.351)			
lag.NNI			0.186*		
			(1.938)		
lag.NII				0.232***	
				(3.133)	
lag.LLP					0.937***
					(20.60)
cum_pruc	-0.0321***	-0.245**	0.0310	-0.0132	-0.0165*
	(-2.762)	(-2.040)	(1.648)	(-0.506)	(-1.906)
Countries fixed-effects	Yes	Yes	Yes	Yes	Yes
Quarter dummies	Yes	Yes	Yes	Yes	Yes
Observations	409	409	409	409	409
Number of countries	13	13	13	13	13
Adjusted R-squared	0.877	0.774	0.764	0.892	0.976

Notes: ROA=return-on-assets, ROE=Return-on-Equity, NII=Net-income Income, NNI=Non-interest Income, LLP=Loan-loss provision. $Mapp$=Cumulative macroprudential policy index. Fixed-effect regression with data at quarterly frequency on an unbalanced sample of 13 countries from 2005Q5 to 2014Q4. For readability, the control variables are not presented here. Robust t-statistics in parentheses. *** p<0.01, ** p<0.05, * p<0.1

4.6.7 Robustness check for interaction model with financial development

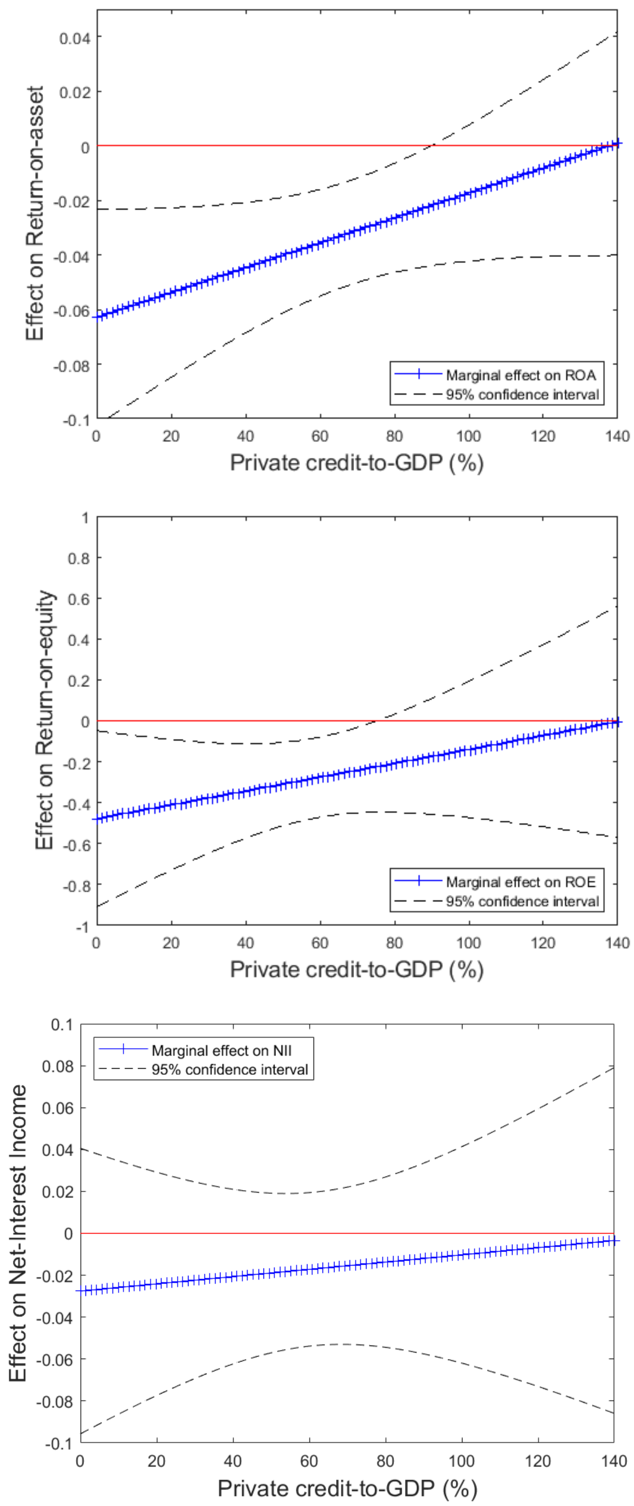
In this section, I present the model of an interaction model that use an alternative measure of financial depth, namely the ratio of private credit to GDP. Table 4.14 presents the regression results while Figure 4.7 shows the associated marginal effect of a tightening of macroprudential policy as a function of the private credit to GDP ratio.

Table 4.14: Interaction model with private credit to GDP

VARIABLES	(1) roa	(2) roe	(3) nni	(4) nii	(5) llp
L.roa	0.296**				
	(2.167)				
L.roe		0.262*			
		(1.919)			
L.nni			0.149*		
			(1.952)		
L.nii				0.137**	
				(2.163)	
L.llp					0.938***
					(24.12)
Mapp	-0.0651***	-0.455**	-0.0458*	-0.0276	-0.0243**
	(-3.180)	(-1.987)	(-1.787)	(-0.793)	(-1.981)
pcmbgdp	-0.00192	0.0291	-0.00704**	-0.00929*	0.00279
	(-0.708)	(0.800)	(-2.043)	(-1.902)	(1.314)
Mapp*pcmbgdp	0.000464*	0.00253	0.000778**	0.000173	0.000210*
	(1.680)	(0.688)	(2.366)	(0.361)	(1.688)
Countries fixed-effects	Yes	Yes	Yes	Yes	Yes
Quarter dummies	Yes	Yes	Yes	Yes	Yes
Observations	685	685	685	685	685
Number of countries	24	24	24	24	24
Adjusted R-squared	0.808	0.643	0.768	0.886	0.980

Notes: ROA=return-on-assets, ROE=Return-on-Equity, NII=Net-income Income, NNI=Non-interest Income, LLP=Loan-loss provision. *Mapp*=Cumulative macroprudential policy index, *dcpsgdp*=ratio of private credit to GDP. Fixed-effect regression with data at quarterly frequency on an unbalanced sample of 28 countries from 2005Q5 to 2014Q4. For brevity, the control variables estimates are not presented here. Robust t-statistics in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Figure 4.7: Marginal effect of macroprudential policies and private credit to GDP



Notes: Marginal effect of a one-point increase in the cumulative macroprudential index on the return-on-assets (top panel), the return-on-equity (middle panel) and the Net-interest income (bottom panel) as a function of the private credit-to-GDP per capita. The dash lines represent the 95% confidence intervals. Source: Table 4.14 and Author's Calculation

Chapter 5

Conclusion

The micro-foundations of modern macroeconomics has put the concept of heterogeneity on the frontline of macroeconomics research. Heterogeneity is now everywhere in Macroeconomics, from the essential characteristics of economics agents to the different reactions to a similar shock. This Ph.D. thesis explores three aspects of heterogeneity in Macroeconomics, namely the determinants heterogeneity in price rigidity, its implications in terms of monetary policy effects, and the heterogeneous effects of macroprudential policy on bank profitability. Each chapter of this thesis makes a distinct contribution to the literature, provides some policy recommendations and opens the door for future research.

Chapter 2 of this thesis provides a new determinant of heterogeneity in price rigidity. So far the literature has identified four main determinants, namely the labor and intermediate inputs cost shares, the sectoral inflation, and the concentration ratio. This chapter proposes the degree of return to scale as a critical determinant of price stickiness and provides theoretical and empirical of a positive association between returns to scale and price rigidity. By doing so, this chapter puts the highlight on returns to scale, which is acknowledged in modern macroeconomics but used with parsimony. The importance of returns to scale also brings the questions of its accurate measurement. This chapter provides motivations for more research about the estimation of firms' returns to scale. Concerning possible policy recommendations, this chapter provides a rationale that countries that experience highly volatile price changes in some sector (for example, food sector in developing countries) should pursue policies that favor more substantial returns to scale for firms. These policies include access to a broader market for firms thanks to regional integration.

Further, Chapter 3 investigates the real effects of monetary policy in a New-Keynesian model with two dimensions of heterogeneity, namely heterogeneity in price rigidity and returns to scale. Chapter 2 provides evidence that the amplification effect originally implied by heterogeneity in price rigidity is likely to be overstressed. The reason behind this is that the heterogeneity in returns to scale decreases the level of the overall level of strategic complementarities. That result casts doubt on the importance of heterogeneity in price rigidity to generate realistic effects of monetary policy. Thus the recent development of Heterogenous Agent Neo Keynesian (HANK) models that put an emphasize on heterogeneity in demand-side agents (such as Households) may be a suitable path to follow when it comes to proposing models that cause sizable effects of monetary policy.

The last chapter of this thesis deals with the heterogeneous effects of macroprudential policies on bank profitability at the country level. While bank profitability is essential to ensure a country's financial sector stability, very few papers attempt to investigate these effects. Chapter 4 provides evidence of an adverse impact of a tightening of the macroprudential framework on the return-on-assets and the return-on-equity, especially in emerging countries with a limited financial sector. This result entails at least two implications. On the one hand, countries need to use the macroprudential policies with caution, especially when they tighten them. On the other hand, a long-run objective should be to domestically develop the overall financial system and enhance its ability to identify and finance profitable projects.

Finally, this thesis as a whole strengthens the importance of heterogeneity in Macroeconomics. While future research is encouraged to utilize the concept of heterogeneity, this Ph.D. points out that heterogeneity required some thorough thinking about its possible implication. As evidenced in the first two chapters of this thesis, heterogeneity in one aspect is likely to be associated with another heterogeneity. Moreover, on the empirical side, econometric methods that emphasize heterogenous effects should be put forward.

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