Firm and product responses to domestic and international regulatory change

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Abstract

The thesis looks at the effects of domestic and international regulatory change on trade costs and firms. The first chapter looks at the effects of a change in the regulation governing oceanic goods trade, the IMSBC code, on the international trade in commodities. The second chapter investigates how trade liberalisation affects the mode of transport, using the removal of quotas under the Multi-Fibre Arrangement to study its effects on the modal decisions of Chinese firms. The final chapter uses firm-level panel data to look at the effect of the feed-in-tariff on renewable energy firms' performance in the UK.

Contents

Introduction

International trade has grown considerably over the last few decades, with most countries trading more today than 20 to 30 years ago (UNCTAD, 2015). This trend has continued in the face of global downturns in recent years, for example the global financial crisis in 2007 and the current pandemic. Along with increases in income and in more information, part of the international trade increase is prominently due to the decline in international trade costs, for example the decline in trade tariffs (WTO 2012). Trade costs can be broadly defined as "include all costs incurred in getting a good to a final user other than the marginal cost of producing the good itself" (Anderson and van Wincoop, 2004). Trade costs are affected by a myriad of factors that have interested economists since the beginning. However, such costs are difficult to measure in practice, with distance used as the most common proxy for such costs in past studies.

The literature of trade costs is vast, with much ongoing research. Technological innovation, culture and "politics" are a few factors that have received significant attention from the economics profession (Jacks, et al 2011, Novy, 2013). Technological innovation may mean that it is cheaper to move goods across long distances. In the 19th and 20th centuries steam power and railroads came into existence, dramatically reducing the cost to transport goods across long distances (Donaldson, 2018). Over the period from 1970 to 2000, trade costs declined on average by 40 percent for the US and 33 percent for 13 OECD (Organisation for Economic Co-operation and Development) countries (Novy, 2013). In the 1960s the wide adoption of "containerisation", the introduction of standard containers to store and transport goods, further decreased freight costs. Bernhofen et al (2016) find that containerisation leads to trade flows increasing to $33.5 million over a 15-year period. During this time, improvements in aviation further lead to declining costs of trade. The above contributed to the "first" and "second" waves of globalisation.

More recently, there has been studies that attempted to estimate the effect of travel cost on trade. Söderlund (2020) looks at the effect of business travel on trade, using the liberalisation of Russian air space as its natural experiment. He finds that the cost of business travel can account for 85% of the cost of trade.

Regulations and policies are another component of trade costs. Tariffs and quotas, policies that are determined by governments, are instruments created to influence the flow of goods and services across national borders. Such measures directly affect trade costs, leading to a variety of effects on firms within an economy.

Despite its importance, there remains much to be explored in the area of trade costs. The main reason for this is the limited availably of data that directly captures the costs of trade. (Anderson and van Wincoop, 2004). The focus of this thesis is to measure and investigate firm responses to trade costs from regulatory change. Broadly, this thesis can be split into two strands. One focusing on trade costs, and the other on the effects of policy on the performance of firms in the domestic economy.

The first chapter of the thesis investigates the effect of regulatory change on oceanic shipping. I investigate the effect of the introduction of a policy, the IMSBC code[1], on global trade. The IMSBC code is part of a broader set of policies that govern commodities trade on the sea. Specifically, the IMSBC code governs the safe transport of commodities for example, as they relate to the stability of the vessel or the potential combustion of the commodity, across the ocean. A change in the IMSBC code will likely affect transport costs such as freight and time costs associated with shipping. A tightening of regulation, reflected in more rules for shippers to follow or more forms to fill, will likely have negative effects on trade. However, the IMSBC code is unique in that it is a regulation related to the safety of shippers. In this capacity, there might be positive effects, as shippers may be more willing to carry cargo knowing that it is safe to do so. To my knowledge, this is the first paper that looks at the effect of the IMSBC code on cross-country trade. This study will investigate the effects of the IMSBC adoption on the trade in commodities over the sea.

One definition of commodities are raw-material goods such as iron ore, charcoal, and zinc sulphide. It forms a part of the international trade in goods with limited research in the Economics discipline (for example, Brancaccio, Kalpuptsidi and Papageorgiou, 2020), despite making up over half of all trade transported over the ocean (UNCTAD). Previous studies of international trade that focused on the trade in goods have either focused on trade as a whole (Anderson van wincoop, 2004), or with disaggregated studies that have yet to focus on the commodities market. More commonly, commodities are seen in the international trade literature as inputs in input-output tables. This chapter presents one of the few studies on the international trade in the commodities market.

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[1] The code provides information on the rules governing the carriage of solid bulk cargoes, includes information on the dangers of shipping certain types of solid bulk cargo and instructions on the procedures to undertake when deciding to ship.

The above also leads to a further difference between this study and others in the literature. When it comes to the actual transportation of goods across the seas, goods other than commodities are carried in containers under fixed routes. This is in contrast to commodities, which are transported, often homogenously, in large "open air" ships in flexible routes.

Another contribution of this paper is the construction of a dataset that identifies commodity goods transported under the IMSBC code. Data on the trade in commodities, like trade in other goods and services, are classified under the Harmonized System (HS) code that is used by customs around the world. For this reason, such trade information is freely available at sources such as COMTRADE and WITS. However, there are many instances where a different definition is used in reality. Regulation that governs oceanic trade is one such example where a different set of rules are used to define goods carried across the ocean. In my study, I construct a novel dataset of commodities defined under the IMSBC code, creating a concordance for such goods between the IMSBC and the HS code. Such a concordance is important, as it allows me to capture the decisions made by shippers in reality, that would not be possible from just using HS code data at face value. Without the identification of this novel dataset, I would be unable carry out research into the effect of the IMSBC code introduction on commodity trade.

The goal of the second chapter is to investigate how trade liberalization affects the mode of transport for goods. I investigate the effects from quota removal, using the lifting of the Multi-Fibre Agreement (MFA) on the decision of firms to ships goods by air or sea. The MFA is a framework for agreements that established quotas limiting clothing and textile imports into countries.

Moving goods over long distance requires time and money. Goods are shipped across borders by different modes of transport. Such modes have very different characteristics (e.g. different costs and time to delivery etc.). Ocean cargo, for example, takes an average of 20 days to go from Europe to the US, whereas air cargo only requires an average of a day (Hummels and Schaur, 2013). Long shipping times results in inventory holding and is perhaps important when firms face demand uncertainty. The mode of transport has important implications for the movement of goods across the globe.

I take advantage of a unique trade liberalisation event that helps establish causality with transportation mode, namely, the removal of the Multifiber Arrangement (MFA). Many previous studies have investigated the effect of the MFA on developed economies (Harrigan and Barrows 2009, Utar 2014). In this chapter I will be focusing on the effects of the MFA removal on the choice of transportation mode, airfreight or ship, by Chinese firms. I investigate the effect of the MFA on exports to the US and EU. China is an attractive country for this study since it is both the top exporter of textile and apparel products in developing economies, as well as one of the top exporters of textile and apparel products globally.

This chapter contributes to the previous research on trade costs through the effects on transportation costs. Similar to Hummels (2013) I use the share of goods transported by air as the dependent variable as the measure of transportation costs. In contrast to their study, I focus on a specific market rather than trade as a whole. In addition, their study focuses on the US, whereas this study focuses on China. The textile and apparel market is an interesting market to study, due to characteristics such as the prevalence of "just-in-time" production processes that more heavily influence export decisions for firms engaged in international trade.

I use firm level data for exports of textile and apparel for Chinese firms. This chapter uses the universe of Chinese textile and apparel firms at the firm-product-country-month level. This allows me to investigate the effects at the micro level.

The final chapter of this thesis investigates the effect of government policies on the renewable energy sector. I investigate the effects of the introduction of the feed-in-tariff scheme on renewable energy firms in the UK. To my knowledge, this is one of a few studies that investigates the effect of the feed-in-tariff in the UK.

Over time, governments around the world have come to acknowledge and devote more resources to the goal of sustainable development. The Paris Agreement, an international agreement in which signatory countries agree to "limit global temperature increase to below 2 degrees' pre-industrial levels" (UNFCCC) came into force in November 2016. In addition to international agreements, many countries are pursuing their own national policies to reach their targets for sustainable development. In 2017, the share of renewables in global final energy consumption was 10.5%.

This chapter will contribute to the literature in several ways. Firstly, this study will add to the existing body of literature on the effectiveness of renewable energy policy. The literature has yet to come to a consensus on the effects of certain renewable energy policy for the UK economy.

Secondly, I identify firms that operate in the renewable energy sector in the UK. The FAME dataset does not include a variable to identify renewable energy firms (for example an industry code).

To the authors knowledge, this will be one of the first study that looks at the effects of renewable energy policy and firm performance. This allows me to investigate micro effect on firms' response to regulatory change. Whilst the analysis of the chapter is limited to the UK, the results that I find here could be applied to other developed economies.

Finally, this chapter will examine several econometric techniques in an attempt to identify the causal effects of the government policy on renewable energy firms. I compare the results of propensity score matching (PSM) to those obtained under difference-in-differences (DiD). In addition, I combine the PSM and DiD methodology and find similar results as those under the original DiD.

1 Chapter 1. Trade costs and maritime shipping: the effect of the IMSBC code

1.1 Introduction

International trade has grown dramatically over the last few decades, with most countries trading more today than they did 20 or 30 years ago. Between 1998 and 2018, international merchandise trade grew at an average rate of 7.1% (WTO international trade statistics, 2019). In tandem with that growth came steep drops in the cost of international trade. Appendix A figure shows the WTO's total trade cost index (TCI), between 2000 and 2018, has fallen by 15%.

The link between trade costs and trade values/volumes is worth investigating. Trade costs encompass a wide range of costs that can be incurred before the goods reach their destination. Anderson and van Wincoop (2004) define trade costs into seven broad categories: 'transportation costs (both freight costs and time costs), policy barriers (tariffs and non-tariff barriers), information costs, contract enforcement costs, costs associated with the use of different currencies, legal and regulatory costs, and local distribution costs (wholesale and retail).' However, such costs are difficult to measure in practice, with distance used as the most common proxy for such costs in past studies.

A prominent explanation for the rise in international trade and fall of trade costs is the decline in transportation costs (Hummels, 2007). From 1850-1913, Economic historians documented substantial reductions in shipping costs arising from technological change (Mohammed and Williamson, 2004). Post World War II, jet engines and containerization further lowered the time and transportation costs of shipping goods over long distances.

Research on the effects of transportation costs has been scarce, with varying results. For example, Limao and Venables (2001) looked at the effect of changing container costs on trade. As part of an investigation on economic growth in East Asia, Abe and Wilson (2009) found cutting port congestion by 10 per cent would decrease transport costs by 3 per cent.

Brancaccio, Kalpuptsidi and Papageorgiou (2020) build a search and matching model for the shipping industry, allowing them to estimate the relationship between the number of ships arriving at port and the likelihood of those ships sailing from the port carrying cargo. One of their findings is that the transportation sector creates network effects in trade costs measured by shipping prices.

This study seeks to investigate the causal relationship between transport costs and trade. I identify an area of transport costs, and the effect of regulation (a part of trade costs) and then link this to trade in a specific good: the international trade in commodities via maritime shipment. Estimating this relationship is challenging as direct measurements of trade costs including transport costs are very limited. There may also be confounders correlated with transport costs and international commodity trade, e.g., other characteristics of the regulatory system which are correlated with income. I address these concerns by introducing a new exogenous cost shock from the viewpoint of shippers. The shock consists of a change in the International Convention for the Safety of Life at Sea (SOLAS) with an amendment where the 'Code of Safe practice for Solid Bulk Cargoes' (the BC code) was replaced with the 'International Maritime Solid Bulk Cargoes code' (the IMSBC code), these codes govern how commodity goods should be transported over the sea. The IMSBC code was adopted in December 2008 and entered into force in January 2011.

I obtained the 2018 version of the IMSBC code published by the International Maritime Organisation (IMO) and combined this with amendment information from the IMO's website allowing me to construct my policy variable. The IMSBC code has been updated in regular intervals of every two years since its introduction in 2008. With each update, cargoes are moved out, and new cargo schedules are added. The details of the updates can be found in section 1.2.2. This movement between schedules will be used to capture changes in transport costs in this study.

The IMSBC code classifies cargo into three different categories Group A, Group B and Group C (see details in section 1.2.2). Each category has a different implicit cost, in the form of the cost of supplying the correct forms and procedures, as well as the time cost involved in following regulations. More procures and requirements are required for some product groups than others. For example, products in Group A are required to present additional information, such as their cargoes' Transportable Moisture Limit (TML), before the ship is allowed to leave port.

I identify and link the cargo schedules in the IMSBC code to traded products by the Harmonised System (HS) codes and assemble a large panel of yearly data on trade and country characteristics globally. Using this information, I implement a difference-in-difference model that compares international trade flows between countries before and after the IMSBC implementation compared to a counterfactual of non-treated products. The consideration of the counterfactual data will be explained in detail in section 1.2.2.

This study will be one of a few that focus on trade in the commodities market. Others include Kohn et al. (2018) and Brancaccio et al. (2020). One convenient characteristic of this market for trade research is that commodities are mostly transported by one mode, the sea transport. In contrast to previous studies, which focused on goods transported via containers, this study focuses on goods (commodities) that are transported via large open ships. Each ship, in general, will carry only one type of good for transport. In the context of this study, this characteristic eliminates a potential issue where ships follow a portfolio of regulations dependent from the different products that they will carry for the voyage[2].

I provide several new findings. Firstly, I show that the overall effect of the implementation of the IMSBC code has been to raise trade volumes in the affected products by a small amount. In that regard, the trade-enhancing effects of regulation dominate overall, consistent with a reduction in risk from carrying cargo. Secondly, this effect is heterogeneous between cargo groups, with a negative effect on Group A commodities and a positive effect on commodities in Group B. Finally, this effect is driven by variation across countries across different income groups, with the impact for Group A primarily coming from low income countries and both income groups for commodities in Group B. These effects are driven by changes in transport and time costs as well as differences in compliance between countries.

Section 1.2 provides the background information on maritime shipping and the IMSBC code. It lays out the policy structure, information, and application to commodity transportation by sea. Further information on the change in policy is also provided. Section 1.3 reviews the existing literature, covering trade and transportation costs. Section 1.4 discusses the data used for the study. This is important since there is no existing dataset that relates IMSBC code to commodity trade data. Section 1.5 discusses the methodology and strategy employed in this study, describing the use of difference-in-differences, fixed effects and gravity covariates to estimate the IMSBC effects on commodity trade on the sea. Section 1.6 discusses the results from the estimation followed by robustness checks, focusing on various

[2] One drawback of looking at open air shipping is that data on certain characteristics, such as liner rates are not available. This could be used to capture transport costs although such data is limited and not commonly available to researchers.

outcomes, including trade volume, trade value, income groups, unit price, and different treatment year. Section 1.7 concludes this chapter.

1.2 Background on maritime shipping and the IMSBC code

Maritime shipping is overseen by the International Maritime Organization (IMO). The IMO is the United Nations agency responsible for shipping over the sea. It is responsible for setting the industry's standards and has remit over the safety, security and environmental impact of international shipping. The main aim of the IMO is to create a regulatory framework for international shipping that is 'fair and effective, universally adopted and universally implemented' (IMO).

This study focuses on commodities that fall under the category of "bulk cargo". There are four main codes for the carriage of bulk cargo as of March 2019 (information below comes from the IMO website):

1. IMSBC code (International Maritime Solid Bulk Cargo Code) – mandatory regulation for carrying solid cargo in bulk form.
2. International Grain Code – applicable to all ships carrying grain in bulk. The term 'grain' covers wheat, maize (corn), oats, rye, barley, rice, pulses, seeds and processed forms thereof, defined as those with behaviour similar to that of grain in its natural state.
3. IBC Code (International code for construction and equipment of ships carrying dangerous chemicals in bulk) – for the carriage of chemicals in bulk as well as the design, construction, and equipment with respect to the ship and the cargo.
4. IMDG Code (International Maritime Dangerous Goods) – regulations on carrying dangerous cargo over the seas. For packaged goods

This study focuses on code 1, the IMSBC code.

1.2.1 Commodity trade by sea

The IMSBC code exclusively affects trade in commodities, or primary goods. Commodities are raw or partly refined materials and include minerals such as iron ore or agricultural commodities such as coconut oil.[3] The international trade in commodities is primarily by sea, where maritime transport accounts for 80% of world trade. Goods are transported in one of two ways: through containers or open shipping. Open shipping is carried out by bulk carriers.

[3] In contrast to other products there is a high concentration of commodities among only a few countries. Production from British Geological Survey

Open shipping (or dry bulk shipping) makes up half of the goods shipped by the sea (tons, UNCTAD) and is the method of transportation for commodities. The key differences between the two types of shipping are summarised below:

Container shipping:

- Heterogeneous goods
- Travels on fixed schedules on fixed routes (liner shipping)

Dry bulk shipping:

- Homogeneous goods
- Flexible routes on the agreed-upon schedule between the exporter and ship
- Dry bulk shipping tends to be open-style ships with cargo loaded directly from the quarry

Almost all commodities are transported on dry bulk carriers, therefore, this study looks at this type of transportation.

Dry bulk shipping involves ships carrying homogeneous unpacked dry cargo. In many instances, the commodity is loaded directly onto the ship from the quarry. For bulk carries, the homogenous good is transported via a single ship, from origin to destination. As such, trips are realised through individual contracts between a supplier and an exporter, with each ship carrying only one type of cargo, and from only one hirer at any one time. This is in contrast to container shipping, where many different cargoes can be loaded onto the ship and transported.

Dry bulk carriers can be classified into four categories, based on size (DWT, the below categories are from Kalouptsidi, 2014):

- Handysize (10,000 – 40,000 DWT[4])
- Handy- max (40,000 – 60,000 DWT)
- Panamax (60,000 – 100,000 DWT)

[4] DWT is deadweight tonnage, a measure of how much a ship can carry. DWT is the sum of the weights of a ship's ballast water, crew, cargo, fresh water, fuel, passengers and provisions etc. Individual category details from Brancaccio et al. 2020

- Capesize (larger than 100,000 DWT)

The market structure of the industry for dry bulk carriers is unconcentrated; there are a large number of small ship-owning firms (Kalouptsidi, 2014).

A unique feature of the dry bulk shipping market is the high number of ships travelling without cargo (ballast). Using satellite data, Brancaccio et al. (2020) find that around 42% of ships are travelling without cargo at any point in time. Ideally, shippers would like to ship their commodity to one country, offload at the port, find a new exporter and ship their commodity to another country. This means that the prices shippers charge for exporters will depend on their likelihood of acquiring cargo on the return trip. This has meant that, for example shipping from China to Australia is 30% cheaper than vice versa (Brancaccio et al. 2020). China mainly imports raw materials, offering limited opportunities for departing ships to reload.

1.2.2 Moving from BC code to IMSBC code

The SOLAS convention is an international treaty which specifies minimum safety standards in the construction, equipment and operation of ships. Under the convention flag states are responsible for ensuring that ships flagged by them comply with the SOLAS standards. The convention also gives signatory governments the right to inspect ships of other contracting states to ensure that the requirements of the convention are met. The SOLAS convention is generally regarded as the most important of all international treaties governing the safety of merchant ships[5]. As of March 2019, there are 165 contracting states, with a combined fleet which constitute approximately '99% of the gross tonnage of the world's merchant fleet'[6].

Under the SOLAS convention, the Code of Safe Practice for Solid Bulk Cargoes (the BC Code) was first introduced in 1965 and it acted as a recommendary code until January 2011, when it was replaced by the IMSBC code and the IMSBC code moved from being recommended to mandatory. The move from BC to IMSBC code also synchronises the update schedules for the different safety codes for maritime shipping with biannual reviews.

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[5] https://www.imo.org/en/About/Conventions/Pages/International-Convention-for-the-Safety-of-Life-at-Sea-(SOLAS),-1974.aspx

[6] Status of Conventions - Comprehensive information including Signatories, Contracting States, declarations, reservations, objections and amendments. Available at IMO's website.

The third purpose of this replacement is to add new products and update information for existing cargoes.

The IMSBC code is updated every two years. There have been four amendments to 2018:

- Amendment 01-11 by the IMO Resolution MSc.318(89) in force in Jan 2011
- Amendment 02-13 by the IMO Resolution MSc.354(92) in force in Jan 2013
- Amendment 03-15 by the IMO Resolution MSc.393(95) in force in Jan 2015
- Amendment 04-17 by the IMO Resolution MSc.426(98) in force in Jan 2017

With each update, some cargoes are moved out, and new cargo schedules are added:

- Amendment 02-13 made changes to 15 existing cargo schedules and added 16 new cargo schedules. Nickel ore was added to Group A category.
- Amendment 03-15 made changes to 19 existing cargo schedules and added 17 new cargo schedules. Iron ore was changed but remained in Group C, Iron and steel slag, and iron ore fines are added to Group A category.
- Amendment 04-17 amended 19 existing cargo schedules and added 18 new cargo schedules.

The primary aim of the IMSBC code is to 'facilitate the safe stowage and shipment of solid bulk cargoes and to give detailed information about the intended solid bulk cargo to the ship and give instructions about the dangers and risks of particular cargoes' (IMO). It aims to be the regulatory bible for an internationally accepted method of dealing with the hazards to safety which may be encountered when carrying cargo in bulk (IMO).

More specifically, the IMSBC code lists which common products are shipped in bulk, highlights the dangers associated with certain shipments of bulk cargoes, advises loading and other procedures, advises cargo properties handling and which test procedures to use to identify characteristic cargo properties. For example, coal is documented as having hazards of creating flammable atmospheres, depleting oxygen and being prone to liquefaction (Liquefaction is the process in which solid material changes and gains the properties of a liquid – details in section 1.2.3). Weather, loading and general precautions are included with, for example, trimming requirements prior to transport. For coal that is loaded onto a gravity-fed self-unloading bulk carrier, shippers must ensure that no excess air is fed into the commodity when ventilating, as this may lead to self-heating of the commodity.

A detailed description of the cargo schedules is discussed in the data section later in this paper.

This code is used daily by sailors to ensure the safe carriage of cargoes. Each commodity has a cargo schedule[7] which lists handling instructions as well as the band it is in.

In both the BC and IMSBC codes, cargoes are categorised into three groups: Group A, Group B, and Group C. The BC code defines three groups as follows (IMSBC, 2018):

- Group A: Bulk materials which may liquefy
- Group B: bulk materials possessing chemical hazards
- Group C: bulk materials which are neither liable to liquefy not to possessing chemical hazards

The IMSBC code defines the three groups similarly, with a greater level of detail and added notes (IMSBC, 2018):

- Group A – cargoes which may liquefy.
- Group B – cargoes which possess a chemical hazard could give rise to a dangerous situation on a ship. It is further classified in two ways: dangerous goods in solid form in bulk and materials hazardous only in bulk.
- Group C – cargoes which are neither liable to liquefy (Group A) nor possess chemical hazards (Group B).

A key identifier for cargoes that are listed in Group A is their particle size distribution. This characteristic makes matching the code to trade difficult, as will be discussed later in the study. Group A has a documented issue: inadequate testing methods and a lack of crew awareness over the potential for liquefaction of some cargoes (Cooke et al. 2018). This issue does not arise for Group B commodities.

Cargoes designated as 'dangerous' in Group B tend to have the following characteristics[8] (IMSBC, 2018)

[7] Cargo schedule refers to any of the materials that can be transported. The code applies to not only mineral ores but other types of materials such as pellet feed etc

[8] From 'Carrying solid bulk cargoes safely'. Lloyd's Register/UK P&I Club/Intercargo, 2013

- Combustible solids: materials that are readily combustible or easily ignitable
- Self-heating solids: materials that self-heat
- Solids that evolve into flammable gas when wet: materials that emit flammable gases when in contact with water
- Solids that evolve toxic gas when wet: materials that emit toxic gases when in contact with water
- Toxic solids: materials that are acutely toxic to humans if inhaled or brought into contact with skin
- Corrosive solids: materials that are corrosive to skin, eyes, metals or respiratory sensitisers.

The major risks present for Group B cargo are fire and explosion, toxic gas and corrosion.

1.2.3 Liquefaction

Liquefaction is the process in which a solid material changes and gains the properties of a liquid. It is commonly seen during earthquakes. Here, the vibrations of the earth turn the solid soil into a liquid.

Liquefaction has long been an issue in the shipping industry. Two factors make liquefaction especially potent in the commodities shipping market. Firstly, commodities are bulk cargo. All bulk cargoes tend to have some moisture content during transport, either naturally or from being left outside before being loaded onto ships. This increases the likelihood of liquefaction taking place.

Secondly, the characteristics of ocean shipping, which is responsible for almost all of commodity trade, increases the likelihood of liquefaction occurring. During an ocean voyage, the cargo is subject to many external forces, such as engine vibrations, waves hitting the ship and the rocking of the ship. Such forces could cause the transported commodities to turn from a solid to a liquid. This sudden change in the properties of a cargo (liquefaction) can affect the stability of the ship, causing it to tilt and, in the worst case, to sink. This is the risk that liquefaction poses to ships and the reason it is related to safety in maritime transport.

A report by Intercargo found that ‘between 1988 and 2015 there have been thirteen total losses of bulk carriers of 10,000-ton deadweight and above with the reported loss of 128 seafarers’ (Table 1.1).

Table 1.1 List of documented ships that have been lost in the past three decades due to liquefaction (Joint Hull committee reports and Intercargo)

	Vessel Details	DOL	Loss of Life
Mega Taurus	1988	16/12/1988	20
Oriental Angel	1990	09/06/1990	0
Sea Prospect	1998	26/08/1998	10
Jag Raghul	2005	01/12/2007	0
Asian Forest	2007	17/07/2009	0
Black Rose	1977	09/09/2009	1
Jian Fu Star	1983	27/10/2010	12
Nasco Diamond	2009	10/11/2010	20
Hong Wei	2001	03/12/2010	10
Vinalines Queen	2005	25/12/2011	22
Harita Bauxite	1983	17/02/2013	15
Trans Summer	2012	14/08/2013	0
Bulk Jupiter	2006	02/01/2015	18
Total	13		128

However, this documented incidence of ships lost as a result of liquefaction is likely to be lower than what is happening in reality. Firstly, not all ships document the cause of sinking. Secondly, when the case is documented, usually only one cause is recorded. When ships capsize, there are usually many confounding factors that lead to their demise. This results in underreporting of liquefaction as a cause of incidents.

Liquefaction has been known in the industry for quite a long time with the Group A category dedicated to this phenomenon. One of the factors for changing from the BC to the IMSBC code was to tackle this risk. The passage of time has led to improvements in shipping technology and safety, but the issue of liquefaction is not fading away. In more recent times, the sinking of two very large ships, M/V Stellar Daisy and M/V Emerald Star, as a result of liquefaction directly led to the addition of new cargo schedules in the IMSBC code.

1.2.4 Mechanism related to trade costs

When a ship arrives in port and wishes to load cargo, a typical procedure would involve cargo information being presented to the shipper. The shipper would then consult the IMSBC code to identify the relevant schedule. The schedule would inform the shipper of the hazards of the cargo and the relevant precautions to be taken for safe carriage.

Typical requirements for Group A cargoes (Lloyds and P&I clubs):

- They must be tested for their Transportable Moisture Limit (TML) before transport. However, an issue with TML testing is that it is a specialised task - worldwide there are not many competent and independent labs, especially in some of the main exporting countries. Many of the mines are also not easily accessible due to being located in remote regions.
- Masters should carry out visual monitoring during loading. If there are any indications of high moisture content, the loading should be stopped.
- Masters may consider trimming the cargo to reduce the likelihood of cargo shift.
- Additional measures should be undertaken to ensure water and other liquids do not enter the cargo during both loading and transit.

Typical requirements for Group B cargoes:

- Must have a document of compliance/dangerous goods for the ship.
- An additional special list, manifest or stowage plan identifying the cargo's location. There must also be instructions on board for emergency response.
- Cargo must be segregated.

Group C cargoes are considered to be "safe" cargoes, and do not have further requirements that needs to be met for the ship to transport the goods.

Trade costs[9] incur with:

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[9] Another measure of the potential trade costs are freight rates; direct measures of freight rates are however hard to find. Freight rates can be split into two components: spot rates and time charter rates. A time charter is a contract where a ship-owner puts the ship at the disposal of a charterer for a certain amount of time. The ship-owners will get a fixed payment from the charterer during the charter period.

- Delays from testing and issuing certificates for cargo (there are only a few testing labs around the world)
- Delays in port. Ships with cargo with moisture in excess of TML are prevented from sailing
- Ships that carry cargo that do not meet regulations could lose their club cover
- Failure to follow regulations could lead to the sinking of the ship

1.3 Literature review

This paper contributes to the literature on trade costs. There is a vast literature studying trade and trade costs, with many theoretical and empirical studies on the topic. Previous theoretical studies include Head and Ries (2001) which used increasing returns to construct a trade cost measure. Anderson and van Wincoop (2003) provide the model for trade costs in the context of the gravity equation. Novy (2013) supplements this by estimating trade costs through inversion of the gravity equation.

Previous empirical studies of trade and transportation costs typically fall into two types, gravity equation econometrics studies and general equilibrium (CGE) simulation models. The CGE method is more commonly used by governments and international organisations for economy-wide policy analysis.

Broadly speaking, trade costs in previous research can be categorised into three groups: border-to-border, behind-the-border and at-the-border. Border-to-border includes costs involved in shipping a good from for example, one port in the origin country to another in the destination country. Behind-the-border involves costs that are incurred to get the goods to the port (or vice-versa), for example infrastructure costs such as the number and quality of road networks. Finally, at-the-border costs are costs that are incurred during border processing. An example would be the customs forms that must be completed before the good can exit the country.

One important theme in the study of trade costs is the difficulty in obtaining direct measures of trade costs (Anderson and van Wincoop, 2004). In their older papers, a common measure is to use the difference in the price of a good across locations as the measure of transportation costs.

Limao and Venables (2001) provide one of the earliest direct measures of trade costs. They obtain quotes from private firms for moving a standard container from Baltimore to destinations around the world. They find significant and consistent evidence that poor domestic infrastructure leads to lower trade volumes.

More recently, the literature on trade costs has focused on a broader set of issues under the term ‘trade facilitation’. One definition of trade facilitation includes ‘all domestic and border systems and procedures that help to move goods and services into and out of a country’. A strand of the literature looks at the differences between different transport modes as a measure of trade costs. Hummels and Schaur (2013) use the time in transit for good as a proxy for quality and model the choice between air and ocean shipping. The authors find that each day a good spends in transit is the equivalent of a tariff of as much as 2.1 per cent.

Studies have also investigated costs at the border. Martinez-Zarzoso and Marquez-Ramos (2008), looks at the effect of export and import delays and fees (documentation delays) on sectoral trade. Wilmsmeier and Martinez-Zaraoso (2010), using transaction-level customs data for 16 Latin American countries, finds that improved port efficiency, upgraded port infrastructure, and private sector participation in port services help reduce maritime transport costs. Djankov, et al (2010) also look at the effect of transit delays on trade, expanding the analysis to 146 countries. Clark et al. (2004) investigates the impact of border costs on maritime shipping costs using HS-6 U.S. import data from developed and developing countries for 1996, 1998, and 2000. They find that improving port efficiency from the 25th to 75th percentile leads to an increase in trade by 25 percent.

Many of the studies in trade facilitation have used three databases: Global Competitiveness Report (GCR), Doing Business (DB) and Logistics Performance Index (LPI). One limitation of such datasets in the literature on trade and transportation costs is that there is little sectoral variation. Secondly, the results are from surveys which may suffer from subjective bias.

All of the above studies and most research in the trade literature have been carried out in the context of container shipping. Investigations of international trade commonly discuss trade in goods which are transported by containers on ships. There are only a handful of papers that look at trade in the bulk shipping market. The major reason for this is the difficulty in obtaining data specifically for the bulk/commodity shipping market. There is a small strand of literature that looks at ships used in bulk shipping. Using ship contract data Kalouptsidi (2014) studies the supply of ships in the commodities market. To my knowledge, there are only two papers that study trade in the commodities market. Fally and Sayre (2018) look at the gains from trade with commodities. Through simulations, they find that the gains from trade are significantly larger after including commodities trade. Brancaccio et al. (2020) build a model for oceanic transportation services and trade, where both trade flows and trade costs are equilibrium objects. Bulk shipping is discussed in the empirical analysis with data on ship movements and prices from bulk carriers.

In this study, the focus will be on trade costs between and at-the-border costs. The effects of regulation change on trade will be examined. The effects of regulation from costs such as documentation delays and fees are examined in this study.

1.4 Data

My main data sources are bilateral commodity trade data and BC and IMSBC code data. To investigate the effect of the IMSBC code on commodity trade I use data from the UN COMTRADE database. The COMRADE database is selected for two main reasons. Firstly, the IMSBC code impacted trade globally, hence the dataset needs to cover as many countries as possible. UN COMTRADE covers trade for all countries in the world. Secondly, the change in the IMSBC code affected the trade in commodities, with different regulations for different commodities. This meant I needed to identify such traded commodities. The COMTRADE database provides information at the HS 6 level, the lowest level of disaggregation available across countries.

Other variables from the COMTRADE database include those that identify the exporting and importing country, the trade value and trade quantity. I use data from 2005-2017. The changes (biannual updates) in the IMSBC code occurred in 2011, 2013, and 2015 allowing for the consideration of pre-treatment years. 2017 is chosen as the endpoint since, after 2017, there are further changes/updates in the code which would change the composition of the control group.

The part of the IMSBC code that is most relevant to this study is the list of ‘cargo schedules’ that identify the list of transported commodities that are in the IMSBC groups. The cargo schedules are what shippers must look at to check whether the transported commodity is in Group A, B or C (or any combination of the three). The cargo schedule contains a brief summary of the commodity followed by shipping information, hazards, storage instructions as well as other safety information.

Figure 1.1 provides an example of the full information provided to shippers on a commodity in the IMSBC code 2018 edition. The cargo schedule provides more detailed information on how to transport commodities, although schedules tend to be two pages in length. The code with the cargo schedule format was adopted under the BC code in 2004. Only the first sections provide identifying information on specific commodities, I thus mainly use information from the description and characteristics sections to match commodities from the IMSBC code to the HS code.

Figure 1.1 Truncated cargo schedule from IMSBC code 2018

RESOLUTION MSC.268(85)
(adopted on 4 December 2008)
ADOPTION OF THE INTERNATIONAL MARITIME SOLID BULK CARGOES (IMSBC) CODE
- 115 -

CHARCOAL

DESCRIPTION
Wood burnt at a high temperature with as little exposure to air as possible. Very dusty, light cargo. Can absorb moisture to about 18 to 70% of its weight. Black powder or granules.

CHARACTERISTICS

ANGLE OF REPOSE	BULK DENSITY (kg/m^3)	STOWAGE FACTOR (m^3/t)
Not applicable	199	5.02
SIZE	**CLASS**	**GROUP**
–	MHB	B

HAZARD
May ignite spontaneously. Contact with water may cause self-heating. Liable to cause oxygen depletion in the cargo space. Hot charcoal screenings in excess of 55°C should not be loaded.

STOWAGE & SEGREGATION
Segregation as required for class 4.1 materials. "Separated from" oily materials.

As the IMSBC code is updated biannually, new cargo schedules are added. Sometimes existing cargo schedules have their information updated although this is rare. Updates to the IMSBC code may also remove exiting cargo schedules and replace them with new, more disaggregated schedules of the same commodity. All this information is used in my dataset.

1.4.1 Matching the IMSBC code to the HS code

One of the contributions of this study is the identification of specific commodities matched to their traded HS codes. I take the cargo schedules from the IMSBC code and match the appropriate schedules to the trade data by HS codes. Not all of the commodities match the HS code. The main reason for this is because in many instances the HS code does not classify products to a detailed enough level of disaggregation. But this level of detail is also absent in most trade datasets available today. How I handle the issue is further explained below.

- HS code descriptions tend to be broad and not perfectly correlated with goods in the IMSBC code. For example, for many Group A products in the IMSBC code particle size is an important determinant of how the product is categorised. There could be similar commodities in Groups A or B depending on the particle size of the commodity in question. This means that some commodities can have multiple entries and be in different groups due to different particle sizes. This information is missing from the HS code. This issue is partly alleviated when combining additional information from other industry and scientific sources (e.g. BSG), which provide information on factors such as end use, which allows a better match to descriptions in the HS code. Commodities with multiple entries due to different particle sizes are dropped from this study.

- There are still some products that have been assigned more than one HS code after the above handling. In these cases, I attempted to identify commodities with precise descriptions such that overall, each commodity was placed under no more than two HS codes in this study.
- Some products listed in the IMSBC code constitute a large proportion of the total trade in the commodity. Where possible I have identified such commodities as the ones that are more likely to provide a closer match to the product categories in the IMSBC code.
- This study focuses on products at the HS6-digit product category level. Higher level codes, such as at the HS8 or HS10 level provide more detailed product information but these tend to have different codes and product descriptions across countries. This does have the drawback of HS6 categories including unrelated products, however, this issue is smaller with commodity products compared with the more heterogeneous nature of general trade products/goods. In the cases where HS items are defined so broadly that they cover more than one commodity in the IMSBC code, these products were excluded from the analysis.

Table 1.2 below provides summary statistics of the main variables used in this study. These variables are defined in Table 1.3. Table 1.4 provides summary statistics for the commodities belonging to Groups A and B.

Table 1.2 Summary statistics of the main variables

Dependent variables	**Mean**	**Median**	**S.D.**	**Observations**
Log quantity (in kg)	8.47	8.61	4.16	5932216
Log trade value (in US dolllars)	9.73	9.81	3.39	5978601
Log unit value	4.87	4.78	1.29	3522618
Log cif/fob ratio	0.49	0.27	1.57	5881738

Independent variables	**Mean**	**Median**	**S.D.**	**Observations**
Log GDP exporter	25.97	26.19	2.08	5926416
Log GDP importer	27.37	27.49	1.76	5958869
Log distance	8.04	8.24	1.14	5958843
Common border	0.12		0.33	5958843
Common language	0.19		0.40	5958843
Common colony	0.05		0.23	5958843
Landlocked	0.20		0.40	5958843

Table 1.3 Commodities affected by change in the IMSBC code and their corresponding control group

Commodity name	**Group**	**HS code**	**Control commodity**	**HS code**
Blende (zinc sulphide)	A	320642	Cadium sulphide	283030
Cement copper	A	7401	copper-zinc base	740322, 740321, 76
Ammonium Nitrate based fertilizer (Type A) UN	B	310230	Other fertilisers	310100
Brown coal briquetts	B	270120	Wood (for fuel, in logs)	440111, 440112
Charcoal	B	4402	Wood (for fuel, in logs)	440111, 440112
Copra (dry)	B	1203	coconut oil	1513
Petroleum coke, calcined	B	271312		271000
Petroleum coke, uncalcined	B	271311	Oils	271000
Quicklime	B	2522	Cement	252321, 252329

Table 1.4 Summary statistics by commodity group

Dependent variables	Observation	Mean	Median	S.D.
Group A				
Log quantity	3740811	8.11	8.29	4.04
Log trade value	3779278	9.57	9.68	3.27
Log unit value	2274247	4.87	4.78	1.34
Log CIF/FOB	3729999	0.48	0.26	1.5
Group B				
Log quantity	4232457	8.85	9.11	4.29
Log trade value	4261936	9.72	9.8	3.43
Log unit value	2429851	4.85	4.77	1.36
Log CIF/FOB	4190949	0.48	0.26	1.56

Independent variables	Observation	Mean	Median	S.D.
Group A				
Log GDP exporter	3752968	26.01	26.2	2.03
Log GDP importer	3769765	27.54	27.74	1.67
Log distance	3779632	8.05	8.25	1.13
Common border	3779632	0.12		0.33
Common language	3779632	0.19		0.39
Common colony	3779632	0.05		0.22
Landlocked	3779632	0.19		0.4
Group B				
Log GDP exporter	4222361	25.98	26.22	2.09
Log GDP importer	4247351	27.36	27.49	1.8
Log distance	4242020	8.01	8.19	1.15
Common border	4242020	0.13		0.34
Common language	4242020	0.2		0.4
Common colony	4242020	0.05		0.23
Landlocked	4242020	0.19		0.39

1.4.2 Treated and Control commodity selection

I consider a commodity to be in the treated group if they were belonging to Group A or group B, or they were moved into Groups A or B after the introduction of the IMSBC code. Commodities that were originally in Group C or remaining in Group C after the IMSBC introduction are selected to be in the control group. The process of constructing the treatment and control groups is presented below:

- Match cargoes in the IMSBC code to the HS code for the commodities in Groups A, B and C. Products not matched to Groups A, B or C are removed from the analysis.

- Commodities in either Groups A or B are the treatment group. This is because groups A and B are both dangerous commodity groups with restrictions under the IMSBC code for the safe carriage of solid bulk cargoes. The treatment group also includes commodities that are moved to or added to groups A or B after the introduction of IMSBC code.
- Group C commodities are in the control group because Group C commodities are non-hazardous and do not have restrictions in the code. This includes commodities that are original in Group C or remaining in Groups C after the IMSBC introduction. I further construct two control Groups, CT1 and CT2, as below:
    - CT1 selects commodities in group C at the broader HS2 level with those that are in Groups A or B (treatment group). For example, the commodity Blende is a Group A product with HS6 code HS320642. I identify all HS2 codes of HS32 products from Group C and include them in CT1. This captures industry-level effects.
    - CT2 selects the Group C commodities based on their similarity to goods in Groups A or B using their product characteristic information. The product characteristic information could be the same/similar extraction process, or the same/similar chemical property, or the same/similar end use. They are complements. The details of the selection process are summarised in the Figure 1.2 decision tree below. This control group is selected based on product characteristics.

These two groups are compared and later in the study provide the support that my results are robust.

Figure 1.2 CT2 grouping based on product characteristics

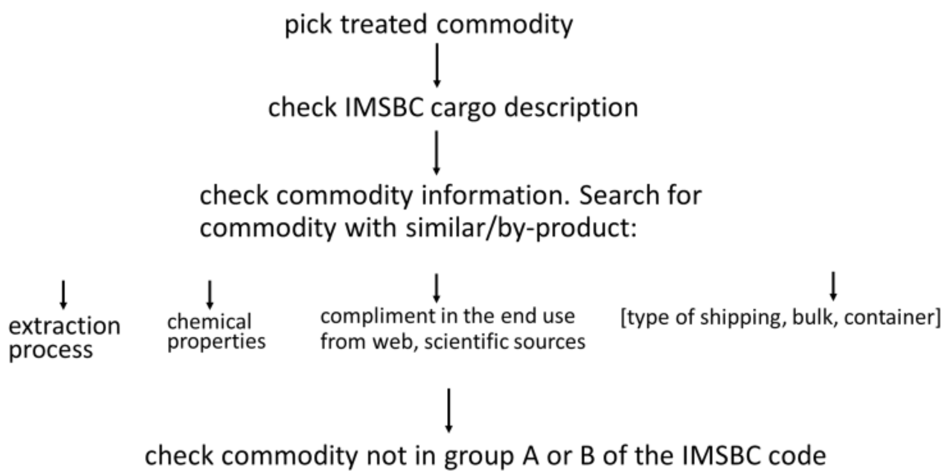


Table 1.5 below shows the result of the construction of the treatment-control groups.

Table 1.5 Treated and control groups HS code list

Regression group	Commodity group	HS2 code							
Treatment group	Group A	32	74						
	Group B	12	25	27	28	31	44		
Control group	CT1	32	74	12	25	27	28	31	44
	CT2	28	74	15	25	27	31	44	

The IMSBC code is not exhaustive, meaning that there were some commodities that were not included in any of Groups A, B, or C. The treatment group includes products that are changed from group C in the BC code to A or B in the IMSBC code. Commodities that were not in any groups in the BC code but added to Group A or B in IMSBC code are also included in the treatment group.

The control groups are selected as mentioned above, with commodities being either the HS2 level similarity to the treated commodities or the characteristic level similarity to the treated commodities.

Some commodities are harder to match from the cargo schedule to the specific HS code, e.g., some Group C cargo schedules are similar but not completely the same as those in the HS code. In such a situation I find it reasonable to assume that the code would not have had an effect or had the same effect as if it was in Group C, since, from a shipper's perspective, the shipper would declare a cargo not in the IMSBC code as Group C, rather than as Groups A or B. There is evidence of this from ship incidents. Ships carrying copper concentrate as Group C cargo have sunk in recent years – the classification of copper concentrates could be either Group A or Group C depending on the moisture and particle size.

Cargoes that are not in the IMSBC code are excluded from the study. This is because of two main reasons. Firstly, cargoes that are not in the IMSBC code will need to notify the competent authority of the port of loading, which will then assess the acceptability of the cargo for shipment. If it is assessed that the cargo may present hazards as those in Groups A or B of the code, the port of loading, the port of unloading and the flag state will then set the suitable conditions for the carriage of the cargo. The effect of this on trade and trade costs is unclear. With three port authorities involved, there could be a significant cost for unlisted cargo, from time delays to storage cost etc. This may affect its position in the next

IMSBC review (e.g., they may be included in Groups A or B in a following biannual update). On the other hand, if most unlisted cargo is declared safe for carriage, then its effects will not be important. Such commodities are excluded from the study.

1.4.3 Parallel trends assumption

As presented above, the treatment group contains hazardous commodities and the control group the non-hazardous. To capture the effect of the regulatory change on commodity trade, trade in hazardous commodity groups is compared to trade in the non-hazardous group.

An assumption that supports the selection of treatment and control groups is that of parallel trends in the pre-treatment period. I plot the trade quantity over the study period for the treatment and control groups as summarised in Table 1.5. These are shown in Figures 1.3, 1.4, and 1.5. Figure 1.3 plots the total trade quantity for the treatment group commodities in Groups A and B against the control group CT2. Figure 1.4 plots the treatment commodities in Group A vs CT2, and Figure 1.5 plots the commodities in Group B vs CT1. The figures provide the support that the trends are parallel pre-treatment.

Figure 1.3 Log trade quantity of Groups A and B treatment vs control group

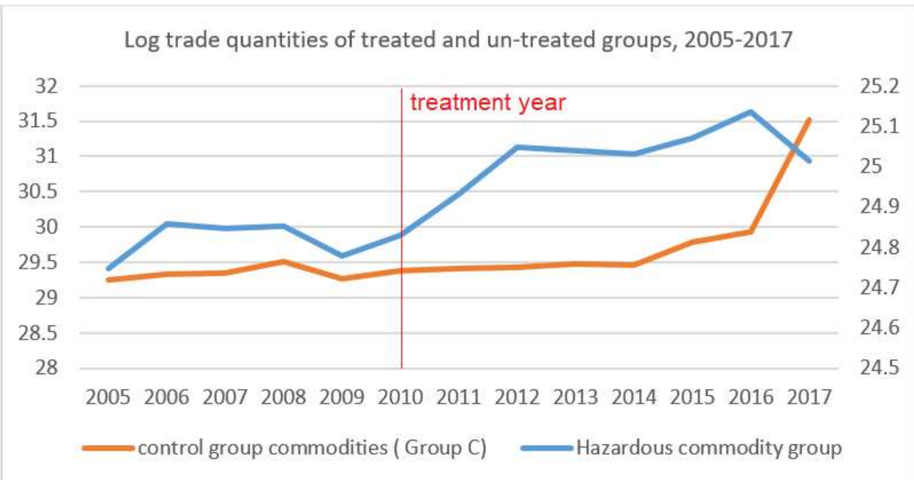


Figure 1.4 Log total trade quantity of Group A treatment vs control group CT2

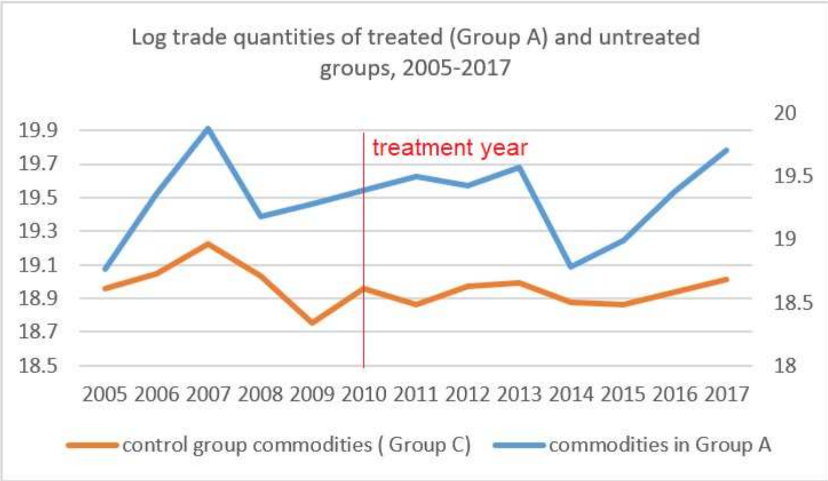
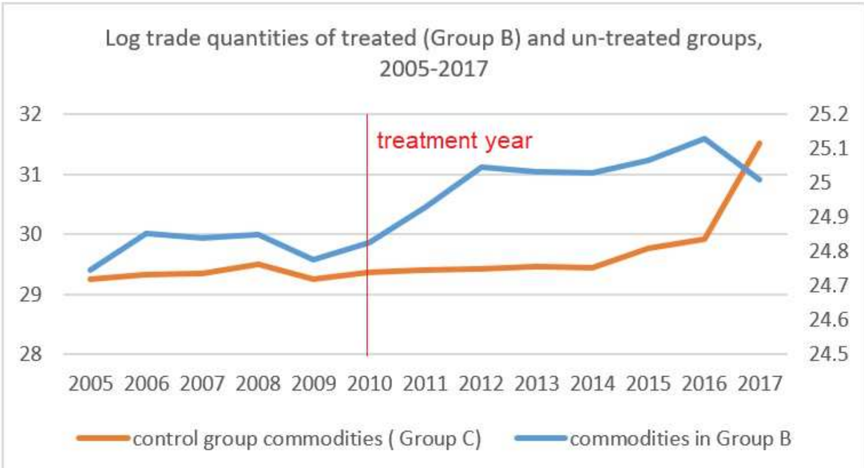


Figure 1.5 Log trade quantity of Group B treatment vs control group CT1



One of the concerns is that there are many commodities in the treatment group with different characteristics. The figures above show this to be the case but with differences spread between Group A and group B. For example, the log total trade quantity for Group A was 18.9 in 2010, and for Group B, it was 25.1.

A possible issue is that commodities are selected into groups on unobservable characteristics, for example political interests. This is unlikely to be true as updates to the code are driven by safety concerns. Amendments to the code directly follow previous accidents or concerns.

It can be seen that the treatment and control groups are independent. An advantage of selection commodities trade to study this question is that these are usually transported using specialist vessels and the mixing of cargoes does not typically occur.

1.5 Framework

The introduction of the IMSBC code was a change in regulation in the safe transport of goods over the sea. I expect the change in regulation to potentially affect trade in the following ways.

The change in regulation has a negative effect on the commodities trade. This is due to the fact that with the IMSBC code commodities have to follow more regulations, which translates to increased costs to ship the same good. For Group A products, a key cost was commodities had to have tested and verified Transportable Moisture Limits (TML). The code requires that Group A commodities can only leave the port once their cargo has a certificate verifying that the cargo has a moisture limit below the TML. For Group B cargo, shippers needed to have a document of compliance as well as ensure segregation requirements were met for the cargo to be carried.

There is anecdotal evidence to suggest that it is time consuming to acquire the certificate for TML. One way to get the TML certificate is to get it from an accredited lab. There are only a handful of testing labs in the world with it taking days or weeks to receive the results. There is evidence from insurers reminding members to get certificates from an approved lab[10]. The other method is to get a surveyor on-site to inspect and approve the cargo, which again increases costs before goods can leave the port. There is also evidence here that approved surveyors are limited and take time to survey the cargo. One reason for this is that for mineral commodities, many tend to be located and mined in remote locations, where access is difficult. In addition, subsequently, many commodities are loaded directly from the mine onto the ship. This meant that the adoption of the IMSBC code thus likely increased costs and uncertainty for commodities.

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[10] Alfred H Knight (Ahk group) provides all three of the industry recognized tests (flow table, penetration and proctor-fagerberg) in their five worldwide labs. “scope of Flow Moisture Point /Transportable Moisture Limit testing for Solid Bulk Cargoes”. Available at: https://www.ahkgroup.com/services/technical-consultancy/

The introduction of the IMSBC code reduces risk and uncertainty for transported commodities and could have positive effects on trade. The IMSBC code is a safety regulation, with its introduction increasing the level of safety for ships carrying cargo. This increased level of safety could lead to shippers being more willing to carry dangerous cargo due to decreased risks during the voyage. The reduced level of uncertainty leads to increased commodity trade.

1.5.1 Empirical model: difference-in-differences

I estimate the effect of regulatory change on trade costs and trade with a new regulatory event not studied before in the literature, the change of the BC to IMSBC code, to help establish causality using the difference-in-differences method. The difference-in-differences design is useful as it eliminates some sources of bias. It is possible that there are secular time trends in the trade in the commodities market. Both the treated and control groups look at the commodities that are imported which may incur changes in the future. DiD can eliminate the changes caused by factors other than the introduced regularity event studied in this paper.

The difference-in-differences model is:

$$lqty_{i,j,s,t} = \beta_1 + \beta_2 treat_{i,j,s} + \beta_3 post_t + \beta_4 treat * post_{s,t} + \beta_5 Gravity_{i,j,t} + X'_i\lambda_1 + X'_j\lambda_2 + X'_{i,j}\lambda_3 + \varepsilon_{i,j,s,t} \quad (1.1)$$

The above equation (1.1) is estimated for imports. $lqty_{i,j,s,t}$ represents imports of commodity *s*, from country *j* to *i* in time *t*. $lqty_{i,j,s,t}$is the log quantity of imports.

$treat$ represents the group of traded commodities that were affected by the change of the code from the BC to the IMSBC code. $treat$=1 for commodities that are included in the treatment group and *treat=0* for the commodities in the control group.

$post$ is the treatment year dummy that is set to year 2010 when the BC code was replaced by the IMSBC code.

β_4 is my parameter of interest which measures response to IMSBC introduction, relative to products that were unaffected by the shock through the interaction between $treat$ and $post$.

Standard gravity covariates (e.g., GDP, distance, common language, common border, common colony, landlocked) are added in further tests of the model. This is to address two possible issues. Firstly, adding control variables can on occasion help to reduce the standard errors on the treatment variable and therefore the precision of the coefficient estimates. A second more important concern is that they may be potentially correlated with the treatment variable, for example measures of country size or wealth could be correlated with the availability or use of commodities and therefore the adoption of the IMSBC code. Including these control variables can therefore be justified on the grounds of omitted variable bias.

GDP is especially important here as commodity trade is heavily influenced by the size of the importing country (Brancaccio et al. 2020), with large countries driving demand in the global market. In addition, as mentioned in section 1.2.1 shippers also decide where to go depending on the ballast opportunities available. Countries with large economic activity are more favourable for shippers since they carry a higher probability that the ship will travel with cargo on the return trip. To an extent the effect of this underlying mechanism will be captured by the GDP variable.

Fixed effects specifications are further added to the model to control for unobserved heterogeneity confounders. Country and country pair fixed effects are ${X'}_i\lambda_1$, ${X'}_j\lambda_2$, and ${X'}_{i,j}\lambda_3$, respectively. ${X'}_i$ and ${X'}_j$ are important since they capture any fixed country-specific characteristics that may impact the trade in commodities over the duration of the IMSBC code. For example, one such concern is that certain countries do not follow or stringently follow shipping regulations from time to time. To the extent that this may be varied over the study period, such effects would be captured partially by the country-fixed effects. ${X'}_{i,j}$ is to capture country pair characteristics to the extent that this is consistent. The supply of certain commodities is located in only a handful of countries, with trade between some countries having lasted over many years. It is not unreasonable to assume that firms in those countries may have established favourable trading conditions with their client. Such conditions may positively or negatively affect trade given a shock (e.g. IMSBC change). Country pair fixed effects will go some way to control for such effects. Some fixed effects may be omitted to capture effects on variables that would be collinear with the fixed effects.

1.5.2 Pre-trends

A key underlying assumption of the difference-in-difference model is the parallel trends assumption (PTA). This is the assumption that the units in the control group should follow the trend of the treated units, had the treatment not taken place. Three years of pre-treatment is common using difference-in-differences, in part due to common limitations with the data (Jaeger et al, 2018). In my study, I use five years of pre-treatment data to mitigate this concern as I have five years' of data available.

Apart from the PTA plotting in figures 1.3, 1.4, and 1.5 which support this assumption, Table 1.6 below shows the result of the pre-trend test on treatment groups A, B and both, versus CT1 and CT2 as control groups, respectively. As shown in the table, prior to the treatment year 2010, the treat*year coefficients are not statistically significantly different from zero, therefore supporting the assumption that the treatment and control group share the same pre-trends. This result differs from the post-treatment results, where the treat*year coefficients are mostly significant after year 2010 (especially with CT2 group). This is as expected and indicates that the parallel trends assumption holds in the study period.

Table 1.6 Pre-trend test result

Dependent variable: Log quantity	Group A		Group B		Both	
	CT1	CT2	CT1	CT2	CT1	CT2
	(1)	(2)	(3)	(4)	(5)	(6)
Treat	0.422***	0.289*	1.654***	1.355***	1.837***	1.870***
	(0.133)	(0.154)	(0.0506)	(0.0591)	(0.0495)	(0.0583)
Year 2005	0.131***	0.202***	0.127***	0.144***	0.131***	0.152***
	(0.0163)	(0.0222)	(0.0185)	(0.0184)	(0.0153)	(0.0171)
Year 2006	0.114***	0.111***	0.0843***	0.129***	0.0891***	0.101***
	(0.0147)	(0.0212)	(0.0173)	(0.0161)	(0.0142)	(0.0158)
Year 2007	0.152***	0.136***	0.113***	0.135***	0.121***	0.129***
	(0.0141)	(0.0206)	(0.0165)	(0.0152)	(0.0135)	(0.0150)
Year 2008	0.139***	0.150***	0.148***	0.151***	0.140***	0.150***
	(0.0133)	(0.0183)	(0.0151)	(0.0143)	(0.0124)	(0.0137)
Year 2009	-0.0752***	-0.0660***	-0.0392***	-0.0277**	-0.0519***	-0.0466***
	(0.0108)	(0.0152)	(0.0126)	(0.0124)	(0.0102)	(0.0114)
Year 2011	-0.0652***	-0.0970***	-0.0780***	-0.0522***	-0.0705***	-0.0765***
	(0.0110)	(0.0144)	(0.0119)	(0.0118)	(0.00963)	(0.0108)
Year 2012	-0.137***	-0.196***	-0.173***	-0.121***	-0.156***	-0.158***
	(0.0139)	(0.0186)	(0.0151)	(0.0141)	(0.0127)	(0.0139)
Year 2013	-0.152***	-0.261***	-0.199***	-0.137***	-0.182***	-0.192***
	(0.0139)	(0.0187)	(0.0151)	(0.0141)	(0.0126)	(0.0139)
Year 2014	-0.165***	-0.261***	-0.184***	-0.131***	-0.177***	-0.187***
	(0.0150)	(0.0205)	(0.0167)	(0.0156)	(0.0139)	(0.0154)
Year 2015	-0.268***	-0.401***	-0.327***	-0.266***	-0.302***	-0.330***
	(0.0171)	(0.0239)	(0.0210)	(0.0205)	(0.0175)	(0.0196)
Year 2016	-0.322***	-0.437***	-0.380***	-0.342***	-0.348***	-0.379***
	(0.0213)	(0.0285)	(0.0271)	(0.0261)	(0.0229)	(0.0251)
Year 2017	-0.308***	-0.339***	-0.309***	-0.269***	-0.303***	-0.317***
	(0.0246)	(0.0318)	(0.0305)	(0.0292)	(0.0260)	(0.0280)
Treat*2005	-0.0947	-0.212	0.0549	-0.00106	0.00315	-0.0722
	(0.151)	(0.189)	(0.0579)	(0.0699)	(0.0565)	(0.0676)
Treat*2006	0.0209	0.0387	0.0447	-0.0342	0.00518	-0.0556
	(0.145)	(0.183)	(0.0572)	(0.0688)	(0.0558)	(0.0663)
Treat*2007	-0.130	-0.0274	-0.0518	-0.0421	-0.0866	-0.0602
	(0.138)	(0.173)	(0.0551)	(0.0652)	(0.0527)	(0.0613)
Treat*2008	-0.0727	-0.154	0.0304	0.00643	0.0235	-0.00907
	(0.138)	(0.175)	(0.0527)	(0.0625)	(0.0515)	(0.0604)
Treat*2009	0.124	0.120	0.0408	0.0362	0.0720	0.0798
	(0.132)	(0.167)	(0.0504)	(0.0600)	(0.0493)	(0.0576)

Treat*2011	-0.0597	-0.0878	0.177***	0.152***	0.151***	0.156***
	(0.131)	(0.163)	(0.0481)	(0.0561)	(0.0470)	(0.0542)
Treat*2012	-0.139	-0.113	0.187***	0.116*	0.143***	0.125**
	(0.140)	(0.173)	(0.0533)	(0.0619)	(0.0520)	(0.0597)
Treat*2013	-0.182	-0.197	0.0800	0.0166	0.0382	0.0416
	(0.138)	(0.175)	(0.0535)	(0.0624)	(0.0525)	(0.0606)
Treat*2014	-0.276*	-0.274	0.104*	0.0437	0.0680	0.0680
	(0.147)	(0.181)	(0.0555)	(0.0647)	(0.0537)	(0.0622)
Treat*2015	-0.275*	-0.354*	0.0424	0.0225	-0.00681	0.0572
	(0.150)	(0.184)	(0.0570)	(0.0644)	(0.0547)	(0.0620)
Treat*2016	-0.0333	0.00116	0.0930	0.115*	0.0633	0.154**
	(0.152)	(0.187)	(0.0591)	(0.0671)	(0.0566)	(0.0647)
Treat*2017	-0.0596	-0.192	0.0330	0.0286	0.0134	0.0608
	(0.162)	(0.199)	(0.0621)	(0.0714)	(0.0596)	(0.0689)
Constant	8.279***	7.728***	8.925***	9.502***	8.514***	8.670***
	(0.0385)	(0.0487)	(0.0415)	(0.0387)	(0.0383)	(0.0407)
Observations	2,331,392	2,123,048	3,774,211	2,442,528	5,473,970	4,565,576
R-squared	0.002	0.003	0.005	0.004	0.005	0.005

Robust standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1

1.6 Results

This section presents evidence on the causal effect of the adoption of the IMSBC code on commodity trade quantity in relation to trade costs. Section 1.6.1 shows the baseline results. I begin with the aggregated group of treated commodities for an indication of the overall effect of the policy change. I find a positive effect on trade quantities from the code transition. Section 1.6.2 then disaggregates this effect. Splitting the results, I find heterogeneous effects across the IMSBC groups. The adoption of the IMSBC code had a negative effect on Group A commodities compared with a large positive effect on Group B.

1.6.1 Baseline results

Table 1.7 estimates a baseline difference-in-differences model with the treated group as commodities in Groups A and B. It shows the estimates using the control group CT2, which uses data based on product characteristics. Another estimation using the control group CT1 which is based on the industry HS2 code level, shows similar effects as to using control CT2.

Table 1.7 Baseline difference-in-difference estimate for Groups A and B treatment with CT2 control

Dependent variable: Log quantity	(1)	(2)	(3)	(4)	(5)	(6)
Treat	1.832***	1.834***	1.583***	1.585***	1.272***	1.273***
	(0.0453)	(0.0453)	(0.0428)	(0.0428)	(0.0413)	(0.0413)
Post	-0.315***		-0.330***		-0.234***	
	(0.0147)		(0.0132)		(0.0105)	
Treat*Post	0.130***	0.130***	0.174***	0.173***	**0.227***	0.226***
	(0.0360)	(0.0360)	(0.0343)	(0.0343)	(0.0334)	(0.0334)
Constant	8.751***	8.575***	8.763***	8.579***	8.715***	8.585***
	(0.0404)	(0.0396)	(0.0295)	(0.0282)	(0.00581)	(0.000576)
Time FE	N	Y	N	Y	N	Y
Country FE	N	N	Y	Y	N	N
Country Pair FE	N	N	N	N	**Y**	Y
Observations	4,565,576	4,565,576	4,565,570	4,565,570	4,562,275	4,562,275
R-squared	0.004	0.005	0.125	0.126	0.231	0.231

Product level clustered standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Looking at the "Treat*Post" coefficients in Table 1.7, the coefficients are all strongly significant at the p<0.01 significance level across all specifications. The estimates suggest that the introduction of the IMSBC code has had a positive and significant effect on commodity trade volumes. Without any fixed effects, as in column (1), the coefficient is 0.130, indicating that a general increase of 13.9%[11] in trade volume is expected after the introduction of the IMSBC code. Results with country pair fixed effects are large and significant (column 5). This suggests that there is heterogeneity in responses within country pairs, with some countries having large effects that are reflected in the overall estimate. Time-fixed effects in column (2) do not change the coefficient (remains at 13.9%). This indicates that the effects on trade are not time sensitive, and will be the same regardless of when the code was introduced.

The 'Treat' coefficients capture the variations between the treated and control commodities. The magnitudes are similar, from 1.272 to 1.834 across all specifications, with the difference within country pairs the smallest. As discussed in the previous paragraph, the introduction of the IMSBC code caused a 13.9% increase in trade volume from this baseline difference (1.832) between the treated and control groups ((between the hazardous commodities and safe commodities). This means that the effect of the change is around 2.65%[11].

Overall, I find a significant effect of the introduction of the IMSBC code on trade volumes. These results provide some indication of the potential effects of the change in regulation. The significant effect of the IMSBC code introduction on trade volumes is consistent with the fact that the IMSBC code is one of the main legislation governing the shipping of commodities across the seas. The positive effect implies that trade increased despite an increase in trade costs. These results will be explored in the upcoming sections.

1.6.2 Disaggregate baseline results

The previous result showed that hazardous groups did have significant effects on trade by estimating the overall effects of both Groups A and B commodities. However, Groups A and B products are subject to different requirements. In this section I now disaggregate the effect

[11] Equals 13.9/524.6=2.65%

by IMSBC group, splitting the sample into commodities in Group A and Group B and estimating the baseline model on CT1 and CT2 control groups, respectively.

I find that the results to sharply differ from the aggregate by IMSBC group. Table 1.8 shows that in contrast to the aggregate, as shown in Table 1.7 using CT1 as the control group, trade in commodities in Group A declined as a result of the adoption of the IMSBC code (trade volumes decreased by 11.2%[12]). Whilst this coefficient is not significant across the specifications (1)-(4) of the model, the negative coefficient is persistent, implying that there was a response by shippers to decrease the amount of Group A commodities in response to the adoption of the IMSBC code. In the specifications (5)-(6) with country pair fixed effects (column (5)) the introduction of the IMSBC code led to a significant decrease of, e.g., 14.3%[13] of traded quantities for commodities in Group A compared with the counterfactual. This indicates that within country pairs the decrease is more severe than across countries. This negative effect on trade volumes is consistent with an interpretation that the introduction of the IMSBC had increased transport costs for Group A products.

[12] coefficient -0.119, column (1) "Treat*Post" coefficient

[13] coefficient -0.154

Table 1.8 Disaggregated baseline estimate - Group A treatment with CT1 control

Dependent variable: Log quantity	(1)	(2)	(3)	(4)	(5)	(6)
Group A	0.414***	0.412***	-0.0932	-0.0954	-0.568***	-0.570***
	(0.0946)	(0.0946)	(0.0940)	(0.0940)	(0.101)	(0.101)
Post	-0.283***		-0.278***		-0.167***	
	(0.0126)		(0.0109)		(0.00939)	
Group A*Post	-0.119	-0.114	-0.0962	-0.0918	**-0.154***	-0.151*
	(0.0810)	(0.0809)	(0.0778)	(0.0778)	(0.0801)	(0.0801)
Constant	8.337***	8.180***	8.337***	8.183***	8.281***	8.189***
	(0.0380)	(0.0378)	(0.0275)	(0.0272)	(0.00516)	(0.000484)
Time FE	N	Y	N	Y	N	Y
Country FE	N	N	Y	Y	N	N
Country Pair FE	N	N	N	N	**Y**	Y
Observations	2,312,412	2,312,412	2,312,412	2,312,412	2,309,415	2,309,415
R-squared	0.001	0.002	0.124	0.124	0.260	0.260

Product level clustered standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 1.9 uses the same estimation with the treated group containing just commodities from group B. The results for Group B are similar to the effects found in the regressions pooling all commodities together (Table 1.7). The introduction of the IMSBC code had a positive effect on the quantity of goods shipped, with an 8.58%[14] increase in the unrestricted model as shown in column (1) of Table 1.9. This is nearly half of the observed increase of the aggregate effect of 13.9% (Table 1.7) when both two treatment groups are included. Some of this difference is due to more group B products compared with Group A, leading to more weighting of Group B products.

The effect is again found to be consistent and significant as I include fixed effects in the model. The consistent effect suggests that there was another factor that counterbalanced the increased costs resulting from complying with the IMSBC code.

[14] Coefficient 0.0823

Table 1.9 Disaggregated baseline estimate - Group B treatment with CT1 control

Dependent variable: Log quantity	(1)	(2)	(3)	(4)	(5)	(6)
Group B	1.673***	1.674***	1.517***	1.519***	1.302***	1.303***
	(0.0385)	(0.0385)	(0.0370)	(0.0370)	(0.0356)	(0.0356)
Post	-0.308***		-0.323***		-0.231***	
	(0.0158)		(0.0141)		(0.0111)	
Group B*Post	0.0823**	0.0827**	0.115***	0.115***	**0.158*** **	0.158***
	(0.0330)	(0.0329)	(0.0315)	(0.0315)	(0.0306)	(0.0306)
Constant	8.996***	8.824***	9.007***	8.827***	8.961***	8.833***
	(0.0411)	(0.0403)	(0.0301)	(0.0284)	(0.00622)	(0.000673)
Time FE	N	Y	N	Y	N	Y
Country FE	N	N	Y	Y	N	N
Country Pair FE	N	N	N	N	**Y**	Y
Observations	3,770,517	3,770,517	3,770,517	3,770,517	3,767,490	3,767,490
R-squared	0.005	0.005	0.130	0.130	0.237	0.237

Product level clustered standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

I find similar results using instead the CT2 control group (Tables 1.10 and 1.11). The reader will recall that the control group used by these regressions consists of commodities that are selected based on additional information and characteristics such as similar end use. Group A goods are again negatively affected in contrast to a positive effect for Group B commodities.

The consistent results from two different control groups lend support to the robustness of my models. All subsequent estimations will use CT2 as the control group.

Table 1.10 Disaggregated baseline estimate - Group A treatment with CT2 control

Dependent variable: Log quantity	(1)	(2)	(3)	(4)	(5)	(6)
Group A	0.269***	0.266***	-0.209**	-0.212**	-0.517***	-0.519***
	(0.0992)	(0.0993)	(0.0894)	(0.0894)	(0.0928)	(0.0928)
Post	-0.374***		-0.365***		-0.255***	
	(0.0178)		(0.0152)		(0.0124)	
Group A*Post	-0.138	-0.135	-0.146	-0.144	**-0.185***	-0.182*
	(0.0999)	(0.1000)	(0.0946)	(0.0947)	(0.0958)	(0.0959)
Constant	7.800***	7.592***	7.797***	7.594***	7.739***	7.598***
	(0.0478)	(0.0468)	(0.0312)	(0.0301)	(0.00687)	(0.000331)
Time FE	N	Y	N	Y	N	Y
Country FE	N	N	Y	Y	N	N
Country pair FE	N	N	N	N	**Y**	Y
Observations	2,105,205	2,105,205	2,105,205	2,105,205	2,102,564	2,102,564
R-squared	0.002	0.003	0.156	0.156	0.266	0.267

Product level clustered standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 1.11 Disaggregated baseline estimate - Group B treatment with CT2 control

Dependent variable: Log quantity	(1)	(2)	(3)	(4)	(5)	(6)
Group B	1.332***	1.334***	1.112***	1.114***	0.779***	0.780***
	(0.0467)	(0.0466)	(0.0438)	(0.0438)	(0.0422)	(0.0422)
Post	-0.276***		-0.296***		-0.197***	
	(0.0145)		(0.0129)		(0.0106)	
Group B*Post	0.0920**	0.0922**	0.162***	0.162***	**0.227*** **	0.226***
	(0.0379)	(0.0378)	(0.0358)	(0.0358)	(0.0348)	(0.0348)
Constant	9.589***	9.434***	9.604***	9.439***	9.560***	9.450***
	(0.0384)	(0.0378)	(0.0292)	(0.0278)	(0.00592)	(0.000955)
Time FE	N	Y	N	Y	N	Y
Country FE	N	N	Y	Y	N	N
Country pair FE	N	N	N	N	**Y**	Y
Observations	2,438,834	2,438,834	2,438,828	2,438,828	2,435,516	2,435,516
R-squared	0.004	0.004	0.131	0.132	0.257	0.257

Product level clustered standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

The previous analysis showed that the adoption of the IMSBC code had a significant, but heterogeneous effect across code groups.

The difference in coefficients (negative for Group A and positive for Group B) supports the earlier hypotheses of trade costs and risk. There are differences in trade costs and the type of trade costs that are incurred by the commodities in the two groups, or how common trade costs are affected differently by the two groups of commodities. Group A commodities experienced an increase in costs from complying with regulations, undertaking tests and obtaining documentation such as the TML certificate, which led to delays in shipment.

For Group B cargo the costs could be smaller, the document of compliance can be obtained from the club. In addition, in contrast to group A cargo, if measures are not followed then shipper understood that there is a risk of damage/sinking of the ship. After the mandatory adoption of the IMSBC code, shippers are thus more willingly to cargo knowing that they would be safe during carriage. This has the effect of reducing uncertainty and, therefore, insurance costs, which offsets the changes in the other types of trade costs incurred.

1.6.3 Effects of Incomes levels

The previous analysis showed that the introduction of the IMSBC code led to an increase in traded Group B commodities and a decrease in Group A commodities. I explore further heterogeneity in the previous effect to explain the possible drivers of the baseline results. It is well documented that the trade in commodities[15] is influenced by economic activity, a major component of demand, and that this activity varies significantly from country to country. Secondly, there could exist variation in the degree of compliance to regulations between countries that is captured by the income of the country. Evidence on the response of shippers to the IMSBC code is sparse, but there is documentation advising shippers to reject cargo from certain countries due to compliance issues. For example, it was advised that shippers do not take iron ore from Indonesia as they have been known to evade TML requirements. I therefore study whether the results differ between countries – specifically between countries of different income groups. Here we assume that low income countries have less capacity to follow more stringent regulation, for example to undertake the moisture content tests that

[15] Brancaccio, Kalpuptsidi and Papageorgiou (2020)

form a mandatory component of the shipment of Group A commodities. We therefore anticipate that the effect of the IMSBC code on this group of commodities will be larger when trade includes a low-income country. Here we define low-income countries according to the definitions used by the World Bank.

Tables 1.12 and 1.13 show the results of the estimation splitting the countries by income groups[16]. The results show a difference between country pairs and within IMSBC groups. In aggregate, the coefficient results are in line with the baseline results, the effect on Group A commodities are negative and positive for commodities in Group B. I find a differences for Group A commodities between high and low income countries and to the baseline results (columns (5) in Tables 1.12 and 1.13). In contrast to the baseline results the coefficient are much smaller for high income countries (-0.0665) and larger for low income countries (-0.289). For high income countries the coefficient also becomes statistically insignificant.

Next, I further disaggregate the countries, into upper, upper middle, lower middle and lower (columns (1)-(4) of Tables 1.12 and 1.13). I find similar results. Again, we use the definitions from the World Bank to classify countries. Coefficients for Group A are negative and for Group B are positive. In addition, the results follow a consistent order. These results suggest three patterns in the results. Firstly, the introduction of the IMSBC code did not affect trade in Group A commodities very much for high income countries but had a large effect for low income countries. Secondly, this effect follows scale, with the coefficient estimates smallest for upper income countries, increasing to the largest for lower income countries. Finally, the same effects are found for Group B commodities, the introduction of the code had the largest effects for the lowest income countries (0.216 in column (6) in Table 1.13 compared with 0.135 in column (6) in Table 1.12 for high income economies). However, the differences across income groups for Group B commodities are less pronounced than those for Group A.

[16] World bank definition

Table 1.12 Estimation on income group – high

Dependent variable: Log quantity	Upper income		Upper Middle income		Both Upper and Upper Middle income	
	(1)	(2)	(3)	(4)	(5)	(6)
Group A	-0.846***		-0.342***		-0.688***	
	(0.0773)		(0.116)		(0.0644)	
Group A*Post	-0.00528		**-0.126**		-0.0655	
	(0.105)		(0.162)		(0.0879)	
Group B		1.332***		1.317***		1.331***
		(0.0278)		(0.0442)		(0.0235)
Group B* Post		**0.163*** **		0.0856		0.135***
		(0.0366)		(0.0594)		(0.0312)
Constant	8.511***	9.172***	7.966***	8.636***	8.327***	9.004***
	(0.00345)	(0.00292)	(0.00483)	(0.00436)	(0.00281)	(0.00243)
Observations	994,991	1,737,593	509,301	794,687	1,504,292	2,532,280
R-squared	0.288	0.254	0.227	0.216	0.271	0.245

Product level clustered standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1

Table 1.13 Estimation on income group – low

Dependent variable: Log quantity	Lower income		Lower Middle income		Both Lower and Lower Middle income	
	(1)	(2)	(3)	(4)	(5)	(6)
Group A	-0.712***		-0.190*		-0.341***	
	(0.147)		(0.107)		(0.0875)	
Group A*Post	-**0.428** **		-0.243		-0.289**	
	(0.197)		(0.150)		(0.121)	
Group B		1.250***		1.250***		1.238***
		(0.0535)		(0.0535)		(0.0354)
Group B* Post		**0.322*** **		0.322***		0.216***
		(0.0721)		(0.0721)		(0.0472)
Constant	8.069***	8.781***	7.864***	8.781***	7.931***	8.482***
	(0.00621)	(0.00563)	(0.00463)	(0.00563)	(0.00372)	(0.00342)
Observations	262,797	417,774	542,096	417,774	804,893	1,234,753
R-squared	0.235	0.234	0.231	0.234	0.232	0.214

Product level clustered standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1*** p<0.01, ** p<0.05, * p<0.1

1.6.3.1 Detailed income groups

The previous results showed that there were heterogeneous effects between country income groups. Those results focused on the importer country. In this section, I further investigate the effects of the policy within different income country pairs. Tables 1.14 and 1.15 show the results of estimating this for the baseline regression for Groups A and B respectively.

Column (1) of Table 1.14 shows the results of the estimation for imports of Group A commodities between high and high income countries. The coefficient of 0.0540 is insignificant. This is in contrast to Group B commodities, which remain significant across the different income pairs.

The estimated coefficients indicate that the policy had greater effects on lower income economies. For Group A commodities, this was between low and low income countries (-0.892). For Group B commodities the greatest effects were between high and low income country pairs (-0.303). The large coefficients for the High-Low country pair are in line with expectations.

Table 1.14 Estimation on Group A commodities between different incomes

Dependent variable: Log quantity	High-High	High-Low	Low-High	Low-Low
	(1)	(2)	(3)	(4)
Group A*Post	0.0540	-0.790***	-0.179	**-0.892*** **
	(0.106)	(0.235)	(0.151)	(0.305)
Constant	8.282***	8.510***	7.673***	8.698***
	(0.000333)	(0.000569)	(0.000374)	(0.000771)
Time FE	Y	Y	Y	Y
Country Pair FE	Y	Y	Y	Y
Product FE	Y	Y	Y	Y
Observations	1,230,808	272,799	602,941	201,578
R-squared	0.434	0.465	0.400	0.392

Product level clustered standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 1.15 Estimation on Group B commodities between different incomes

Dependent variable: Log quantity	High-High	High-Low	Low-High	Low-Low
	(1)	(2)	(3)	(4)
Group B*Post	0.0803**	**0.303*** **	0.220***	0.260***
	(0.0401)	(0.0680)	(0.0606)	(0.0915)
Constant	8.971***	9.278***	8.162***	9.403***
	(0.000486)	(0.00110)	(0.000672)	(0.00134)
Time FE	Y	Y	Y	Y
Country Pair FE	Y	Y	Y	Y
Product FE	Y	Y	Y	Y
Observations	2,013,192	517,946	890,610	343,653
R-squared	0.412	0.438	0.375	0.392

Product level clustered standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

1.6.3.2 Gravity covariates

The results of section 1.6.2 found a significant effect from the introduction of the IMSBC code that was heterogeneous between the different commodity groups. In this section, I include in the model the standard covariates found in the gravity model of trade (GDP, distance, landlocked etc.). It is likely, for example, that larger economies import more commodities compared with smaller countries as they are needed to produce more goods consumed in the country. Tables 1.16 and 1.17 show the results of the estimation for Group A and Group B commodities, with differing fixed effects included in the regression, respectively.

I find that the results are consistent with the estimates from the baseline regression. With the introduction of the IMSBC code trade volumes for Group A commodities declined whilst those of Group B increased. The coefficients are slightly smaller in the country fixed effects specification with -0.175 (columns (3) and (4) in Table 1.16) and 0.102 (column (2) in Table 1.17) for Group A and B commodities, respectively.

Secondly, I find coefficients for the gravity coefficient that are broadly in line with those found in previous trade literature. With positive effects for variables such as GDP (both exporter and the importer countries), common border, colony and common language, and negative effects for distance (the broad measure of trade costs in the gravity model).

One coefficient that is different to those in the gravity literature is the GDP of the partner country. Here the coefficient fluctuates between being positive and negative between different specifications of the model for both Groups A and B. In the literature this coefficient is mostly found to be positive. I will further investigate country incomes in the next section.

Table 1.16 Estimation of Group A commodities with gravity covariates

Dependent variable: Log quantity	(1)	(2)	(3)	(4)	(5)	(6)
Group A	-0.0852	-0.0909	-0.356***	-0.357***	-0.517***	-0.519***
	(0.100)	(0.100)	(0.0923)	(0.0926)	(0.0930)	(0.0932)
Post	-0.548***		-0.353***		-0.294***	
	(0.0179)		(0.0171)		(0.0152)	
Group A*Post	**-0.214****	-0.210**	-0.175*	-0.175*	-0.188**	-0.187*
	(0.0986)	(0.0986)	(0.0959)	(0.0960)	(0.0960)	(0.0961)
log GDP exporter	0.476***	0.480***	0.181***	0.337***	0.0994***	0.225***
	(0.0158)	(0.0158)	(0.0369)	(0.0441)	(0.0334)	(0.0404)
log GDP importer	0.236***	0.237***	-0.00473	0.0884**	0.0306	0.103***
	(0.0219)	(0.0219)	(0.0386)	(0.0424)	(0.0342)	(0.0377)
log distance	-0.407***	-0.408***	-0.878***	-0.877***		
	(0.0333)	(0.0332)	(0.0333)	(0.0332)		
common border	1.445***	1.441***	0.753***	0.751***		
	(0.115)	(0.115)	(0.108)	(0.108)		
common language	0.00316	7.28e-05	0.0570	0.0561		
	(0.0845)	(0.0845)	(0.0684)	(0.0683)		
common colony	0.882***	0.886***	0.418***	0.415***		
	(0.115)	(0.115)	(0.109)	(0.108)		
landlocked	-0.888***	-0.882***	-0.0465	-0.0427		
	(0.0809)	(0.0810)	(0.174)	(0.174)		
Constant	-7.836***	-8.263***	10.16***	3.306**	4.335***	-1.117
	(0.799)	(0.806)	(1.047)	(1.537)	(0.942)	(1.407)
Time FE	N	Y	N	Y	N	Y
Country FE	N	N	Y	Y	N	N
Country Pair FE	N	N	N	N	Y	Y
Observations	2,087,568	2,087,568	2,087,568	2,087,568	2,085,041	2,085,041
R-squared	0.096	0.097	0.197	0.198	0.264	0.264

Product level clustered standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1

Table 1.17 Estimation of Group B commodities with gravity covariates

Dependent variable: Log quantity

	(1)	(2)	(3)	(4)	(5)	(6)
Group B	1.528***	1.531***	1.399***	1.402***	1.301***	1.304***
	(0.0373)	(0.0373)	(0.0364)	(0.0364)	(0.0359)	(0.0359)
Post	-0.453***		-0.378***		-0.319***	
	(0.0162)		(0.0161)		(0.0136)	
Group B*Post	0.103***	0.102***	0.132***	0.129***	**0.161*** **	0.159***
	(0.0328)	(0.0328)	(0.0316)	(0.0315)	(0.0309)	(0.0308)
log GDP exporter	0.433***	0.436***	0.523***	0.676***	0.391***	0.511***
	(0.0129)	(0.0130)	(0.0347)	(0.0399)	(0.0286)	(0.0341)
log GDP importer	0.104***	0.104***	-0.170***	-0.0597	-0.111***	-0.0250
	(0.0164)	(0.0164)	(0.0368)	(0.0408)	(0.0303)	(0.0337)
log distance	-0.488***	-0.489***	-0.842***	-0.842***		
	(0.0275)	(0.0275)	(0.0312)	(0.0311)		
common border	1.575***	1.571***	0.912***	0.909***		
	(0.0986)	(0.0986)	(0.104)	(0.103)		
common language	-0.232***	-0.236***	-0.0771	-0.0777		
	(0.0722)	(0.0722)	(0.0621)	(0.0620)		
common colony	0.713***	0.714***	0.279***	0.277***		
	(0.0975)	(0.0975)	(0.0888)	(0.0887)		
landlocked	-0.809***	-0.806***	-0.449***	-0.447***		
	(0.0697)	(0.0698)	(0.164)	(0.164)		
Constant	-1.144*	-1.452**	6.826***	-0.380	1.901**	-3.761***
	(0.637)	(0.642)	(0.924)	(1.376)	(0.780)	(1.186)
Time FE	N	Y	N	Y	N	Y
Country FE	N	N	Y	Y	N	N
Country Pair FE	N	N	N	N	Y	Y
Observations	3,727,796	3,727,796	3,727,796	3,727,796	3,725,001	3,725,001
R-squared	0.091	0.092	0.170	0.171	0.234	0.235

Product level clustered standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1

1.6.4 Robustness

In this section I test the robustness of the model. I account for alternative measures of trade with trade values and unit values.

1.6.4.1 Trade value

I use trade value as an alternative measure of trade in Table 1.18. The results are consistent with my previous findings. The effect of the code on Group A commodities is negative (and insignificant) and the effect on Group B commodities is positive and significant. Interestingly, the size of the effects is much smaller for Group A (-0.0861 in column (1), Table 1.18) compared with my earlier results with trade volumes (-0.119 in column (1) Table 1.8), and comparable in Group B for trade volume and trade value (0.0833 and 0.0823 in Table 1.18 and Table 1.9, respectively).

Table 1.18 Estimation of trade value for Group A and Group B commodities

Dependent variable: Log trade value	(1)	(2)	(3)	(4)	(5)	(6)
Group A	-1.185***					
	(0.0780)					
Group A*Post	-0.0861	**-0.0943**	-0.0188			
	(0.0648)	(0.0667)	(0.0647)			
Group B				0.349***		
				(0.0283)		
Group B*Post				**0.0833*** **	0.104***	0.0773***
				(0.0247)	(0.0237)	(0.0243)
Constant	9.705***	9.699***	9.695***	9.704***	9.712***	9.711***
	(0.000370)	(0.000189)	(0.0214)	(0.000531)	(0.000299)	(0.0217)
Time FE	Y	N	Y	Y	N	Y
Country FE	N	N	Y	N	N	Y
Country Pair FE	Y	Y	N	Y	Y	N
~~Product FE~~	~~N~~	~~Y~~	~~Y~~	~~N~~	~~Y~~	~~Y~~
Observations	2,327,841	2,327,841	2,330,841	3,795,522	3,795,519	3,798,541
R-squared	0.283	0.381	0.252	0.248	0.347	0.251

Product level clustered standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

1.6.4.2 Trade value – income groups

I repeat the same regression with trade value investigating within income country pairs. I find results that are again similar to before shown in Tables 1.19 and 1.20. For Group A commodities, the largest effects are found with trade between low income countries. I find coefficients similar to using trade quantity, for example for trade between low and low income countries I find a coefficient of -0.757 (column (4) in Table 1.19) for trade value compared with a value of -0.892 (column (4) in Table 1.14) whilst using trade quantity.

Table 1.19 Trade value of Group A commodities - income groups

Dependent variable: Log trade value	High-High	High-Low	Low-High	Low-Low
	(1)	(2)	(3)	(4)
Group A*Post	0.124	-0.515***	-0.138	**-0.757*** **
	(0.0891)	(0.192)	(0.128)	(0.243)
Constant	10.00***	9.528***	9.260***	9.405***
	(0.000280)	(0.000461)	(0.000317)	(0.000615)
Time FE	Y	Y	Y	Y
Country Pair FE	Y	Y	Y	Y
Product FE	Y	Y	Y	Y
Observations	1,239,584	276,150	608,292	202,482
R-squared	0.398	0.457	0.355	0.341

Product level clustered standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

The effect on Group B commodities is again found to be positive, with the same pattern within country pairs mostly the same as before. The only difference here is that the effect between high income countries, whilst positive (0.0391, column (1) in Table 1.20), is found to be insignificant. All other income pairs' results are comparable to the results discussed in section 1.6.3.1 using trade volume.

Table 1.20 Trade value of Group B commodities - income groups

Dependent variable: Log trade value	High-High	High-Low	Low-High	Low-Low
	(1)	(2)	(3)	(4)
Group B*Post	0.0391	0.197***	0.141***	**0.224*** **
	(0.0325)	(0.0595)	(0.0480)	(0.0772)
Constant	9.966***	9.815***	9.132***	9.583***
	(0.000392)	(0.000956)	(0.000529)	(0.00113)
Time FE	Y	Y	Y	Y
Country Pair FE	Y	Y	Y	Y
Product FE	Y	Y	Y	Y
Observations	2,027,953	521,637	898,792	345,012
R-squared	0.356	0.424	0.319	0.347

Product level clustered standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

1.6.4.3 Unit value

To see the effect of the IMSBC code on prices, I estimate equation 1.1 with unit values as the independent variable[17]. One of the issues with using unit values is that they suffer from a compositional issue, the value is not the price of a good but rather an average of several unobserved sub-goods. This issue is mitigated in this study; as dry bulk goods/commodities are mostly homogeneous. This requires the addition of commodity fixed effects to control for this difference.

Table 1.21 shows the results of the estimation. I find that the introduction of the IMSBC code has had a positive effect on prices for commodities classed as Group A, with a positive and significant coefficient of 0.148. I find the introduction of the IMSBC code to have a negative effect on prices for Group B commodities. This effect is found to be small being -0.0430. Interestingly, these results are opposite to the findings made in the previous sections where the IMSBC code effect is negative on Group A commodities, and positive on Group B commodities where the trade volume or trade value are concerned.

[17] I use 2005 as the base year here.

Table 1.21 Baseline regressions using unit value as the dependent variable

Log unit value	(1)	(2)
Group A	0.00828	
	(0.0189)	
Group A*Post	0.148***	
	(0.0334)	
Group B		-0.0346***
		(0.00768)
Group B*Post		-0.0430***
		(0.0124)
Constant	4.862***	4.844***
	(0.00103)	(0.000927)
Observations	1,436,466	2,181,450
R-squared	0.064	0.059

Robust standard errors in parentheses:

*** p<0.01, ** p<0.05, * p<0.1

1.6.4.4 Unit value – income groups

The analysis is repeated with disaggregated income groups. For Group A goods in Table 1.22, I find the largest price effect for imports from low to high income countries (High-Low). I find the smallest effects between high to low countries with an insignificant coefficient for country pairs where the importer is a low income economy. This is in contrast to before, when I found the impact of the policy to have the most effects between Low-Low income country pairs.

Table 1.23 shows the estimation results for Group B commodities. I find negative effects on unit values for all country pairs, with the exception of the Low-Low combination.

Overall, I find results that are mostly consistent with my results in earlier sections (with the exception of trade between low and low income economies).

Table 1.22 Estimation of unit value for disaggregated incomes - Group A

Dependent variable: Log unit value	High-High	High-Low	Low-High	Low-Low
	(1)	(2)	(3)	(4)
Group A*Post	0.143**	**0.397*** **	0.0438	0.0916
	(0.0587)	(0.128)	(0.0943)	(0.139)
Constant	4.849***	4.852***	4.896***	4.861***
	(0.000115)	(0.000250)	(0.000130)	(0.000249)
Time FE	Y	Y	Y	Y
Country Pair FE	Y	Y	Y	Y
Product FE	Y	Y	Y	Y
Observations	837,907	144,219	356,678	97,511
R-squared	0.070	0.139	0.066	0.097

Product level clustered standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 1.23 Estimation of unit value for disaggregated incomes - Group B

Dependent variable: Log unit value	High-High	High-Low	Low-High	Low-Low
	(1)	(2)	(3)	(4)
Group B*Post	-0.0334*	**-0.0995*** **	-0.0439	0.0160
	(0.0190)	(0.0364)	(0.0315)	(0.0500)
Constant	4.824***	4.835***	4.893***	4.866***
	(0.000189)	(0.000443)	(0.000270)	(0.000497)
Time FE	Y	Y	Y	Y
Country Pair FE	Y	Y	Y	Y
Product FE	Y	Y	Y	Y
Observations	1,286,939	274,478	464,470	155,338
R-squared	0.067	0.129	0.058	0.080

Product level clustered standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

1.6.5 Trade costs

In the previous sections, I have found that the introduction of the IMSBC code has had a significant effect on the trade in commodities. There could be a number of ways in which this change could have been transmitted to the commodities market. This section examines in more detail the mechanism of trade costs.

I use the cif/fob ratio as the measure of trade costs[18]. Cif (cost, insurance, and freight) is recorded including transport and insurance costs whereas fob (free on board) ignores such costs. Previous studies in the literature have used measures such as freight costs and times as a measure of trade costs. Due to data constraints, those studies are limited to a small number of countries (Moore, 2018). All of the studies also focused on container shipping, where such costs are much easier to obtain (for example, the cost to ship a standardised container). To the author's knowledge, such data is not available for the bulk shipping market.

Column (1) of Tables 1.24 and 1.25 shows the result of estimating equation 1.1 with the cif/fob measure as the dependent variable. I find results consistent with before. The coefficient for Group A commodities are positive and negative for Group B. Columns (6) adds in GDP as a control variable.

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[18] Complying with the IMSBC code incurs costs. Without access to individual ship data/contracts it is hard to quantity the costs and changes in behavior as a result of the IMSBC code. There is evidence from P&I insurance groups that if ships did not follow regulations this would impact insurance costs.

Table 1.24 Estimation of Cif/fob with gravity covariates – Group A

Dependent variable: Log cif/fob	(1)	(2)	(3)	(4)	(5)	(6)
Group A	-0.00482	-0.288***	-0.0217	-0.0214	-0.00455	-0.00886
	(0.00826)	(0.0306)	(0.0192)	(0.0192)	(0.00829)	(0.00799)
Group A*Post	0.0111	**-0.0598****	-0.0137	-0.0141	0.0109	0.0208
	(0.0132)	(0.0284)	(0.0223)	(0.0223)	(0.0132)	(0.0129)
log GDP exporter						0.346***
						(0.0365)
log GDP importer						-0.249***
						(0.0389)
Constant	1.311***	1.314***	1.328***	1.313***	1.355***	-0.708
	(2.49e-05)	(0.0224)	(0.0163)	(0.0144)	(0.00641)	(1.357)
Time FE	N	Y	N	Y	N	Y
Country FE	N	N	Y	Y	N	N
Country Pair FE	N	N	N	N	Y	Y
Observations	1,391,868	1,393,443	1,393,443	1,393,443	1,391,868	1,375,345
R-squared	0.825	0.002	0.428	0.428	0.825	0.826

Product level clustered standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 1.25 Estimation of Cif/fob with gravity covariates – Group B

Dependent variable: Log cif/fob						
	(1)	(2)	(3)	(4)	(5)	(6)
Group B	0.00853*	-0.0307**	-0.0345***	-0.0346***	0.00793*	0.00526
	(0.00443)	(0.0133)	(0.00910)	(0.00910)	(0.00444)	(0.00442)
Group B*Post	**-0.0113***	0.00394	-0.0153	-0.0152	-0.0107*	-0.00570
	(0.00639)	(0.0131)	(0.0100)	(0.0100)	(0.00640)	(0.00634)
log GDP exporter						0.323***
						(0.0365)
log GDP importer						-0.220***
						(0.0375)
Constant	1.272***	1.274***	1.287***	1.274***	1.315***	-0.986
	(0.000047)	(0.0232)	(0.0161)	(0.0142)	(0.00641)	(1.336)
Time FE	N	Y	N	Y	N	Y
Country FE	N	N	Y	Y	N	N
Country Pair FE	N	N	N	N	Y	Y
Observations	2,276,787	2,278,466	2,278,466	2,278,466	2,276,787	2,248,163
R-squared	0.826	0.001	0.429	0.429	0.826	0.827

Product level clustered standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Brancaccio et al. (2020) find that ‘a 1% increase in shipping prices leads to a 1.02% decline in trade flows’. In their study they find that for dry bulk shipping, the average price is ‘14,000 dollars per day, with trips lasting on average for 2.9 weeks’. This gives us some idea of the cost of complying with the IMSBC legislation.

1.6.6 Income groups detailed

I estimate the equation with disaggregated income groups, for both Group A and Group B commodities, finding a significant and positive effect between Low-Low income economies for Group A, and a negative and significant effect between High-High income economies for Group B, respectively. (Tables 1.26 and 1.27).

Table 1.26 Estimation of Cif/fob for disaggregated incomes - Group A

Dependent variable: Log cif/fob	High-High	High-Low	Low-High	Low-Low
	(1)	(2)	(3)	(4)
Group A*Post	-0.0105	-0.0129	0.0249	**0.0796***
	(0.0102)	(0.0389)	(0.0196)	(0.0455)
Constant	-0.264***	-0.571***	-0.371***	-0.603***
	(3.55e-05)	(8.94e-05)	(6.41e-05)	(0.000119)
Time FE	Y	Y	Y	Y
Country Pair FE	Y	Y	Y	Y
Product FE	Y	Y	Y	Y
Observations	907,263	177,877	329,686	82,063
R-squared	0.835	0.826	0.793	0.832

Product level clustered standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 1.27 Estimation of Cif/fob for disaggregated incomes - Group B

Dependent variable: Log cif/fob				
	High-High	High-Low	Low-High	Low-Low
	(1)	(2)	(3)	(4)
Group B*Post	**-0.0124*** **	0.00425	0.00737	0.0176
	(0.00447)	(0.0142)	(0.00896)	(0.0193)
Constant	-0.231***	-0.643***	-0.322***	-0.623***
	(5.55e-05)	(0.000237)	(9.72e-05)	(0.000302)
Time FE	Y	Y	Y	Y
Country Pair FE	Y	Y	Y	Y
Product FE	Y	Y	Y	Y
Observations	1,500,969	340,680	486,345	137,554
R-squared	0.837	0.802	0.789	0.816

Product level clustered standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

1.6.7 Testing voluntary compliance

Voluntary compliance began in December 2008 with mandatory compliance in 2011. The delay between announcement and implementation is an adjustment period for firms to adjust to the new regulation. In this study, the mandatory compliance year (2011) is used as treatment. To check for anticipation effects in this section I test the robustness of the results to this change by changing the year of treatment. Tables 1.28 and 1.29 show the results from using 2008 as the year of treatment. The insignificant coefficients suggest that for the commodities in my sample, most countries followed the code once it became mandatory in 2011. This reassuring for my results, since it suggests that shippers had time to prepare and followed the regulations once they became mandatory.

Table 1.28 Estimation using 2008 as treatment year for Group A

Dependent variable: Log quantity						
	(1)	(2)	(3)	(4)	(5)	(6)
Group A	0.221**	0.221**	-0.261***	-0.260***	-0.558***	-0.558***
	(0.106)	(0.106)	(0.0954)	(0.0954)	(0.0976)	(0.0976)
Post 2008	-0.380***		-0.376***		-0.274***	
	(0.0182)		(0.0151)		(0.0129)	
Group A*Post2008	-0.0433	-0.0424	-0.0462	-0.0449	**-0.0904**	-0.0892
	(0.103)	(0.103)	(0.0966)	(0.0967)	(0.0974)	(0.0975)
Constant	7.860***	7.592***	7.859***	7.594***	7.791***	7.598***
	(0.0483)	(0.0468)	(0.0314)	(0.0301)	(0.00904)	(0.000332)
Time FE	N	Y	N	Y	N	Y
Country FE	N	N	Y	Y	N	N
Country Pair FE	N	N	N	N	Y	Y
Observations	2,105,205	2,105,205	2,105,205	2,105,205	2,102,564	2,102,564
R-squared	0.002	0.003	0.156	0.156	0.266	0.267

Product level clustered standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 1.29 Estimation using 2008 as treatment year for Group B

Log quantity	(1)	(2)	(3)	(4)	(5)	(6)
Group B	1.674***	1.674***	1.499***	1.498***	1.288***	1.287***
	(0.0272)	(0.0272)	(0.0254)	(0.0254)	(0.0242)	(0.0242)
post2008	-0.137***		-0.129***		-0.106***	
	(0.00702)		(0.00657)		(0.00626)	
Group B*post2008	0.000867	0.00128	0.00661	0.00723	0.0172	**0.0183**
	(0.0461)	(0.0461)	(0.0429)	(0.0429)	(0.0405)	(0.0405)
Constant	9.042***	8.996***	9.043***	8.999***	9.042***	9.006***
	(0.00404)	(0.00330)	(0.00375)	(0.00306)	(0.00356)	(0.00289)
Time F.E	N	Y	N	Y	N	Y
Country F.E	N	N	Y	Y	N	N
Country Pair F.E	N	N	N	N	Y	Y
Observations	1,670,871	1,670,871	1,670,871	1,670,871	1,667,950	1,667,950
R-squared	0.003	0.003	0.147	0.147	0.246	0.247

Product level clustered standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

All estimates are summarised in Table 1.30 below.

Table 1.30 Summary of all estimates

Dependent variable	Groups		Treatment*Post coefficient	
			Group A	Group B
Trade Volume	Control group	CT2	Group A + Group B: 0.227***	
		CT1	-0.154*	0.158***
		CT2	-0.185*	0.227***
	Income group	High - Upper	-0.00528	0.163***
		High - Upper Middle	-0.126	0.856
		High - Both Upper and Upper Middle	-0.0655	0.135***
		Low - Lower	-0.428**	0.322***
		Low - Lower Middle	-0.243	0.322***
		Low - Both Lower and Lower Middle	-0.289**	0.216***
	Income pair	High-High	0.0540	0.0803***
		High-Low	-0.790***	0.303***
		Low-High	-0.179	0.220***
		Low-Low	-0.892***	0.260***
	Gravity covariates	GDP	-0.214***	0.161***
Trade Value	Baseline		-0.0861	0.0833***
	Income group	High-High	0.124	0.0391
		High-Low	-0.515***	0.197***
		Low-High	-0.138	0.141**
		Low-Low	-0.757***	0.224**
Unit Price	Baseline		0.148***	-0.0430***
	Income group	High-High	0.143***	-0.0334**
		High-Low	0.397***	-0.0995***
		Low-High	0.0438	-0.0439
		Low-Low	0.0916	0.0160
Cif/fob	Baseline		-0.0598**	-0.0113*
	Income group	High-High	-0.0105	-0.0124***
		High-Low	-0.0129	0.00425
		Low-High	0.0249	0.00737
		Low-Low	0.0796*	0.0176
Treatment year	2008		-0.0904	0.0183

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Overall, across all specifications, the country-pair-fixed effect in several occasions produced the largest treat*post coefficients. This suggests that the impact of the treatment on the trade differs depending on the conditions between countries with potentially large effects.

1.7 Conclusions

Direct measures of trade costs are very limited and it's fair to say that they do not exist. There may be confounding factors correlated with trade costs and international trade. These factors have limited the scope of research in the literature. In this chapter, I investigated the effect of a regulatory change on transport and time costs, the IMSBC Code which governed the safety of shippers on the seas. The implementation of this Code brought about changes in costs, such as, loading times in port, contract enforcement costs and freight costs, and the costs are measured by trade quantity, trade value, unit value, and CiF/FOB, etc.

One contribution of this chapter is the identification of a novel dataset from the IMSBC Code matched to the goods in the HS code.

This study is one of a few that investigated the commodities market. I found a positive effect overall in the shipment of commodities as a result of the implementation of the IMSBC Code.

Disaggregating the results, I found heterogeneous effects between different product groups and countries. This suggests a trade-off between the cost of compliance and the benefits from reduced uncertainty (from carrying dangerous cargo).

Product groups are defined by the chemical properties of the commodity and its associated risks. For product groups, I found that for commodities in Group A – those prone to liquefaction – the implementation of the policy led to a decrease in trade. This was likely the result of increased costs, which decreased the benefits of that commodity's trade. By contrast, I found that Group B products experienced an increase in trade after the implementation of the IMSBC Code. Group B cargo are classified as 'dangerous cargo', for such goods, here, complying with the legislation reduced risk (and the accompanying uncertainty), which increased trade.

Finally, this study found a heterogeneous effect of the policy according to country income. Wealthier economies benefitted more since they were more able to afford the costs of complying with the regulation, whereas poorer countries suffered as a result of the legislation.

Having accomplished the aforementioned objectives, it is important to discuss the limitations of my work and identify potential avenues for further improvement. One of the limitations for this chapter is the dataset used. As described, the data used is from COMTRADE and shippers' information from the IMSBC code. Whilst they provide information such as the commodity, export/import quantity, distance, and common border, etc, the data lacks information on other aspects, for example information on the origin and destination ports, which would be valuable in my analysis. In addition, alternative methods could be considered for the empirical analysis. Finally, more data on direct measures of trade costs, such as the time it takes through port, insurance costs and other ship costs would help provide more insight into the mechanism with the effect of the introduction of the IMSBC code.

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2 Chapter 2: Transportation Mode Choice and Trade Liberalisation: Evidence from China

2.1 Introduction

International trade is conducted by firms in different countries exporting and importing goods. Every day, billions of dollars of goods are moved across borders from one country to firms and consumers in another country. As agents in economies send their goods to consumers in foreign destinations, they make decisions about the mode of transport of the good. Some goods are moved by sea, some by air and some via land. Modes of transport may vary across industries with different characteristics, these include but not exclusively, speed of delivery, unit costs, product characteristics to name a few. The modes of transport for goods can be broadly summarized as by air, by sea and by land with land transport including transport by roads, railways, inland waterway, post and others.

Trade is inevitably associated with transportation costs, which has drawn increasing attention in research since early 2000 (Evans and Harrigan, 2005; Hummels, 2007). Both the theoretical and empirical literature has highlighted the importance of the cost of moving a good from one country to another. Moving goods over long distances, e.g., crossing borders or changing ports, takes time and incurs costs. Air transport is fast and expensive while sea cargo is slow and cheap. Short distance trade is conducted mainly by road or railway, when speed is less critical. Port efficiency and transport infrastructure are also determinants of shipping cost (Clark, 2004; Avetisyan and Hertel, 2021). The choice of transportation mode must take into account all of these measures and more.

How do transport modes affect trade? Lengthy shipment times delay inventory, spoil product life cycles (e.g., for fast-changing fashions and technology), and may displease customers (Hummels and Schaur, 2013). High-value and high-quality goods tend to use expensive modes of transport in the interest of saving time; reducing costs is commonly the goal for the transport of low-end products not requiring swift delivery speeds (Hummels, 2007). If the cost of transporting goods is high, then there will be fewer firms that are able to produce and export their goods while generating a profit. If the shipments of goods cannot meet delivery deadlines, meanwhile, trade will be disrupted. Time delays have therefore been recognised as a significant trade barrier in developing economies (Minor and Hummels, 2013). In reality, a firm has options about how to move their products from where they are produced to where they are consumed. Thus, the mode of transport is important in trade and influenced by decisions made at the level of the firm.

Governments impose restrictions on trade to protect their domestic industries. For example, a quota restricts trade by limiting the quantity of goods that can be imported into a country which has many effects on the domestic economy. An imposed quota restriction can also be lifted by the government. Firms are heterogeneous and do not all respond to changes in quotas in the same way. Theoretical models (Harrigan and Barrows, 2009; Bernhofen et al, 2018; Khandelwal, Schott, and Wei, 2013; Utar, 2014) tell us that firms will adjust their export strategies under quota change. The firm might begin exporting more products abroad when the quota is lifted or fewer when the quota is imposed. The number of firms exporting might increase or decrease (according to intensive and extensive margins of trade). The lifting of quotas typically downgrades product quality (Harrigan and Barrows, 2006). In more detail, export behaviour can be influenced by a range of factors usually including logistics, procedures and formalities at the border. The effect of trade policies is in turn also influenced by the underlying infrastructure of the economy. Common results from previous studies have found that trade policies such as quotas affect variables such as trade values, prices, quality and quantity (Harrigan and Barrows, 2006, 2009; Bernhofen et al, 2018; Khandelwal, Schott, and Wei, 2013; Utar, 2014).

Whether or not trade policy could have effects on transportation decisions is a less studied area of research. The little research examining transportation modes as determinants of trade are by Hummels and Schaur (2004, 2007, 2010, and 2013), Evans and Harrigan (2005), Martinez-Zarzoso and Nowak-Lehmann 2007 (2007), Llano, C, T. De la Mata, et al. (2016). Early literature studying the impact of quotas on product quality include Krishna (1987), who provides a model under imperfect competition. It is reasonable to anticipate that if a quota liberalisation reduces the value and/or quality of transported products, it would also reduce the high cost of transport, since high-value/quality products are usually shipped by high-cost but time-saving modes. Research in this area is constrained by data limitations, e.g., the difficulty of measuring trade costs (Anderson etal, 2004); and the limited availability of transportation data. Using the most recent transportation data obtained, this chapter hopes to explore the links between trade policy and transportation mode.

I take advantage of a unique trade liberalisation event that helps establish causality with transportation mode, namely, the removal of the Multifiber Arrangement (MFA). The MFA began in 1974, introducing a series of bilateral and unilateral agreements that restricted the quantity of traded products among countries. In 1994, at the end of discussions in the

Uruguay Round, a new agreement on textiles and apparel was reached, the Agreement on Textiles and Clothing (ATC). Under the ATC, textiles and apparel would be integrated into The General Agreement on Tariffs and Trade (GATT) ruling over a ten-year period [UNCTAD, 2005]. The restrictions set out under the MFA would be phased out over four phases – in 1995, 1998, 2002 and 2005 respectively, with the largest quantity of quotas, 49%, removed in 2005. This study will investigate the effect of the 2005 removal of quotas on the modes of transportation in trade.

Historically the global textiles and apparel market has been expanding in value and consolidating in suppliers. The top ten exporting developing countries comprised 58% of global clothes exports in 2011[19]. In 2000, the share of exports for developing countries in the top were 35% for textiles and 36% for apparel. In 2018, the share of exports for developing countries in the top 10 are now 58% and 54%, for textile and apparel respectively. In 2018, total global textile and apparel exports were £750.6 billion.

There are also several benefits to researching this industry. Firstly, the relatively large size and importance of the textile industry results in a greater availability of data. Secondly, the industry uses a variety of transport modes to transport its products. In contrast to other industries (for example the steel industry) which may favour or be restricted to only one or two possible transportation modes, textile and apparel products use all types of transportation e.g., land, air and sea. Thirdly, the textiles industry is an industry that has historically been subject to tariffs and quotas, with regulatory changes a longstanding topic in the area. Investigating this industry will therefore provide results that can usefully be extended to other industries and their transportation patterns.

The data available for exploration in this study come from the transaction level Chinese Customs Trade Statistics dataset. China continues to be a key driver in global trade, being the leading merchandise trader in 2018 and the leading exporter of services among developing economies. The textile industry in China is the largest in the world in overall production and exports, being reaching around 34.5% exporting value of the world total in 2018[20]. The USA and the EU are the largest importers of textiles and clothing in the world. In 2018, textiles exported to the EU and the USA reached 32.8% and 9.1% of the world total respectively, while clothing exports were 58.4% and 17.4% of the world total, respectively. In

[19] From WITS, 2012

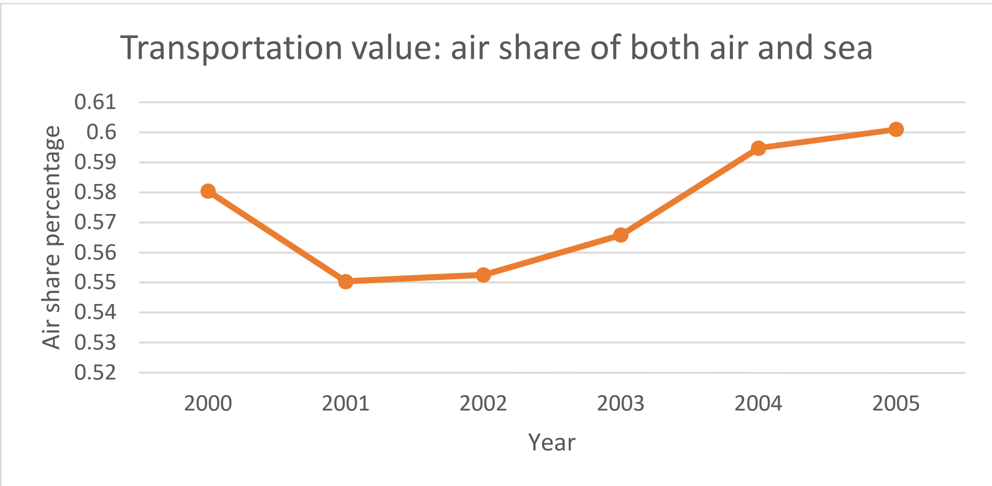
[20]WTO, 2019

this study, the transportation data for exporting textile products from China to the rest of the world during the period 2000-2006 will be used.

A change in quotas can have a variety of effects on firm exports. The channel of interest in this study is the change in transport mode because it is vital to trade and trade cost. To explore how quota changes affects mode of transport, I take advantage of a unique quota liberalisation event to help establish causality, the removal of MFA quots. I focus on China as the developing country of interest, because of both the benefit it derived from the MFA and its importance to trade in the global economy. In addition, many of the products are transported over long distances from China to other economies which makes the focus on air and sea transportation necessary. In this study, firm product level Chinese customs data will be used to compare the model choice of quota constrained Chinese firms' products to those that were not. The variations both in products and across markets are exploited for identification and the impact of this shock on textile and clothing producers in China will be explored.

The mode of transportation in my study is measured by the percentage of product value transported by air over the total product value transported by air and by sea. This is an air share value which takes into account both air and sea transportation. Figure 2.1 shows the status of the air share value changes over years in my working data.

Figure 2.1 Working data: Air share value distribution during the study period



This study expects to contribute to three main strands of literature. Firstly, it will contribute to the literature concerned with estimating the effects upon transportation mode (Hummels and Schaur, 2004, 2007, 2010, and 2013; Evans and Harrigan, 2005; Inmaculada and Felicitas, 2007; Llano, C, T. De la Mata, et al, 2016). In particular, the transport modal choice of firms engaged in trade will be examined and the trade-off between air and sea transport will be compared. The study will focus on a particular market, namely the market for textiles and apparel and will explore whether the MFA led to changes in firms' decisions about the export of goods via air transport to the US and EU, a detailed explanation of the focus on the US and EU may be found in section 2.3.2.

Secondly, this paper will contribute to the literature concerned with the effects of trade liberalization at the firm level in developing economies. There is a large literature on the effects of low-cost exports on the markets of developed economies (Utar, 2014). Variables of interest in such studies commonly include innovation, productivity and employment. In contrast, few studies have investigated the effects of low-cost exports on developing economies themselves.

Finally, this study will add to the body of literature that evaluates the economic impacts of MFA (Harrigan and Barrows, 2009; Bernhofen et al, 2018; Khandelwal, Schott, and Wei, 2013; Utar, 2014). In contrast to previous studies that either focuses on US exports or on Chinese exports to the US, this study estimates the effects of Chinese exports to both the US and EU. In 2018 these three countries were responsible for over 60% of the global trade in the textile and apparel sector so this study will cover a large proportion of economies under the MFA.

2.2 Literature review

In this section, I review the relevant research literature in five areas: firstly, the international trade and transportation cost in relation to modes of transport; secondly, trade facilitation and choice of transport mode as influenced by border/port logistical performance; thirdly, the effect of MFA quota removal on trade that focuses on trade prices, volumes, productivity and employment; fourthly, trade quota effect on the quality of shipped products; finally, the effect of MFA on the mode of transport from the limited research conducted previously.

2.2.1 Transportation costs and mode of transportation

From 1998 to 2018, the international merchandise trade grew at an average rate of 7.1% (WTO international trade statistics, 2019). From 1955-2004 the rise can predominately be attributed to a decline of international transport costs (Hummels, 2007).

One of the earlier papers to investigate the varying effects of the cost of transport was that conducted by Evans and Harrigan (2005). Evans and Harrigan investigates how the time to delivery varies with distance. They use a dataset consisting of the import of apparel for the US, with the quantity of apparel imports as the dependent variable. According to their findings, distance captures the effects of timely delivery measured by the product type (timeliness demand type) and source location, the closer the export market of the firm, the more important this becomes.

Harrigan (2010) investigates the rationale for countries to ship goods by air. He uses data on yearly US imports from 1990 to 2003. The paper uses a Ricardian model to estimate the effects of transport costs on comparative advantage. Harrigan finds that a firm's decision to ship by air is affected by the distance to the export market, with a greater distance to the supplier increasing the likelihood of air shipment. In contrast to Harrigan's paper, whose focus is on the trade-off between air and land transport, this paper focuses on the substitutability of air and sea where both modes are suitable for long distance but defer with respect to timeliness and cost.

Hummels and Schaur (2010) investigates firm response to demand volatility. They focus on air transport as a channel through which firms use to smooth demand volatility. Using monthly data on US imports from the rest of the world between 1990 and 2004, they provide an alternative to the effects of distance on trade. They find that the option of air transport allows firms to smooth demand volatility for their goods. They also relate their model to the introduction of the jet engine as an additional choice for firms trying to hedge demand volatility.

Later research by Hummels and Schaur (2013) examines the transportation choice of firms. Using data from 1991-2005 consisting of US imports from the rest of the world, they develop a model that allows them to capture the time savings that firms gain by using a particular mode of transport. The dependent variable is the relative share of air versus sea transport. Using variation in the price across countries they then estimate the time savings associated with a particular mode of transport. Further specifications of the model include using additional variables, such as other products, the cost of entry and time.

They find that a day of transit is equal to an increased cost of 2 per cent the value of the good. A similar empirical analysis is carried out in my study, using the same measure of the share of air divided by sea transport. In contrast to Hummels' study, however, I use export data from China to both the US and Europe, focusing on a particular market.

Research by Martinez-Zarzoso and Nowak-Lehmann (2007) looks at the determinants of maritime transport and road transport costs. Using Spanish exports to Poland and Turkey they find transport conditions, efficiency and service quality important determinants for maritime transportation costs. Transport conditions include consolidated and refrigerated cargo. Efficiency and service quality include factors such as increases in the number of lines and frequency of service. These factors may vary in response to changes in regulation and consequent changes in the mode of transport.

Different transportation modes may face competition with an economy (Llano et al, 2017). They investigate the transport of goods by four different transport modes (road, train, ship and aircraft) among the fifty provinces of Spain. They find significant competition effects between road and other modes of transport. Their discussion is restricted to a single country, however, which suggests that the mode of transport is worth exploring on a broader scale.

Overall, transportation costs are dependent upon distance, speed, efficiency, service and competition level. All those factors influence the choice of the transportation mode.

2.2.2 Trade facilitation and modal choice

There is a small literature investigating the modal choice of firms in the context of trade facilitation. Trade facilitation is defined as the 'facilitation of trade as the improvement in logistics at both customs and ports of entry and the development of more efficient administrative processes (Wilson et al, 2003)’. Research using Latin American trade data (ALADI) to examine trade facilitation and modal choice has found that higher logistics performance increases demand for international air transport (Avetisyan and Hertel, 2021). Ravibadu (2013) finds that as compared to other transport attributes, transit time significantly influences modal choices for road and rail transport however that influence is not found in the case of sea or air. These studies do not focus on the effects of regulation on the choice of transport mode, which is the focus in this chapter.

Some authors have examined the modal choice by direct and indirect facilitation. For example, increased inefficiencies, as a direct facilitation factor, leads to increases in delivery time and delivery costs (Djankov et al., 2010). Bourdet and Persson (2014) focuses on the number of days it takes to comply with all relevant legislation. Djankov et al. (2010) find that delays in trade by one day reduces trade levels by 1%. Comparing direct and indirect costs, an OECD (2013) study finds that indirect costs have a greater effect on trade. The growth of air transport in trade means that transit time, as an indirect facilitation factor, has increasing significance in shipping costs. Alessandria et al. (2010) find that delivery lags and transaction level economies of scale play an important role in international trade. These factors influence the mode of transport, which may also be affected by changes in regulation.

As can be seen from the above review, choices in transport modes can be affected by trade facilitation in several ways, but it unclear whether trade facilitation would be influenced by the changes in regulation. This topic is therefore worth further exploration in this chapter.

2.2.3 Effects of MFA quota removal on trade

The seminal paper by Harrigan and Barrows (2009) provides one of the earliest studies on the effect of the MFA removal on importing firms. The study examines the effects of the MFA removal from the viewpoint of developed economies. Their data consist of global imports of textiles and apparels into the US. Although they have data from 2002 to 2005, Harrigan and Barrows restrict their results to 2004-2005, one year prior to the MFA’s abolition. They find both price and quality drops of 38% and 11% respectively in domestic firms as a result of the regulatory change. The studies do not go into detail on the role of firms as a part of this change. This is an avenue that is explored in my chapter.

Bernhofen et al. (2018) investigate the effects of the MFA removal on Chinese domestic firms. They use 6-digit HS code data from the Chinese Customs Trade dataset. The sample by Bernhofen et al. (2018) sample covered 472 products and 19,093 firms from 2000 to 2006. Their analysis focuses on the effect of the quota removal on export prices. The study uses a difference-in-differences specification to estimate the effects of the quota removal on Chinese firms, and they find an average price drop of 25% as the result of the quota removal. The study only looks at trade between the US and China. Although both are very important countries in the global economy, this does lead to a slightly more restricted outcome when generalising the results to other studies or countries. In my study, I use a larger selection of countries, expanding the sample to also include the EU.

Khandelwal, Schott, and Wei (2013) investigate the effect of trade liberalization on Chinese firms exporting to US, EU and Canada. Using data from 2000 to 2006, they find large productivity gains for Chinese firms resulting from the removal of the MFA. In addition, they estimate that export prices fell by about 20% for product-country pairs that were covered by the MFA compared to a small increase with those not covered. This drop is attributed to new firms and incumbents.

Utar (2014) investigates the effect of the MFA removal on Danish firms. His study focuses on within firm changes, with a particular emphasis on the effects of the MFA removal on employment. The study uses detailed matched employer-employee data from 1997 to 2007. Similar to others in the literature, they use a difference-in-difference specification to estimate the effect of the MFA removal. He finds a significant impact of Chinese exports on firm employment.

In summary, the MFA quota liberalisation has had effects on export prices, productivity increases, and firm employment change.

2.2.4 Product quality linked to transportation costs and quotas

Product quality has long been associated with transportation costs, e.g., “shipping the good apples out” (Alchian and Allen, 1964) which examines the relative quality of goods shipped to distant versus local markets within a country. Ever since, there has been a large theoretical literature and some empirical work (Borcherding and Silberberg, 1978; Bertonazzi and Maloney et al, 1993; Cowen and Tabbarok, 1995). Increase in transportation costs raises demand for high quality products (Hummels and Skiba, 2004). The study extended the theory to examine not only transportation costs but also ad valorem tariffs in international trade. With f.o.b prices as a measure of product quality they find that a doubling of shipping costs results in a lower bound of an 80% increase in average f.o.b prices. Minor and Tsigas (2008) explore the potential causal connections between trade, time and developing country exports, finding that reduced delivery times increases the exports of high value added manufactures commodities. The average increase in export prices was 1.6% of f.o.b value.

The above proposition is that imposing trade restrictions such as tariffs and quotas leads to importing the quality of imports, whereas its removal tends to result in quality downgrading. As mentioned earlier, Harrigan and Barrows (2009) focus on US importing from China and other countries following MFA quota liberalisation, finding that import prices fell by 38% in 2005 for quota-constrained products from China while those from other countries experienced a small drop. The price decline seen for Chinese products is also accompanied by substantial quality downgrading in the quota-constrained products. This result is reflected in other studies. Bernhofen, Upward, and Wang (2018) finds that the MFA quota removal led to price falls of around 25%, with the entry of new low-price exporters and products reasons for this fall. More recent research further supports the quality downgrading effect from the MFA liberalisation. Fernandes (2020) discusses the effect of MFA liberalization for the Portugal clothing market and find that domestic suppliers upgraded their quality in response to import competition from low qualify Chinese products. The quality drop following MFA quota liberalisation is an interesting point but is expected in light of general findings that lifting restrictions increases quantities.

2.2.5 MFA quota removal and mode of transport

Research directly investigating the link between MFA quota liberalisation and transportation mode is limited. Some studies briefly discuss the issue but do not go in any depth[21]. Ernst (2005) focuses on employment but includes a transportation variable in the study's gravity model about the effects of the MFA on trade and employment. The study found that "MFA phasing out implies significant changes in the worldwide trade structure, leading to strong output and employment shifts in and between countries". Countries with good sea transport connections and lower labour costs are more likely to benefit from MFA changes.

[21] For example in Khandelwal, 2013

Brambilla (2010) analysed the sharp decline in Sub-Saharan textile and clothing production following the end of the Agreement on Textiles and Clothing. The research suggests that transport costs may be one of the factors impeding multi-national production, and so their production costs are prohibitive.

My study will build upon and extend the existing literature by investigating the effect of MFA removal on the mode of transportation. Similar to existing literature, my study will investigate effects at the firm level.

2.3 Data

2.3.1 Background information

Historically, there has been many regulations in the textiles and apparels market. The Multifibre Arrangement (MFA) was the broadest of those policies. Beginning in 1974, the MFA introduced a series of bilateral and unilateral agreements that restricted the quantity of traded products between countries. These restrictions and quotas were mainly between developed economies, such as the EU and US, and developing countries such as India and China. The intention of the MFA was to limit the potential and actual harm to domestic industries from rapidly increasing imports from developing economies, particularly from Asia.

In 1994, at the end of discussions in the Uruguay Round, a new agreement on textiles and apparel was reached, the Agreement on Textiles and Clothing (ATC). Under the ATC, textiles and apparel would be integrated into The General Agreement on Tariffs and Trade (GATT) rules over a ten-year period (UNCTAD, 2017). The restrictions set out under the MFA would be phased out over four phases in 1995 (phase I), 1998 (phase II), 2002 (phase III) and 2005 (phase IV). Each later phase involved the removal of more products and quotas. The USA, Europe and Canada were required to remove at least 16, 17 and 18 per cent of their 1990 quota volumes in 1995, 1998 and 2002 respectively, with the remaining 49 per cent to be removed in phase IV in 2005. Special safeguard mechanisms were put in place that allowed countries to re-impose quotas if their domestic industries were shown to be suffering from imports from other countries. This mechanism was activated for imports from China for both the USA and Europe, shortly after the removal of quotas in 2005.

The ATC allowed countries to choose the phase in which quotas for particular products would be removed. This order of products varied across counties. In general, less politically sensitive products/industries were removed first with the most politically sensitive products delayed until the final phase (Khandelwal et al., 2013). In addition, since the products in each phase was decided in 1995, the choice of products would not be affected by demand and supply conditions in later years.

China joined the WTO in 2001 and was not subject to the ATC rules before that time. In 2002 China experienced the first three stages of the ATC. The removal of quotas on the remaining products occurred on January 2005.

2.3.2 Data used in this study

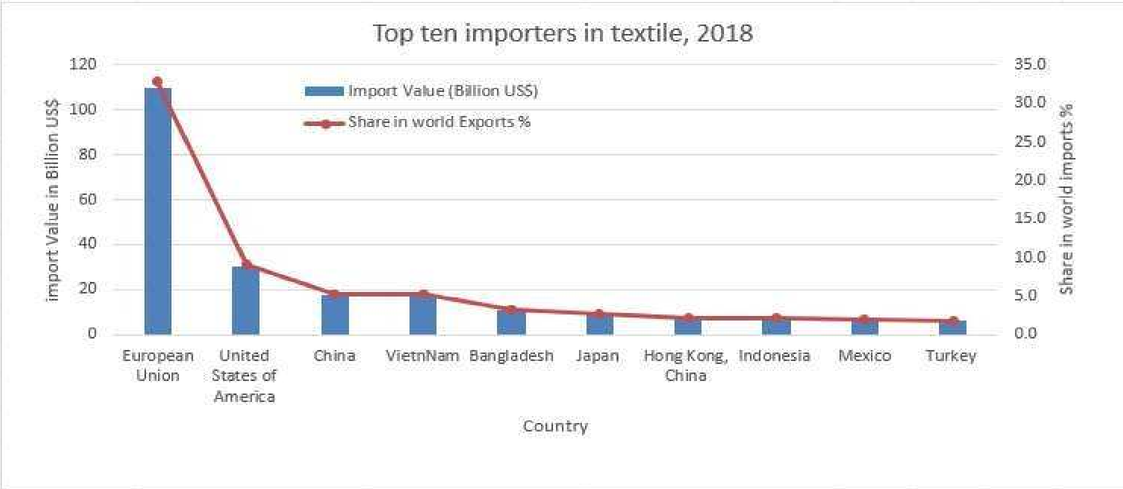
The data used in this study comes from the transaction level Chinese Customs Trade Statistics dataset. This is a dataset that provides information on Chinese firms. They include exports, imports, product description at the HS8 level, as well as firms' characteristics, such as the number of employees, whether the firm is state owned, location etc.

I restrict my sample to products (and firms) within the textile and apparel industry. The MFA protected textile markets in developed countries from exports from developing countries. I restrict my analysis to exports to two countries, the US and the EU. This is for the following reasons:

- The US and the EU are top importers of textile and apparel products in the world (Figures 2.2 and 2.3).
- In addition, both the US and EU contribute for the vast majority of textile and apparel products exports out of China (Figure 2.4). Therefore, this study focuses on the exports from China to the US and EU.
- Japan is the largest export market for Chinese textile and clothing products. The country did not however have MFA quotas restricting exports from China and hence is excluded from this study.
- Other countries, such as Canada, has a relatively small trade compared with the US and EU (Figure 2.5), and it is outside the top ten trade partners for textile and apparel with China as shown in Figure 2.4. Therefore, this study also excludes Canada from the initial analysis.

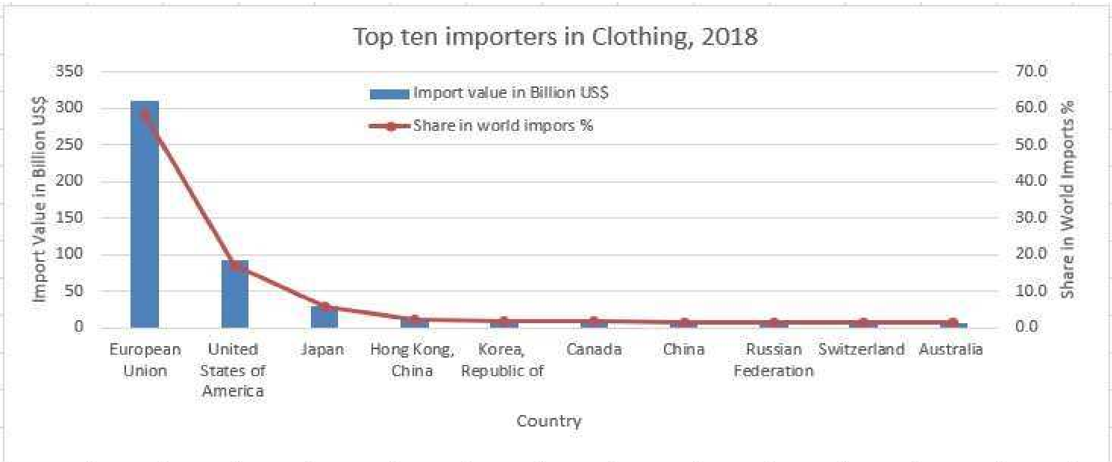
- Because the export markets chosen for this study are the US and EU, this study will focus on long distance transportation modes, namely, air and sea shipment.

Figure 2.2 Top ten importers of textile in the world in 2018



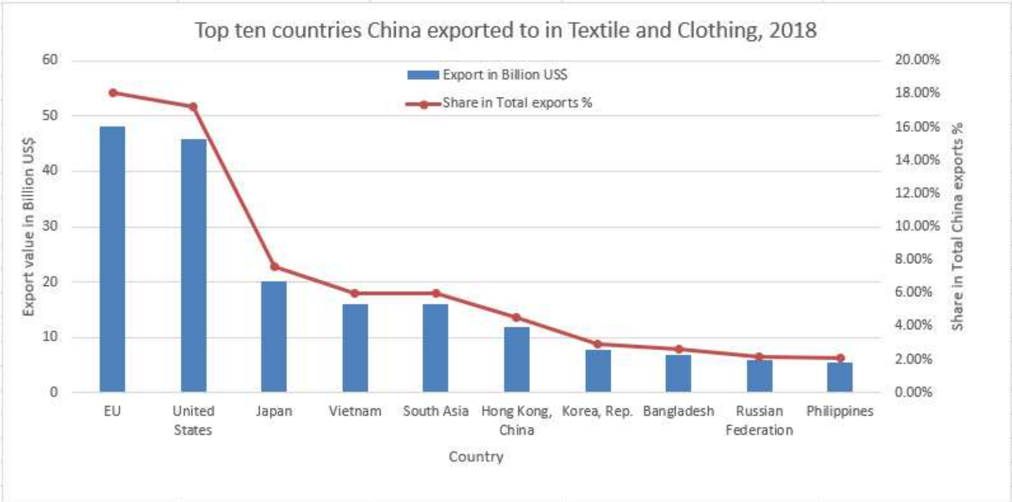
Source: WTO

Figure 2.3 Top ten importers of clothing in the world in 2018 [Data source WTO]



Source: WTO

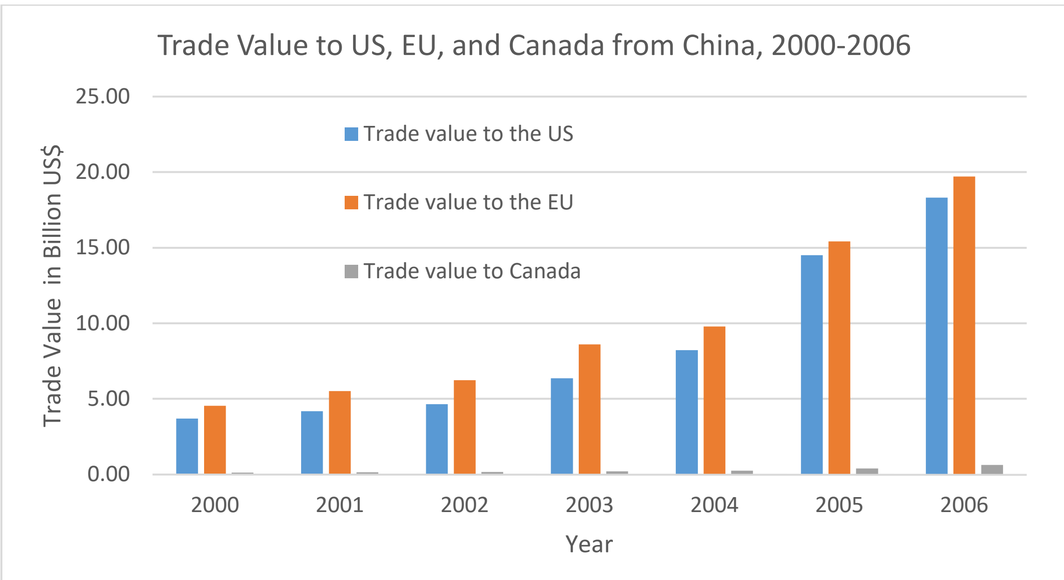
Figure 2.4 Top ten countries China exported to of T&C in 2018



Source: WITS

Figure 2.5 below plots trade value by country (EU region is referred in this chapter as 'country' for convenience) across time with my data. Exports of clothing and textile products have increased over time. There is a similar positive trend for the US and EU, with overall a larger quantity of clothing and apparel products exported to the EU compared with the US. In contrast, exports to Canada are small compared with those going to the US or EU. As mentioned above, this means I exclude Canada from the main regression results. Clothing and textile exports to Canada will however be used as part of the robustness check.

Figure 2.5 T&C trade value to US, EU, and Canada from China for the study period



Source: Calculations from my own data

In summary, the decision to focus only on the US and EU was motivated by the fact they are the biggest trading partners with China. Using these large volume exporters meant zero trade flows occurring for many products categories was less likely to occur and that export flows were more likely to occur in every time period. Results from the US and EU should provide a good reference point for the effects. In the literature, researches tend to mostly focus on only one market, e.g. US or EU respectively. However, there are differences in quotas between countries, which is supported in my results section.

I identify Chinese products in the dataset covered by the MFA and ATC from the ATC text. Table 2.1 shows the products and their corresponding descriptions. The products are identified to the HS6 level, the lowest code level which is common to products across all countries. The quotas were lifted at the same time in the US, EU and Canada in phase IV.

Table 2.1 Textile and clothing products by HS code

Harmonized System (HS) Product Code	Product Description
HS 50	Silk
HS 51	Wool, fine/coarse animal hair, horsehair yam
HS 52	Cotton
HS 53	Other vegetable textile fibres; paper yarn & w
HS 54	Man-mad e filaments
HS 55	Man-made stap le fibres
HS 56	Wadding, felt & nonwoven; yarns; twine, cordage
HS 57	Carpets and other textile floo r cover ings
HS 58	Special woven fab; tufted te x fab; lace; tapes
HS 59	Impregnated, coated, cover/laminated textile f
HS 60	Knitted or crocheted fabrics
HS 61	Art of app are l & clothing access, knitted or c
HS 62	Art of apparel & clothing access, not knitted/
HS 63	Other made up textile articles; se ts; wo rn clo

Source: Source: World Integrated Trade Solutions (WITS, 2019)

The dataset also includes information on the trade regime, I restrict my sample to only those in the "ordinary trade" category. This excludes, for example, firms with processing trade in the sample.

I aggregate the monthly data and produce variables on firm id, product code, trade value, trade quantity, destination country and the transportation mode during all years. Nearly all of the products covered by the MFA and ATC fall under the HS codes 50-63 so I restrict my data to only products within this range.

Figures 2.6 and 2.7 show the number of exporting firms and products over the years, respectively. The number of firms grew rapidly during this period with an especially marked increase after 2004. This is also true for the number of products as shown in Figure 2.7.

Figure 2.6 No. of Chinese firms exporting to US and EU during the study period

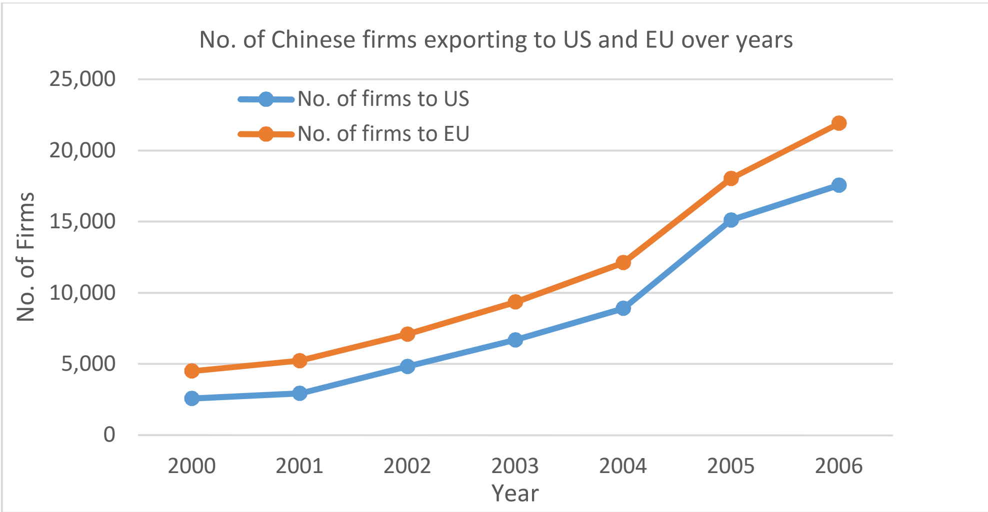
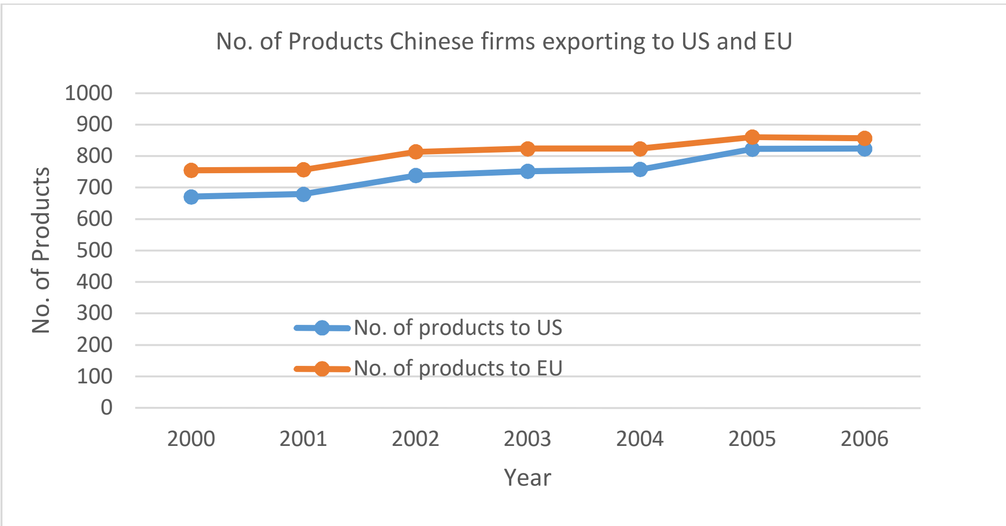


Figure 2.7 No. of products Chinese firms exporting to US and EU during the study period



2.3.3 Textile and apparel quotas

Quotas restrict the quantity of goods that can be traded between countries. The MFA limited the amount of clothing and textile goods that could be imported into an economy. In reality, the number of imports may have been less than the maximum amount allowed under the quota. Intuitively, a quota would have effects if the amount of goods imported is at the maximum quota level, that is, if it is a “binding” quota.

In practice, where data are available, papers in the literature have used “fill rates” to distinguish binding and non-binding quotas. A quota fill rate is the percentage of a quota that is used over the maximum that is allowed, and can be used to decide whether or not a quota is binding. Bernhofen et al. (2018) used a fill rate of 0.9 for a binding quota. Other authors, such as Khandelwal (2013) have assumed that the quotas for products are binding without using fill rate calculations. As described in section 2.3.1, countries were required to remove the largest number of quotas during phase IV in 2005. This suggests that the quotas in phase IV are the most binding. In this study, I use phase IV quotas as binding quotas and consider them at the product-country level. This covers the products as shown in Table 2.1 in section 2.3.1.

Quotas for textiles and apparels destined for the US were implemented through the US office of Textile and Apparel (OTEXA). The dataset provides information on the 3 digit categories for quota, e.g., code 223 is non-woven fabrics and code 410 is woven fabric. Within each category are the 10 digits HS codes which can be matched up to the HS6 level. I use this information to match the products in my dataset that the US imports.

Textile and apparel quotas for the EU are available from the Systeme Integre de Gestion de Licenses (SIGL) database. The SIGL database provides quotas by year for a range of textile and apparel in the European Union. The quotas categories in the SIGL do not necessarily exactly match the same categories under the HS classifications. The product categories under the ATC are not homogeneous or necessarily comprehensive. Although two similar textile products could be subject to completely different quotas when entering the EU using one of them is sufficient to cover all products. For this reason, the list of textile and apparel products that are subject to the MFA/ATC in Europe are taken from Khandelwal et al., 2013. I use this information to match the products in my dataset that the EU imports.

Using the results of the above data matching, Figure 2.8 shows the number of Chinese firms exporting to the US and EU that are subject to quotas during the study period of my working data. There is an increasing trend followed by a jump in 2005. Figure 2.9 shows the number of products subject to quotas exported to the US and EU. There is a steady increase with the number of products remaining relatively stable over the years.

Figure 2.8 No. of Chinese firms exporting to US and EU under quota

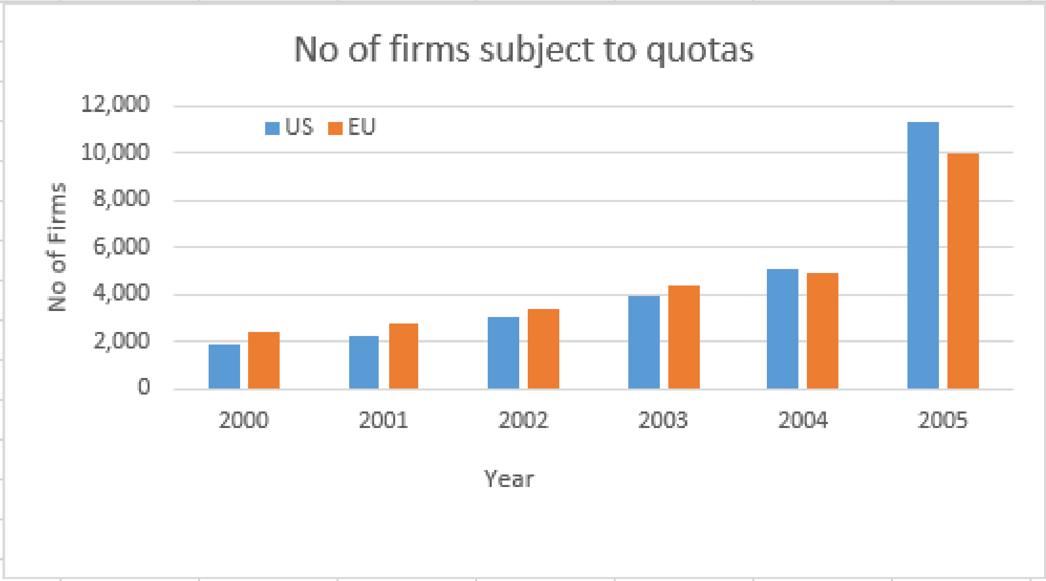
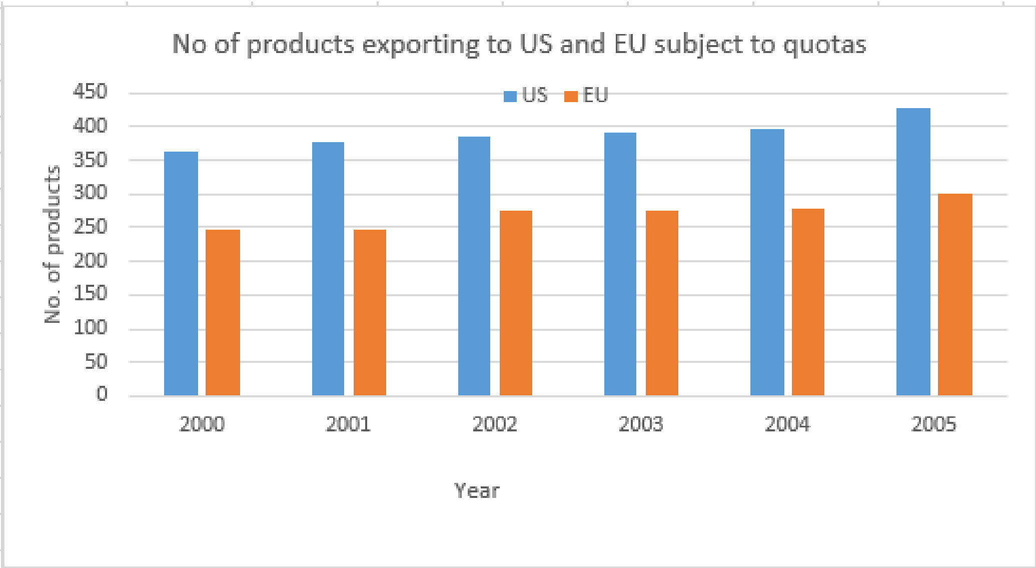


Figure 2.9 No. of products exporting to US and EU subject to quota



2.4 Research design and analytical framework

2.4.1 Conceptual framework

The purpose of this study is to investigate the effect of trade liberalization on the choice of transport mode. There are many channels through which firms may respond to a change in quotas: by changing the prices on quota products, by changing the amount of goods that are shipped, by changing the products that are traded, by new firms entering the market, by changing how the good is transported to its destination (e.g. by air or by sea), and by other changes (e.g. by improving quality). Figure 2.7 shows the variation in products and Figure 2.6 shows how the number of firms changed in my sample.

For the chosen trade liberalization event of MFA quota removal, a question is whether it was a significant event on transport mode choice for the textile and apparel industry. Past studies have shown that the MFA led to large price changes for Chinese firms exporting textile products to the USA (Bernhofen et al 2018, Khandelwal, Schott, and Wei, 2013). In 2005, a couple of months after the quota removals emergency measures were enacted in the US and Europe, re-imposing quotas on a selection of textile products.

In this study, the framework is as follows:

a) The MFA liberlisation reduces the value and quality of the traded products. The Alchian-Allen hypothesis, referred to as “shipping the good apples out”, has effects that transportation costs lead firms to ship high quality goods abroad, with lower quality products for the home market. This hypothesis is supported by a large literature linking international trade quotas to quality (for example, Falvey (1979) shows similar effects under the assumption of perfect competition. Krishna (1990) provides a survey for imperfect competition).
b) High value/quality products tend to be shipped by time-saving but high/higher cost transport modes (Hummels, 2007). For example, expensive consumers electronics such as laptops are shipped by air freight. Other studies of product quality include, e.g., Hummels and Skiba (2004), Minor and Tsigas (2008), Harrigan and Barrows (2009), Bernhofen, Upward, and Wang (2018), and Fernandes (2020).
c) Therefore, the removal of MFA quotas could lead to a reduction of goods shipped by high-cost transport modes i.e. air shipment.

2.4.2 Identification strategy for the share value of goods shipped by different transportation modes

The dataset used in this study contains information on products exported by a firm to a particular country in a particular year. The HS2 code in Table 2.2 below is taken from Table 2.1 and the product description can be found therein.

Table 2.2 Product level information

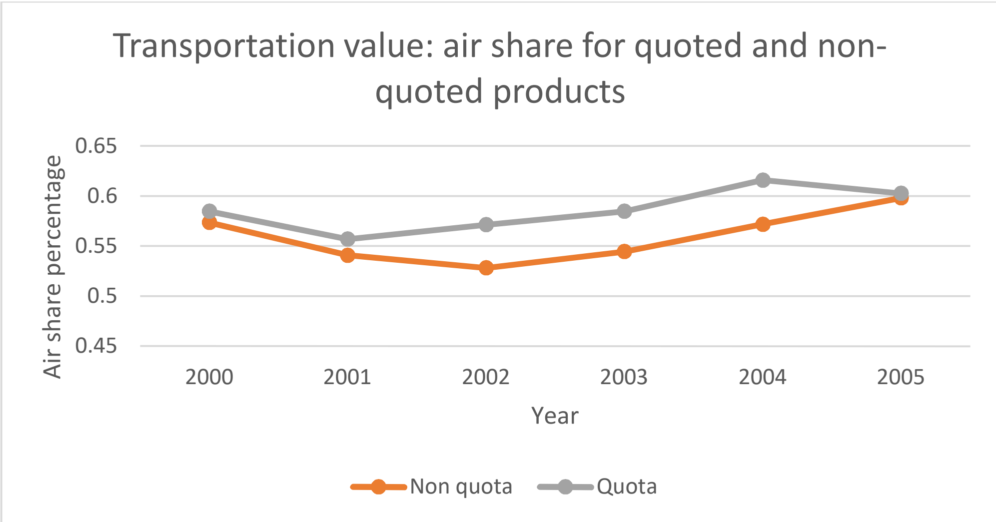
HS 2 Code	Total distinctive products
50	0
51	0
52	131
54	105
55	122
56	45
58	67
59	42
61	138
62	167
63	101
Total distinctive products	918

To explore the way goods are transported between China and its trading partners, I examine the empirical relationship between changes in the shares of goods transported by different transport modes, using an exogenous event, the abolishment of MFA tariffs in 2005, whilst controlling for confounding factors.

As mentioned, this study only considers two modes of transport, sea and air. This supports investigating trade to Europe and the USA, located relatively a long distance away from China such that other transportation channels, e.g., rail and road transportation, are limited. Shipment by these means represent the vast majority of textile trade between China and the US and EU. In 2019 for example, 85% of EU-China textile trade was transported via the sea and air[22]. Consequently, estimating the absolute value of air transport in relation to total transport would mean similarity/proportionality when utilizing the two transport modes as the denominator. This variable is the "Air share" and captures the importance of both sea and air transport.

Figure 2.10 shows the distribution of air share for quota and non-quota products in my data.

Figure 2.10 Transportation value measured by air share for quota and non-quota products



Using a share value allows me to look at the effects on both air and sea transport together. This avoids running the same regression twice. I construct my measure of transport modes as a ratio of the trade value shipped by air over the total amount shipped by sea and air. This is a share value which captures the effects of both modes of transportation. The percentage change of this share value reflects the effects of the changes in both modalities.

At the product level, the share value of transport mode is calculated by the trade value of the products shipped by air divided by the total trade value of the products shipped via air and sea in that year to the same destination. At the firm-product level, the share value of transport is calculated by the total trade value of the product shipped by air for the firm divided by the total trade value of the product shipped by air and sea for the firm in that year to the same destination.

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[22] Source: Eurostat, "Extra-EU trade since 2000 by mode of transport, by NST/R"

2.4.3 Missing values and the construction of treatment-control groups

The panel dataset contains missing observations. With the missing data, it is difficult to know whether the variable is zero or truly missing. Regressions will drop missing observations which, if not truly missing, may lead to bias. In my data not all products have observations across all years in the sample. Table 2.3 summarizes the information for product observations across all years with one and two years' being missing. I deal with this issue by restricting the analysis to a reduced sample with missing observations removed. As may be seen from Table 2.3, the missing value rate is relatively low, around 9.9% missed in one year across the study period and 6.7% missed in two years across the study period. My working data retains around 85% of the original data.

Table 2.3 Working data: product level missing values across years

Year	No. of products without missing values in each year	No. of products missing in each year (percentage)	No. of products missing in 2 years in each year (percentage)
2000	705	59 (7.7%)	27 (3.7%)
2001	705	74 (9.5%	23 (3.2%)
2002	705	73 (9.4)	56 (7.4%)
2003	705	80 (10.2)	57 (7.5%)
2004	705	85 (10.8)	66 (8.6%)
2005	705	92 (11.5)	75 (9.6%)
Total	4230	463 (9.9)	304 (6.7%)

The construction of the treatment and control groups requires the identification of the treatment and the products that are affected by the treatment and those that were not affected. The treatment here is the MFA quota removal. MFA/ATC quotas were imposed on the product level and removed on January 2005. Products that had a binding quota in place at the end of 2004 are in the treatment group. Products that had quotas released earlier are not included in the treatment group. The control group contains the products that had never been under quotas throughout the study period.

2.4.4 Specification

In this study, I use the removal of MFA quotas on US and EU products as an exogenous policy shock on Chinese exporting firms. Since not all textile and apparel products exporting to the US and EU are subject to quotas as well as the subsequent quota removal, I am able to use a difference in difference approach to estimate the effect of the shock on firms' modal choice expressed by the share trade values.

I begin my analysis be examining trade at the product level. My empirical analysis employs the following baseline difference in difference equation:

$$airshare_{zct} = \alpha + \beta_1 Quota_{zc} + \beta_2 Post_t + \beta_3 Quota_{zc} * Post_t + \varepsilon_{z,c,t} \quad (2.1)$$

The dependent $airshare_{zct}$ is the air share value for individual product z exported to destination c at year t. Here I define the treatment variable, $Quota$, to take the value one for textile and apparel products that have a binding quota in 2004 and zero otherwise.

$Post$ is the standard time dummy for difference-in-differences. It is a variable equal to one for all years and after 2004 and zero otherwise. The interaction between $Quota$ and $Post$ measures response to the removal of the MFA, relative to products that were unaffected by the shock.

I estimate the above equation beginning with total exports to the US and EU followed by analysis over disaggregated countries, that is, I estimate the equation over three different samples:

1. The first pooling all countries together.
2. The second with exports to the US only.
3. The third for Chinese exports to the EU countries.

The use of these different samples allows me to test for variations by country. I anticipate that the decision for transport modal choice could be different by individual countries that import T&C from China.

In later specifications of the model, I add fixed effects in order to capture the effects on individual groups, e.g., time fixed effect and country fixed effect. Fixed effects will be included via dummies in the regression equation. The time fixed effects control for time-varying factors, e.g., any differences that may exist between different years due to factors such as changes in fuel prices on global market, or changes in demand for T&C. The country fixed effects control for country-varying factors, e.g., differences in country infrastructure, or differences in cultural and norms, etc. These account for unobserved heterogeneity such as those in the quality of institutions, distribution networks and local customs. Product fixed effects and firm fixed effects are also added to control for product level and firm level heterogeneity. Including more fixed effects can help to control for more sources of unobserved heterogeneity, but it may also affect the estimate precision. Different combinations are used to see if a balance between including enough effects to control for relevant sources of heterogeneity and avoiding over-specification, could be found.

These fixed effects allow all variant factors, the heterogeneity in years, in countries, in products, or in firms, to be isolated, with the regression just measuring the effect of the quota removal on transport mode.

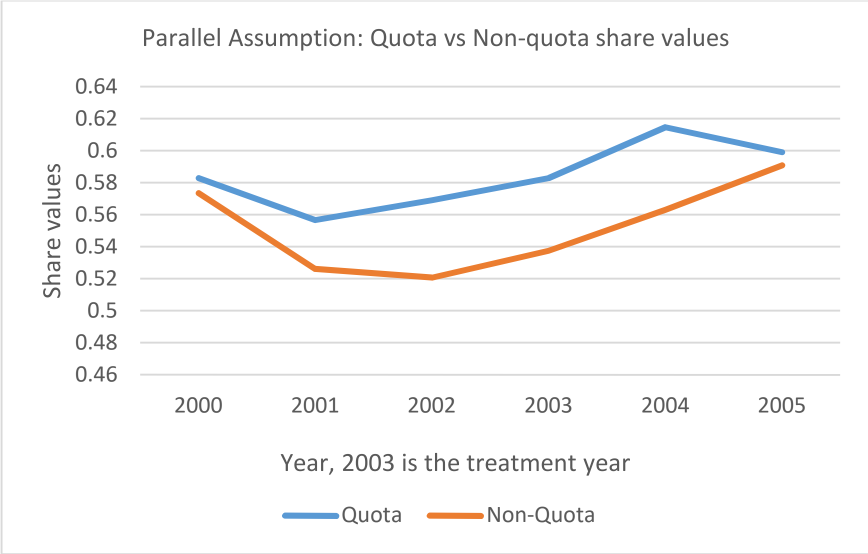
Finally, I estimate the equation at the lowest level of disaggregation in my dataset, at the firm-product-country level. This exploits differentials within products and firms, allowing identification of firms effect, if any. Using equation (2.2) below, I estimate whether the transport modal choice was driven by factors within or between firms following the MFA quota removal.

$$airshare_{izct} = \alpha + \beta_1 Quota_{izc} + \beta_2 Post_t + \beta_3 Quota_{izc} * Post_t + \varepsilon_{i,z,c,t} \quad (2.2)$$

Here I add the subscript i to represent individual firms. The remaining variables are the same as before in equation (2.1). The treatment variable, $Quota$, is equal to one for a specific product from a specific firm to a specific country that had a binding quota in 2004 that was subsequently removed in 2005, and zero otherwise. As an addition to the aforementioned fixed effects for equation (2.1), I include firm fixed effects in analysis for equation (2.2). Firm fixed effects control for any time invariant firm characteristics. In particular, firm fixed effects would control for any systematic differences for firms between the treatment and control groups. Such a fixed effect is included to capture firm unobservable factors; these include factors such as branding.

The difference in difference analysis of the effect on share values assumes that the trends in the treatment and control groups are the same prior to the MFA removal. Figure 2.11 plots the share of goods transported via air for quota bound and non-quota products. The figure shows that the trends are similar pre quota removal providing support that the parallel trend assumption stands.

Figure 2.11 Trend comparison for treatment and control groups on air share value



Shares of clothing and textile products exported via air declined from 2000 to 2001 and rose thereafter. The two series diverge after the quota removal in 2004, with the share of previously quota bound products exported via air declining compared with an increase in quota free products transported via the air.

Table 2.4 shows the pre-trend test result with the year 2003 as the reference year. The coefficients of Quota*2000, Quota*2001, Quota*2002 shows that the results are not statistically significantly different from zero, therefore supporting the assumption that the treatment and control group share the same pre-trends. This indicates that the parallel assumption stands in the pre-treatment period.

Table 2.4 Pre-trend tests result

Dependent Variable: Share (value) of goods transported via air	(1)
Quota	0.0522***
	(0.0110)
Year 2000	0.0194*
	(0.0117)
Year 2001	-0.00485
	(0.0117)
Year 2002	-0.00968
	(0.0114)
Year 2004	0.00151
	(0.0112)
Year 2005	0.0257**
	(0.0111)
Quota*2000	-0.0167
	(0.0160)
Quota*2001	-0.0262
	(0.0160)
Quota*2002	-0.0205
	(0.0157)
Quota*2004	0.0110
	(0.0154)
Quota*2005	-0.0176
	(0.0152)
Constant	0.587***
	(0.00798)
Observations	14,705
R-squared	0.009

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

2.5 Results analysis

This section presents evidence on the effect of MFA removal on firms' choices of modal transport. I begin with product level regressions, then disaggregating the effect by splitting the sample into the US and EU. Subsequently, I carry out the analysis at the firm-product level, repeating the same analysis as above by aggregating sample and then moving to the US and EU respectively.

2.5.1 Product level analysis

The analysis here is at the product level and gives a good baseline estimate of the possible effects. MFA quotas are defined at the product level with some quota lines targeting very specific goods[23].

Table 2.5 shows the results from estimating equation 2.2 for Chinese exports to both the US and the EU. The first regression (1) is an estimate without adding any fixed effects. Regression (2) adds year dummies, regression (3) considers both year and country fixed effects. Regression 4 considers year, country, and product fixed effects.

Looking at the *Constant* coefficient in the table, it shows that the baseline average share is ranging from 59.4% to 60.8% across all regressions. This provides a base for further discussion about changes of air share values affected by quota lifting. Each fixed effect column will be assessed against its own baseline average. The time effect represented by *Post* coefficient is displayed in regression (1) but absent from all other regressions where year-fixed-effect dummies are included. With the year dummies the results are looking within years. This coefficient indicates that regardless of quota removal, owing to factors unrelated to the trade policy change, the air share increased by 2.01 percentage point over the study period.

Next, still focusing on regression (1), the initial share value difference between quota products and non-quota products represented by the *Quota* coefficient is 4.38 percentage point, indicating a preference for air shipment over sea for the products with a quota. When the quota was removed, this had the effects of decreasing this share by 1.35 percentage

[23] A firm could be exporting more than one product to various destinations. When analysing at the product level, product firm IDs are ignored.

points as seen by the *Quota*Post* coefficient. Using this coefficient alongside the post-dummy, this indicates that relative to the counterfactual the quota removal led to a small increase in the share of air freight over time. That is, as a result of the quota removal, relatively more goods (by value) were shipped by sea compared to the counterfactual. Though the percentage change is small, it is significant in terms of the alteration of the trend directions.

Table 2.5 DiD estimate for Chinese exports the US and EU at product level

Dependent Variable: Share (value) of goods transported via air	(1)	(2)	(3)	(4)
Quota	0.0438**	0.0439**	0.0566***	0.0314***
	(0.0161)	(0.0161)	(0.00838)	(0.0101)
Post	0.0201**			
	(0.00797)			
Quota*Post	-0.0135**	-0.0135**	-0.0147**	-0.0185***
	(0.00513)	(0.00514)	(0.00518)	(0.00587)
Constant	0.597***	0.601***	0.594***	0.608***
	(0.0139)	(0.0133)	(0.00441)	(0.00530)
Year F.E	N	Y	Y	Y
Country F.E	N	N	Y	Y
Product F.E	N	N	N	Y
Observations	13,266	13,266	13,266	13,261
R-squared	0.006	0.008	0.037	0.270

Standard errors in parentheses: *** p<0.01, **p<0.05, * p<0.1

With year-fixed effects as shown in regression (2), the result is similar to those in column (1), meaning that there is no significant difference in share value change within a particular year across the study period.

When adding country effects to (2) as shown in regression (3), there is a small increase in the estimated coefficient of the effect of the quota removal. Within a country, the behavior of changing transportation modes is very similar.

Adding product fixed effects to the regression in (4), leads the estimated coefficient on the post-quote period to increase in magnitude 1.85 - this implies a change in the share of air freight relative to the counterfactual of 0.38 percentage point.

Overall, this negative effect is persistent throughout the model. The coefficient does not change very much through columns 1 to 4 with the estimated effect to being approximately -1.35 to -1.85 percentage points. The results suggest that due to the removal of the MFA, the share of products shipped by air decreased as relatively more goods were shipped by sea. This means that less expensive goods are traded to US and EU following the MFA quota removal, hence the air freight proportion is reduced.

Next, I disaggregate the data into exports to the US and those to the EU separately in order to explore heterogeneity in the effects across regions because of their respective transportation policies and geographies. Table 2.6 below shows the results for exports to the US.

For this estimation many of the results are insignificant. However, some inference can be made regarding the value of the coefficients. The baseline average, represented by the c*onstant* coefficient, is 0.595, slightly lower than the baseline average for exporting to both the US and EU in Table 2.5 previously (0.597). Regression (1), which excludes any fixed-effect dummy variables, indicates a 7.42 percentage-point natural increase in share values regardless of the quota situation. This is 5.21 percentage points[24] more than exporting to both US and EU destinations in Table 2.5, and 5.54 percentage points[25] more than exporting to the EU in Table 2.7. This suggests that textile products are more likely to be transported by air to the US than to the EU.

The initial share value difference between the quota products and the non-quota products is very small as expressed by *Quota* coefficient (0.869 percentage point), much smaller than in the two-destination scenario (4.38) in Table 2.5 and in the case of exporting to the EU (6.15) in Table 2.7. This suggests that the US does not treat quota products and non-quota products differently when transport mode is concerned. But the quota removal results in a larger effect on share value decline for the US (-6.03 in column 1) than for the EU, a 1.58 percentage-

[24] 7.42-2.01 = 5.21

[25] 7.42-1.88 = 5.54

point decline in Table 2.7. This effect is persistent across all specifications of the model (around 6.03 percentage points) when fixed effect elements are considered.

Overall, we cannot say that the liberalization of the MFA has any effects on firms' choice of shipment mode to the US.

Table 2.6 DiD estimate for Chinese exporting to US at product level

Dependent Variable: Share (value) of goods transported via air	(1)	(2)
Quota	-0.00869	-0.00876
	(0.0235)	(0.0234)
Post	0.0742	
	(0.0548)	
Quota*Post	-0.0603	-0.0603
	(0.0571)	(0.0571)
Constant	0.595***	0.608***
	(0.0225)	(0.0205)
Year F.E	N	Y
Observations	1,891	1,891
R-squared	0.002	0.004

Standard errors in parentheses: *** p<0.01, ** p<0.05,

Turning to the other export market, the EU in Table 2.7, I again find a negative effect of the MFA quota removal on the share value. In contrast to the findings for the US, the coefficients are now significant. The quota removal at the beginning of 2004 led to a 1.58 to 1.65 percentage-point decline in the value share of goods transported via air shipment. This effect is persistent across the different specifications of the model, except for the last one - column (4). Regression (4) takes into account year-fixed-effect, country-fixed effect, and product-fixed effect. The *Quota*Post* coefficient in column (4) shows that the air share declined much more (2.04) after the inclusion of year, country and product-fixed effects.

Table 2.7 DiD estimate for Chinese exporting to EU at product level

Dependent Variable: Share (value) of goods transported via air	(1)	(2)	(3)
Quota	0.0615***	0.0616***	0.0606***
	(0.00793)	(0.00794)	(0.00791)
Post	0.0188**		
	(0.00808)		
Quota*Post	-0.0158**	-0.0159**	-0.0165**
	(0.00580)	(0.00581)	(0.00582)
Constant	0.597***	0.601***	0.602***
	(0.0143)	(0.0137)	(0.00367)
Year F.E	N	Y	Y
Country F.E	N	N	Y
Observations	11,375	11,375	11,375
R-squared	0.012	0.014	0.040

Standard errors in parentheses:*** p<0.01, ** p<0.05, * p<0.1

Overall, I find that there is adjustment at the product margin regarding firms' choice of transport. The overall effect is negative and significant. There is some variation between the destination markets, with the effect driven by clothing and textile exports to the EU.

2.5.2 Firm product-level analysis

Using product-level data, the results have shown that the removal of quotas on 1 January 2005 led to a decline in goods shipped via air compared with air and sea. I now consider the role of firms in this change using firm-product level data.

In this analysis, I estimate the equation at the lowest level of disaggregation in my dataset, using data on the *izc* level rather than the *zc* level.

Table 2.8 shows the results from estimating the equation with all US and EU countries. As can be seen, one benefit of pooling the data is that it increases the number of observations for analysis. Comparing regression (1) of the firm-product level estimate in this table with regression (1) of the product level estimate in Table 2.5, the baseline averages of share value are similar in the range 59.7 to 60.8 percentage points (Table 2.5) and 56.1 to 58.0 percentage points (Table 2.8), respectively. The air share increases more at the firm-product level (3.98 percentage points) than at the product level (2.01) over time regardless of the quota. This means that the choice of the mode of transportation depends more on characteristics at the firm level than on characteristics of products.

The estimate of quota removal effect at 3.0 percentage points in (1) is again negative and significant but larger than the result at the product level (1.35 as in Table 2.5). This indicates again that air share response to quota removal is more a firm-level decision than it is a product-level decision. Columns (2) to (5) add more fixed effects, the coefficients are similar, with estimates around 2.63 to 4.80 percentage points.

The last column includes fixed effects for each firm (column 5). By including firm-fixed effects this controls for time invariant firm characteristics. There is a strong effect of 4.8 percentage-point decline in air share within firms, the largest effect compared to other regressions.

Table 2.8 DiD estimate for Chinese firms exporting to US and EU at firm-product level

Dependent Variable: Share (value) of goods transported via air	(1)	(2)	(3)	(4)	(5)
Quota	0.0304	0.0322	0.0627***	0.0216***	0.0380***
	(0.0313)	(0.0309)	(0.0159)	(0.00431)	(0.00639)
Post	0.0398***				
	(0.00789)				
Quota*Post	-0.0300**	-0.0318***	-0.0294**	-0.0263***	-0.0480***
	(0.0111)	(0.0108)	(0.0121)	(0.00456)	(0.00533)
Constant	0.561***	0.575***	0.557***	0.580***	0.573***
	(0.0113)	(0.0111)	(0.00710)	(0.00278)	(0.00304)
Year F.E	N	Y	Y	Y	Y
Country F.E	N	N	Y	Y	Y
Product F.E	N	N	N	Y	Y
Firm F.E	N	N	N	N	Y
Observations	209,474	209,474	209,474	209,471	205,077
R-squared	0.001	0.003	0.020	0.105	0.258

Standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1

Turning to each destination, for the US (Table 2.9) I again find a negative effect of the quota removal on the value share of goods transported by air. This effect is varied, from very small, 0.0462, to 5.65 percentage points. The coefficient becomes significant with the inclusion of product fixed effects. The effect is the largest with firm-fixed effects, with the effect on the value share of goods being 5.65 percentage points. Comparing Table 2.9 to Table 2.6 for exporting to the US at firm-product level and at product level, it is apparent that transport mode decisions are governed largely by decisions made at the level of the individual firm.

Table 2.9 DiD estimate for Chinese firms exporting to the US at firm-product level

Dependent Variable: Share (value) of goods transported via air	(1)	(2)
Quota	-0.0659***	-0.0652***
	(0.0124)	(0.0123)
Post	0.0314*	
	(0.0163)	
Quota*Post	-0.000462	-0.00119
	(0.0172)	(0.0172)
Constant	0.594***	0.606***
	(0.0116)	(0.0106)
Year F.E	N	Y
Firm F.E	N	N
Observations	56,342	56,342
R-squared	0.002	0.003

Standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1

Table 2.10 shows the results for the EU. In line with earlier results, the effect of the quota removal is negative and significant. The decline in air share is more than in the US market at around 4.6 percentage points. With the inclusion of firms the effects are now larger, the coefficient is -4.69, more than double the effect at the product level. These results reinforce the idea that firms should be taken into account with the quota removal for a specific market.

Table 2.10 DiD estimate for Chinese firms exporting to the EU at firm-product level

Dependent Variable: Share (value) of goods transported via air	(1)	(2)	(3)	(4)	(5)
Quota	0.0794***	0.0804***	0.0786***		
	(0.0101)	(0.00996)	(0.0101)		
Post	0.0405***				
	(0.00816)				
Quota*Post	-0.0468***	-0.0479***	-0.0471***	-0.0353***	-0.0469***
	(0.00755)	(0.00742)	(0.00711)	(0.00651)	(0.00559)
Constant	0.560***	0.574***	0.575***	0.610***	0.608***
	(0.0116)	(0.0114)	(0.00377)	(0.00120)	(0.00102)
Year F.E	N	Y	Y	Y	Y
Country F.E	N	N	Y	Y	Y
Product F.E	N	N	N	Y	Y
Firm F.E	N	N	N	N	Y
Observations	153,132	153,132	153,132	153,132	149,645
R-squared	0.007	0.009	0.023	0.109	0.259

Standard errors in parentheses: *** p<0.01, ** p<0.05, **p<0.1

Table 2.11 shows the summary of the DiD regression results for the *Quota*Post* coefficients from all estimations.

Table 2.11 *Quota*Post* coefficients for all DiD estimations

DiD Regression		**"Quota*Post" Coefficient**				
Regression at	Product export to	No fixed effect	Year fixed	Year and Country fixed	Year, Country, and Product fixed	Year, Country, Product, and Firm fixed
Product level	US and EU	-0.0135	-0.0135	-0.0147	-0.0185	.
	US	-0.0603	-0.0603	.	-0.0646	.
	EU	-0.0158	-0.0159	-0.0165	-0.0204	.
Firm-product level	US and EU	-0.0300	-0.0318	-0.0294	-0.0263	-0.0480
	US	-0.0005	0.0012	.	-0.0355	-0.0565
	Eu	-0.0468	-0.0479	-0.0471	-0.0353	-0.0469

In summary, from Table 2.11, the product level results are consistent with the firm-product level, both showing a decline in air share in a single-digit percentage. The firm-product level decline is slightly higher than the product level, indicating a more likely firm decision on transport modes under MFA quota removal. With fixed effects, variations can be observed but they are small.

2.5.3 Clustered standard errors

The MFA quotas are applied on products and this differed between countries. For example, the US decides which quotas to remove on which products imported to the US. Other countries, such as Germany and France and others in the European Union have a common policy. The European Union has a common quota policy for all member countries, but they are not exactly the same as in the US. A product, being exported to different countries, is subject to the country's quota and transportation regulations. Therefore, the product variable is not independent from the country variable with respect to transportation mode. When calculating the standard error in DiD for exporting products to both the US and EU, I used clustered standard error at the country level, as shown in Tables 2.5 and 2.8. The country level clustering is also applied to the regression of exports to EU countries shown in Tables 2.7 and 2.10. Since the regressions are also carried out to estimate the quota removal effect when exporting to individual countries, as shown in Tables 2.6, 2.7, 2.9, and 2.10, the results as detailed in 2.5.1 and 2.5.2 support this claim strongly hence clustering at country level is adequate.

When estimating the effect for the US individually as in Tables 2.6 and 2.9, clustering at the country level is not applicable as it is a single country. In Table 2.6, the standard error is clustered at product level, while in Table 2.9, it is clustered at firm level. The firm level clustering supports the analysis that shipment modal is more of a firm decision than product decision under MFA quota removal.

The standard errors are summarized in the below Table 2.12.

Table 2.12 Standard errors for DiD regressions at different cluster levels

DiD Regression		**Standard Error on "Quota*Post" Coefficient**					
Regression at	Product export to	Clustered at	No fixed effect	Year fixed	Year and Country fixed	Year, Country, and Product fixed	Year, Country, Product, and Firm fixed
Product level	US and EU	Country level	0.0051	0.0051	0.0052	0.0059	.
	US	No clustering	0.0571	0.0571	.	0.0463	.
	EU	Country level	0.0058	0.0058	0.0058	0.0062	.
Firm-product level	US and EU	Country level	0.0111	0.0108	0.0121	0.0046	0.0053
	US	Firm level	0.0172	0.0172	.	0.0166	0.0170
	Eu	Country level	0.0076	0.0074	0.0071	0.0065	0.0056

In my results, it is common that the clustered standard error is larger than the non-clustered. In my regression, the estimated coefficients remain significant at the 1.0 percentage level, despite the different levels of clustering used. Overall, the firm-product level errors are slightly higher than at the product-level, which is also expected since it follows the previous discussed trend. The exports to the EU behaves similarly to the exports to both the EU and US, whereas the US does not, this implies that the EU is better represented in the analysis than the US.

2.5.4 Test on missing values

The previous analysis used a sample of textile and clothing products exports across all years in the study period. Not all products are exported every year and if they are not exported in certain years, the values could be zero, treated as missing values or missing observations. This includes the addition of new products over the years. Products with missing observations were omitted from the previous analysis. In this section, I check whether the results are sensitive to missing observations by adding the missing observation products back to my working data. I run regressions on two subsamples of the data: one that contains products having only one missing observations across the study period; and another with products having two missing observations across the study period. Both are estimated at the product and firm-product level, for exports to both US and EU markets.

Table 2.13 shows the results with one missing value. All Quota*Post coefficients show a decline in air share at a similar scale as the scenario without missing values, and the estimate is significant. This indicates that missing a year's export data does not change the results of the quota removal effect.

Table 2.13 DiD estimate for exports to US and EU at product level with one missing observation

Dependent Variable: Share (value) of goods transported via air	(1)	(2)	(3)
Quota	0.0455**	0.0455**	0.0592***
	(0.0167)	(0.0167)	(0.00768)
Post	0.0230**		
	(0.00799)		
Quota*Post	-0.0154**	-0.0153**	-0.0162***
	(0.00526)	(0.00524)	(0.00503)
Constant	0.607***	0.611***	0.604***
	(0.0137)	(0.0131)	(0.00405)
Year F.E	N	Y	Y
Country F.E	N	N	Y
Observations	14,911	14,911	14,911
R-squared	0.006	0.008	0.035

Standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1

The analysis is repeated with the sample having two missing observations (Table 2.14). The results again show a decline of air share at the similar scale as for non-missing value data and they are significant. The MFA removal effect is consistent for when exports stop for two years (or two years' data are miscollected) and for non-missing data.

Table 2.14 DiD estimate for exports to US and EU at product level with two missing observations

Dependent Variable: Share (value) of goods transported via air	(1)	(2)	(3)
Quota	0.0464**	0.0466**	0.0596***
	(0.0170)	(0.0170)	(0.00937)
Post	0.0236***		
	(0.00724)		
Quota*Post	-0.0163**	-0.0164**	-0.0178**
	(0.00688)	(0.00689)	(0.00686)
Constant	0.605***	0.609***	0.603***
	(0.0143)	(0.0137)	(0.00472)
Year F.E	N	Y	Y
Country F.E	N	N	Y
Observations	14,359	14,359	14,359
R-squared	0.007	0.008	0.039

Standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1

Tables 2.15 and 2.16 are the results to test missing values at firm-product level, again working with one and two missing observations, respectively. Both results show a decline of air share, the same as at the product level, and they are significant.

Table 2.15 DiD estimate for exports to US and EU at firm-product level with one missing observation

Dependent Variable: Share (value) of goods transported via air	(1)	(2)	(3)	(4)	(5)	(6)
Quota	0.0225	0.0241	-0.0540***	0.0564***	0.0194***	0.0341***
	(0.0309)	(0.0304)	(0.0122)	(0.0147)	(0.00355)	(0.00520)
Post	0.0391***					
	(0.00775)					
Quota*Post	-0.0274**	-0.0290**	-0.0271***	-0.0272**	-0.0236***	-0.0452***
	(0.0115)	(0.0111)	(0.00470)	(0.0124)	(0.00523)	(0.00446)
Constant	0.568***	0.582***	0.627***	0.563***	0.584***	0.577***
	(0.0124)	(0.0121)	(0.0209)	(0.00619)	(0.00245)	(0.00261)
Year F.E	N	Y	Y	Y	Y	Y
Country F.E	N	N	N	Y	Y	Y
Product F.E	N	N	Y	N	Y	Y
Firm F.E	N	N	N	N	N	Y
Observations	220,402	220,402	220,400	220,402	220,400	216,033
R-squared	0.001	0.002	0.088	0.020	0.103	0.255

Standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1

Table 2.16 DiD estimate for exports to US and EU at firm-product level with two missing observations

Dependent Variable: Share (value) of goods transported via air	(1)	(2)	(3)	(4)	(5)	(6)
Quota	0.0318	0.0337	-0.0487***	0.0641***	0.0219***	0.0379***
	(0.0313)	(0.0309)	(0.0102)	(0.0158)	(0.00414)	(0.00630)
Post	0.0397***					
	(0.00792)					
Quota*Post	-0.0297**	-0.0316***	-0.0299***	-0.0292**	-0.0261***	-0.0476***
	(0.0112)	(0.0110)	(0.00468)	(0.0122)	(0.00475)	(0.00512)
Constant	0.562***	0.576***	0.625***	0.557***	0.582***	0.575***
	(0.0114)	(0.0112)	(0.0200)	(0.00708)	(0.00273)	(0.00308)
Year F.E	N	Y	Y	Y	Y	Y
Country F.E	N	N	N	Y	Y	Y
Product F.E	N	N	Y	N	Y	Y
Firm F.E	N	N	N	N	N	Y
Observations	211,653	211,653	211,641	211,653	211,641	207,246
R-squared	0.002	0.003	0.092	0.020	0.107	0.259

Standard errors in parentheses: *** $p<0.01$, ** $p<0.05$, * $p<0.1$

2.6 Robustness

In this section, I describe a number of robustness checks designed to determine whether the results I obtained are valid, implying a causal relationship. Firstly, I conduct placebo tests, using 2003 as the treatment year at the firm-product level. Secondly, I use data on Canada as an alternative to trade to the US and EU which were discussed in section 2.5.

2.6.1 Timing of treatment

All MFA quotas were removed at the end of 2004 and this study uses this year as the time of treatment. However, there were other phases of quota removal in earlier years that could have had potential indirect impacts on the textile and clothing products used in this study. I undertake a placebo test changing the year of treatment to 2003, one year before the quotas were phased out.

Table 2.17 below shows the result of DiD estimation using 2003 as the treatment year at the firm-product level. Quota*Post coefficients are found to be insignificant, meaning that there is no significant effect on air share change before the quota removal at the beginning of 2005. Secondly, the constant coefficients are all significant which only means that the baseline average is calculated for each regression and they are as expected.

Table 2.17 Placebo test using 2003 as treatment year at firm-product level

Dependent Variable: Share (value) of goods transported via air	(1)	(2)	(3)	(4)	(5)
Quota	0.0184	0.0180	0.0510**	0.0138***	0.0263***
	(0.0327)	(0.0324)	(0.0189)	(0.00490)	(0.00612)
Post	0.0263***				
	(0.00839)				
Quota*Post	0.00455	0.00399	0.00172	-0.00177	-0.00622
	(0.00876)	(0.00858)	(0.0113)	(0.00378)	(0.00388)
Constant	0.555***	0.575***	0.556***	0.580***	0.571***
	(0.0114)	(0.0111)	(0.00724)	(0.00272)	(0.00311)
Year F.E	N	Y	Y	Y	Y
Country F.E	N	N	Y	Y	Y
Product F.E	N	N	N	Y	Y
Firm F.E	N	N	N	N	Y
Observations	209,474	209,474	209,474	209,471	205,077
R-squared	0.002	0.002	0.019	0.105	0.258

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Comparing the results in this table to those in Table 2.8, the coefficients are small in magnitude. This result is as expected, indicating that there was no influence by the quota removal in earlier years.

2.6.2 Different destination country

Up to this point, the analysis examined exports from China to the US and EU. As discussed in section 2.3.2, the levels of textile and apparel exports from China to Canada is low as compared to the exporting values to the US and EU (around 30 times less. Figure 2.5). In addition, Canada is outside the top ten trading partners with China in textile and apparel industry (Figure 2.4). Therefore, Canada was excluded from previous regression analysis.

Geographically, Canada is adjacent to the US, which makes it reasonable to assume that two countries' transportation choice may be similar. So next, I examine the effect of quota removal on a third destination, Canada. Table 2.18 below reports the estimates at the firm-product level with exports to Canada.

Table 2.18 Alternative trade to Canada at firm-product level

Dependent Variable: Share (value) of goods transported via air	(1)	(2)	(3)	(4)
Quota	0.0749***	0.0725***		
	(0.00727)	(0.00729)		
Post	0.0712***			
	(0.00837)			
Quota*Post	-0.0119	-0.00943	-0.0111	-0.0542***
	(0.0118)	(0.0118)	(0.0115)	(0.0116)
Constant	0.440***	0.467***	0.501***	0.500***
	(0.00460)	(0.00389)	(0.00362)	(0.00342)
Year F.E	N	Y	Y	Y
Product F.E	N	N	Y	Y
Firm F.E	N	N	N	Y
Observations	22,584	22,584	22,572	20,868
R-squared	0.014	0.016	0.137	0.414

Standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1

The above results for the Quota*Post coefficients are all insignificant, indicating a weak effect on the air share change when exporting textile goods to Canada following the quota removal in 2005. Comparing this result to the earlier result in Table 2.8 for exporting textile products to US and EU, it may be seen that while the trends between the two are similar, the magnitude of the Canada estimate is very small, ranging between 0.94 and 1.19 percentage points for regressions (1) to (3). Interestingly, in column (4) when firm fixed effect is added in, the quota removal effect (-5.42 percentage points) is comparable to the US and EU market (-4.80) and this result is highly significant. This supports the previous findings and indicates that firms may play a central role in shipment decisions regardless of the good's shipping destination.

The second test on the Canada market is to estimate the quota effect on air share at product-level. The results are shown in Table 2.19, and the results confirmed this being insignificant for all Quota*Post coefficients.

Table 2.19 Alternative trade to Canada at product level

Dependent Variable: Share (value) of goods transported via air	(1)	(2)
Quota	0.0152	0.0150
	(0.0171)	(0.0170)
Post	0.0624**	
	(0.0282)	
Quota*Post	0.0551	0.0553
	(0.0400)	(0.0399)
Constant	0.511***	0.523***
	(0.0121)	(0.0109)
Year F.E	N	Y
Observations	1,439	1,439
R-squared	0.017	0.023

Standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1

2.7 Conclusions

This chapter looked at the effect of a specific policy change, the MFA liberalization, and its effects on the shipment decisions of Chinese firms exporting to the US and EU markets.

I employ the difference-in-difference approach with fixed effects to estimate the effects. The results are robust for factors such as early intervention and alternative exporting destinations.

Using the share of the value of goods shipped by air alone relative to air and sea combined, I find that the MFA liberalization had a significant effect on the transport-mode choice of exporting firms. There is a significant decline in air share following MFA liberalization when exporting from China to the US and to the EU. Although the effect is small, it is sufficient to alter the direction of the trend, since the air share would continue to grow in the absence of quota removal. This effect was consistent throughout the different specifications and fixed effects of the model.

The quota effects on the transport mode are focused on the firm, as I find effects that are more pronounced at the firm product compared with the product level.

Disaggregating the results, I find a difference for the choice of shipment between the US and the EU. As a result of the MFA, the share of goods shipped by air declined in the overall share of the mode of shipment for exports to the EU, and this is not the case for exports to US. This suggests that the quality of Chinese exports to the EU declined post MFA, followed with shippers switching to less expensive and time sensitive modes of transport. Overall, the findings indicate such effects to be relatively small, being around a relative 2% decline in air shipment for the EU.

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3 Chapter 3: The effect of government policy on the renewable energy market

3.1 Introduction

The renewable energy sector is a relatively young but growing sector that has historically been characterised by a high degree of government intervention across the globe. These policies have been provided to sustain the sector, under the assumption that in their absence the renewable energy sector would not function up to expectations. In this chapter, I examine the impact of such policy on firms in UK, evaluating whether the policy is effective on improving firm performance.

As the challenges of climate change becomes ever more apparent, economies have increasingly begun seeking measures to fulfil the objectives of environmentally sustainable development (Chen, 2015). The Paris Agreement, which aimed to combat climate change by limiting global temperature increase to below 2 degrees pre-industrial levels, came into force in November 2016. COP26 (Conference of Parties, the 26th conference), which took place in October 2021, finalised the outstanding elements of the Paris Agreement with the signatures of nearly 200 countries. Climate change is an ongoing challenge with a history of policies aimed to achieve sustainable development. This motivates the present study, which will assess past policies' effects on renewable energy policy, and thereby support future policy making in the renewable energy field.

In recent years, trends toward sustainable development have gathered apace. Prices of renewable energy technologies have been falling worldwide and this, combined with technological advances, has led to increased uptake of renewable energy in industrialised economies. For example, 7th June 2017 marked the first day that the UK was generating more of its energy through wind, solar and nuclear than through gas and coal combined (BBC news, June 2017).

Given the above trends, it is appropriate to examine the underpinnings of the renewables energy market. In the current status quo, all economies and markets with renewable energy uptake have in place a network of government policies that provide incentives for generating and/or uptaking of renewable energy. This is based on the notion that at current levels and given the relative infancy of renewables, a market in renewables is unable to sustain itself. The current cost advantage enjoyed by fossil fuels over renewables are based on market prices that do not factor in externalities which if included would likely make renewables much more affordable energy sources (Odgen, Williams and Larson 2004).

Many renewable energy policies are employed by governments around the world. Some of these policies are short-term while others are long-term; some are market-based while others are command-and-control (Stavins, 2003). Feed-in-tariffs (FIT) is one policy instrument common to many governments since the early 2000s. It is designed to support the development of renewable energy sources by providing a guaranteed, above-market price for producers. Appendix G shows the list of the years when countries introduced FIT on solar and wind sources (OECD, 2020). Among 36 OECD countries, 30 countries had FITs in place, seven countries (Austria, Denmark, Greece, Germany, Portugal, Spain, and Sweden) started FITs in year 2000. The USA introduced FITs in 2005 and the UK in 2010. Among the non-OECD countries, twenty-three countries have implemented FITs. By 2020, 53 countries around the world had FIT policies in place.

Currently, the literature has yet to come to a consensus about the general effectiveness of renewable energy policy, and this study will therefore seek to determine the effectiveness of the FIT in the UK. The UK government considers renewables a vital part of the energy mix and a key component of the transition towards a low-carbon economy. Alongside other policies, the introduction of the FIT helps the UK to achieve its renewables objectives - the EU target of 15% of final energy demand from renewables by 2020, as well as 30% of electricity generated from renewables by 2020[26]. Under the FIT scheme, agents who generate electricity, for example through the installation of solar panels or wind turbines are paid a tariff that provides a known rate of return over a number of years for all the electricity they generate.

The main objective of the FIT is to encourage the uptake of small-scale renewables as well as low-carbon electricity generation. One of the ancillaries is to engage non-energy professionals in the electricity market. Past research has focused on two areas: one is to investigate the effects of the policy on innovation (Groba and Breitschopf, 2013; Calel and Dechezleprêtre, 2016; Palage et al, 2019), while the other is to evaluate the effectiveness and efficiency of the policy (Menanteau et al,2003; Harmelink, et al, 2006; Mitchell et al, 2006; Del Rio and Bleda, 2012, Bolkesjø, et al, 2014). The research findings support the

[26] Review of the Feed-in Tariffs Scheme. Government response. 15 December 2015

view that market-based instruments, such as FITs do incentivise innovation and technology advances, while also improving profitability and investment, etc.

There is one area, however, that has attracted less research: the quantified firm response in reaction to the FIT. The FIT tends to encourage uptake of small-scale renewable energy generation, and it is anticipated that firms will be attracted, that their participation might generate profit, and that therefore firm revenue will increase.

Previous research into policy effects has mainly focused on using OLS (Ordinary Least Square), GMM (Generalized Method of Moments) and DiD (difference-in-difference) (Gelabert et al, 2011; Costa-Campi and Trujillo-Baute; 2015, Jarate-Kazukauske, et al, 2014). Similar to previous research this study will use the DiD methodology. However, the FITs scheme is open to a large number of firms with the potential to affect many different types, making the selection of a counterfactual group less straightforward. To deal with this complication, I will also apply the propensity score matching (PSM) integrated with difference-in-difference (DiD) estimation in this study, comparing their results and combining the two in modelling following works such as Binci (2018) and Amamou et al (2020).

This study will contribute to the existing literature in three ways. Firstly, this study will estimate the effect of energy policy by identifying the population of firms engaged in the renewable energy sector (renewable energy firms, REFs) in the UK during the policy period, (and assemble the dataset from scratch from available information). Secondly, past studies on the role of government in the sector have focused on the effects of policy on technology and innovation. In this chapter, such discussion focuses on whether government policy improved firm performance. Whilst the development of technology is important a complementary question of interest is the effect of government policy on firms' operating in such a market. To the authors' knowledge, this is one of the few studies to examine the effect of government policy at the firm level. [27]

Thirdly, this paper will examine several econometric techniques in an attempt to arrive at an estimate close to the aggregate effect of government policy on REFs. Counterfactual impact evaluation has been of growing importance in its use as a tool in to improve the decision making process of policy in the EU (Bondonio and Greenbaum, 2010). With the influx of

[27] In addition to existing studies that looked at the innovation effects with firms.

micro-level data, this study aims to carry out a counterfactual impact evaluation of government policy on firms operating in the renewable energy sector.

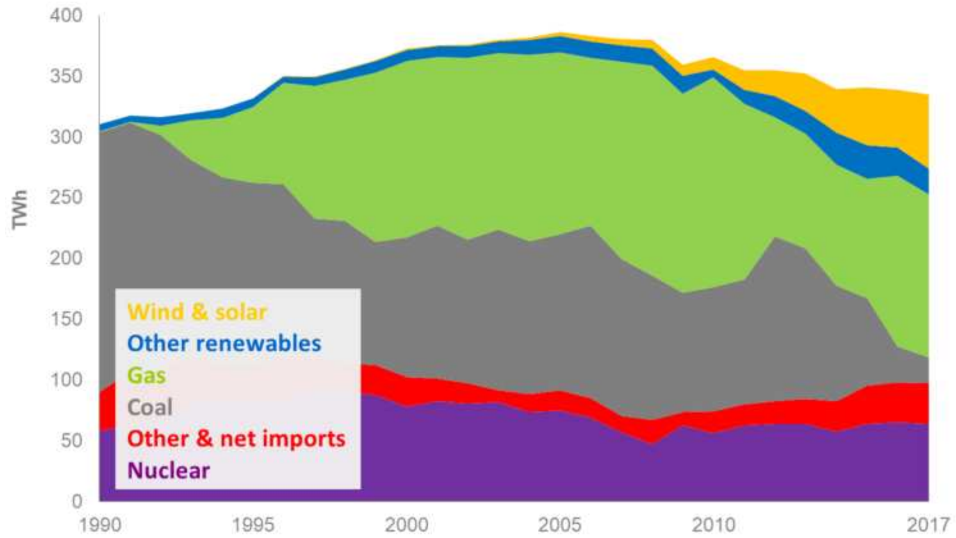
Despite falling costs and increasing optimism, investments in renewable technologies still face an uncertain future. As governments across the globe review the next wave of renewable energy policies and look to implement new ways of supporting the renewables market, it is now a prudent time to review and assess the impact past endeavours have had on firms in the renewable energy market.

The rest of this chapter is organized as follows. Section 3.2 provides the background information about the UK's renewable energy policy from 2007 to 2014, with a focus on the feed-in tariffs (FITs). Section 3.3 provides the literature review, examining renewable energy and innovation, the effectiveness and efficiency of renewable energy instruments, and the empirical methods used in the estimate of the FIT effects on REFs. Section 3.4 examines the data and data construction. Section 3.5 describes the conceptual framework of the investigation with the PSM and DID. Section 3.6 shows the results from the PSM, DiD, and the PSM and DiD together. Discussion of various factors that affect the estimation and the results are also presented. Section 3.7 concludes the chapter.

3.2 Background information about renewable energy policies in the UK

Forms of renewable energy have existed throughout human history, with windmills being a prime example, used in the Middle Ages and earlier. Yet, coal burning dominated the energy market for centuries, followed by gas and oil. The 1970s represented a turning point, with the oil crisis and miners' strikes. The UK government started tightening traditional energy sources and introduced renewable energy in the early 1990s. By 2017, nearly twenty years on, 29.4% of the UK's electricity was being generated by renewables – 39.7% by gas, 20.9% by nuclear, 6.7% by coal, and 3.2% by oil and other. Figure 3.1 below shows the trends in electricity generation (measured by Terawatt-hour -TWh) during those twenty years (BEIS, 2018[2]).

Figure 3.1 Electricity supplied by fuel type, 1990-2017[28]



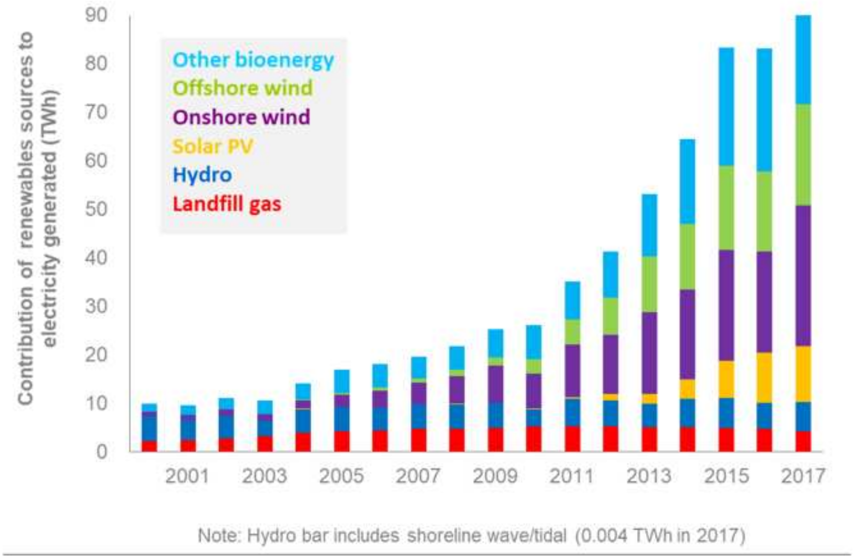
The percentage of renewable energy has steadily increased over time with energy generation via coal declining the most dramatically. Figure 3.2 below shows the sources of different renewable energies. Wind generation (both on-shore and off-shore) takes the lead in renewable energy generation.

Figure 3.2 also shows that, from around 2005 onwards, the renewable energy generation and supply increased nearly exponentially. Solar generation in particular has grown

[28] Source: UK Energy in Brief, 2018.

considerably, and in 2016 reached 10% of renewables. During this period, the UK government introduced many policies to encourage renewable energy uptake. The focus of this study will be mainly this period of rapid transition to renewables, from 2007 to 2014.

Figure 3.2 Electricity generation from renewable sources, 2000-2017 [Source: UK Energy in Brief, 2018]



Source: UK Energy in Brief, 2018

3.2.1 Renewable energy policies, 2007 - 2014

In 2007, the UK government agreed to the European Union’s target of generating 20% of the European Union's energy supply from renewable sources by 2020 (Eurostat, 2020). In subsequent years multiple policies were introduced to meet that target. Table 3.1 shows all renewable energy policies that were introduced during the 2007 to 2014 time period in the UK.

Table 3.1 All renewable energy policies in the UK between 2007 and 2014

Policy	Policy start year	Policy end year
Environmental Transformation Fund (ETF)	2007	2011
Energy Act 2008	2008	
Climate Change Act 2008	2008	
Planning and Energy Act 2008	2008	
Renewable Transport Fuels Obligation (RTFO)	2008	
Low Carbon Transition Plan	2009	
Renewable Energy Strategy 2009	2009	
Low Carbon Industrial Strategy (LCIS)	2009	
National Renewable Energy Action Plan (NREAP)	2010	
Energy Act 2010	2010	
Feed-in Tariffs (FIT) for renewable electricity for photovoltaic and non-photovoltaic technologies	2010	2019
Energy White Paper 2011	2011	
Renewable Heat Incentive (RHI) for domestic and non-domestic generators (industry only)	2011	2022
Green Deal	2013	2015
Electricity Market Reform (EMR)	2013	Ongoing
Contracts for Difference (CfDs)	2014	Ongoing

Stavins (2003) characterises policies as either command-and-control or market-based approaches. Command-and-control regulations tend to restrict firms to follow the same set target. By contrast, goals in market-based policies can be more flexible, with each individual firm following their own interests. The above policies in Table 2.1 can be grouped into:

- **Command and control based policies:** Energy Act 2008, Climate Change Act 2008, Planning and Energy Act 2008, RTFO, Energy Act 2010, Low Carbon Transition Plan, Renewable Energy Strategy 2009, LCIS, NREAP and Energy White Paper 2011
- **Market-based policies:** Environmental Transformation Fund, Feed-in-Tariff, Renewable Heat Incentive, Green Deal, Electricity Market Reform and Contracts for Difference.

Market-based instruments are used to encourage innovation and increase the deployment of renewable energy technologies (Calel and Dechezleprêtre, 2016). Feed-in-Tariffs, the focus of this study, is in this group. The policies in this group are highlighted in bold in above Table 3.1 and are further described below.

Consider market-based policies: the Environmental Transformation Fund (EFT) is established to support the innovation and development of low-carbon technologies over 3 years. The fund is offered to both domestic and international projects. Domestic projects have budget of GBP 400 million for the demonstration and deployment of low-carbon, non-nuclear, energy and energy efficiency technologies. International projects with a budget of £800 million focus on the development and poverty reduction through environmental protection. (IEA, 2017). The EFT ran for 3 years and then closed in March 2011.

The feed-in-tariffs for renewable electricity for photovoltaic (PV) and non- photovoltaic (non-PV) technologies is a financial incentive to encourage the uptake of small-scale renewable and low-carbon electricity generation. The scheme started on April 2010 and closed on April 2019. More details about this scheme can be found in section 3.2.2 below.

The Renewable Heat Incentive provides financial incentives to encourage the uptake and generation of renewable heat. The scheme provides payments for heat energy generated over a 20-year period from renewable heat generators. The scheme for non-domestic generators (industry) started in 2011 and the application period closed in March 2022.

The Green Deal aims to allow homeowners to pay for energy-efficient home improvements through the savings on their energy bills (gov.uk, 2013). It ran for 3 years and closed in 2015.

The Electricity Market Reform program promotes investment in secure and low-carbon electricity generation, while improving affordability for consumers. Two key parts of the reform are (DECC, 2014):

- Contracts for Difference (CfDs), introduced in 2014, aims to support low-carbon electricity generation by paying developers a flat rate for the electricity they generate over a fifteen-year period.
- The Capacity Market aims to ensure reliable supplies of electricity through payment of providers for reliable electricity capacity.

The EMR is implemented in stages, 2015-2017 (stage 1), 2017-2020 (stage 2), 2020s (stage 3), and beyond 2020 (stage 4).

CfDs is an arrangement in private law between the Low-Carbon Contracts Company (LCCC) and a low carbon electricity generator (UK gov, 2014). Under the CfDs, the generator receives a payment equal to the difference between the ‘reference price’ (defined as the average price for electricity in the market) and the actual, ‘strike price’. The scheme aims to provide greater certainty about future revenue streams and aims to encourage the investment in low-carbon electricity generation in the UK. The CfD follows a bi-annual Allocation Round (AR) style, having the first AR from October 2014 to March 2015, the second in March to September 2017, the third in May to September 2019, the fourth in December 2021 to July 2022, and now at the fifth AR continuing now.

These market-based policies all encourage the uptake of renewable energy generation, technology development, and consumption deployment but they differ in focus and scope. The EFT, RHI, and the Green Deal each have a narrow goal; the EFT aims to alleviate poverty, the RHI to finance only renewable heat, and the Green Deal to assist with energy bills. The EMR and CfD are long-term schemes that are still ongoing, and hence are excluded from this study. FITs are the focus of this study, meanwhile, because they have a low threshold for entry and are widely implemented.

Feed-in-tariffs — or pricing systems have the potential to drive down costs through technological advancements and economies of scale, developing domestic industries and producing jobs. Pricing systems, where well implemented, can provide increased predictability and consistency in markets, which in turn encourages banks and other financial institutions to provide the capital required for investment and attracts private investment for research and development (R&D).

More generally, the rationale for using feed-in-tariffs can be broadly split into two arguments. Firstly, feed-in-tariffs offsets technology specific cost disadvantages in comparison to conventional fossil fuel-based power generation. Secondly, feed-in-tariffs correct the market failure of knowledge externalities in the renewables market. With its introduction, renewable energy development and production would potentially create positive externalities, such as learning-by-doing and R&D spillovers to the rest of the market.

3.2.2 UK feed-in-tariffs information

The UK Government introduced the FIT scheme in April 2010, having designed it to encourage the uptake of a range of small-scale low-carbon and renewable electricity generation. By offering a higher price than the market price, the government aims to incentivise small-scale renewable and low-carbon forms of energy production, enabling them to directly compete against higher carbon technologies for electricity generation. 'Small-scale' is important here, defined as the amount generated is up to 5MW (see the description in the technology list, below). This reflects the policy's aim of incentivising small to medium sized firms/households to increase renewable energy generation. Both individuals and businesses are eligible for the scheme.

Figure 3.3 provides an illustration of the scheme for a participant. Agents with accredited installations generate energy. This generated electricity could be used or sold to the grid.

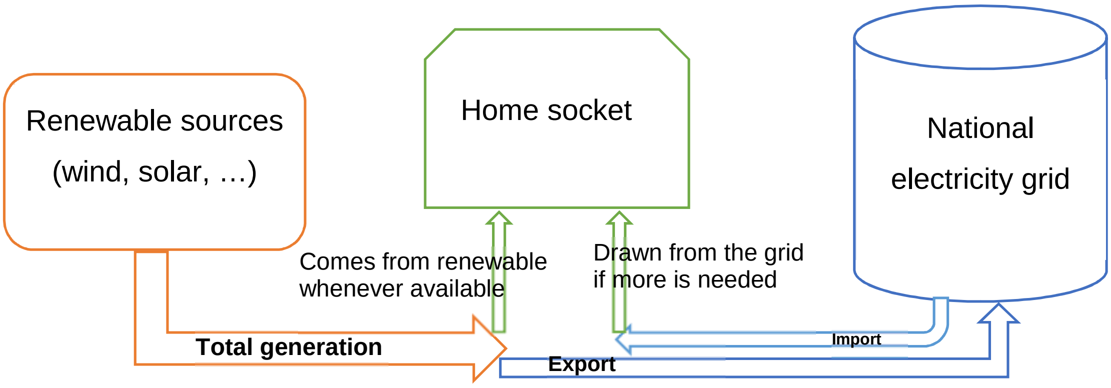


Figure 3.3 Diagram of situation used in FITs for the consumer

The scheme operates by requiring participating licensed electricity supplier (FITs Licensees) to make fixed tariff payments for both electricity generated and electricity exported to the National Grid. The two tariff payments work in the following way:

- Generation tariff: the energy supplier pays a set rate for each unit (or kWh) of electricity that consumers generate.
- Export tariff: the energy supplier pays a further rate for each unit that consumers generate and export back to the electricity grid, meaning agents can sell any electricity they generate but don't consume themselves.

Generation of electricity from five renewable energy technologies are eligible under the FITs scheme. Each technology is subject to a different range of tariffs. The technologies are (from OFGEM):

- Solar photovoltaic (PV) – Up to 5MW Total Installed Capacity (TIC)
- Wind - Up to 5MW TIC
- Hydro - Up to 5MW TIC
- Anaerobic digestion - Up to 5MW TIC

- Micro-combined heat and power (CHP) – Up to 2kW TIC

Installations are permitted a capacity of up to 5 Megawatts (or 2KW Kilowatts for Micro-combined heat and power).

There are further tariff bands split between the amounts of electricity generated. Tariff rates for the scheme are adjusted annually. They are determined by a number of factors (from OFGEM):

- Eligibility and Tariff dates
- Technology type
- Capacity
- Energy efficiency requirement (EER)
- Multi-site generator
- Deployment cap

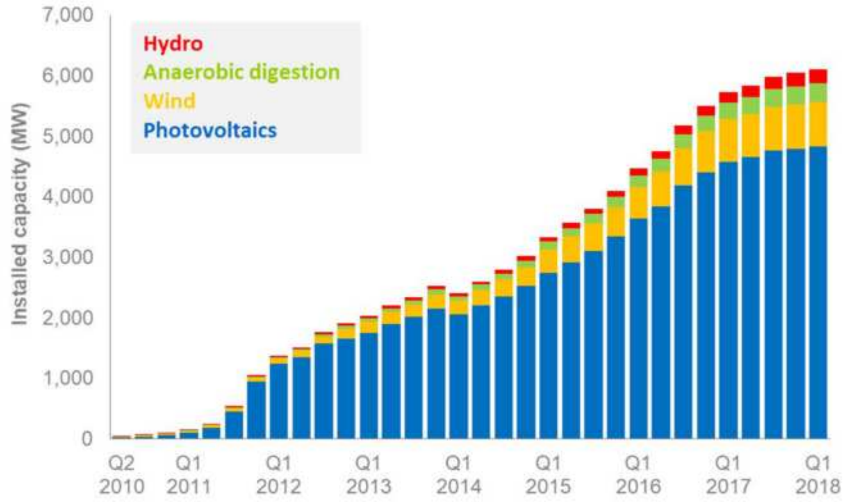
The deployment cap acts as a limit on the capacity that can receive a particular FITs tariff in each tariff period. The EER applies only to solar PV installations excluding stand-alone. Stand-alone installations are those with a total installed capacity greater than 250KW and not wired to any relevant buildings.

Firms/households are further split into two types of participants in the FIT scheme:

- FIT generators – the owners of accredited installations
- FIT licensees – licensed electricity suppliers who registered applications and make FIT payments for the electricity produced by accredited installations.

Since its introduction in 2010, the FIT scheme has achieved targets faster than the government anticipated. One year after the scheme began, in 2011/12, 498.2 GWh was reported as being generated under the FITs scheme. This represents an eight-fold increase in electricity generation from that reported in 2010/11. Looking at specific technologies, solar PV contributed 52 percent, up 30% from 2010/11. Wind, hydro installations and anaerobic digestion contributed 19%, 10% and 14%, respectively (BEIS, 2018). Figure 3.4 shows the increase in installed capacity of renewable energies following FITs over the period of 2010 to 2018.

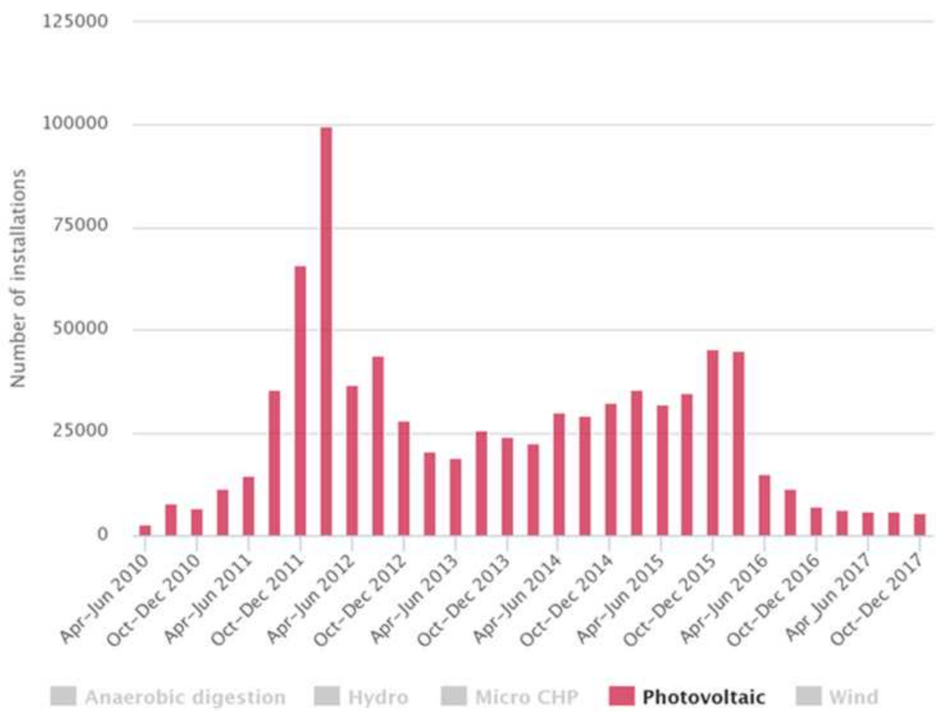
Figure 3.4 Installation capacity following FITs, 2010-2018



Source: BEIS, 2018

The largest impact of the scheme has been on solar (photovoltaics) and wind energies, being over 80% and 10% respectively. Figure 3.5 illustrates the installed capacity from renewables, with a large jump in solar installations in Q3 2011 and Q1 2012. This study focuses on solar and wind energy generation.

Figure 3.5 Additional solar installations per quarter (listed on the Central FIT Register) in the UK

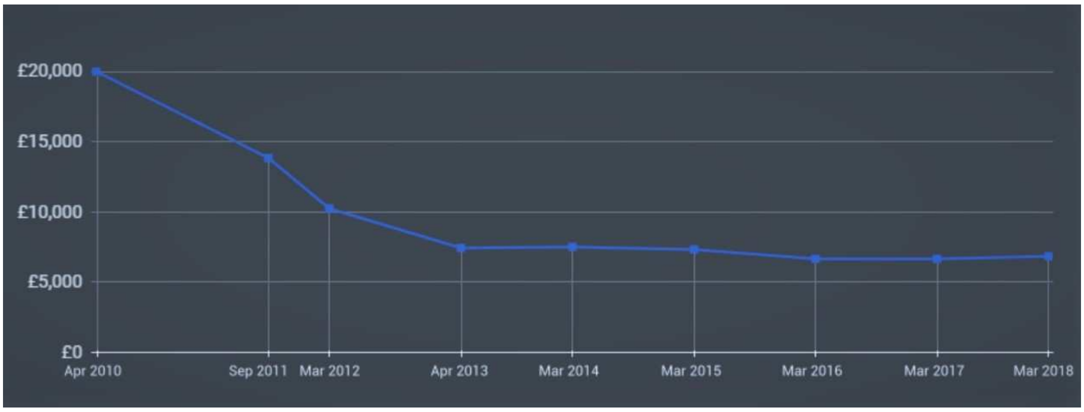


After running 10 years, the FITs scheme closed to new applicants on March 31, 2019. The BEIS 2018 report “Impact Assessment for FITs Closure” [BEIS, July 2018], it states that “As costs decline, public attitudes change and technology develops, the requirement for government support is reducing. Government proposes to close the current FITs flat rate export tariff, given the government’s desire to move towards fairer, cost reflective pricing and the continued drive to minimise support costs on consumers as set out in the Industrial Strategy and Clean Growth Strategy.”

In the above statement, “the cost decline and technology development” mainly refers to the decrease of solar PV installation cost given that solar PV installation accounts for around 98% of all FITs installation [FITS Annual Report 2019-20, Ofgem]. The below Figure 3.6 shows the solar installation cost (4KW) changes over time; a sharp decline in the first 5 years before flattening out.

Figure 3.6 Solar installation cost (4KW) changes over time

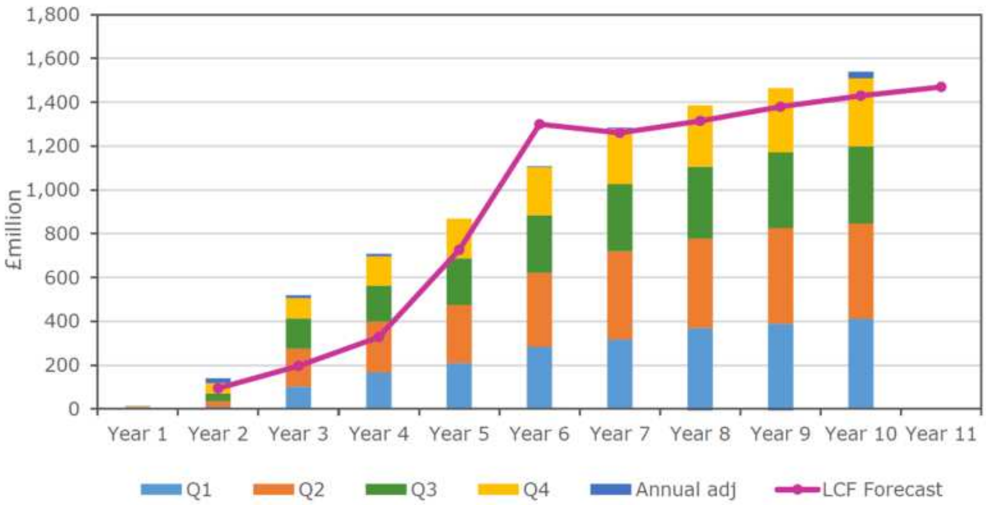
[UK Domestic Solar Panel Costs and Returns 2019, Green business Watch].



The FITs’ incentives were intended to make renewable energy generation financially viable to firms and customers. The UK government funded the scheme through the levelisation fund and this had been steadily increasing over the years from £180 million in 2012 to around £1,530 million in 2019. The government cost in funding FITs is shown in Figure 3.7 below.

Figure 3.7 Levelisation fund vs Levy Control Framework (LCF) forecast (in nominal terms)

[Ofgem, FITs annual report 2019-20]



It is worth noting that while the FITs scheme has ended, there are still other mechanisms and policies in place to support renewable energy adoption in the UK, such as the Contracts for Difference (CfD) scheme and the Smart Export Guarantee (SEG). These mechanisms aim to carry on encouraging investment in renewable energy projects and ensure fair compensation for the electricity generated from renewable sources.

3.3 Literature review

The growth in awareness of climate change has led to research into renewable energy policies over the past decade. In this section, I provide a review of the theoretical and empirical literature relevant to assessing the FIT policy effects on renewable energy firms: renewable energy policy and innovation; the effectiveness of renewable energy policy; and the econometric methods used in empirical investigations.

3.3.1 Renewable energy policy and innovation

Environmental policy has been an area of active research in the economics profession. In the context of the current study for renewable energy policies, past research into environmental policy can be separated into two branches. The first branch is the study of policies that aim to protect the environment through the reduction of harmful pollution by consumers and firms (Brunnermeier & Cohen, 2003; Popp, 2002, Popp et al, 2011; Lanoie, et al., 2011; Johnston et al, 2010). The second branch looks at the protection of the environment through the encouragement of uptake of renewable energy sources (Harmelink, et al, 2006; Alizamir, et al, 2016; Palage et al, 2019). The first branch focuses on renewable energy with regards to technology, this second branch is the area of this study.

Some earlier work focused on theoretical models that examine the effects of various environmental policies (e.g. taxes and tradable permits) on environmental innovation. Policies were generally separated into market-based (e.g. tradable permits) and command-and-control (e.g. standards), with most authors predicting that market-based policies will induce more environmentally friendly innovation than command-and-control policies (Chen, 2015). Helm (2002) among others argues that market-based instruments offer the best solutions to the market failure problem in addition to long-term contracts. Overall, the debate continues on whether market-based or command-and-control policies are the best solutions spurring the deployment of renewables in the economy.

Recent investigations have focused on the innovation effects of renewable energy policy, (Groba and Breitschopf, 2013; Palage et al, 2019). Surveying the literature on renewable energy policy's impact on innovation, Groba and Breitschopf (2013) find that policy intervention has been an effective tool to change relative prices and stimulate innovation. Their analysis of different types of policies seen in the literature yields the result that successful technological change requires a mix of market-pull and technology-push policies, with market-based approaches more effective than command-and-control measures. Palage et al (2019) examines the innovation effects of three renewable energy support policies, public R&D, FITs and renewable energy certificates (REC). Using the unconditional negative binomial estimator to examine the patent applications for renewable solar technology, they find that technology-push instrument (public R&D) is more influential that the two demand pull instruments (FITs and REC).

Calel and Dechezleprêtre (2016) investigates the impact of the European Union Emissions Trading System (EU ETS) on the firm patent application of low-carbon technologies. They use matched treated and untreated firms along with the Tobit estimator to mitigate the problem of zero observations, which is common with patent data. Variables in their study include firm level turnover and employment, as well as the country and economic sector in which firms operate. They find that the ETS has increased low-carbon innovation among regulated firms by up to 10% and a small increase in patenting by firms.

Eugster (2021) finds that the tightening of environmental policies has contributed to clean energy innovation, with a net positive effect on electricity innovation overall.

Another link to innovation is the studies on technology and technological diffusion. Jaffe et al, (2015) reviews technological change and the tools for researchers. With green technologies, they summarise that empirical findings generally support market-based instruments over command-and-control technologies, with the former being more likely to have significantly larger and positive effects over time on the innovation and diffusion of environmentally friendly technologies.

Popp, Hascic, and Medhia (2011) investigate how technological innovations, represented by patent applications of renewable technologies, affect the investment in wind, solar photovoltaic, geothermal, and electricity from biomass and waste. They use patent data from 25 OECD countries to estimate the investment per capita in renewable energy with a standard linear regression estimator. Explanatory variables include a measure of the global knowledge stock for technology, GDP per capita, electricity growth rate, electricity industry supply, and some policy variables (Kyoto protocol, FIT, and renewable energy certificate). They conclude that a 10% increase in knowledge stock increases investment in biomass by 2.6%, and investment in wind by 0.6%.

3.3.2 Effectiveness and efficiency of renewable energy policy

From the early 2000s, studies began to emerge that sought to determine the effectiveness and efficiency of renewable energy policy. Menanteau et al (2003) provides one of the first studies of the possible theoretical mechanisms of different renewable energy policies, focusing on the distinction between price-based and quantity-based approaches. The paper focuses primarily on discussion, however, rather than comparing outcomes through econometric estimation. The paper compares different renewable energy polices through the investigation of different cost curves and learning effects. The study subsequently looked at deployment figures and took them as an indication of the effect of government policy.

Studies that sought to carry out an empirical investigation on renewable energy policy can be further split into two sections. Firstly, the largest quantity of research on the effects of FITs are studies that estimate the scheme's profitability to participants and would-be economic agents. In this area, the authors tend to look at the design of the tariff, calculate the returns and profits of the agent from engaging in the scheme, and then extrapolating to form a conclusion on the viability of the tariff (for example Alizamir, et al, 2016).

Secondly, studies that tried to econometrically estimate the policy effects of policy have used a wide range of variables to define and measure policy success. Initial studies measured policy success, the dependent variable, as the expansion of the renewables market as a percentage of the total electricity generating market. Subsequent studies began to move towards measuring the effect of policy on both a specific renewable energy technology, as well as a shift in the literature to focus on the adoption of specific renewable energy technologies as the measure of success. More recently, studies including those by Bolkesjø, Eltvig and Nygaard (2014) have used cumulative installed capacity as a measure of policy success. My study aims to bring the analysis to the firm level, using firm revenue as the dependent variable of analysis.

Studies at this time tended to examine the effect of policies on the renewable energy market as a whole. For example, Harmelink, Voogt and Cremer (2006) used a step-wise monitoring methodology to look at the effect of various announced policies on the growth of renewable electricity generation in the EU. They use eight instruments including-tax incentives rebates, feed-in tariffs, bidding and environmental taxes, with 25 success and risk factors as outcomes. They conclude that the EU 15 countries are likely to miss their renewables target. Such studies do not isolate the effect of a specific policy on a specific renewable energy source.

Following this, scholars applied panel data methods to investigate policy impacts on renewable energy deployment (and innovation). Johnstone et al (2010) conclude that 'broad-based policies' (for example, tradeable energy certificates) provides greater benefits to technologies that are close in cost to fossil fuels. Feed-in-tariffs are found to be more conductive towards mature technologies. Marques and Fuinhas (2012) finds that "incentive/subsidy" policies which includes feed-in-tariffs again have a significant impact.

Feed-in-tariffs have remained a popular choice for those studies that examined renewable energy policy effectiveness. In subsequent years, there has been a bias towards studies showing feed-in-tariffs as being one of the superior policy measures having significant effects on renewable energy development (Bolkesjø, Eltvig and Nygaard, 2014).

Overall, the literature has not come to a consensus on quantifying the effects renewable energy policy has had on the renewable energy market. In particular, substantial debate exists around the optimal mix of policy instruments to be used to encourage renewable energy uptake, as well as what criteria should be used to determine the optimal mix. The same situation exists around the type of optimal technology to use. As part of their conclusion, Del Rio and Bleda (2012) states that whilst "feed-in-tariffs are likely to be superior to other policy instruments", a mix with other technologies, research and development is still needed. Research on effects at the firm level are also scarce.

3.3.3 Econometric methods used in empirical investigations of the impact of renewable energy policy

The past studies that carried out empirical investigations on the effect of renewable energy policy have mainly used the standard econometrics techniques of OLS, fixed and random effects modelling, GMM, and DiD to carry out their analysis (Gelabert etal, 2011, Costa-Campi and Trujillo-Baute, 2015, Jarate-Kazukauske, et al, 2014).

When estimating the relative intensity of the impact of the feed-in tariff and the electricity wholesale price on the Spanish industrial retail price, Costa-Campi and Trujillo-Baute (2015) used OLS with various dummy variables. They found a lower impact of renewables on prices than previous studies, with the marginal effect of renewables on prices exhibiting a decreasing trend.

Jarate-Kazukauske, et al (2014) carries out an empirical investigation of the Tradeable Green Certificate and feed-in-tariffs policies on electricity generating firms in twenty-four EU countries. The study uses random effects as well as a GMM estimator to estimate the effect of the Tradable Green Certificate programme. The study compares the effect of the tradable green certificates on profitability and the effect of the feed-in-tariffs on firm profitability. The

GMM is used in their study to capture any occurrence of persistence in firm profitability. The GMM requires that the errors of the model are not serially correlated. The authors include another version of the model with lags of the dependent variable as regressors to control for this issue. They note that the installed capacity in feed-in-tariff countries is three times that of countries with the Tradable Green Certificate scheme. However, the study, despite comparing the effectiveness of the Tradable Green Certificates and feed-in-tariffs never shows an estimate of the effect of feed-in-tariff on firm profitability.

Romano et al (2016) estimates the impact of FIT adoption by countries using PSM. One of their main purposes is to identify the determinants of countries adopting FITs. The country characteristics include social, economic and policy structures. Using a panel probit model through PSM, they carried out a comparative analysis among countries which have adopted FIT and those which haven't. They identify the main negative determinates including energy intensity and energy consumption and main positive determinates as high levels of carbon emission, high levels of coal production, and high energy dependency from abroad.

This study will investigate the effect of the feed-in-tariff, further extending the debate on the effectiveness, efficiency, and innovation effects of government policy on the renewable energy industry. The study moves the investigation to the firm level, investigating the effects of policy on firm performance using the DiD and PSM methodologies.

3.4 Data

Data for the study was gathered from the Bureau van Dijk FAME database. The FAME dataset is a dataset covering firm level information in the UK and Ireland. Information in the FAME dataset is drawn from reports deposited at Companies House. FAME is fundamentally a financial dataset, with its information on firms drawn directly from balance sheet data. It covers company financials, in detailed format with up to 10 years of history.

Since all forms of companies in the UK must be incorporated and registered with Companies House (as required by the United Kingdom Companies Act 2006), this provides a large sample of firms. All limited companies, including inactive, small and subsidiary companies, must file both annual company returns and annual financial statements. Only certain registered unlimited companies and sole traders are excluded. The registered limited companies in the UK constitutes 98% of all corporate body types as at the end of 2021 (Official statistics, 2021). Hence, the exclusion of these companies does not affect my investigation.

This study will use data for firms between 2007 and 2014, taking into account the time of the FIT introduction in 2010. This provides three years of data for pre-FIT policy and four years of post-policy data. The study stops at 2014 to avoid biases from the introduction of a concurrent renewable energy policy, namely, the Renewables Heat Incentive which was activated in early 2015.

3.4.1 Identification of firms

The Standard Industrial Classification (SIC) code in FAME data identifies only the standard industry sectors, there is no separate classification for renewable energy firms (REFs) in SIC code.

For the purpose of this study a renewable energy firm is a firm that manufactures, sells, or installs products that are used for renewable energy purposes. I construct my dataset by manually looking through the heading variables - overview, history, main products and services, and summary description - to identify the firms that have a renewable energy component (see below for further explanation). Out of the five renewable energy sources under the FIT scheme, I limit the study to two: solar and wind energy sources. This is for two reasons. Firstly, solar and wind sources can be identified from the data. The information for whether the firm is a “renewable energy” firm is mainly from the “summary description” variable that provides some information on the company. There is no guideline on how this question should be answered. As a result, the information provided by the variable varies greatly, but it can be seen that most firms list their main business market in this variable, which allows the easy extraction of the required information using keywords like solar, wind, renewable, etc. Many of the texts are similar to/reflect business profiles from the company websites themselves. Such information is used by the firm to attract customers. Therefore, it is reasonable to believe that firms would provide their business information in this variable as accurately as they can.

Secondly, those two energy sources were chosen since solar and wind power are some of the largest and growing percentages of the renewable market in the UK as well as globally as can be seen in Figure 3.4 in section 3.2.2.

REFs are identified based on the below criteria:

- Whether firms manufacture or install solar or wind energy. Solar energy firms are those that manufacture solar energy components, e.g. solar panels, solar inverter etc, or those that install solar energy components for end users. Wind energy firms are those that manufacture wind energy components, e.g., wind turbines, wind nacelle, etc, or that install wind components.
- An additional variable for identifying a firm is to see the major market in which the firm operates. A firm operating in a renewable energy market is a renewable energy firm.
- Whether the firm focuses on the manufacture of solar and wind energy technology, e.g., concentrated solar power technology, solar water heater technology, solar/wind process heat technology, etc.
- Major oil companies that have renewable energy as part of their portfolio are excluded. For these firms, changes in firm performance are reflected by changes in fossil fuels and not by changes in renewables which is a small part of the overall business.
- Firms that manufacture generic compounds that are used in many industries (for example safety harnesses) are excluded since they are not supported by FIT directly.

These criteria agree with the FIT targets. In the government review in 2015 (DECC 2015), they found that the scheme led to investment in small-scale renewable generation, engaged non-energy professionals and highlighted the role small-scale generation can play in a larger renewables market. My strategy for the identification of the REFs based on the above criteria is therefore adequate.

Table 3.2 below shows the distribution of industries in which the identified REFs operate in. Going from the population (155 identified REFs) to the treated samples reduces the number of industries by 11. The industries with the greatest number of firms are SIC 25, which includes “the manufacture of metal products (such as parts, containers and structures), usually with a static, immovable function”. Industries SICs 26-30 cover the manufacture of combinations or assemblies of metal products into more complex units. SIC 30 is the code for other manufacturing products (SIC, 2020). The table indicates that many of the REFs that were dropped were not in the manufacturing industries. As mentioned earlier I excluded firms that supplied generic inputs to REFs, which were captured by many of these other industries that are subsequently dropped from my analysis, e.g SIC 49 (land transport and transport via pipelines), SIC 52 (Warehousing and support activities for transportation), SIC 64 (Financial service activities, except insurance and pension), SIC 68, etc.

Table 3.2 Reported operating industrial sectors of all REFs identified based on selection criteria (on P155)

sic two-digit code	No. of firms in each industry for all identified REFs	No. of firms in each industry for the treated REFs
20 - Manufacture of chemicals and chemical products	3	3
23 - Manufacture of other non-metallic mineral products	7	5
24 - Manufacture of basic metals	2	
25 - Manufacture of fabricated metal products, except machinery and equipment	20	12
26 - Manufacture of computer, electronic and optical products	9	8
27 - Manufacture of electrical equipment	13	10
28 - Manufacture of machinery and equipment n.e.c.	14	12
30 - Manufacture of other transport equipment	5	3
32 - Other manufacturing	19	15
33 - Repair and installation of machinery and equipment	1	1
35 - Electricity, gas, steam and air conditioning supply	6	4
42 - Civil engineering	2	1
43 - Specialised construction activities	5	3
45 - Wholesale and retail trade and repair of motor vehicles and motorcycles	2	1
46 - Wholesale trade, except of motor vehicles and motorcycles	12	6
47 - Retail trade, except of motor vehicles and motorcycles	2	1
49 - Land transport and transport via pipelines	1	
52 - Warehousing and support activities for transportation	1	
64 - Financial service activities, except insurance and pension	1	
68 - Real estate activities	1	
70 - Activities of head offices; management consultancy activities	8	
72 - Scientific research and development	3	1
74 - Other professional, scientific and technical activities	1	
77 - Rental and leasing activities	1	
82 - Office administrative, office support and other business support activities	4	
96 - Other personal service activities	1	
Missing	11	
Total No. of industries	27	16
Total No. of firms	155	86

Table 3.3 shows firm entry and exit for all REFs in the dataset. Entry is defined as a new firm that came into existence during the time period under study. The decision to drop exiting firms was made to avoid the under-performing firms being the main driver of the results. This could cause bias however, in the latter section (3.6.2.3) I ran another estimation including these dropped firms. The results showed that including the firms that were dropped, had a small effect from the FITs. Within the time period that is investigated in this paper (2007-2014), eighteen REFs entered in the pre-treatment period and twenty REFs entered during the post-treatment period.

Table 3.3 Firm entry and exit for all REFs in the dataset

Year	Number of renewable firms entering the market	Number of renewable firms exiting the market
2007	7	
2008	3	1
2009	8	2
Total before FIT	18	3
2010	2	1
2011	7	
2012	5	1
2013	5	2
2014	1	3
Total after FIT	20	7
Total entering and exiting	38	10

Overall,155 REFs operating in the UK are identified for the study. Removing firms that should be excluded based on the criteria presented earlier and based on the above decision to drop exited firms, reduces the number of REFs to 86, which forms the treated REF group. The summary statistics of both the treated and the excluded firms are shown in next section in Table 3.6.

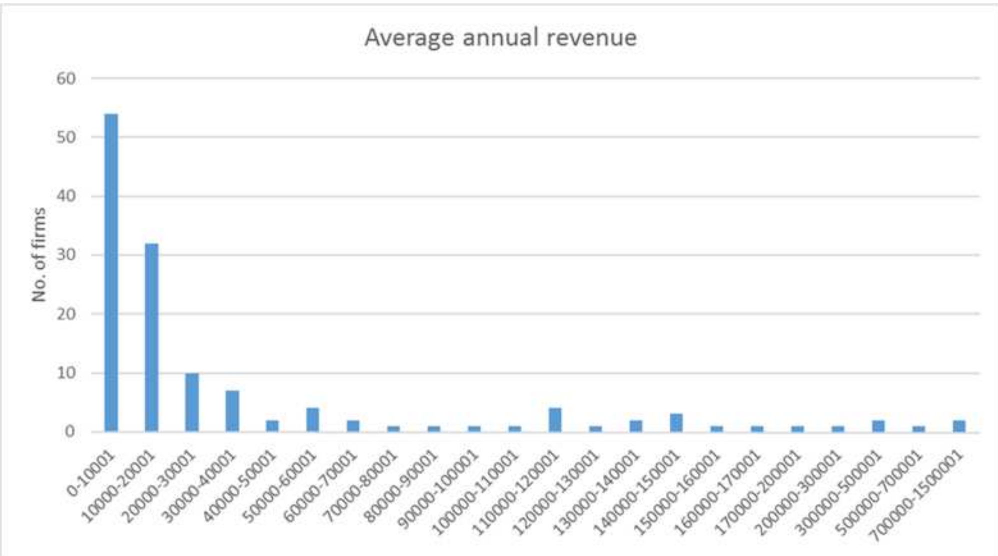
For small to medium-sized enterprises (SMEs are defined as businesses with 0 to 249 employees and less than 50 million euros (£42 million) turnover in the UK by the Department for Business, Energy and Industrial Strategy, BEIS), it is likely that they would state their main business areas in their company reports. This leaves some firms (usually large firms which manufacture multiple products) that may sell renewable energy products but do not state this in their company information. These firms, when excluded from REFs from my study, are unlikely to significantly affect the estimation results, since it is likely that they do not mention renewables as it does not contribute a significant proportion of their revenues. This also consistent with the fact that FIT targets firms with small scale generation so large firms likely do not participate in the scheme. Later in the chapter I run an estimation where the largest firms are excluded from the control group; this serves as a robustness check to see whether the presence of such unidentified firms poses a problem for my sample.

After identifying the REFs, non-renewable firms that will serve as counterpart firms in the study are identified from the sample of manufacturing and related firms that share the same SIC code at 2 digits as those in the renewable energy sector operating in the UK. The non-renewable energy firms will also be identified using the propensity score matching (PSM) method in later sections.

3.4.2 Summary statistics of firm level information

Figure 3.8 shows the firm revenue information in my working data. The majority of the firms are small to medium-sized firms which accounts for around 99.5% of all companies in my data. Large firms are only accounted for less than 0.5%, but their revenue proportion is around 49%.

Figure 3.8 Distribution of firms on average annual revenue (£)



The summary statistics for the identified renewable group and non-renewable group are displayed in Tables 3.4 and 3.5. Table 3.4 provides statistics on all 155 REFs identified from the FAME database and Table 3.5 shows the reduced sample of 86 renewable firms and their counterparts. The non-renewables groups are also identified for full-size and reduced-size samples and their statistics are provided alongside renewables in Tables 3.4 and 3.5, respectively.

Table 3.4 Summary statistics of identified renewable and non-renewable groups

Variable	Observations	Mean	Std. Dev.	Min	Max
Renewables					
Firm age (years)	1176	23.67	18.61	1.75	106.35
Turnover (millions £)	678	779.44	2100.88	0.02	19243.70
Fixed assets (millions £)	875	331.95	1247.47	0.00	11067
No. of employees	658	297.13	979.69	1.00	14767
Non-renewables					
Firm age (years)	166864	29.78	23.12	0.33	152.07
Turnover (millions £)	83898	831.60	7516.97	0.00	464000
Fixed assets (millions £)	129172	404.07	12361.31	0.00	2150000
No. of employees	84054	384.65	3046.88	1.00	119371

Table 3.5 Summary statistics of the reduced number of firms that are identified as renewable and non-renewable

Variable	Observations	Mean	Std. Dev.	Min	Max
Renewables					
Firm age (years)	680	26.88	18.93	3.35	106.35
Turnover (millions £)	500	560.41	1003.79	0.05	7005.00
Fixed assets (millions £)	595	277.31	993.17	0.00	7633.59
No. of employees	489	234.27	427.69	1.00	4127.00
Non-renewables					
Firm age (years)	58904	33.06	22.41	2.79	144.54
Turnover (millions £)	45057	530.95	3962.82	0.01	211000
Fixed assets (millions £)	53282	198.56	2610.00	0.00	176000
No. of employees	44102	249.19	1616.99	1.00	103383

Firm age is a self-calculated variable measuring the number of years from the firm's initial incorporation date[29] until 2014, the end of the study year. There are old firms that only transitioned to operate in the renewables market later in their lifetimes, pushing up the overall average for the firm age variable to 26.88 from 23.67. One weakness of the data is that I couldn't identify the precise date at which a firm transitioned to include renewable energy products in its product mix, yet this does not compromise the analysis since it is reasonable to include both old and FIT-stimulated new firms in the estimate. T-tests of the differences between the two groups find that firm ages between the renewables and non-renewables are not significantly different from one another (Table 3.6). It is important to note that not all REFs identified have firm age data, and those without such data are removed from the analysis.

Table 3.6 Result from t-tests of the differences between variables of renewable and non-renewable firms in the full and reduced-size samples

Variables	Whole sample	Reduced sample
	Pr(|T| > |t|)	Pr(|T| > |t|)
Firm age (years)	1.0e-3	1.0e-3
Turnover (millions £)	0.857	0.868
Fixed assets (millions £)	0.461	0.462
No. of employees	0.863	0.838

T-test also shows that turnover, fixed assets and the number of employees all tend to be larger and are found to be significantly different between the renewable and non-renewable firms, in both whole and reduced samples. This supports the view that further matching will be needed to have suitable treatment and control groups.

Table 3.7 suggests that compared with the REFs in the treatment group in Table 3.4, the dropped firms tend to be younger (Firm age of 14.97 compared to 23.67) while having more employees (551.66 compared to 297.13).

[29] Only active firms are included in the study

Table 3.7 Summary statistics of dropped firms

Variable	Observation	Mean	Std. Dev.	Min	Max
Firm age (years)	512	14.97	18.91	0.00	86
Turnover (millions £)	151	161.40	395.46	31.00	1924.37
No. of employees	143	551.66	1929.91	1.00	14767
Fixed assets (millions £)	242	51.35	177.69	0.63	1106.7

3.5 Methodology

This paper is interested in investigating the effect of government renewable energy policy on the performance of REFs. The specific policy to be investigated is the feed-in-tariff that was introduced in the UK in April 2010, as described in section 3.2.2. The REFs are identified in section 3.4.1.

3.5.1 Conceptual framework

The aim of the FIT scheme is to encourage participation and uptake of small-scale renewable energy generation and installation. Participating firms receive payments, which in turn could lead to improved firm performance. The results from investigating one of the more widely implemented renewable energy policies should lead to more quantifiable results and provide contributions to the debate on the influence and effectiveness of government intervention in economic markets.

The effects of the scheme can be measured through two channels: through stimulating the demand side of the market, and through a direct examination of the firm performance. Many previous studies have tended to use demand side measures, such as generating capacity, as the proxy for renewable energy deployment (Peters, et al, 2012). This assumes that the effect of the FITs stimulates the demand side of the market, which then flows to firms that in turn increase their installed capacity or through the entry of new firms. For example, the policy encourages the purchase and construction of renewable energy technologies. As consumers purchase more, for example, solar panels, this should feedback to firms that manufacture more solar PV panels at a lower price. As a result of the scheme, this in turn could have a positive effect on the revenue, or other performance measures of the firm. In addition, once the consumer has installed the renewable technology in their home, they may be more willing to purchase other renewable energy goods in the future, further impacting the revenue of REFs that produce such products. In detail, the study will investigate:

- The effect of the feed-in-tariff on REFs firm performance (e.g. firm revenue).
- Whether the design of the tariff affects the performance and effectiveness of the policy. The FIT consists of a series of tariff bands that has changed every year since its introduction. In particular, the bands for solar energy have changed drastically over the time period covered in the data, with compensation only a small fraction of the initial amount by the end of the tariff duration.

To estimate the FITs scheme's causal effect, we need to compare the outcomes of a treated group and a control group over time. The treatment and control groups are identified based on the criteria in section 3.4.1 but there may be confounding variables that may cause selection bias. The bias could come from observable and unobservable characteristics. Observable characteristics in the dataset include firm age, firm size and turnover etc. Unobservable characteristics may come from firm culture, access to scare resources and managerial skills that could affect firm performance. As reviewed in the literature section, Propensity Score Marching (PSM) is a method able to minimise selection bias caused by observable characteristics so it will be used to capture the causal effect on the matched treatment-control groups.

To deal with the unobservable characteristics which may influence the estimation of the causal effect, difference in differences (DiD) is used. DiD is chosen also because it is anticipated that there exists between group variance (renewable and non-renewable) and within group time variance (before and after FITs). One of the challenges with using the DiD is the selection of the comparable control group that would have occurred in the absence of the feed-in-tariff. I used two methods to select the control group for DiD, firstly, as described in section 3.4.1 the control group will be drawn from the group of firms in the manufacturing and the same sectors of the economy as in the treatment group; the second approach is to use the matched treated and un-treated pairs from PSM as describe in (Binci, 2018; Amamou et al, 2020). The results from the three estimators, PSM, DiD, and the combination of PSM and DiD, will be compared. Overall, the use of PSM allows better handling of observable bias, DiD with unobservable bias, with the combination of PSM and DiD taking into account both.

3.5.2 Propensity score matching

Propensity score matching was developed in the 1980s (Rosenbaum and Rubin, 1983) based on earlier work by Rubin (1974). It has seen many applications in labour market studies in the economics profession. In recent years there has been a stream of new/newly reviewed literature examining estimators that limit the selection bias in public programme evaluations in non-experimental settings (Lindley, et al, 2015). PSM seeks to solve the selection bias problem by matching a control group to the treatment group based on observable characteristics of the observations. The 'matched' pairs of observations can then be compared to estimate the true effect of treatment.

The identifying assumption for matching states that the Conditional Independence Assumption (CIA) must be fulfilled. This is the condition that given observable differences between the treated and non-treated group are controlled, the resulting outcome if the treatment were not applied would be the same across the control and treated groups.

PSM is carried out in two phases. The first phase selects observed covariates and calculates the propensity score then matches individual observations to the treatment and control groups. The propensity score is an index reflecting the probability of participation. The larger the number of characteristics used for matching, the lower are the chances of finding a match. Rosenbaum and Rubin (1983) show that 'matching on a single index reflecting the probability of participation would achieve consistent estimates of the treatment effect in the same way as matching on all covariates'. In this phase, I will go through two rounds of variable selection. The second phase then estimates the treatment effect by Average Treatment Effect on the Treated (ATT).

Once propensity scores have been calculated, there is a need to assess the scores' overlap between the treatment and control group, i.e., to assess the common support. The treatment effect estimate would not be sufficient if there is no common support or the common support is too small since that would indicate that a treated individual would lack a comparable individual with a similar propensity score. Ideally, all propensity scores from the control group should fall in the range of the propensity scores of the treatment group (i.e., in the plot of the graph of density against propensity score for the treated and untreated groups). In this study, a treated individual will be dropped from the analysis if there is no common support found in the control group.

Matched pairs are also assessed by whether or not they are balanced on covariate distribution. It is expected that treatment and control groups behave similarly after matching as if they are randomly assigned.

This study uses the probit model to estimate the propensity score. The dependent variable is a dummy equal to one if the firm is a renewable energy firm. Given that the dataset is a panel the observable characteristics that the treatment and control groups will be matched on is the average of the variables before the time of policy introduction, 2010. That is, we match on firms that are similar before the treatment, since it is expected that firms will differ after the treatment takes place.

The final probit model from the first stage estimation is of the form:

$$\Pr(P_i = 1) = \Phi(\beta_1 + \beta_2 SME + \beta_3 Age + \beta_4 Industry) \quad (3.1)$$

Where SME is a dummy equal to one if the firm is a small or medium-sized enterprise. This variable is similar to other measures such as $Firmsize$ in the database. $FirmSize$ is a variable containing different bands of the number of employees. Despite their similarity, there are small differences between SME and $FirmSize$, since SME is constructed using more than just the number of employees in the firm; it also takes into account firm revenues and asset information.

Age represents the duration of the firm in years.

$Industry$ represents a vector of dummies that represent the primary industry in which the firm operates. The variable consists of the 2 digit SIC industry codes.

One of the challenges with PSM is the selection of observable characteristics that should be used to match the control and treatment groups. This requires that the outcome variables are independent of treatment conditional on the propensity score. Only the variables that simultaneously influence the participation decision and the outcome should be included. In the context of this paper, the participation decision can be thought of as the decision to produce renewable energy products, which would then allow the firm to gain eligibility to the feed-in-tariff. Here, the accepted approach is to use variables that are informed by economic theory as well as knowledge of the institutional settings in which the policy was implemented.

3.5.3 Difference-in-differences

The PSM estimates the policy effect without explicitly separating pre- and post-treatment periods. The DiD evaluates the policy effect by comparing between groups (renewable and non-renewable) and within groups (pre-treatment and post-treatment), i.e., comparing the means of the renewable firms before and after the introduction of the FITs differenced by the comparison of means with an appropriate set of firms that captures the scenario if the FITs scheme did not take place. That is, a simple comparison of the means of outcomes of renewable energy firms before and the introduction of the FITs would not capture the true effect of the policy. Estimates of the true effect of the policy would need to compare this change with what would have happened in the absence of the introduction of the policy, a suitable control group.

In this study, the treatment group is the population of solar and wind REFs, as described in section 3.4.1. The control group, representing the counterfactual is selected as the group of remaining manufacturing and related firms in the UK.

The difference-in-difference model has the following form:

$$y_{it} = \beta_1 + \beta_2 Age_{it} + \beta_3 Renewables_i + \beta_4 Post_t + \beta_5 Renewables_i . Post_t + u_{it} \tag{3.2}$$

The dependent variable y is the turnover (and the fixed assets in later sections), of the firm i at year t. *Renewables* is a variable equal to 1 if a firm is a renewable energy firm and zero otherwise. *Post* is a variable equal to 1 from 2010. The interaction *Renewables**Post* is then the standard variable that captures the effect of the policy. The other variables are the same as those aforementioned in the discussion of PSM.

Fixed effects will be added to the DiD to control for the unobservable heterogeneity, e.g., firm fixed effect which looks at the firm-varying factors that may affect the outcome, such as managerial differences etc.

3.5.4 Parallel trends assumption, lag and lead effects

A key assumption underlying the DiD model is the parallel trends assumption. This is the assumption that absent treatment, the underlying trends between the treatment and control groups would have been similar.

Figures 3.9 and 3.10 plots the average revenue of the firms in the treatment and control groups over time. The revenue is indexed to 100 in 2007, the start of the study period, to enable comparisons between the two groups over time. Control group 1 in Figure 3.9 is set as the group of firms operating in the same industry sectors as REFs. Control group 2 contains the same set of firms as in the control group 1, with the exception of the omission of firms with SIC code 45. SIC 45 encompasses all motorcycle and vehicles (including trucks and lorries) and their activities (except renting and manufacture activities). As seen in Figure 3.10, the trend of control group 2 resembles that of the treatment group well. Control group 2 is more likely to satisfy the parallel trends assumption and thus will be selected as the control group for the difference-in-differences approach in this chapter. A full list of the industry codes is given in Table 3.2 in section 3.4.1.

Figure 3.9 Average annual revenue for the renewables and non-renewables groups. The feed-in - tariff policy was enacted at time 0 on the x-axis

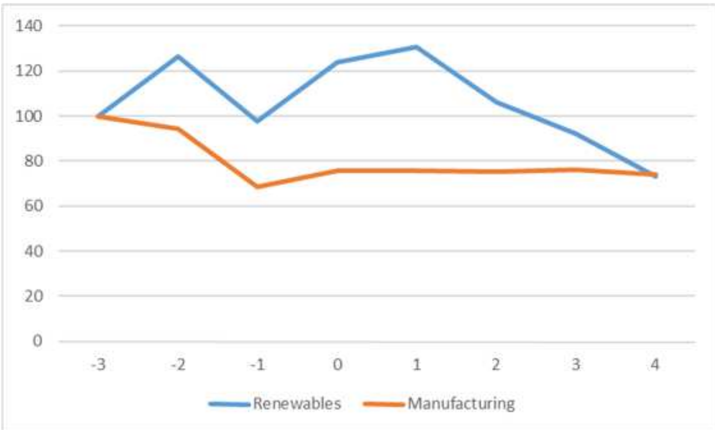
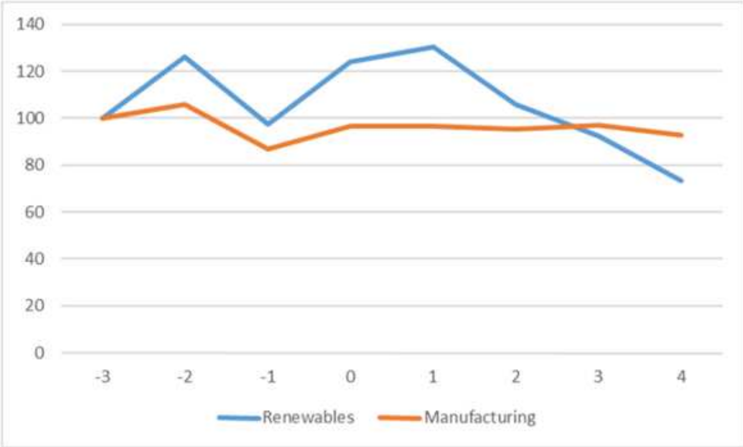


Figure 3.10 Average annual revenue for the renewables and non-renewables groups. The feed-in - tariff policy was enacted at time 0 on the x-axis.



Apart from plotting the trends, I also undertook a pre-trend test. Table 3.8 shows the result, by including interactions of the treatment variable with year dummies and 1 year lead as the reference. The coefficients on the interaction terms in 2007 (3-year lead coefficient -0.161) and 2008 (2-year lead coefficient -0.178*) are insignificant and weakly significant. An F-test confirms that the coefficients are not significantly different from 0 - that is there were no anticipation effects when the policy was introduced. This table shows that the parallel trends assumption is met[30].

The interaction terms also capture the effect of the policy across time, the results show that the policy had a positive and significant (0.230*) effect 1 year after the introduction of the policy, with the effect becoming insignificant (0.207) from 2012 afterwards. This is somewhat supported by events in the real world, as the tariffs payments were significantly reduced from 2011 onwards.

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30 Autor (2003) carries out an application of this test.

Table 3.8 Pre-trend test results

VARIABLE - log turnover	
Time dummies	
2007	0.027**
	(0.011)
2008	0.077***
	(0.009)
2010	0.072***
	(0.006)
2011	0.165***
	(0.008)
2012	0.193***
	(0.009)
2013	0.214***
	(0.009)
2014	0.256***
	(0.01)
3 Year Lead	-0.161
	(0.123)
2 Year Lead	-0.178*
	(0.091)
treatment Year	0.124
	(0.076)
1 Year Lag	0.230*
	(0.128)
2 Year Lag	0.207
	(0.147)
3 Year Lag	0.165
	(0.152)
4 Year Lag	0.218
	(0.168)
Constant	9.374***
	(0.006)
Observations	45,557
Number of id	7,517
R-squared	0.043

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Notes: The control group is non-renewables group 2. Lead and lag terms represent the Renewables variable interacted with a time dummy for years before and after the treatment year

3.6 Results

This section presents the results from PSM, DiD and combined PSM and DiD, which include discussions with fixed effects, and with different measures of firm performance.

3.6.1 PSM estimation

PSM starts with the selection of the matching variables used for calculating propensity score. The available variables are *Firm age, Firm size, Industry* sector, *Fixed assets,* number of *employees*, and *export* activity.

3.6.1.1 Matching variables

I began by including variables which at least theoretically should influence the decision of firms to produce renewable energy products, the first variable being *Firm age*. A firm that is older could have more experience and expertise. A possibility is that the firm survived due to having a highly skilled and productive workforce. Similarly, an older firm might be likely to sell a diverse range of products, and more willing to enter new markets and in turn sell renewable energy products. The outcome of Firm age is shown in column 1 Table 3.9 and it is found to be small but significant.

The participation decision could also be influenced by the size of the firm. Larger firms have more financial resources, allowing them to overcome barriers more easily to entering new markets. This is especially true in the renewable energy industry. Despite the downward trend of prices of renewable technologies, there still exists significant sunk costs that firms must incur before production can take place. In addition, larger firms are more likely to diversify their products, operating in multiple markets and offering a portfolio of goods and services to achieve their goals of profit maximisation. The variable *SME* indicating the firm size is added to the model (column 2, Table 3.9) and is again found to be statistically significant.

The industry the firm operates in could also influence the decision of firms to participating renewable energy market. If a non-renewable energy firm operated in the same market as a renewable energy firm within the manufacturing sector, then this could affect the participation decision. There could exist synergies in production. For example, a firm that produces metal structures might find it easier to produce products for wind farms. The industry code, SIC, can be used as a variable for matching. The final column of Table 3.9 tests the 2-digit SIC codes effects. All except one of the industries were found to be significant. This column is also the final specification after the first round of variable selection, where firms are matched based on *firm age*, whether or not they are a *SME* and the *industry sector* in which they operate.

After the first round of variable selection, I estimate the probability that the firm is a renewable energy firm as a function of the above selected variables using the probit model, and the results are as shown in Table 3.9. Overall, the variables are all significant (except for one category of industry, namely, the manufacture of chemicals and chemical products) and they support the theory that such variables influence the decisions of firms to participate in the scheme.

Table 3.9 Results from the PSM estimation on the first round of variable selection

Variables	(1)	(2)	(3)
Age	1.01e-3**	1.00e-3**	1.02e-3**
	(0)	(0)	(0)
SME		-0.13**	-0.22**
		(0.09)	(0.1)
Industry (SIC code)			
Manufacture (10-33)			
of chemicals and chemical products			0.41
			(0.28)
of other non-metallic mineral products			1.01***
			(0.25)
of fabricated metal products, except machinery and equipment			0.82***
			(0.19)
of computer, electronic and optical products			0.83***
			(0.21)
of electrical equipment			1.08***
			(0.2)
of machinery and equipment n.e.c.			0.9***
			(0.19)
of other transport equipment			0.92***
			(0.27)
Other			
repair and installation of machinery and equipment (33)			0.81***
			(0.18)
electricity, gas, steam and air conditioning supply (35)			0.72*
			(0.38)
civil engineering (42)			2.43***
			(0.7)
specialised construction activities (43)			1.57***
			(0.31)
Wholesale and retail trade (45)			
repair of motor vehicles and motorcycles			1.83***
			(0.57)
wholesale trade of motor vehicles and motorcycles			1.43***
			(0.24)
retail trade of motor vehicles and motorcycles			1.1**
			(0.44)
Scientific research and development (71)			1.52***
			(0.5)
Constant			-2.88***
			-0.17

Notes: Results estimates a Probit model that the variables affect participation into the treatment group. Columns 1, 2 and 3 adds additional variables in the match with SME and SIC codes respectively. *** p<0.01, ** p<0.05, * p<0.1

From this base specification, further variables were added and tested to see whether they influenced the participation decision. Given that SME was found to be significant, $fixed\ assets$ was added to try and capture the effect of the size of the firm in more detail. Fixed assets was used since it does not fluctuate with the day to day operations of the firm, and is thus more likely to capture the underlying size of the firm. It was, however, found to be insignificant in the estimation (Table 3.10, column 1).

A similar indicator is $the\ number\ of\ employees$ of the firm (Table 3.10, column 2). A larger firm will have more employees. Employees was also found to be insignificant in this round of estimation.

Another variable considered is *Export*. REFs export and import goods and services. It is possible that the effect of a policy in another country may influence the operations of a firm in the UK. The variable export, which is equal to 1 if the firm has overseas revenue, seeks to capture this. As shown in Table 3.10 column (3), the resulting coefficient of this variable was not found to be significant, suggesting that the effect through the trade channel was limited.

Table 3.10 Results from the PSM estimation on the second round of variable selection

Variables	(1)	(2)	(3)
Age	1.01e-3*	1.00e-3	1.02e-3**
	(0)	(0)	(0)
Log fixed assets	0.03		
	(0.02)		
Log employees		0.09	
		(0.04)	
Log export			-0.06
			(0.09)
Manufacture of			
of chemicals and chemical products	0.49*	3.4	0.44
	(0.29)	(124.24)	(0.27)
of other non-metallic mineral products	1.08***	3.98	1***
	(0.26)	(124.24)	(0.25)
of fabricated metal products, except machinery and equipment	0.81***	3.64	0.79***
	(0.2)	(124.24)	(0.18)
of computer, electronic and optical products	0.84***	3.74	0.81***
	(0.23)	(124.24)	(0.21)
of electrical equipment	1.17***	3.87	1.06***
	(0.21)	(124.24)	(0.2)
of machinery and equipment n.e.c.	0.93***	3.79	0.88***
	(0.21)	(124.24)	(0.19)
of other transport equipment	0.63		0.92***
	(0.38)		(0.27)
Other			
repair and installation of machinery and equipment	0.88***	3.66	0.84***
	(0.2)	(124.24)	(0.18)
electricity, gas, steam and air conditioning supply	0.79**	3.67	0.68*
	(0.4)	(124.24)	(0.38)
civil engineering	2.52***	5.79	2.41***
	(0.71)	(124.24)	(0.7)
specialised construction activities	1.64***	4.55	1.52***
	(0.32)	(124.24)	(0.31)
Wholesale and retail trade			
repair of motor vehicles and motorcycles	1.96***	4.88	1.87***
	(0.56)	(124.24)	(0.56)
wholesale trade, except of motor vehicles and motorcycles	1.44***	4.3	1.4***
	(0.26)	(124.24)	(0.24)
retail trade, except of motor vehicles and motorcycles	1.21*	4.13	1.07***
	(0.45)	(124.24)	(0.44)
Scientific research and development	1.6***	4.67	1.49***
	(0.51)	(124.24)	(0.5)
Constant	-3.34***	-6.41	-3***
	(0.24)	(124.24)	(0.16)

Notes: Dependent variable is whether the firm is a renewable energy firm. Fixed assets and number of employees are added as variables to further investigate the role of firm size for matching. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Given that the *industry* and *firm age* are found to influence the participation decision, the interaction terms between the variables was also added to test whether there were any additional effects between them. The variables were found to be either insignificant or the effects were negligible.

3.6.1.2 Different matching techniques

After selecting the variables for the propensity score calculation, the propensity score is used to match the renewable and non-renewable energy firms. The most straightforward matching estimator is nearest neighbour matching. This method can be carried out with or without replacement. The results show very little difference between the two methods in my data as shown in Table 3.11. This is to be expected since I have a lot of individuals in the control group compared with the treatment group. Nearest neighbour could also be carried out with oversampling, allowing more than one control firm to be matched to each treatment firm. This method tends to lead to lower variance with the trade-off of higher bias. Row 3 in Table 3.14 shows an example where three control firms are matched to one single renewable energy firm. The 1-nearest neighbour without replacement is the best amongst three but the differences are small.

Table 3.11 Testing different matching techniques for the PSM

Variable - log turnover	Average treatment effect on the treated (ATT)	Outcome mean of treated group	Outcome mean of control group
1-Nearest neighbour without replacement	-0.07 (0.24)	9.80	9.87
1-Nearest neighbour with replacement	-0.12 (0.24)	9.80	9.92
3-Nearest neighbour with replacement	0.11 (0.19)	9.80	9.69
Calliper (0.0025)	-0.08 (0.24)	9.80	9.88

Notes: (standard errors in parentheses)

A drawback of nearest neighbour matching is that if the closest neighbour is very far away then the risk of bad matches increases. This issue can be avoided by using a calliper parameter which specifies a maximum 'distance' the firms can be away from the matched firm. This distance is measured in propensity score. Radius matching is a variant of calliper matching, one that was suggested by Dehejia and Wahba (2002). This method has the added benefit of using as many comparison members as are available within the caliper, extra members are used when the match is good, fewer used when the match is bad. A possible drawback of caliper matching is that it may not be possible to know what tolerance level is reasonable. The largest distance in my data is only 0.0055, so imposing any caliper greater than 0.0055 will not have any effect. The result of using a caliper of 0.0025 is shown in the final row of Table 3.11.

Table 3.11 also shows the treatment effects were not found to differ significantly between the different matching techniques. In all cases, the effect of the policy was found to be negative and insignificant. The results imply that changes in method mainly resulted in similar firms being matched together.

3.6.1.3 Quality of match

The quality of the match is checked with balance tests. The balance test examines whether the distribution of the observed covariates is similar between the treated and control groups after matching. In practice, the balance test is applied to unmatched pairs and matched pairs respectively, with then a comparison of the t-tests and %bias reductions. If matching is successful, then the differences between the matched pairs should be smaller than the unmatched pairs.

Table 3.12 shows the results of the balancing test for the final specification of the PSM model. Taking one example, SME, before matching the percentage of bias between treated and untreated is 7.04%; after matching it reduced to 4.23%. Then the percentage of the bias reduction (how much the matching gets improved) is 40%. The table shows that quality of matching is quite high, with many of the means between the treated and control groups becoming similar as well as experiencing a sharp decline in bias after matching.

Table 3.12 Covariate balance test for the final PSM model

Variable		Mean of treated group	Mean of control group	%bias	%reduction of bias	t	p>t	V(T)/V(C)
Age	U	7367.40	9833.30	33.47		-2.52	0.01	0.65
	M	7367.40	8297.50	12.63	62.28	-0.77	0.44	0.74
SME	U	0.71	0.76	7.04		-0.92	0.36	
	M	0.71	0.68	4.23	40.0	0.51	0.61	
SIC_20	U	0.03	0.06	100.0		-1.30	0.19	
	M	0.03	0.04	33.0	66.67	-0.45	0.65	
SIC_23	U	0.05	0.02	60.0		1.61	0.11	
	M	0.05	0.04	20.0	66.67	0.38	0.70	
SIC_25	U	0.15	0.12	20.0		0.78	0.44	
	M	0.15	0.13	13.33	33.33	0.46	0.65	
SIC_26	U	0.09	0.06	33.33		0.96	0.34	
	M	0.09	0.08	11.11	66.67	0.29	0.77	
SIC_27	U	0.13	0.05	61.54		3.17	0.00	
	M	0.13	0.15	15.39	75.0	-0.46	0.65	
SIC_28	U	0.14	0.09	35.71		1.64	0.10	
	M	0.14	0.16	14.29	60.0	-0.44	0.66	
SIC_30	U	0.04	0.02	50.0		1.21	0.23	
	M	0.04	0.04	0.0	100.0	0.00	1.00	
SIC_32	U	0.16	0.13	18.75		0.91	0.36	
	M	0.16	0.15	6.25	66.67	0.22	0.83	
SIC_33	U	0.01	0.01	0.0		-0.05	0.96	
	M	0.01	0.03	200.0	.	-0.58	0.56	
SIC_35	U	0.00	0.00	.		.	.	
	M	0.00	0.00	.	.	.	.	
SIC_42	U	0.01	0.00	100.0		5.89	0.00	
	M	0.01	0.01	0.0	100.0	0.00	1.00	
SIC_43	U	0.04	0.00	100.0		4.10	0.00	
	M	0.04	0.05	25.0	75.0	-0.38	0.70	
SIC_45	U	0.01	0.00	100.0		3.56	0.00	
	M	0.01	0.01	0.00	100.0	0.00	1.00	
SIC_46	U	0.08	0.01	87.5		4.92	0.00	
	M	0.08	0.05	37.5	57.14	0.65	0.52	
SIC_47	U	0.01	0.00	100.0		1.12	0.26	
	M	0.01	0.03	200.0	100.0	-0.58	0.56	
SICc_72	U	0.01	0.00	100.0		2.41	0.02	
	M	0.01	0.01	0.00	100.0	0.00	1.00	

Notes: U represents Un-matched groups and M the matched groups

3.6.1.4 PSM estimation

Table 3.13 below shows the results for the final specification. It finds that ATT is negative but insignificant (-0.12 and 0.51), which is somewhat unexpected, as the feed-in-tariff was expected to have positive effect on turnover.

Table 3.13 PSM estimate on firm turnover

Variable	ATT	Treated	Controls	Difference	S.D.	T-stat
log turnover	Unmatched	9.80	9.63	0.17	0.16	1.08
	Matched	9.80	9.92	**-0.12**	0.24	**0.51**

Furthermore, Table 3.14 shows the PSM estimation using OLS regression on the panel data. The effect remains negative (-0.801) and insignificant.

Table 3.14 OLS regression carrying out the PSM method using panel data

log post turnover	
Renewables	-0.0801
	(0.116)
Constant	10.04***
	(0.0902)
Observations	683
R-squared	0.001

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Following on from this initial estimation, below I consider parameters at a more disaggregated level, such as at different growth levels, at different employee levels, or at the levels of with or without R&D activities.

Growth

The first set of parameters to consider is $growth$. Different variations of the initial variables, such as the percentage growth in turnover and in employees were tested. The result is shown in Table 3.15 and the variables are found to be insignificant (-0.11 and 0.08).

Table 3.15 PSM results with growth variables

Variable - log turnover	ATT (standard error)	Outcome mean of treated	Outcome mean of untreated
With turnover growth	-0.11 (0.27)	9.90	9.79
With employee growth	0.08 (0.24)	10.13	10.21

Note: Growth variables are calculated from 2007-2009 data

In addition, using the growth variables significantly reduces the sample of treatment firms[31], and is the reason that the point estimates are used in the preferred propensity score model. These two reasons meant that growth variables were not included in the final specification of the model.

Research and development

REFs are generally considered to be more innovative than other manufacturing firms. Ideally, this means that research and development expenditure should be included as a covariate in the matching procedure.

To capture the possible effect of R&D and ensure that R&D expenditures are not driving my results, I restrict the control group to be only those firms having a certain level of R&D expenditure as a percentage of annual revenues.

Table 3.16 provides the percentage of R&D expenditure for the control group in the pre-treatment period (2007-2009), with only the total 581 firms reporting R&D expenditures. The percentages show that many firms in the control group do not have significant expenditures allocated to R&D, with half of firms only devoting only 2% of annual revenues to R&D and three quarters of firms spending less than 5%. The mean expenditure is skewed upwards

[31] From turnover growth the number of matched observations drops to 63 treatment firms. For employee growth the number of matched observations drops to 55 treatment firms.

due to the existence of a small number of firms at the top of the distribution with significant R&D expenditures.

Table 3.16 Percentage R&D expenditure in the control group[32]

Percentiles	Percentage R&D
1%	0.00
5%	0.00
10%	0.00
25%	0.01
50%	0.02
75%	0.04
90%	0.08
95%	0.13
99%	0.37
Min	0.00
Max	0.86
Mean	0.04
Std. Dev.	0.07
No of observations	581

Table 3.17 is the result of PSM estimate on this data, showing that more innovative firms are used for comparison, the effect of the feed-in-tariff changes from negative to positive. This indicates that if REFs are those that are more innovative and spend more on R&D, then there is a positive effect of the feed-in-tariff. However, like previously the ATT is again found to be insignificant, likely again as a result of small sample size in the data.

[32] Percentage expenditures are calculated from the average R&D expenditure from 2007-2009 divided by average revenues in that period.

Table 3.17 PSM results with different levels of R&D percentage in the control group

Variable - log turnover	ATT (Standard error)
Firms with greater than 2% percent R&D	-0.45 (0.31)
Firms with greater than 4% percent R&D	0.03 (0.26)
Firms with greater than 8% percent R&D	0.55 (0.42)

Firm age

A further check of the data is to split the dataset by *firm age* into younger (<10 years) and older (10-20 years) firms. The earlier estimations found that age is a significant determinant. A question of interest is whether this effect is concentrated within younger firms or older firms of more experienced. Table 3.18 indicates this not to be the case. The effect of the feed-in-tariff was again found to be insignificant.

Table 3.18 PSM results of splitting the dataset to young and old firms

Variable - log turnover	ATT (Standard error)
Age < 10	0.14 (0.33)
10 < Age < 20	0.13 (0.21)

Overall, the results from the PSM suggests that the effect of the policy was generally negative but insignificant. One possible reason for this unexpected result could be that PSM can only account for observable variables whilst the unobservable variables, e.g., firm culture, firm managerial style, etc, may influence both the treatment and outcome. Another reason would be the limited data size that may produce less precise results, as discussed in Data section. From this, an alternative approach could be employed that takes into account the unobservable variables, or both observable and unobservable. This leads to the work of the next two sections.

3.6.2 Difference-in-differences estimation

3.6.2.1 Baseline results

The initial results from the differences in differences approach is shown below in Table 3.19[33].

Column (1) shows the baseline model, with a positive and significant effect at around 33.5% (0.289*** in the table). *Year* dummies are included across all specifications to capture year fixed effect during this period of time. The results were found to be significant across all three specifications of the model, suggesting that revenues experienced significant changes over the time period of study.

Column (2) includes *firm age* as a control variable. Firm age is included Firm age is included since older firms have more knowledge and are more likely to take advantage of new opportunities. In addition, the firm age variable here also captures potential time trends that impact the renewable energy industry as a whole. Firm age is found to have a significant and small effect of 1.0% on renewable energy firm revenues that persists across specifications.

Column (3) added firm fixed effect to the estimation controlling for time-invariant firm-specific characteristics. *Renewables* is dropped since such variables for a specific firm do not vary with time.

Across models (1), (2) and (3), the coefficient on the variable *Renewables* is found to be insignificant, suggesting that there were no differences between the treatment and control groups before the introduction of the feed-in-tariff policy.

In summary, across all specifications of the model, the coefficients of *Renewables*Post* have shown that the feed-in-tariff has significant effects on firm revenues, with the introduction of the policy increasing the revenue of the average solar and wind panel firm with a coefficient of 0.289.

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[33] Estimation is clustered on firm level and using robust standard errors

Table 3.19 Baseline difference-in-difference results

Dependent - log turnover	(1)	(2)	(3)
Age		0.010***	0.033***
		(0.001)	(0.002)
Renewables*Post	**0.289****	0.289**	0.287**
	(0.139)	(0.139)	(0.139)
Constant	9.261***	9.014***	8.565***
	(0.018)	(0.025)	(0.056)
Year FE	Y	Y	Y
Firm FE	N	N	Y
Observations	44723	44723	44723
R-squared			0.044
Number of id	7125	7125	7125

Notes: Clustered standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

3.6.2.2 Research and development

REFs tend to be more innovative as they step in new things and new technology quickly. Similar to the test undertaken with R&D in the PSM method, Table 3.20 shows the results from restricting the control group to be those firms with $R\&D\ expenditure$ that is equal to or greater than 2% of annual revenues. The effect of the feed-in-tariff is found to be insignificant.

Table 3.20 Difference in differences estimation with R&D firms

VARIABLE - log turnover	(1)
Age	0.035***
	(0.007)
Renewables*Post	-0.016
	(0.079)
Constant	9.045***
	(0.188)
Year FE	Y
Firm FE	Y
Observations	1817
R-squared	0.079
Number of id	260

Notes: Data for the control group are restricted to only those firms with R&D expenditures equal to or greater than 2% of annual revenues. Clustered standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Including the R&D restriction should lead to more robust results, however a disadvantage of applying this restriction is a large drop in the number of observations used in the regression. A likely reason for the insignificance could be the loss of information associated with applying the restriction. The sample size is reduced quite substantially meaning the coefficients are estimated more imprecisely (increasing the likelihood of a type 2 error).

3.6.2.3 All identified REFs including non-manufacturing firms

One concern is that all identified REFs should have been included as part of the analysis of the effect of the feed-in-tariff on firms. Table 3.21 thus estimates the difference-in-differences again, now including all 155 identified REFs. Compared with the results obtained in Table 3.19 when the reduced treated samples (86 REFs) were estimated, the effect of the policy is found to be smaller than that obtained previously yet still positive and significant (coefficient is 0.237 compared to 0.289). These results from the difference-in-differences model suggest that the firms that were dropped, including those that exited had a small effect from the FITs.

Table 3.21 Difference-in-differences using all 155 identified REFs identified in the study

log turnover	
Age	0.033***
	(0.002)
Renewables all*Post	0.237*
	(0.125)
Constant	8.567***
	(0.056)
Year FE	Y
Firm FE	Y
Observations	44865
Number of id	7161
R-squared	0.043

Clustered standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

3.6.3 Combining PSM and DiD for estimation

The results obtained from the propensity score matching method were very different from those obtained in difference-in-differences. In this section, I combine the two methods, using the PSM treated and untreated matching groups to DiD for cross group time variant estimation.

Combining the two approaches confers some advantages. A critical assumption of the matching method is that ‘conditional on a set of observable characteristics mean outcomes are independent of programme participation’ (Marco Caliendo, 2008). By combining the DiD with matching, this assumption can be relaxed, allowing for unobservable but temporally invariant differences in outcomes between participants and nonparticipants (Caliendo and Kopeining, 2008).[34]

[34] A counter-argument to using the two methods together is that if the source of bias not captured in observables (PSM) or the bias is not from un-observables that are constant over time (DiD), then there is very little advantage to be gained from using the two methods together.

In practice, this involves carrying out the DiD using the matched treatment and control group that is obtained from the PSM. The results are shown in Table 3.22 below. The effect of the FIT is found to be of a similar magnitude as obtained using the DiD sample in the previous section (0.301 for combined approach compared to 0.289 for DiD alone). The standard error for the interaction coefficient has increased, suggesting that under the PSM the groups may not have been precisely identified.

Table 3.22 PSM with Difference-in-indifferences

log turnover	(1)	(2)	(3)
Age		0.035***	0.0319**
		(0.013)	(0.013)
Renewables*Post	0.309*	**0.301***	
	(0.160)	**(0.159)**	
Renewables*Post*2010			0.213*
			(0.118)
Renewables*Post*2011			0.359**
			(0.160)
Renewables*Post*2012			0.183
			(0.189)
Renewables*Post*2013			0.410*
			(0.227)
Renewables*Post*2014			0.349*
			(0.194)
Constant	9.673***	8.957***	9.026***
	(0.0692)	(0.325)	(0.308)
Year FE	Y	Y	Y
Firm FE	Y	Y	Y
Observations	1.011	1,011	1,011
R-squared	0.066	0.066	0.070

Notes: The above results use the DiD with the treatment-control pairs selected using PSM. Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

One of the reasons for the different results could be because the effects of the policy differs across time. Column (2) of Table 3.22 shows the model including interactions between the treatment group and post and time. The results show this to unlikely be the case as the effects of the policy are found to be positive and significant across most periods post policy introduction. The only period that is insignificant (and has a smaller magnitude) in 2012 could be reflecting a delayed response to the annual reduction in tariff payments introduced at the beginning of 2011.

Overall, the results suggest that the effect of the feed-in-tariff on firm performance do not yield statistically significant results when employing Propensity Score Matching (PSM). Difference-in-Differences (DiD) showed a positive and significant effect from the feed-in-tariff.

3.6.4 Fixed assets

Firm fixed assets are regarded as another indicator of firm performance. Instead of using firm turnover as the dependent variable, the regressions from using fixed assets as the dependent are shown in Table 3.23. The results suggest that the effect of the FITS was channelled through fixed assets. Taken together with earlier results, this suggests that firm level productivity was indeed affected by the introduction of the FIT.

Table 3.23 DiD with fixed assets as the dependent variable.

VARIABLE - log fixed assets	
Age	0.04***
	(0.003)
Renewables*Post	**0.264****
	(0.128)
Constant	6.089***
	(0.076)
Observations	53,877
Number of id	7,405
R-squared	0.017

*** p<0.01, ** p<0.05, * p<0.1

In response to the feed-in-tariff, firms may increase purchases of equipment to meet the increased demand from consumers. Such purchases would be reflected in the fixed assets of the firm. Table 3.24 carries out the estimation using PSM-DiD, the results are found to be insignificant. The coefficient is however positive, similar to the result under DiD, which could suggest a positive effect of the tariff on firms.

Table 3.24 Fixed assets PSM-DiD

Dependent variable: log fixed assets	
Age	0.0209*
	(0.0118)
Renewables*Post	0.146
	(0.173)
Constant	5.175***
	(0.494)
Year FE	Y
Firm FE	Y
Observations	1,171
R-squared	0.080

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

3.7 Robustness test

In this section, I consider some possible alternative strategies and present a series of robustness checks for my analysis. The main results from the PSM-DiD model shows that the introduction of the feed-in-tariff can significantly increase a firm’s turnover, some extra regressions will be conducted to ensure the robustness of this result.

Alternative time period

I use the dataset and set 2008 as the treatment year for the feed-in-tariff policy. There were no major environmental policies during this time, however the year had one of the most environmental policies introduced during my sample period. The results in Table 3.25 are reported in table below. I find that the effect is insignificant.

Table 3.25 Treatment year 2008 PSM-DiD

Dependent variable: log turnover	(1)
Age	0.0180**
	(0.00768)
Renewables*Post	0.252
	(0.242)
Constant	9.505***
	(0.222)
Year FE	Y
Firm FE	Y
Observations	1,011
R-squared	0.064

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Firm location

Firm earnings are not equal across regions in the UK. In particular, within England, some authors have discussed the existence of a north-south divide, with differences in cultural, economic and social differences between the two regions. I divide my data into two groups, south and north regions according the firm location. The results are shown in Table 3.27 below. I find that the effect of the feed-in-tariff to be both positive and significant in both southern and northern regions with a slightly higher effect in the south. Overall, the findings support my main conclusion to be robust.

Table 3.27 Firm location PSM-DiD

	(1)	(2)
Dependent variable: log turnover	South	North
Age	0.267*	0.0194
	(0.135)	(0.0410)
Renewables*Post	0.192**	0.145**
	(0.0828)	(0.0708)
Constant	2.538	9.197***
	(3.732)	(1.094)
Observations	384	359
R-squared	0.077	0.091

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

3.8 Conclusions

This chapter investigated the effect of government policies on the renewable energy sector. Specifically, I investigated the effects of the introduction of the feed-in-tariff scheme on the performance of REFs in the UK.

One of this chapter's contributions is the additional evidence it provides for an existing literature that has yet to reach a consensus on the efficacy of renewable energy policy. In this chapter, I found evidence that feed-in-tariff schemes can boost the performance of firms in the domestic economy.

I investigated both propensity score matching as well as the difference-in-differences methodology. Overall, I found similar effects with the standard difference-in-difference and that combining both the difference-in-difference and propensity score matching. In addition, I also found that the propensity score matching method was more strongly influenced by data limitations as compared with the difference-in-differences methodology.

Other authors have found feed-in tariffs to have a variety of effects for the domestic economy. One explanation for the difference between their results and mine is that I focused on effects at the firm level. In addition, I used a novel dataset covering the population of REFs. This is likely to have influenced the results since my data included many small- and medium-sized firms from the population of REFs in the UK.

Overall, this study finds that the introduction of the feed-in-tariff had a positive effect on firms in the renewable energy sector in the UK.

The data used in this study has certain limitations. As described in the data section, the dataset was constructed based on the company house data and other sources. The data availability is incomplete in places, and limits the number of firms in the treatment group. This has impacts on the estimated effect in precision, generalisability and sensitivity to outliers. The PSM-DiD methodology was used to tackle this.

While this study focuses on the UK, the issues addressed in this study are also important for other countries. As more and more countries seek to reduce fossil fuel dependence, the outcomes for the UK can serve as a reference for these economies.

4 Conclusions

Global trade has grown considerably during the past few decades. Trade costs, which are an important factor in international trade, have seen declines during the same period of time (Hummels, 2007). Over time, there has been an increase in trade liberalisation along with regulatory changes that have accompanied the abovementioned trends. In this thesis, I have investigated the effects on firms in response to changes in trade costs from regulatory changes.

In the first chapter, I investigated the effects of a change in the IMSBC Code on oceanic commodities trade, providing one of the first results on that topic. In order to capture the effects of the IMSBC Code, I identified and matched commodities listed in the IMSBC Code to those under the HS code. Using a difference-in-difference methodology, I found that the introduction of the IMSBC Code led to an increase in the overall trade in commodities.

I disaggregated commodities and found heterogeneous effects on different product groups. For Group A commodities, the introduction of the regulation led to a decrease in trade, whereas for Group B products, the regulation led to an increase in the number of commodities exported. This result was robust to a range of measures, including the inclusion of various fixed effects, including using the value share of goods transported via air.

One of the limitations of this chapter is that the data used were at the country level. This was done to provide results on the effects on global commodity trade. The analysis could be carried out at the firm level, in line with more recent empirical studies in trade, but this would limit the sample to just a handful of countries that provided data at such a level. Many developing economies, which are the major exporters of commodities globally do not provide such detailed trade data. The use of firm-level data could capture more detailed effects. More productive firms could be better placed to respond to an increase in regulation. In addition, the level of ‘connections’ a firm has to the local authority would likely impact their responses to the changing regulation. There is some evidence of this being a factor in developing economies (e.g. Philippines, UK P&I Club Webinar 2020). Unfortunately, these effects cannot by precisely measured using aggregate data.

Another minor limitation of the study was that it managed to identify only a subsample of the overall commodities contained within the IMSBC Code. In the future, if new information becomes available, it would be useful to expand the analysis to encompass the entire population of commodities covered by the IMSBC legislation.

The second chapter provided results on how regulatory change affects firms' choices for shipping modes in trade. The chapter investigated firm-responses to the removal of the Multifiber Arrangement (MFA) in 2005. Using difference-in-differences, I found no effect of the MFA on the exports of textiles and apparel to the US or Europe as a whole. However, disaggregating the results, I found a difference in the choice of shipment between the US and Europe, there was a decline in the share of the air shipment of textiles and apparel to the EU. As a result of the MFA liberalisation firms switched to using more oceanic shipping. The quota removal led to a decrease in the quality of exported products and hence a switch to less expensive modes of transport. The results were robust to the use of other dependent variables, such as the share of the quantity of textile and apparel exports to the US and EU.

The third chapter of this thesis investigated the effect of government policies on the renewable energy sector. After identifying REFs in the UK, I investigated the effects of the introduction of the FIT scheme on the performance of REFs.

I used both propensity score matching as well as the difference-in-differences methodology to investigate the effects of the FITs on REFs. The PSM did not find a significant effect on UK firms from the policy. Under the DiD, the effects are positive. I combined the DID with PSM, allowing for unobservable but temporally invariant differences in outcomes between participants and nonparticipants, and found the effect of the FIT to be positive and of similar magnitude to using the DiD alone.

One of the limitations of this chapter was that the study examined only the domestic channels through which the FIT affected firms. In reality, firms export and import renewable energy goods such as solar panels from outside the UK. This limitation was due to the unavailability of the relevant data, but with those data, the investigation would offer an interesting avenue for future research.

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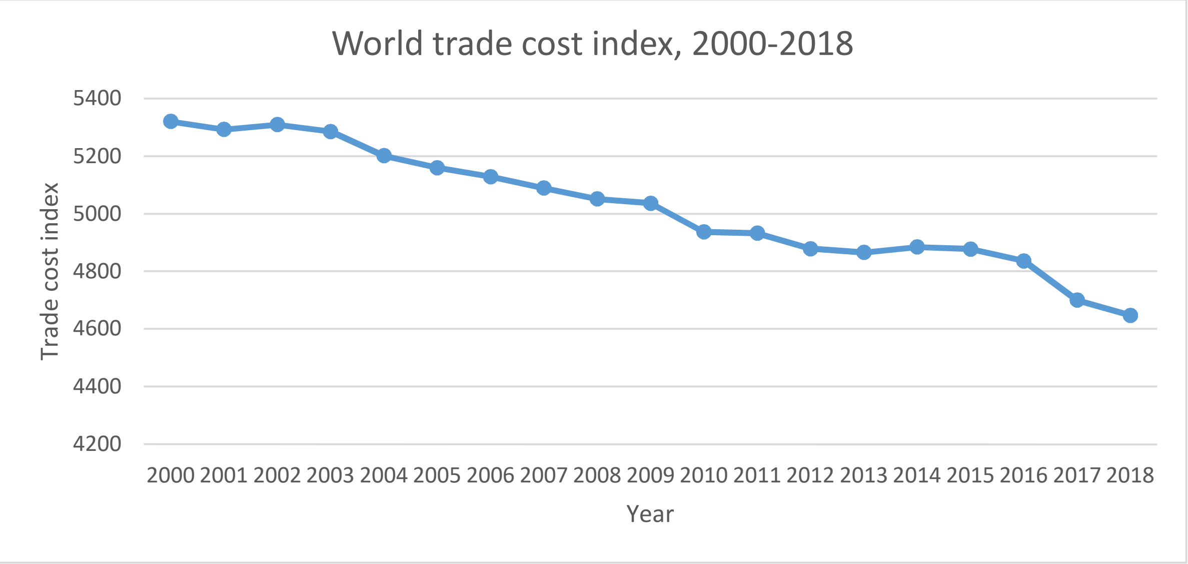
5 Appendices

5.1 Appendix A. Trade cost index between 2000 and 2018

Data source is World Trade Organization (WTO, Chapter 8, 2019).



5.2 Appendix B. Corruption and compliance with regulation

The IMSBC code is a mandatory code that all oceanic shippers transporting commodity goods have to follow. However, there is limited evidence that some countries do not enforce the legislation vigorously and in some cases ignore it altogether (i.e. not requiring a TML certificate from a certified lab before cargoes leave port). Data on such occurrences do not exist. I attempt to estimate the influence of this effect on my results using corruption as a proxy variable for the likelihood a country enforces the IMSBC code. The corruption variable is calculated from the World Governance Indicators control of corruption index. Table below estimate the baseline difference-in-difference restricting the sample to be between countries with a positive corruption index. Table below does the same with countries with worse corruption. Both results are positive and significant and suggesting that non-compliance does not drive my main results.

Trade B1. Between countries with less corruption

Dependent variable: log quantity	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Treat	1.774***	1.774***	1.549***	1.550***	1.213***	1.214***	
	(0.0685)	(0.0685)	(0.0659)	(0.0659)	(0.0619)	(0.0619)	
Post	-0.425***		-0.432***		-0.334***		
	(0.0221)		(0.0195)		(0.0167)		
Treat*Post	0.115**	0.118**	0.200***	0.203***	0.263***	0.265***	0.260***
	(0.0539)	(0.0539)	(0.0522)	(0.0522)	(0.0517)	(0.0517)	(0.0469)
Constant	8.900***	8.661***	8.907***	8.663***	8.857***	8.669***	8.687***
	(0.0711)	(0.0698)	(0.0470)	(0.0467)	(0.00935)	(0.000839)	(0.000421)
Time FE	N	Y	N	Y	N	Y	Y
Country FE	N	N	Y	Y	N	N	N
Country Pair FE	N	N	N	N	Y	Y	Y
Product FE	N	N	N	N	N	N	Y
Observations	1,993,222	1,993,222	1,993,222	1,993,222	1,992,800	1,992,800	1,992,794
R-squared	0.005	0.006	0.125	0.126	0.224	0.224	0.421

Robust standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1

Table B2. Trade between countries with worse corruption

Dependent variable: log quantity	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Treat	1.817***	1.820***	1.545***	1.548***	1.396***	1.399***	
	(0.106)	(0.106)	(0.0977)	(0.0977)	(0.0968)	(0.0968)	
Post	-0.768***		-0.554***		-0.465***		
	(0.0537)		(0.0395)		(0.0321)		
Treat*Post	-0.00372	0.00501	0.164**	0.165**	0.231***	0.230***	0.206***
	(0.0839)	(0.0835)	(0.0754)	(0.0754)	(0.0739)	(0.0738)	(0.0713)
Constant	9.506***	9.064***	9.387***	9.068***	9.341***	9.073***	9.104***
	(0.0873)	(0.0874)	(0.0482)	(0.0399)	(0.0184)	(0.00174)	(0.000938)
Time FE	N	Y	N	Y	N	Y	Y
Country FE	N	N	Y	Y	N	N	N
Country Pair FE	N	N	N	N	Y	Y	Y
Product FE	N	N	N	N	N	N	Y
Observations	658,091	658,091	658,091	658,091	657,382	657,382	657,379
R-squared	0.010	0.015	0.188	0.190	0.261	0.262	0.436

Robust standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1

5.3 Appendix C. BC code identified commodities list

This is drawn from the 2018 IMSBC code.

Commodity name	Group	HS code
Blende (zinc sulphide)	A	320642
CEMENT COPPER	A	7401
COPPER CONCENTRATE	A	260300
LEAD CONCENTRATE	A	260700
LEAD ORE RESIDUE	A	262021, 262029
MANGANESE CONCENTRATE	A	260200
NEFELINE SYENITE (mineral)	A	252930
NICKEL CONCENTRATE	A	2604
SLIG, iron ore	A	2613
Zinc ore, concentrates	A	260800
FLUORSPAR	A and B	252921, 252922
Ammonium Nitrate based fertilizer (Type A) UN 2067	B	310230
BROWN COAL BRIQUETTES	B	270120
Calcium fluoride	B	252922 (not an exact
CHARCOAL	B	4402
COPRA (dry) UN 1363	B	1203
IRON OXIDE, SPENT UN 1376	B	282110
PETROLEUM COKE, calcined	B	271312
PETROLEUM COKE, uncalcined	B	271311
Quicklime	B	2522
Barley malt pellets	B or C	1107 is malt
Ground nuts, meal	B or C	1202
BORAX, ANHYDROUS, crude	C	284011
CALCIUM NITRATE FERTILIZER	C	310260

5.4 Appendix D. Commonly used energy components mentioned in the study

Fluorspar

Fluorspar, also known as Fluorite, is the mineral form of calcium and fluorine. Exists as yellow, green or purple crystals. Its common uses include refrigeration, manufacture of chemicals, ceramic, and metallurgical processes.

Quicklime

Commonly known as Calcium oxide. Common uses include drying agent, fertiliser lime, soil stabilization.

Manganese concentrate

Refined manganese ore in which the bulk of waste materials have been removed. Common uses include steel production.

Brown coal briquettes

Brown coal briquettes are briquettes manufactured by pressing dried brown coal particles into compressed blocks. Traditionally produced as a means of using up 'small coal'. Common uses include As fuel or kindling. Wood selected as the control.

Charcoal

Wood burnt at a high temperature with as little exposure to air as possible. Very dusty, light cargo. Common use include Fuel. For the control group I was mainly selecting from solid fuels (such as wood, charcoal, peat, coal, wood pellets, corn, wheat, rye, and other grain).

Zinc sulphide (Blende)

This is the main form of zinc found in nature, where it mainly occurs as the mineral sphalerite. The more stable cubic form is known also as zinc blende or sphalerite. Common use include: the sulfides of zinc and of cadmium are the most important basic materials of sulfide-type phosphors.

Petroleum coke (calcined and uncalcined) (B)

Petroleum coke, abbreviated coke or petcoke, is a by-product from the refining of crude oil. It is a black, finely divided residue from petroleum refining in the form of powder and small pieces. Calcined petroleum coke is heated or refined raw coke. Common use include fuel source in electric power plants and cement kilns.

Iron oxide, spent

Iron oxide, spent is iron oxide that has been converted to iron sulfide. Can be regenerated to iron oxide by exposure to the air.

5.5 Appendix E. Identified concentrates list

Concentrate name	HS code	Treated/controls
Copper ores and concentrates	260300	T
Iron ores and concentrates; agglomerated (excluding roasted ir	260112	T
Iron ores and concentrates; non-agglomerated	260111	T
Lead ores and concentrates	260700	T
Manganese ores and concentrates, including ferruginous manganese ores	260200	T
Nickel ores and concentrates	260400	T
Zinc ores and concentrates	260800	T
Slag, ash and residues; (not from the manufacture of iron or steel), containing	262011	T
Slag, ash and residues; (not from the manufacture of iron or steel), containing	262019	T
Silver ores and concentrates	261610	C
Slag, ash and residues; (not from the manufacture of iron or steel), containing	262040	Removed
Aluminium ores and concentrates	260600	C
Antimony ores and concentrates	261710	C
Chromium ores and concentrates	261000	C
Cobalt ores and concentrates	260500	C
Molybdenum ores and concentrates; other than roasted	261390	C
Molybdenum ores and concentrates; roasted	261310	C
Niobium, tantalum, vanadium ores and concentrates	261590	C
Ores and concentrates n.e.c. in chapter 26; other than antimony	261790	C
Precious metal ores and concentrates; (excluding silver)	261690	C
Thorium ores and concentrates	261220	C
Tin ores and concentrates	260900	C
Titanium ores and concentrates	261400	C
Tungsten ores and concentrates	261100	C
Uranium ores and concentrates	261210	C
Zirconium ores and concentrates	261510	C
Slag, dross; (other than granulated slag), scalings and other waste from the	261900	Removed
Slag, granulated (slag sand); from the manufacture or iron or steel	261800	C
Slag, ash and residues; (not from the manufacture of iron or steel), containing	262021	C
Slag, ash and residues; (not from the manufacture of iron or steel), containing	262029	C
Slag, ash and residues; (not from the manufacture of iron or steel), containing	262030	C
Slag, ash and residues; (not from the manufacture of iron or steel), containing	262060	C
Slag, ash and residues; (not from the manufacture of iron or steel), containing	262091	C
Slag, ash and residues; (not from the manufacture of iron or steel), containing	262099	C
Slag and ash; ash and residues from the incineration of municipal waste	262110	C
Slag and ash n.e.c. in chapter 26; including seaweed ash (kelp) but excluding ash	262190	C

HS 261900 removed due to possible being part of commodity “Pyrite ashes”. Pyrite ashes are obtained as a result of the sulfuric acid production process during the roasting of pyrite ores. These wastes are generally landfilled or dumped into the sea.

The list is partially drawn from 2018 IMSBC code.

5.6 Appendix F. Full BC cargo list

This is drawn from 2018 IMSBC code.

Cargo name	Group
ALFALFA	C
ALUMINA	C
ALUMINA, CALCINED	C
ALUMINA, SILICA	C
ALUMINA SILICA, pellets	C
ALUMINIUM FERROSILICON POWDER UN 1395	B
ALUMINIUM NITRATE UN 1438	B
ALUMINIUM REMELTING BY-PRODUCTS UN 3170	B
ALUMINIUM SILICON POWDER, UNCOATED UN 1398	B
ALUMINIUM SMELTING BY-PRODUCTS UN 3170	B
AMMONIUM NITRATE UN 1942	B
AMMONIUM NITRATE BASED FERTILIZER (Type A) UN 2067	B
AMMONIUM NITRATE BASED FERTILIZER (Type B) UN 2071	B
AMMONIUM NITRATE, BASED FERTILIZER (non-hazardous)	C
AMMONIUM SULPHATE	C
ANTIMONY ORE AND RESIDUE	C
Antimony ore residue	C
Bakery materials	B or C
BARIUM NITRATE UN 1446	B
Barley malt pellets	B or C
BARYTES	C
BAUXITE	C
Beet, expelled or extracted	B or C
BIOSLUDGE	C
Blende (zinc sulphide)	A
BORAX, ANHYDROUS, crude	C
BORAX, ANHYDROUS, refined	C
BORAX (PENTAHYDRATE CRUDE)	C
Bran pellets	B or C
Brewer's grain pellets	B or C
BROWN COAL BRIQUETTES	B
Calcined clay	C
Calcined pyrites	A and B
Calcium fluoride	B
CALCIUM NITRATE UN 1454	B

CALCIUM NITRATE FERTILIZER	C
Calcium oxide	B
Canola Pellets	B or C
CARBORUNDUM	C
CASTOR BEANS UN 2969	B
CASTOR FLAKE UN 2969	B
CASTOR MEAL UN 2969	B
CASTOR POMACE UN 2969	B
CEMENT	C
CEMENT CLINKERS	C
CEMENT COPPER	A
Chalcopyrite	A
CHAMOTTE	C
CHARCOAL	B
Chile saltpetre	B
Chilean natural nitrate	B
Chilean natural potassic nitrate	B
Chrome ore	C
CHROME PELLETS	C
CHROMITE ORE	C
Chromium ore	C
Citrus pulp pellets	B or C
CLAY	C
COAL	A and B
COAL SLURRY	A
Coconut	B or C
COKE	C
COKE BREEZE	A
COLEMANITE	C
COPPER CONCENTRATE	A
COPPER GRANULES	C
COPPER MATTE	C
Copper nickel	A ?
Copper ore concentrate	A
Copper precipitate	A
Copra, expelled or extracted	B or C
COPRA (dry) UN 1363	B
Corn gluten	B or C
Cotton seed expellers	B or C
CRYOLITE	C

Deadburned magnesite	C
DIAMMONIUM PHOSPHATE	C
DIRECT REDUCED IRON, (A) (Briquettes, hot-moulded)	B
DIRECT REDUCED IRON, (B) (lumps, pellets, cold moulded briquettes)	B
DOLOMITE	C
Dolomitic quicklime	B
D.R.I.	B
FELSPAR LUMP	C
FERROCHROME	C
FERROCHROME, exothermic	C
FERROMANGANESE	C
Ferromanganese, exothermic	C
FERRONICKEL	C
FERROPHOSPHORUS	B
Ferrophosphorus briquettes	B
FERROSILICON UN 1408	B
FERROUS METAL BORINGS UN 2793	B
FERROUS METAL CUTTINGS UN 2793	B
FERROUS METAL SHAVINGS UN 2793	B
FERROUS METAL TURNINGS UN 2793	B
FERTILIZERS WITHOUT NITRATES	C
FISH (IN BULK)	A
FISHMEAL, STABILIZED UN 2216	B
FISHSCRAP, STABILIZED UN 2216	B
FLUORSPAR	A and B
FLY ASH	C
Galena (lead sulphide)	A
Garbage tankage	B
Gluten pellets	B or C
GRANULATED SLAG	C
Ground nuts, meal	B or C
GYPSUM	C
Hominy chop	B or C
ILMENITE CLAY	A
ILMENITE SAND	C
IRON CONCENTRATE	A
IRON CONCENTRATE (pellet feed, sinter feed)	A
Iron disulphide	C
IRON ORE	C
Iron ore (concentrate, pellet feed, sinter feed)	A

IRON ORE PELLETS	C
IRON OXIDE, SPENT UN 1376	B
IRON PYRITES	C
Iron swarf	B
Iron sponge, spent	B
IRONSTONE	C
LABRADORITE	C
LEAD AND ZINC CALCINES	A
LEAD AND ZINC MIDDLINGS	A
LEAD CONCENTRATE	A
LEAD NITRATE UN 1469	B
LEAD ORE	C
Lead ore concentrate	A
LEAD ORE RESIDUE	A
LEAD SILVER CONCENTRATE	A
Lead silver ore	A
Lead sulphide	A
Lead sulphide (galena)	A
Lignite	B
LIME (UNSLAKED)	B
LIMESTONE	C
Linseed, expelled	B or C
Linseed, extracted	B or C
MAGNESIA (DEADBURNED)	C
MAGNESIA (UNSLAKED)	B
Magnesia, clinker	C
Magnesia, electro-fused	C
Magnesia lightburned	B
Magnesia calcined	B
Magnesia caustic calcined	B
Magnesite clinker	C
MAGNESITE, natural	C
Magnesium carbonate	C
MAGNESIUM NITRATE UN 1474	B
MAGNETITE	A
Magnetite-taconite	A
Maize, expelled	B or C
Maize, extracted	B or C
MANGANESE CONCENTRATE	A
MANGANESE ORE	C

M.A.P.	C
MARBLE CHIPS	C
Meal, oily	B or C
METAL SULPHIDE CONCENTRATES	A and B
Mill feed pellets	B or C
Milorganite	C
MONOAMMONIUM PHOSPHATE	C
Muriate of potash	C
NEFELINE SYENITE (mineral)	A
NICKEL CONCENTRATE	A
Nickel ore concentrate	A
Niger seed, expelled	B or C
Niger seed, extracted	B or C
Oil cake	B or C
Palm kernel, expelled	B or C
Palm kernel, extracted	B or C
Peanuts, expelled or extracted	B or C
PEANUTS (in shell)	C
PEAT MOSS	A and B
PEBBLES (sea)	C
PELLETS (concentrates)	C
Pellets (cereal)	B or C
Pellets, wood pulp	B
Pencil pitch	B
PENTAHYDRATE CRUDE	A
PERLITE ROCK	C
PETROLEUM COKE, calcined	B
PETROLEUM COKE, uncalcined	B
PHOSPHATE ROCK, calcined	C
PHOSPHATE ROCK, uncalcined	C
PHOSPHATE, defluorinated	C
PIG IRON	C
PITCH PRILL	B
Pollard pellets	B or C
POTASH	C
Potash muriate	C
POTASSIUM CHLORIDE	C
POTASSIUM NITRATE UN 1486	B
Potassium nitrate/sodium nitrate (mixture)	B
POTASSIUM SULPHATE	C

Prilled coal tar	B
PUMICE	C
PYRITE (containing copper and iron)	C
PYRITES, CALCINED	A and B
PYRITES	A
Pyrites (cupreous, fine, flotation, or sulphur)	A
Pyritic ash	A and B
PYRITIC ASHES	A
PYRITIC CINDERS	A
PYROPHYLLITE	C
QUARTZ	C
QUARTZITE	C
Quicklime	B
RADIOACTIVE MATERIAL, LOW SPECIFIC ACTIVITY (LSA-1) UN 2912	B
RADIOACTIVE MATERIAL, SURFACE CONTAMINATED OBJECTS (SCO-1)	B
Rape seed, expelled	B or C
Rape seed, extracted	B or C
RASORITE (ANHYDROUS)	C
Rice bran	B or C
Rice broken	B or C
Rough ammonia tankage	B
RUTILE SAND	C
Safflower seed, expelled	B or C
Safflower seed, extracted	B or C
SALT	C
SALT CAKE	C
SALT ROCK	C
Saltpetre	B
SAND	C
Sand, ilmenite	C
Sand, zircon	C
SAWDUST	B
SCRAP METAL	C
SEED CAKE Type (a) UN 1386	B
SEED CAKE Type (b) UN 1386	B
SEED CAKE UN 2217	B
SEED CAKE (non-hazardous)	C
Seed expellers, oily	B or C
SILICOMANGANESE	B
SILVER LEAD CONCENTRATE	A

Silver lead ore concentrate	A
Sinter	
Slag, granulated	C
SLIG, iron ore	A
SODA ASH	C
SODIUM NITRATE UN 1498	B
SODIUM NITRATE AND POTASSIUM NITRATE MIXTURE UN 1499	B
Soyabean, expelled	B or C
Soyabean, extracted	B or C
STAINLESS STEEL GRINDING DUST	C
Steel swarf	B
Stibnite	C
STONE CHIPPINGS	C
Strussa pellets	B or C
SUGAR	C
SULPHATE OF POTASH AND MAGNESIUM	C
Sulphide concentrates	B
SULPHUR UN 1350	B
Sunflower seed, expelled	B or C
Sunflower seed, extracted	B or C
SUPERPHOSPHATE	C
SUPERPHOSPHATE (triple granular)	C
Swarf	B
TACONITE PELLETS	C
TALC	C
TANKAGE	B
Tankage fertilizer	B
TAPIOCA	C
Toasted meals	B or C
Triple superphosphate	C
UREA	C
VANADIUM ORE	B
VERMICULITE	C
WHITE QUARTZ	C
WOODCHIPS	B
WOOD PELLETS	B
WOOD PULP PELLETS	B
ZINC AND LEAD CALCINES	A
ZINC AND LEAD MIDDLINGS	A
ZINC ASHES UN 1435	B

ZINC CONCENTRATE	A
Zinc, dross, residue or skimmings	B
Zinc ore, burnt	A
Zinc ore, calamine	A
Zinc ore, concentrates	A
Zinc ore, crude	A
ZINC SINTER	A
ZINC SLUDGE	A
Zinc sulphide	A
Zinc sulphide (blende)	A
ZIRCON SAND	C

5.7 Appendix G. The introduction year of the solar PV and wind sources in the Feed-in-tariffs by countries

This is drawn from OECD statistics for FIT (OECD, 2020).

OECD	Country	FIT Source	Year of introduction
	Australia	Solar PV	2008
		Wind	non
	Austria	Solar PV	2000
		Wind	2000
	Belgium	Solar PV	non
		Wind	non
	Canada	Solar PV	2007
		Wind	2007
	Chile	Solar PV	non
		Wind	non
	Czech Republic	Solar PV	2002
		Wind	2002
	Denmark	Solar PV	2000
		Wind	2000
	Estonia	Solar PV	2003
		Wind	2003
	Finland	Solar PV	2011
		Wind	non
	France	Solar PV	2001
		Wind	2000
	Germany	Solar PV	2000
		Wind	2000
	Greece	Solar PV	2000
		Wind	2000
	Hungary	Solar PV	2011
		Wind	2011
	Iceland	Solar PV	non
		Wind	non
	Ireland	Solar PV	non
		Wind	2006
	Israel	Solar PV	2009
		Wind	2009
	Italy	Solar PV	2005
		Wind	2000
	Japan	Solar PV	2010
		Wind	2012
	Korea	Solar PV	2003
		Wind	2003
	Latvia	Solar PV	2009
		Wind	2009
	Lithuania	Solar PV	2013
		Wind	2013
	Luxembourg	Solar PV	2006

		Wind	2000
	Mexico	Solar PV	non
		Wind	non
	Netherlands	Solar PV	2003
		Wind	2003
	New Zealand	Solar PV	non
		Wind	non
	Norway	Solar PV	non
		Wind	non
	Poland	Solar PV	non
		Wind	non
	Portugal	Solar PV	2000
		Wind	2000
	Slovak Republic	Solar PV	2009
		Wind	2009
	Slovenia	Solar PV	2009
		Wind	2009
	Spain	Solar PV	2000
		Wind	2000
	Sweden	Solar PV	2000
		Wind	2000
	Switzerland	Solar PV	2005
		Wind	2005
	Türkiye	Solar PV	2006
		Wind	2006
	United Kingdom	Solar PV	2010
		Wind	2010
	United States	Solar PV	2006
		Wind	2006
Non-OECD	Albania	Solar PV	non
		Wind	2012
	Algeria	Solar PV	2004
		Wind	2004
	Argentina	Solar PV	2007
		Wind	2007
	Armenia	Solar PV	non
		Wind	2009
	Belarus	Solar PV	non
		Wind	2011
	Bosnia and Herzegovina	Solar PV	2011
		Wind	2011
	Brazil	Solar PV	2002
		Wind	2002
	Bulgaria	Solar PV	2007
		Wind	2007
	China (People's Republic of)	Solar PV	2011
		Wind	2006
	Croatia	Solar PV	2007
		Wind	2007
	Cyprus	Solar PV	2004
		Wind	2009
	Dominican Republic	Solar PV	2007
		Wind	2007

	Ecuador	Solar PV	2000
		Wind	2000
	Egypt	Solar PV	2014
		Wind	2014
	Ghana	Solar PV	2013
		Wind	2013
	India	Solar PV	2002
		Wind	2000
	Indonesia	Solar PV	2010
		Wind	2010
	Iran	Solar PV	2008
		Wind	2008
	Jordan	Solar PV	2012
		Wind	2012
	Kazakhstan	Solar PV	2013
		Wind	2013
	Kenya	Solar PV	2010
		Wind	2009
	Liechtenstein	Solar PV	non
		Wind	non
	Malaysia	Solar PV	2012
		Wind	non
	Malta	Solar PV	non
		Wind	non
	Mauritius	Solar PV	non
		Wind	non
	Moldova	Solar PV	non
		Wind	non
	Mongolia	Solar PV	non
		Wind	non
	Morocco	Solar PV	non
		Wind	non
	North Macedonia	Solar PV	2007
		Wind	2007
	Romania	Solar PV	non
		Wind	non
	Russia	Solar PV	non
		Wind	non
	Saudi Arabia	Solar PV	non
		Wind	non
	South Africa	Solar PV	2009
		Wind	non