Three Essays in International Macroeconomics: An Investigation of Macroeconomic Puzzles, International Trade and Financial Frictions

KARBE, SUSANNE,INGRID

Doctoral Thesis

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by **Susanne Karbe**

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Abstract

In this thesis I examine three aspects of international macroeconomics.

In the first chapter I re-examine four prominent puzzles in international macroeconomics in light of contemporary data, analysing whether the data patterns underlying these puzzles still exist today. As these data patterns are frequently used as validation mechanisms for models of international trade, this is important to ensure models yield output in line with up-to-date data. The key contributions of this chapter are as follows. First, I illustrate that greater awareness of the fact that stylised facts can change over time and differ across country groups is important. Second, to account for the heterogeneity of data patterns across country-groups, models need to include mechanisms that are appropriate for the countries that are being modelled.

The second chapter studies the role resource allocation plays for the dynamic response of labour productivity to various macroeconomic shocks in a DSGE model of international trade. Two main results emerge. First, capital introduces an element of persistence into the economy. Second, when firms can adjust their employment of labour and capital in response to macroeconomic shocks and enter and exit the domestic market endogenously, the response of labour productivity is driven by the interaction of resource allocation and endogenous selection into domestic production. This reverses the initial response of labour productivity to an aggregate technology shock and a trade shock relative to the model with only labour as a factor of production.

In the third chapter I examine the effect of financial frictions in a two-country DSGE model of international trade, finding that they amplify the response of the model economy to macroeconomic shocks. I then analyse the extent to which trade affects the amplification effect of financial frictions and find that international trade dampens their effect.

Declaration and Statement of Joint Work

I declare that this thesis is entirely my own work other than where I have clearly indicated that it is the work of others (in which case the extent of any work carried out jointly by me and any other person is clearly identified in it). This work has not been submitted for any other degree or qualification.

The material presented in Chapters 3, 4 and 5 of this thesis were written as collaborations with Dr Anamaria Nicolae and Professor Stephen Millard. I contributed approximately 90 percent of the work in Chapter 3, and 80 percent of the work in Chapters 4 and and 5.

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Contents

Chapter 1

Introduction

"The importance of international trade to economic prosperity is well documented and has been acknowledged for centuries. [...] Over time, openness to trade allows ideas and technologies to flow more freely and encourages innovation and productivity growth" (Nilsson *et al.* (2019)). This quote illustrates how relevant international trade is for economic well-being. Understanding the underlying drivers of international trade and of economic ties between countries is therefore of paramount importance. In this thesis I address three areas of international macroeconomics. In Chapter 3 I re-examine four prominent puzzles in international macroeconomics in the light of contemporary data, in Chapter 4 I analyse how resource allocation and international trade affect the dynamic response of labour productivity to a variety of macroeconomic shocks and in Chapter 5 I investigate the extent to which international trade affects the amplifying effect of financial frictions.

In Chapter 3 I address four prominent puzzles in international macroeconomics. Standard models of international trade were historically unable to match several data patterns that have widely been considered to be stylised facts. These are that the cross-country correlation of output exceeds the cross-country correlation of consumption; that output, consumption, investment and employment are positively correlated across countries; that the real exchange rate and relative consumption are negatively correlated; and that terms of trade are very volatile relative to output. Standard models of international trade predict different patterns, as they tend to yield a cross-country correlation of consumption that exceeds the cross-country correlation of output, negative correlations between investment and employment and sometimes output, a positive correlation between the real exchange rate and relative consumption, and a small volatility of the terms of trade. The inability of these models to match and therefore explain each of the four prominent stylised facts of international business cycles is referred to as a puzzle.

The data patterns underlying these four puzzles are frequently used as validation mechanisms for international trade models, and many papers attempt to build models that resolve the puzzles. However, the vast majority of this literature uses very US-focused and relatively old data. In Chapter 3 I re-examine the four prominent macroeconomic puzzles with recent data and examine whether the data patterns underlying them still exist today. More specifically, I address the following research question. Using recent data, do we still find that the cross-country correlation of output exceeds the cross-country correlation

of consumption, that output, consumption, investment and employment correlate positively across countries, that the real exchange rate and relative consumption are negatively correlated across countries, and that terms of trade are more volatile than output? The results are as follows. First, I find that the cross-country correlation of output exceeds the cross-country correlation of consumption for a much smaller percentage of country-pairs in recent data than in older data, as only 65% of the sample exhibit this ranking of the cross-country correlations of output and consumption. Furthermore, this pattern no longer holds for a majority of developed countries, whereas it still holds for a majority of developing countries. Second, terms of trade are less volatile than output in recent data for the majority of countries, especially in the European Union (EU). Third, the real exchange rate is still negatively correlated with relative consumption for a large majority of country-pairs that are not part of the European Monetary Union. For country-pairs that are part of the euro area (henceforth EA) this is not the case, as a small majority of these country-pairs has a real exchange rate that is positively correlated with their relative consumption. Fourth, positive co-movement among macroeconomic variables continues to persist in recent data and across many country-pairs.

In Chapter 4 I address the importance of resource allocation and endogenous entry into domestic production in an international trade model. I hereby contribute to the literature that shows: (1) international trade is important for the dynamic response of the economy to macreconomic shocks and (2) endogenous entry into domestic production has important implications for the business cycle. However, international trade models tend to abstract from endogenous entry into domestic production, and models that account for endogenous entry tend to abstract from international trade. The joint effect of these two characteristics is therefore not well understood. Furthermore, insofar as endogenous entry and international trade are combined in a unified framework, usually only one factor of production is considered. However, we also know that resource allocation can have important implications for the economy. In Chapter 4 I therefore address the following research question: How does resource allocation affect the transmission of macroeconomic shocks in an international trade model with endogenous entry into domestic production? To address this question I compare the response of my model with two factors of production to the response of the model of Millard *et al.* (2021) (henceforth MNN), which includes exactly the same features as my model except for physical capital and elastic labour supply. With this analysis I aim to examine whether abstracting from a second factor of production matters, and to what extent such an omission is relevant. This may have important implications for policy makers, as the analysis yields insight into how a variety of macroeconomic variables are affected by different macroeconomic shocks in the short-run and in the long-run when both resource reallocation and selection into domestic production are accounted for. The results are as follows. First, capital introduces an element of persistence into the economy, as the time it takes for the variables to return to their steady state levels increases. Second, when firms can adjust their employment of labour and capital in response to macroeconomic shocks and enter and exit the domestic market endogenously, the response of labour productivity is driven by the interaction of resource allocation and endogenous selection into domestic production. This reverses the initial response of labour productivity to an aggregate technology shock and a trade shock relative to MNN.

In Chapter 5 I study the implications international trade has for the well-known amplification effect of financial frictions. I hereby pay specific attention to the effect on labour productivity. This analysis is

motivated by three facts that arise from the literature: (1) international trade considerably increases aggregate productivity, (2) financial frictions have a significant impact on productivity, and (3) financial frictions affect international trade. However, while there is a vast amount of literature examining the impact of financial frictions on productivity, an equally vast amount of literature examining the impact of international trade on productivity, and an increasing amount of literature on the effect of financial frictions on international trade, the link from financial frictions to productivity through international trade remains to be understood. Indeed, to the best of my knowledge no paper examines how international trade affects the amplification effect of financial frictions. In Chapter 5 I therefore address the following research question. How and to what extent does international trade affect the amplification effect of the financial frictions? To address this question, I first replicate the well-known effect of financial frictions: financial frictions are shown to amplify the response of the economy to macroeconomic shocks in an open economy setting. In a second step I show that international trade dampens this amplification. This occurs because of a terms of trade and a competitive effect. In the case of a positive technology shock to the economy, the exchange rate depreciates, inducing a deterioration in the terms of trade. In the foreign economy, the improvement in the foreign terms of trade allows more firms to enter their export market, thereby increasing competition in the home market. Both the terms of trade and competitive effect decrease the profitability of home firms. Net worth and the level of borrowing therefore increase by less relative to the closed economy, which leads a dampened financial accelerator effect. In the case of a negative sunk entry cost shock and a positive preference shock the opposite applies: the terms of trade and competitive effect increase the profitability of home producers, causing net worth and thus the level of borrowing to fall by less relative to the closed economy. This dampens the financial accelerator effect in the open economy. These results show that models that abstract from international trade either overstate or understate the impact of financial frictions on labour productivity and the economy.

The thesis is structured as follows. In Chapter 2 I present a review of the literature of the three areas of international macroeconomics the subsequent chapters address. In Chapter 2.2 I present a review of the literature on macroeconomic puzzles, in Chapter 2.3 I present a review of the literature on international trade and in Chapter 2.4 I present a review of the literature on financial frictions. In Chapter 2.5 I summarise the literature review and the contributions of my research to the literature. In Chapter 3 I re-consider four prominent puzzles of international macroeconomics with contemporary data, analysing whether the patterns underlying these puzzles still exist today. In Chapter 4 I analyse how resource allocation and endogenous entry into domestic production affect the dynamic response of the economy and specifically labour productivity to a variety of macroeconomic shocks. In Chapter 5 I analyse the extent to which international trade affects the amplification effect of financial frictions. Chapter 6 concludes.

Chapter 2

Literature Review

2.1 Introduction

In this section I present a comprehensive review of the literature that studies international macroeconomic puzzles, international trade and financial frictions. To identify the gap in the literature for each of these strands of literature I first provide an overview of the seminal papers in the respective fields, before describing how the literature evolved. I then identify the gap in the literature and describe my contribution.

The section proceeds as follows. In Chapter 2.2 I will present a review of the literature on macroeconomic puzzles. In Section 2.2.1 I present a review of the literature in the field and in Section 2.2.2 I present an overview of the data this literature uses. I go into unusual depth in this section, as it is the data that is used and its limitations that motivates the analysis of the chapter on macroeconomic puzzles. In Section 2.3 I present a review of the literature on international trade. In Section 2.4 I present a review of the literature on financial frictions. Hereby Section 2.4.1 presents a very brief review of the literature on the importance of finance for economic development, Section 2.4.2 presents a review of the literature on financial frictions in general and Section 2.4.3 focuses on the literature that studies the effect of financial frictions on international trade. Section 2.5 concludes the literature review by providing a summary of the research questions.

2.2 Macroeconomic Puzzles

In this section I will present a review of the literature on puzzles in international macroeconomics. Macroeconomic models are frequently built to match certain moments in data. Moments in data that occur frequently and are documented extensively are referred to as stylised facts.[1] If the model in question matches such stylised facts, then there is a good case to argue that it explains certain aspects of the data well. If the model does not match the stylised facts, the case is less strong. Stylised facts are thus

[1] This term was originally coined by Kaldor (1961), who claimed that "the theorist, in my view, should be free to start off with a 'stylized' view of the facts - i.e. concentrate on broad tendencies, ignoring individual detail, (...) without necessarily committing himself on the historical accuracy, or sufficiency, of the facts or tendencies thus summarized." Kaldor (1961) defined 6 broad stylised facts on the process of economic change and development in his seminal work.

frequently used as a validation mechanism for economic models.

In the early 1990s, three seminal papers documented that standard international trade models have trouble matching certain stylised facts on a regular basis. Backus *et al.* (1992) showed that standard international trade models often yield a cross-country correlation of consumption that exceeds the cross-country correlation of output, while in data the opposite is true. Backus *et al.* (1993) confirm this finding and also show that the terms of trade are more volatile than output in data, while they are substantially less so in models. The paper's third finding is that in data, output, consumption, investment and employment are positively correlated across countries. Most international business cycle models, on the other hand, yield negative correlations of investment and employment, and sometimes of output. Backus and Smith (1993) found that in data, the real exchange rate is negatively correlated with relative consumption. This is contrary to standard theory, which predicts positive co-movement between the two variables.

The inability of standard international trade models to explain the documented data patterns is commonly referred to as puzzles. These puzzles have been referred to by slightly different terms in the literature. In this thesis they will be referred to as follows. The inability of models to match and therefore explain a cross-country correlation of output that exceeds the cross-country correlation of consumption is termed the Quantity Puzzle, and the inability of models to generate and therefore explain positive co-movement of output, consumption, investment and employment is called the Positive Co-movement Puzzle. The inability of standard models of international trade to explain the stylised fact that the real exchange rate is negatively correlated with relative consumption is termed the Backus-Smith Puzzle, after the two academics that first documented this empirical regularity. I will refer to the inability of models to match and therefore explain the large volatility of terms of trade as the Terms of Trade Puzzle.

2.2.1 The Literature

Since the seminal papers of Backus *et al.* (1992), Backus and Smith (1993) and Backus *et al.* (1993), which pointed out four major discrepancies between theory and empirical evidence, much literature has emerged seeking to explain one or several of the macroeconomic puzzles. I will first address the literature on the Quantity Puzzle, followed by the literature addressing the Positive Co-movement Puzzle, the Backus-Smith Puzzle, and the Terms of Trade Puzzle.

2.2.1.1 Quantity Puzzle

The Quantity Puzzle refers to the inability of standard models of international trade to explain the stylised fact that cross-country correlations of output are higher than cross-country correlations of consumption. This data pattern was first documented by Backus *et al.* (1992). Since this paper, literature has mainly investigated how or the extent to which international trade, asset market incompleteness, the type of shock that drives the business cycle, market expectations or financial frictions can explain the puzzle. Many of these papers do not succeed in changing the ranking of the cross-country correlation of consumption and output, but do reduce the size of the puzzle by yielding more similar values for the two correlations.

Backus *et al.* (1992) build a 2-country 1-good model with complete markets and access to international capital markets, and demonstrate how this model yields business cycle moments that deviate from data. They then introduce transport costs into their model to examine whether they resolve the Quantity Puzzle, finding that while they reduce the size of the difference between the cross-country correlation of output and consumption, they do not change their ranking. To examine the puzzle further the authors eliminate international borrowing. The results of this exercise are similar to those with trading frictions, which the authors argue means that the Quantity Puzzle is not simply the result of international risk sharing with complete markets.

In a similar fashion to Backus *et al.* (1992), Ghironi and Melitz (2005) also examine both trade in goods and trade in bonds as explanations for the Quantity Puzzle. Ghironi and Melitz (2005) build a 2-country DSGE model of international trade with monopolistic competition, heterogeneous firms, incomplete asset markets and fixed and variable costs of exporting. They generate this model's business cycle statistics and show that it reduces the Quantity Puzzle relative to the model of Backus *et al.* (1992). While the model does not yield a cross-country correlation of consumption that is lower than that of output, it does increase the output correlation, thereby reducing the size of the puzzle.

The argument that trade costs are important for the puzzle is further supported by Obstfeld and Rogoff (2001). They build a standard 2-country 2-good small country endowment model, and extend it by incorporating standard iceberg trade costs, meaning that τ percent of any good is paid as transport costs. They show that while the model does not necessarily generate cross-country correlations of consumption that are lower than those of output, trade costs do reduce consumption correlations, bringing the model closer to data. Eaton *et al.* (2016), who re-examine the puzzles of Obstfeld and Rogoff (2001) in a quantitative framework, confirm this finding.

Incomplete asset markets have also often been investigated as a potential solution to the Quantity Puzzle, as complete markets may allow a higher extent of risk pooling than incomplete markets. Thus Kollmann (1996) builds a 2-country RBC model in which international asset markets are incomplete in the sense that only risk-free bonds can be used in international transactions. The author shows that this model reduces the cross-country correlation of consumption. Kehoe and Perri (2002) include a friction in international credit markets in a standard 2-country business cycle model, namely that international loans are feasible only to the extent to which they can be enforced by the threat of exclusion from future intertemporal and interstate trade. Kehoe and Perri (2002) compare the business cycle statistics of this model to that of a complete markets model and a model in which only a single non-contignent bond can be traded, and find that the Quantity Puzzle is strongly reduced. In contrast to these two papers, Dmitriev and Roberts (2012) find that asset market incompleteness is not crucial to solve the puzzle, as they show that a model with complete asset markets is able to reduce the Quantity Puzzle as well. Time non-separable preferences are crucial for their result.

Xiao (2004) and McKnight and Povoledo (2017) build on the above papers, as they investigate the extent to which asset market incompleteness in combination with market expectations can resolve the Quantity Puzzle. Xiao (2004) builds a 2-country 1-good economy in which market expectations propagate through

financial markets, and finds that both asset market incompleteness and market expectations are important in resolving the Quantity Puzzle. McKnight and Povoledo (2017) disagree with this result. They build a 2-country 2-good model with incomplete asset markets and find that this model does not resolve the Quantity Puzzle when business cycle fluctuations are solely driven by self-fulfilling expectations. According to the authors, the difference in this result and the result of Xiao (2004) lies in the number of goods produced in the economy. When expectational errors are allowed to correlate with technology shocks, the model of McKnight and Povoledo (2017) is brought closer to data and the size of the Quantity Puzzle is reduced.

The two papers described above examine how models in which market expectations drive cyclical fluctuations can resolve the Quantity Puzzle. A number of papers analyse this issue from a different point of view, and investigate whether the size of the puzzle is affected by what shocks drive the business cycle. Stockman and Tesar (1995) build a 2-country model with a non-tradable and a tradable sector. When the authors include shocks to tastes in addition to technology shocks, the empirical fit of the model improves. The cross-country correlation of aggregate consumption remains higher than that of output, but the two values are more similar. Like Stockman and Tesar (1995), Wen (2002) include both technology and demand shocks in their model, which is a simplified version of the model of Backus *et al.* (1992), and show that this generates a cross-country correlation of output that exceeds that of consumption, thereby resolving the Quantity Puzzle. Jiang (2017) examines this result further by examining the extent to which a model driven solely by demand shocks resolves the Quantity Puzzle, finding that such a model succeeds in generating the correct ranking of the correlations of output and consumption. As a demand shock causes home agents to consume more of both the domestic good and the foreign good, imports of foreign goods increase under this shock. This raises foreign output as well as domestic output, thereby increasing international output co-movement.

While Stockman and Tesar (1995) and Jiang (2017) investigate the importance of demand shocks, Mandelman *et al.* (2011) and Gars and Olovsson (2017) investigate the importance of factor-specific technology shocks for resolving the puzzle. Mandelman *et al.* (2011) include investment-specific technology shocks in an otherwise standard international real business cycle model and show that these successfully resolve the Quantity Puzzle. Gars and Olovsson (2017) examine the extent to which oil-specific technology shocks and oil supply shocks matter for the Quantity Puzzle. To do this Gars and Olovsson (2017) build a model with two countries that use capital, labour and oil as inputs to produce a country-specific tradable intermediate good, and one country that extracts and sells oil. When they include a shock to the efficiency of oil and an oil supply shock, the Quantity Puzzle disappears. Crucial for this result is the factor-specificity of the productivity shock; when using standard productivity shocks the puzzle reappears.

A further factor that has been examined for the Quantity Puzzle is financial frictions. Thus Faia (2007) studies a unified model with differences in financial systems and exchange rate regimes, analysing the implications different variations of the framework have for international macroeconomic puzzles. To do this Faia (2007) builds a 2-country DSGE model with optimising agents, characterised by adjustments costs on prices, imperfect financial integration and different degrees of financial fragility. Financial frictions are modelled as an external finance premium paid by firms to obtain external finance, which is

affected by macroeconomic conditions. Faia (2007) finds that the model does not make much progress in addressing the Quantity Puzzle. In contrast, Yao (2019) argues that financial frictions reduce consumption correlations, thereby reducing the size of the Quantity Puzzle. To show this Yao (2019) builds a 2-country DSGE model with financial frictions, which are modelled as a collateral constraint on investors that are tied to the value of capital and real estate holdings. Yao (2019) argues the presence of the collateral constraint increases cross-country output correlations and decreases cross-country correlations of consumption, thereby bringing the model closer to data. This occurs because the collateral constraints lead to a more synchronised housing market, increasing output correlations. At the same time, they limit borrowing and make consumption smoothing more difficult, thereby lowering the consumption correlation. Iliopulos *et al.* (2021) agree that financial frictions matter for the Quantity Puzzle, but argue that adaptive learning in place of rational expectations is important in resolving the puzzle as well.

2.2.1.2 Positive Co-movement Puzzle

Many of the papers investigating the Quantity Puzzle also examine the Positive Co-movement Puzzle. I will only briefly refer to these papers here.

In Backus *et al.* (1992) the benchmark model yielded a negative correlation of output. The authors show that both with the introduction of trade costs and financial autarky the model succeeds in generating a positive correlation of output. Similarly, Ghironi and Melitz (2005) show that their model that includes transport costs succeeds in generating positive co-movement for both output and consumption. Backus *et al.* (1993) extend this analysis to investment and employment. In their model, the introduction of trade costs does not yield a positive output correlation; this positive output correlation is only yielded in their extreme experiment of autarky in finance and goods. Investment and employment correlations remain negative in all experiments, which suggests that trade costs do not explain the Positive Co-movement Puzzle.

Bhattarai and Kucheryavyy (2020) also argue that trade costs are not essential in resolving the Positive Co-movement Puzzle. The authors build a general competitive open economy business cycle model with capital accumulation, trade in intermediate goods, production externalities in intermediate and final good sectors and iceberg trade costs. They also build dynamic versions of three workhorse quantitative models of trade, showing that their model is isomorphic to these models in terms of general equilibrium predictions. In their quantitative exercise Bhattarai and Kucheryavyy (2020) assess whether the various models they use are able to resolve well-known empirical puzzles, relative to a standard open business cycle model without any externalities. They show that the models are not able to resolve the Positive Co-movement Puzzle. Bhattarai and Kucheryavyy (2020) then illustrate that their model leads to higher cross-country output, investment, and employment correlations and a lower consumption correlation relative to a standard international real business cycle model. Vital for their result of bringing the model closer to data are negative capital externalities in intermediate good production.

As with the Quantity Puzzle, asset market incompleteness has been suggested as a solution for the Positive Co-movement Puzzle. Heathcote and Perri (2002) build a 2-country, 2-good economy and analyse

three variants of the model: the model with complete asset markets, the model with incomplete markets and the model under financial autarky. They show that the model under financial autarky yields the strongest positive co-movement among all four variables. Like Heathcote and Perri (2002), Kehoe and Perri (2002) compare the business cycle statistics of three alternative models. However, the third model does not feature financial autarky but includes frictions in international credit markets. In their model, co-movement of output, investment and employment is negative in both the complete and incomplete markets model, whereas all three correlations are positive in a model with frictions in international credit markets.

Financial frictions are further addressed as a potential avenue for solving the puzzle in a number of papers. For example, De Walque *et al.* (2017) develop a 2-country new Keynesian model with sticky local currency pricing, distribution costs and demand elasticity increasing with relative price, and anaylse its business cycle statistics. They show that their model's match with data improves when risk premium shocks are enabled, and argue that this suggests internationally linked financial sectors may be an interesting avenue for further research into this puzzle. Indeed, Yao (2019) argues that the presence of a collateral constraint is crucial for bringing the model closer to data in this respect.

Faia (2007) also investigates this avenue, and illustrates that both the extent of financial integration and the monetary regime are important in addressing the Positive Co-movement Puzzle. As shown above, Faia (2007) builds a framework in which she can address both financial integration and monetary regimes. She finds that smaller financial diversity increases cross-country correlations for a given monetary regime, and that moving from independent monetary policies to more coordinated monetary policies increases cross-country correlations, for any given degree of financial diversity. Financial diversity is proxied by the premium firms pay on external finance. Faia (2007) thus shows that both similarity in financial frictions and monetary policies are important in generating international positive co-movement among macroeconomic variables.

In a different manner, Kollmann (2001) argues that co-movement can be generated with nominal ridigities. To show this they build a 2-country DSGE model with sticky prices and nominal prices and assume a flexible exchange rate as well as shifts in productivity and money supply. Price stickiness is implemented following the Calvo price-setting mechanism. The authors argue that a model with nominal rigidities generates a higher effect on real variables, which creates stronger co-movement among output and investment. Crucially, both rigidities in prices and wages are required to generate high co-movement.

As with the Quantity Puzzle, some papers also argue that the way shocks are modelled is important in addressing the discrepancies between data and theory. Thus Wen (2002) and Jiang (2017) argue demand shocks yield positive co-movement among macroeconomic variables, while Gars and Olovsson (2017) show that accounting for oil shocks is important for resolving the Positive Co-movement Puzzle.

Further literature investigates the role production structure plays in creating international co-movement. Thus Bergholt (2015) develops a standard 2-country New-Keynesian model with an international market for firm-to-firm trade in production inputs. According to the author, with firm-to-firm trade a terms of

trade appreciation shifts the markup of importing firms in the same direction as foreign mark-ups, which reinforces the income effect and results in stronger propagation of foreign shocks to tradable industries. This result that trade between firms is important for creating more co-movement among macroeconomic variables is echoed by Huang and Liu (2007). Huang and Liu (2007) show that accounting for trade among intermediate inputs and multi-stage processing is crucial for generating positive co-movement in response to a monetary expansion. Huang and Liu (2007) extend an open economy model by incorporating trade in intermediate inputs and multiple stages of processing, and assume that commodity prices are set in buyer's local currency and pricing decisions are staggered. In this set-up, both staggered pricing and international trade in intermediate goods across multiple stages are essential for the model's empirical success. The authors explain that conventionally, a monetary expansion has two channels: the demand externality, which causes demand to increase in both countries, and the terms of trade externality, which by means of a currency depreciation changes the terms of trade in favour of one country against the other. The latter externality tends to offset aggregate demand effects, as it hurts foreign country's purchasing power. Huang and Liu (2007) argue that the staggered price setting during multi-stage processing increases the demand externality and attenuates the terms of trade externality, thereby increasing co-movement. Since multiple border crossings of intermediate goods and staggered prices progressively dampen the movements in marginal costs and incentives for firms to change prices, they lead to gradual adjustments in price levels and large and persistent responses of real variables in both countries.

Wong and Eng (2013) agree that vertical specialisation is vital in generating positive co-movement. They show this by including three processing stages to allow for back-and-forth trade in intermediate goods in a 2-country New-Keynesian model.

2.2.1.3 Backus-Smith Puzzle

The third puzzle I address in this thesis is the Backus-Smith Puzzle. In 1993, Backus and Smith argued that under perfect purchasing parity, one would assume that the real exchange rate of two countries is correlated with their relative consumption. This occurs due to the following mechanism, where $Q_t = \frac{\epsilon_t P_t^*}{P_t}$ is the real exchange rate at time t, C_t is domestic consumption at time t and C_t^* is foreign consumption at time t. ϵ_t is the nominal exchange rate, P_t the price level at home and P_t^* the price level in the foreign country. The comparison of the real exchange rate and relative consumption is given by:

$$Q_t; \frac{C_t}{C_t^*}.$$

In response to a productivity shock, domestic goods become cheaper to produce. As home goods now cost less, they are worth less, and the exchange rate depreciates. Q_t therefore increases. At the same time, the fact that prices decrease mean that domestic consumption, C_t, rises. As both the real exchange rate and home consumption increase, the real exchange rate and relative consumption are positively correlated. Indeed, Backus and Smith (1993) argue that this correlation is expected to be unity. However, the paper also found that data does not correspond to this theory, as the real exchange rate and relative consumption are negatively correlated or not correlated.

The Backus-Smith Puzzle has attracted much attention in the literature. For example, Obstfeld and

Rogoff (2001) consider the Backus-Smith Puzzle in their paper. While they do not formalise their argument, they claim that asset market incompleteness is the major reason for why the correlation of the real exchange rate and relative consumption is so low. They argue that given the volatility of nominal exchange rates, making these variables almost perfectly correlated would require a level of risk sharing that is greater than the one we see even in domestic markets.

The possibility of asset market incompleteness as a potential solution to the Backus-Smith Puzzle is examined in more detail by Corsetti *et al.* (2008) and Benigno and Thoenissen (2008). Benigno and Thoenissen (2008) argue that limited international asset trade combined with a non-traded goods sector is important in addressing the puzzle, as shifts in the prices of non-tradable goods contribute to generating a negative correlation between the real exchange rate and relative consumption. Corsetti *et al.* (2008) build a 2-country 2-good model similar to that of Stockman and Tesar (1995), but with incomplete asset markets and the introduction of distribution services produced with the intensive use of local inputs, which leads to a low price elasticity of tradable goods. In this model, the predicted correlation between the real exchange rate and relative consumption is negative. Low price elasticity is vital for this result as it leads to a positive terms of trade response to a productivity shock, which reduces relative wealth and consumption abroad. Relative consumption therefore increases while the real exchange rate appreciates, yielding a negative correlation.

Raffo (2010) claims that such a negative correlation can be achieved through investment specific technology shocks. To show this Raffo (2010) modifies the model of Backus *et al.* (1992) by introducing variable capital utilisation. Raffo (2010) argues that investment-specific technology shocks work in a similar way to demand shocks, as they increase domestic production, domestic prices and imports from abroad. This leads to an appreciation of the terms of trade, which in turn leads to an appreciation of the real exchange rate, yielding a negative correlation between the exchange rate and relative consumption. Like Raffo (2010) suggests, Jiang (2017) argues that the puzzle can be resolved by using demand shocks. In this model, home bias ensures that home consumption increases by more than foreign consumption, increasing relative consumption. At the same time, the foreign price level decreases by more than the home price level, causing the exchange rate to appreciate.

Itskhoki and Mukhin (2021) argue that instead of supply shocks, it is financial shocks in presence of home bias that can explain the Backus Smith Puzzle. The authors build on a standard international real business cycle model with home bias in consumption and imperfect financial markets. They show that when depreciations are mainly driven by financial rather than supply shocks, the model yields a negative correlation between the real exchange rate and relative consumption ratio. This is because a financial shock that increases demand for foreign currency assets leads households to delay their consumption, requiring a currency depreciation to shift global expenditure towards these goods.

In contrast to the above three papers, Lambrias (2020) argues that it is not the type of shock that matters for the Backus-Smith Puzzle, but whether the shock is anticipated or not. This paper develops a 2-country, complete-market model with tradable and non-tradable goods, imperfect substitutability of capital across the tradable and non-tradable sectors, and news shocks. The imperfect substitutability of

capital across sectors increases the Harold-Balassa-Samuelson effect, which in turn decreases the correlation between the real exchange rate and relative consumptions. If innovations are unanticipated, agents' expectations change without a corresponding change in economic fundamentals. This renders the correlation between the real exchange rate and relative consumption negative, resolving the Backus-Smith Puzzle.

While the above papers yield the negative correlation between the real exchange rate and relative consumption that is observed in data, other papers that investigate the puzzle fail to generate this correlation. Chari *et al.* (2002) examine the importance of sticky prices for the puzzle and McKnight and Povoledo (2017) investigate whether indeterminacy and self-fulfilling expectations can solve the puzzle. Both papers find that their avenues do not solve the Backus-Smith Puzzle. McKnight and Povoledo (2017) do manage to generate a negative correlation between the real exchange rate and relative consumption in their model with market expectations, but only when they use strong negative cross-country correlations for technology shocks. When they use shock correlations that are supported by data, the Backus-Smith Puzzle remains, meaning self-fulfilling expectations themselves cannot resolve the puzzle.

2.2.1.4 Terms of Trade Puzzle

The fourth puzzle addressed in this thesis is the Terms of Trade Puzzle. Stockman and Tesar (1995) show that including demand shocks increases the variability of the terms of trade, while Raffo (2010) illustrates that the same result can be achieved by including investment-specific technology shocks. Heathcote and Perri (2002) argue that financial autarky is necessary to generate high terms of trade volatility, Corsetti *et al.* (2008) show that a low price elasticity of demand for tradable goods motivated by distribution services generate a high terms of trade volatility and McKnight and Povoledo (2017) show that accounting for self-fulfilling expectations explain the puzzle.[2]

2.2.2 The Data used in the Literature

I next present and evaluate the data used in the literature to analyse the four puzzles of international macroeconomics addressed in this thesis. As explained previously, for my purposes it is important to describe the data used in detail.

The vast majority of literature that studies puzzles in international macroeconomics uses US data. This is probably due to a mix of reasons that includes data availability, consistency with the literature and publishability. To address the Quantity Puzzle and the Positive Co-movement Puzzle, papers usually calculate the correlation of a given US variable with the same variable from a different country, or construct a foreign aggregate and calculate the correlation of a given US variable with the same variable of that constructed aggregate. Some papers do both. To address the Backus-Smith Puzzle, most papers either consider the exchange rate and relative consumption of the US and a foreign aggregate or of the US and an individual foreign country. To address the Terms of Trade Puzzle, the vast majority of papers

[2] As all papers in this paragraph have been mentioned in a previous section of the literature review, I did not go into detail in describing them.

consider the volatility of the terms of trade of the US.

Below I describe the data used in different papers in the literature. Hereby I describe both the data period that was used as well the countries that were considered. If a foreign aggregate was used as the foreign country, I describe the composition of this aggregate.

- Backus *et al.* (1992) consider the US and a variety of individual countries, as well as a European aggregate. The individual countries are: Australia, Austria, Canada, Finland, France, Germany, Italy, Japan, South Africa, Switzerland and the UK. The aggregate is composed of Austria, Finland, France, Germany, Italy, Switzerland and the UK. The data period for the international correlations covers 1970Q1-1986Q4.

- Backus *et al.* (1993) also consider the US and a variety of individual countries as well as a European aggregate to calculate international correlations. The individual countries are Australia, Austria, Canada, France, Germany, Italy, Japan, Switzerland and the UK. The European aggregate is constructed by the OECD. The data used is from 1970 - mid 1990.

- Backus and Smith (1993) use quarterly data for 8 OECD countries from 1971-1990 to examine the Backus-Smith Puzzle. These are Australia, Canada, France, West Germany, Japan, Sweden, the UK and the US.

- Stockman and Tesar (1995) use annual data for Canada, France, Germany, Italy, Japan, the United Kingdom, and the United States. The paper computes the output and consumption correlations of individual country-pairs. However, it uses different country-pairs for the computation of the cross-country correlations of output than for the cross-country correlations of consumption; the only overlapping-pairs are US-Canada, US-Japan and Canada-Japan. The data period is 1970-1984.

- Kollmann (1996) uses an aggregate of the G7 countries. The international correlations he reports are the average of the correlations of all country-pairs. The data used covers 1973Q1 - 1994Q3.

- Kollmann (2001) uses G7 data. To calculate international correlations he uses the US and the aggregated G6 excluding the US, using 1980 GDP shares in total G6 GDP. The G6 are composed of Japan, Canada, Germany, France, Italy and the UK, and the data period covers 1970Q1 - 1991Q3.

- Chari *et al.* (2002) use data from 1973Q1-1994Q4 for the US and a European aggregate composed of France, Germany, Italy and the UK.

- Kehoe and Perri (2002) also use the US and an aggregate RoW composed of the EU15 for their international correlations.[3] The data used covers 1970Q1-1998Q4.

- Heathcote and Perri (2002) calculate international correlations between the US and an aggregate RoW that is composed of the EU15, Japan and Canada. Their data period covers 1973Q1-1998Q4.

- Ambler *et al.* (2004) use quarterly data from 1960Q1-2000Q4 for 20 different industrialised countries.

[3] the EU15 include Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden and the UK

– Faia (2007) uses data for the following country-pairs: Germany-France, Germany-Italy, Germany-Spain, Germany-UK and Germany-US. The paper uses data for the period 1971-1996 and 1997-2004.

– Benigno and Thoenissen (2008) use data for the US and a weighted aggregate of the EU15 and Japan, using annual data for 1970-2000 from the Penn World Tables.

– Corsetti *et al.* (2008) compute the international correlations of a number of individual countries vis-á-vis a trade-weighted RoW that is formed of those individual countries. These are Austria, Belgium/Luxembourg, Canada, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, Netherlands, Portugal, Spain, Sweden, the UK and the US. Their data is annual and covers 1970-2001.

– Raffo (2010) use data for the US and an aggregate composed of theEU 15, Canada and Japan. The data is for the period 1970Q1-2007Q3.

– Mandelman *et al.* (2011) use an aggregate of the euro area 15 countries, Canada, the UK, Japan, South Korea and Australia, using data covering 1973Q4 - 2006Q4.

– Rabanal *et al.* (2011) study the US and an RoW aggregate composed of 15 countries from the euro area, the UK, Canada, Japan, and Australia. The data covers 1973Q1-2006Q4.

– Dmitriev and Roberts (2012) use data for the US and a European aggregate composed of the EU15. Their data covers 1970Q1-2008Q2.

–[Wong and Eng (2013) use an aggregate of 4 South East Asian economies, namely Malaysia, Indonesia, the Philippines and Thailand, and an aggregate of 5 East Asian economies, namely Japan, Hong Kong, Korea, Taiwan and Singapore. The data is quarterly and spans 1987Q1-2008Q4.

– Gao *et al.* (2014) use data from 1973Q1-2007Q4 for the US and an aggregate RoW composed of 19 European countries, [4], Japan and Canada.

– Bergholt (2015) use quarterly data from 1982Q4 - 2007Q4 from Canada and the US.

– De Walque *et al.* (2017) use data from 1970Q2 to 2014Q4 from the US and the EA.

– Gars and Olovsson (2017) use quarterly data from 1980Q1-2016Q4 for the US and 15 OECD countries.

– Jiang (2017) use annual data from 1950-2010 for the G7 and the US.

– Yao (2019) use quarterly data from 1972Q1-2008Q4 for the US and an RoW aggregate consisting of Canada, Japan and 19 European countries.

– Lambrias (2020) uses annual data for the US and the EU15 that covers 1970-2007.

– Iliopulos *et al.* (2021) use quarterly EA and US data from 1973Q1 - 2014Q4.

[4]These are Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden, the United Kingdom, Iceland, Luxembourg, Switzerland and Turkey,

– Itskhoki and Mukhin (2021) use quarterly data for the United States relative to the PPP-weighted sum of France, Germany, Italy, and the United Kingdom. The authors use two data periods, namely 1973–94 and 1973-2017.

The above description of the data shows that the vast majority of the literature studies the international business cycle statistics of the US vis-á-vis a foreign country or foreign aggregate, which most frequently is a European or OECD aggregate. The data period covers ranges from 1970 - 2016. In the majority of cases, the data covers years in the 1970s and the 1990s. The more recent papers use data that extends until the mid 2000s (these papers include Gao *et al.* (2014), Dmitriev and Roberts (2012), Lambrias (2020), Mandelman *et al.* (2011), Rabanal *et al.* (2011)) or sometimes even mid 2010s (these papers include Gars and Olovsson (2017), De Walque *et al.* (2017) and Iliopulos *et al.* (2021)).

All papers above address one or more of the four macroeconomic puzzles. Tables 2.1 and 2.2 selected some papers to illustrate the puzzles once again, in numeric form. The tables describe the data moments the papers compute, as well as the data moments yielded by the standard theoretical models they employ.

The vast majority of the literature shows that in data, either for a foreign aggregate or an individual country vis-á-vis the US, there is positive co-movement for output, consumption, investment and employment.

Regarding the Quantity Puzzle, when a foreign aggregate and the US are considered, the cross-country correlation of output always exceeds that of consumption in the literature. When individual countries are considered vis-á-vis the US, this is the case in the vast majority of cases the literature considers. Few papers investigate countries vis-a-vis a country that is not the US. Of the papers that do, Ambler *et al.* (2004) is the paper that uses the largest number of country-pairs, examining 190 cross-country observations.This paper argues that among the 190 observations, there was not a single exception to cross-country output correlation exceeding cross-country consumption correlation. Thus, for 100% of their country-pairs that did not include the US, the pattern underlying the Quantity Puzzle held. The same can be said for a number of different countries vis-a-vis Germany: for the 4 country-pairs studied by Faia (2007), this data pattern holds in both periods the paper considers. The data pattern does not hold in Stockman and Tesar (1995), who show the cross-country correlation of consumption exceeds that of output for Canada-Japan. Wong and Eng (2013) take a different approach altogether. Instead of looking at cross-country correlations, they look at cross-regional correlations in East and South East Asia. For this, they calculate the business cycle statistics for an aggregate of South East Asian economies and an aggregate of East Asian economies. For these two regions, the authors find that the cross-country correlation of consumption exceeds the cross-country correlation of output. Both country-pairs that do not include the US for which the data pattern underlying the Quantity Puzzle does not hold include an Asian country. This raises the question of whether the data pattern underlying the Quantity Puzzle depends on certain country characteristics.

The very vast majority of papers that addresses the Backus-Smith Puzzle finds the real exchange rate is negatively correlated with relative consumption. Similarly, for the Terms of Trade Puzzle the vast majority of the literature finds that terms of trade are more volatile than output for the countries or

Table 2.1: International Correlations in the Literature

Paper	*Output Correlations*	*Consumption Correlations*	*Investment Correlations*	*Employment Correlations*	*Correlation Q & Relative C*
BKK 1992 Data	0.70	0.46			
BKK 1992 Theory	-0.18	0.88			
BKK 1993 Data	0.66	0.51	0.53	0.33	
BKK 1993 Theory	-0.21	0.88	-0.94	-0.78	
KP 2002 Data	0.51	0.32	0.29	0.43	
KP 2002 Theory	-0.46	0.28	-0.99	-0.53	
HP 2002 Data	0.58	0.36	0.3	0.42	
HP 2002 Theory	0.18	0.65	0.29	0.14	
Chari 2002 Data	0.60	0.38	0.33	0.39	-0.35
Chari 2002 Theory	0.49	0.49	0.49	0.49	1.0
Cor 2008 Data	0.68	0.6	0.25	0.54	-0.71
Cor 2008 Theory	0.39	0.37	0.45	0.49	0.98
DR 2012 Data	0.56	0.46	0.43	0.31	
DR 2012 Theory	0.01	0.9	-0.21	-0.49	
Jiang (2017) Data	0.58	0.38	0.49	0.52	-0.27
Jiang (2017)Theory	-0.10	0.98	-0.64	-0.99	0.74
Gars 2017 Data	0.4	0.23	0.27	0.6	
Gars 2017 Theory	-0.01	0.63	-0.44	-0.52	
Lam 2020 Data	0.53	0.46	0.32	0.47	-0.2
Lam 2020 Theory	0.16	0.48	-0.05	0.15	0.22
Itsh 2021 Data	0.35	0.3			-0.4
Itsh 2021 Theory	0.35	0.4			1.0

[1] Due to space reasons, I used abbreviations.
Q is the real exchange rate and C is consumption,
BKK 1992 is Backus *et al.* (1992),
BKK 1993 is Backus *et al.* (1993),
HP 2002 is Heathcote and Perri (2002),
KP 2002 is Kehoe and Perri (2002),
Chari 2002 is Chari *et al.* (2002),
Cor2008 is Corsetti *et al.* (2008) ,
DR 2012 is Dmitriev and Roberts (2012),
Gars 2017 is Gars and Olovsson (2017),
Lam 2020 is Lambrias (2020),
Itsh 2021 Itskhoki and Mukhin (2021).

Table 2.2: Terms of Trade Volatility in the Literature

Country	*BKK 1993 Data*	*BKK 1993 Theory*	*ST 1995 Data*	*ST 1995 Theory*	*HP 2002 Data*	*HP 2002 Theory*	*Raffo 2010 Data*	*Raffo 2010 Theory*
Australia	3.99	0.48					2.76	1.3
Austria	1.35	0.48						
Belgium							1.24	1.3
Canada	1.99	0.48	1.18	0.79			1.32	1.3
Finland							1.09	1.3
France	3.91	0.48					2.04	1.3
Germany	1.76	0.48					2.39	1.3
Italy	2.07	0.48	2.92	0.79			3.10	1.3
Japan	5.36	0.48					4.02	1.3
Netherlands							0.93	1.3
New Zealand							1.64	1.3
Portugal							1.84	1.3
Spain							3.54	1.3
Sweden							1.27	1.3
Switzerland	1.48	0.48						
UK	1.05	0.48					1.35	1.3
US	1.92	0.48	2.30	0.79	1.79	0.78	1.72	1.3

[1] Due to space reasons, I abbreviated the papers.
BKK 1993 is Backus *et al.* (1993),
ST 1995 is Stockman and Tesar (1995),
HP 2002 is Heathcote and Perri (2002),
Raffo 2010 is Raffo (2010).

aggregates considered. Even when terms of trade are less volatile than output, they are only very slightly less volatile.

2.2.3 The Gap in the Literature

Since the seminal papers of Backus *et al.* (1992), Backus and Smith (1993) and Backus *et al.* (1993), much literature has attempted to address puzzles in international macroeconomics. The vast majority of the papers illustrate that in data: (1) the cross-country correlation of output exceeds the cross-country correlation of consumption, (2) there is positive international co-movement for output, consumption, investment and employment, (3) the real exchange rate and relative consumptions are negatively correlated, and (4) terms of trade exhibit a volatility that is larger than that of output.

However, the data used to draw these conclusions has two major drawbacks. The first drawback is that it is very US-centered. Indeed, only very few papers consider country-pairs that do not include the US at all. Intuitively, however, in order to consider patterns found in data to be robust stylised facts, they should hold across a large number of country-pairs. The second drawback of the data used in the literature is that it does not tend to include very recent data. Among the more recent papers, some papers simply employ data from older papers, while others only use data up to the early 2000s. There are also papers that include more recent data. However, to the best of my knowledge for such papers the data period also starts in 1970 or 1980. If data patterns changed between the late 1900s and early 2000s, such data samples would not necessarily be able to show said change.

These data limitations raise two questions. Firstly, do the observed patterns persist when using country-pairs that do not include the US? Secondly, does the increasing globalisation in recent decades have any repercussions for the existence or size of the puzzles? These questions are important, as they may have significant implications for the literature. From a policy-making perspective, it is important to know whether the stylised facts apply only to the US, or whether they hold more generally. For the literature, it is important to know whether the stylised facts that underlie and give rise to the puzzles still exist in the data today. Insofar as they do not, they no longer serve as a validation mechanism for economic models.

In order to address the questions formulated above I will use more recent data to analyse whether the four prominent macroeconomic puzzles described in this section still exist. In other words, I examine whether the stylised facts that have been addressed in the literature still persist today. Concretely I will:

1. Provide evidence for the data patterns underlying the puzzles in the data period most frequently used in the literature.

2. Provide an analysis of the international correlations for a large number of country-pairs using recent data.

3. Provide an analysis of the international business cycle statistics for a large number of individual countries vis-à-vis the US using recent data.

The first exercise will ensure that my results for recent data are not driven by my choice of database. The second analysis enables me to examine whether the data still deviates from the predictions of standard international trade models, and therefore whether the puzzles I address in this chapter still exist. The third analysis allows me to determine whether the prevalence of the data patterns underlying the puzzles depends on whether the US is included in the sample. As the literature addressing the macroeconomic puzzles is very US-focused, this allows me to place my findings in the context of the literature and determine whether a US-focused approach overstates the prevalence of the data patterns underlying the macroeconomic puzzles.[5]

I therefore contribute to the literature by examining whether the data patterns that have been documented extensively in literature and underlie the macroeconomic puzzles I consider in this thesis: (1) hold more generally also for country-pairs that do not include the US and (2) still hold in recent data.

These contributions matter, because stylised facts are often used as a validation mechanism for macroeconomic models. This makes sense, as we want our models to explain what actually happens in the real economy. However, if stylised facts no longer exist in recent data, then they are no longer useful as a validation mechanism, and building models to explain the puzzles they gave rise to is redundant. Furthermore, if the likelihood that data pattern holds depends on certain country characteristics, awareness of this heterogeneity in the occurence of data patterns is important, and models should be built that can account for this heterogeneity.

2.3 International Trade

In this part of the literature review I will present a review of the vast literature investigating the relationship between international trade and productivity.

In order to present this review I proceed as follows. Section 2.3.1 presents a brief overview of the development of the literature on international trade theory from its inception. In Section 2.3.2 I will then present a review of the empirical literature on the relationship between international trade and productivity and in Section 2.3.3 I proceed to consider theoretical models in the literature. Hereby I will present a review of literature that builds direct extensions of the most prominent model of new trade theory in Section 2.3.3.1, a review of theoretical literature that attempts to account for certain empirical patterns in Section 2.3.3.2, a review of literature analysing implications of the new trade models in Section 2.3.3.3 and a review of literature analysing transition dynamics in Section 2.3.3.4. In Section 2.3.3.5 I present a review of the literature that investigates the importance of endogenous entry into domestic production in international trade models, which leads me to identify the gap in the literature in Section 2.3.4.

[5] When I refer to prevalence or prominence in this chapter I refer to the proportion of country-pairs for which a data pattern holds.

2.3.1 Overview of the Development of International Trade Theory

International Trade Theory can be traced back to Adam Smith's 1776 *Wealth of Nations* and David Ricardo's 1817 *On the Principles of Political Economy and Taxation.* Adam Smith formulated the concept of absolute advantage, arguing that some countries can produce certain commodities more cheaply than other countries. According to Smith (1776), by specialising in the production of the good in which they have an absolute advantage, both countries maximise the consumption of both the goods they import and the goods they export.

A few decades after Smith's formulation of the concept of absolute advantage, David Ricardo argued that it would not only be advantageous for a country to trade with a different country if it could produce a commodity at a lower cost, but also if it could produce both commodities more cheaply at home. According to Ricardo (1951), what matters for an incentive to trade is not absolute advantage, so the ability to produce a commodity more cheaply in absolute terms, but relative advantage, the ability to produce a commodity more cheaply in relation to a different commodity than the foreign country.

While Ricardo showed that a country will always gain from trade if it has a comparative advantage in the production of a certain good, his theory did not explain where that comparative advantage comes from. This explanation is provided by the Heckscher-Ohlin trade theory, which claims that which commodity a country exports depends on which factor of production it has in abundance. Every country has more or less of a certain factor of production than other countries, and the commodity requiring more of the abundant factor of production is the commodity in whose production that country has a comparative advantage. The resulting trade will lead to an equalisation in the relative prices of commodities, as well as in the equalisation of factor prices (Samuelson (1948)).

The trade theories just presented all explain inter-industry trade, or trade in different types of goods. However, they provide no insights into intra-industry trade. For this reason, new trade models were developed in the 1980s that could account for the existence of intra-industry trade. These new theories fall under what is termed "new trade theory". [6] A pioneering paper in this new trade theory is Krugman (1980), which develops an international trade model in which trade is caused by economies of scale. In this model, labour is the only one factor of production, and there is full employment and monopolistic competition. Each firm produces a differentiated good and consumers have heterogeneous preferences. In response to opening to trade, the market size increases, which allows for the exploitation of economies of scale. There is thus an increase in the scale of production, which increases real wages and the range of goods available for consumption. In this model, welfare is therefore increased via higher real wages and a greater product variety.

A further development of international trade literature took place in the early 21st century to take into account the empirical finding that firms within the same industry exhibit very large productivity differences that are correlated with the firms' export status. In a seminal paper, Melitz (2003) incorporates firm heterogeneity into an international trade model with monopolistic competition, increasing returns

[6] For an overview of this literature, see Bernard *et al.* (2007).

to scale and sunk entry costs. In this model, firms face an initial uncertainty over their productivity. Upon entry, for which they pay a sunk cost, firms draw their productivity from a common productivity distribution. Melitz (2003) shows that exposure to trade in this setting induces only the more productive firms to export due to the presence of fixed export costs: only firms with productivity above a certain threshold level will export as they are the only ones that can afford to pay per-period fixed exporting costs. These more productive firms will increase their scale of production, increasing wages and forcing the least productive firms to exit the export market, which further re-allocates market towards the most productive firms. Melitz (2003) shows that this re-allocative process results in an increase in aggregate productivity.

Like Melitz (2003), Bernard *et al.* (2003) develop a model to account for the fact that only some firms trade and that exporters tend to be more productive and larger. In order to do this, they develop a Ricardian trade model of heterogeneous firms, imperfect competition and differentiated goods. Because of export costs, only firms with higher-than-average productivity export. In order to ascertain the impact of trade on productivity, Bernard *et al.* (2003) run a counterfactual exercise in which they simulate a 5% worldwide decline in geographic trade barriers that leads to a 15% increase in world trade, finding that this increases US manufacturing productivity by 4.7%. According to Bernard *et al.* (2003), the main factor behind this increase are productivity gains within plants driven by a decline in the price of intermediate inputs, as cheaper inputs from abroad replace domestic inputs. A further channel is the reallocation of production, as over 3% of lower-than average productivity firms exit the market and high productivity plants expand.

2.3.2 Empirical Literature on International Trade and Productivity

At the same time this theoretical literature emerged, a vast amount of literature investigated the relationship between international trade and productivity empirically, especially between exporting and productivity. This literature was pioneered by Bernard *et al.* (1995) and Bernard and Jensen (1999), who first showed that exporters tend to be larger firms, pay higher wages and be more productive. This finding that exporting firms, or trading firms more largely, are generally larger and more productive than non-trading firms was reproduced in much subsequent work (see for example Castellani (2002) Helmpan *et al.* (2004), Andersson *et al.* (2008), Melitz and Trefler (2012), Wales *et al.* (2018)).

Two broad hypotheses are brought forward in the literature to explain this finding. The first explanation is the self-selection hypothesis, embodied in the majority of the theoretical literature on this topic, such as Melitz (2003) and Bernard *et al.* (2003). This hypothesis maintains that sunk entry or fixed exporting costs ensure that only larger and more productive firms enter the export market, as these are the only firms that find it profitable to pay the sunk entry or fixed cost. More productive firms thus self-select into the export market, increasing their market shares and inducing resource and profit reallocations toward the most profitable firms, thereby increasing aggregate productivity. An alternative, though not mutually exclusive, hypothesis is that exporting has an effect on firm-level productivity: exporting itself has beneficial effects on firm performance. This could happen through a variety of mechanisms: by increasing market size and enabling the exploitation of economies of scale, by creating access to new and

better technologies, product designs, technical and managerial expertise, or by exposure to higher quality standards and more competition in foreign markets that stimulates innovation.

In the following sections I will present a review of the literature that empirically examines how trade affects productivity. First, I will present a review of the literature explicitly examining the effect of exporting on aggregate productivity. In Section 2.3.2.2 I will then present a review of the literature emphasising that firms self-select into export markets and in Section 2.3.2.3 I will present a review of the literature providing evidence that exporting itself has an effect on firm-level productivity.

2.3.2.1 Effect of International Trade on Aggregate Productivity

Some studies examine the effect of trade on aggregate productivity. Alcalà and Ciccone (2004) do this by using real openness as a trade measure. Using data for 138 countries for 1985 from the Penn World Tables, they find that trade is a significant and robust determinant of aggregate productivity. According to their estimates, an increase in real openness taking a country from the 30th percentile to the median value would raise productivity by 80%, an increase taking a country from the 20th percentile to the median value would raise productivity by 160%, and an increase in real openness taking a country from the 20th percentile to the 80th percentile would raise productivity by a factor of 6.

Like Alcalà and Ciccone (2004), Bernard *et al.* (2006) investigate the effect of trade on aggregate productivity, but also investigate the channels through which this trade occurs. Using manufacturing plant data for 1987-1997 from the US Bureau of Census, they find that industry productivity rises when trade costs fall: a one standard deviation decrease in trade costs is associated with an increase of productivity growth of 0.2 percentage points per year. Furthermore, plants in industries with larger declining trade costs are shown to experience larger export growth and falling trade costs are found to be associated with subsequent increases in productivity of surviving plants.

Blyde and Iberti (2012) follow Bernard *et al.* (2006) in investigating the effect of lower trade costs on aggregate productivity, but do this for a developing country by using plant-level data from Chile for 1995-2006. Firstly, they find that changes in trade costs are negatively associated with industry TFP. Declining trade costs are also found to increase the probability of becoming an exporter, and to increase export growth.

The above papers all examine the effect a change in trading costs has on aggregate productivity. While still studying the effect of trade on aggregate productivity, Harris and Li (2008) use a slightly different approach, as they investigate the contribution of exporters to aggregate productivity growth. In order to do this, they use a weighted FAME database, with data on the United Kingdom from 1996-2004, and decompose productivity into its various components. They find that exporting firms contribute 2.32% per annum to aggregate labour productivity growth whereas non-exporting firms contribute 1.55% per annum, and exporting firms contribute 1.2% to aggregate TFP growth while non-exporting firms only contribute 0.81%.

Further papers examine the effect of trade on aggregate productivity by investigating the effects of specific trade liberalisation episodes in the affected countries. Thus Pavcnik (2002) quantifies the incidence of productivity gains from the trade liberalisation in Chile on Chilean manufacturing firms, using data from the Census of Chilean manufacturing plants from 1979-86. Pavcnik (2002) finds that after the trade liberalisation, the productivity of plants in import-competing sectors grew between 3% to 10% more than that of plants in non-traded goods sectors. According to Pavcnik (2002), this suggests that the exposure to foreign competition forced plants in sectors that used to be protected from international competition to become more productive. In order to determine the effect of a trade liberalisation on productivity growth, Pavcnik (2002) then decomposes aggregate productivity growth, finding that 6.6% of the 19% growth was due to productivity increases within plants and 12.7% was due to reallocations from less productive to more productive plants.

Lileeva (2008) and Lileeva and Trefler (2010) investigate the effect of the trade liberalisation following the Free Trade Agreement (FTA) in 1989. Lileeva (2008) examines the effect of this agreement on Canadian manufacturing firms, using data from 1980-1996. It is shown that Canadian tariff cuts, which increased import competition, increased industry level productivity by inducing plants to exit the market and increasing the market shares of highly productive plants. Regarding the effect of US tariff reductions, Lileeva (2008) finds that a 1 percentage point fall in US tariffs increases annual productivity growth by 3-4%. The productivity effects are shown to increase with export intensity, and were much larger for new entrants into the export market. Lileeva and Trefler (2010) also examine how the Canada-U.S. FTA of 1989 affected labour productivity in Canada. Using plant-level data for 1984-1996, they calculate that the decline in trade costs following the 1989 FTA increased aggregate productivity by approximately 14%.

All papers studying the effect of trade on aggregate productivity thus show that trade contributes substantially to the level and growth of aggregate productivity. In the subsequent sections I will now present a review of the literature that examines the channels through which these effects occur.

2.3.2.2 Self-Selection Hypothesis

The most popular explanation for the positive effect of trade on aggregate productivity is the self-selection hypothesis. A review of the literature investigating and endorsing this channel will be presented in this section.

As mentioned in the introduction to Section 2.3.2, the empirical literature on international trade and productivity was pioneered by Bernard *et al.* (1995). Using plant-level data on United States manufacturing firms, the authors found that exporting plants perform substantially better than plants that do not export. Bernard and Jensen (1999) build on this work and attempt to determine the direction of causality of this relationship. To examine this the authors use plant-level data from the United States during the period of 1984 to 1992. They first replicate the finding that exporting firms are generally more productive than non-exporting firms, both in terms of labour productivity and in terms of TFP. The authors then divide the sample into 1984-88 and 1988-1992. They select all plants that did not export in any of the years of the first period and compare the initial levels and growth rates of productivity of

those plants that became exporters in the second period and those plants that remained non-exporters in the second period. They find that plants that became exporters were 20% – 45% larger in terms of employment, had a 7% – 8% higher labour productivity and paid higher wages. Future exporting plants were thus found to have a better performance in both size and productivity already several years before they started exporting, implying that prior success determines export status.

Aw *et al.* (2000) also examine whether exporting increases productivity, using firm-level data from Taiwan for 1981, 1986 and 1991, and plant-level data for Korea for 1983, 1988 and 1993. First, Aw *et al.* (2000) replicate the finding that exporting plants in both Taiwan and Korea tend to have higher productivity than non-exporting plants. The authors then go on to examine the productivity of entering plants to determine the direction of causality between exporting and productivity. In Taiwan, they find that plants entering the export market have substantially higher productivity than non-exporting plants already prior to exporting, a differential that varies between 4.8 and 14.8%. This finding implies that the self-selection hypothesis holds. Aw *et al.* (2000) also find that this initial difference widens in 3 of the 5 industries they study in the year following entry, increasing between 6 and 8.3%. For some plants, thus, exporting seems to increase productivity. As in Taiwan, Aw *et al.* (2000) find that in all industries in Korea new exporters have higher productivity than non-exporters already prior to entry. This differential widens post entry, but in Korea this change is never statistically significant. The authors thus present evidence for self-selection in both countries, and some evidence for learning-by-exporting in Taiwan. Regarding exiting firms, Aw *et al.* (2000) find that firms exiting after year t are on average 6.2 to 13.3% less productive than continuing exporters in year t already. This is consistent with the self-selection hypothesis, as it suggests that the less productive firm self-select out of the export market. In Korea, the pattern is similar yet not statistically significant in most industries. Overall, Aw *et al.* (2000) argue that their findings "suggest that the movements of producers with different levels of productivity into and out of the export market more closely reflect a process of market selection (...) than a process of productivity improvement flowing from export market experience".

Further support for the self-selection hypothesis and staunch opposition to the learning-by-exporting hypothesis is provided by Bernard and Jensen (2004). Using firm-level data from the US for 1983-1992, they find strong evidence that exporting plants are more productive than non-exporting plants, and that this productivity difference predates entry into export markets. Specifically, the authors investigate the differences of TFP growth rates across export statuses. They find that in the year they enter, export starters have significantly faster productivity growth rates than non-exporting firms, a differential that ranges between 1.2% to 2.5%. Bernard and Jensen (2004) further find that plants exiting the export market have productivity growth rates 0.2% to 0.9% lower than continuing exporters. In order to investigate the learning-by-exporting hypothesis in more detail, the authors consider a five-year interval to investigate the implications of entry and exit for productivity. They find that continuing exporting does not result in faster productivity growth rates. Furthermore, it is shown that "times of transition, either in or out, are indeed associated with large productivity changes. However, these predate the start (or end) of exporting and are completed soon after entry (exit)". Bernard and Jensen (2004) thus find considerable evidence for the self-selection hypothesis. However, exporting does not seem to improve productivity.

Kox and Rojas-Romagosa (2010), Arnold and Hussinger (2005) and López (2009) provide support for Bernard and Jensen (2004)'s findings. Kox and Rojas-Romagosa (2010) use firm and plant-level data for Dutch services and manufacturing sectors for the period of 1997 – 2005 and 1999 – 2005 respectively to examine the relationship between exporting and productivity. In order to test the self-selection hypothesis, Kox and Rojas-Romagosa (2010) test whether the probability of exporting depends on the ex-ante labour productivity of a firm, finding that it does. They find that in manufacturing, labour productivity in year $t-3$ is a good predictor for whether a firm starts to export in year t: a 1% higher labour productivity in year $t-3$ yields a 2.8% higher probability of exporting in year t. In services, they find that the labour productivity in year $t-1$ is a good predictor for whether a firm starts to export in year t. Kox and Rojas-Romagosa (2010) also test the learning-by-exporting hypothesis by evaluating labour productivity growth of new exporters 1, 2 and 3 years after they start exporting. They find no support for the learning-by-exporting hypothesis.

Arnold and Hussinger (2005) use firm-level data from the German manufacturing sector from 1992-2000 to investigate the relationship between exporting and productivity. They find that exporters are more productive than non-exporters, and that this productivity advantage already exists prior to exporting. Specifically, they show that at $t-3$, the average productivity of future exporters is almost equal to those who will not start exporting later. In the two periods preceding their entry into the export market, these future exporters experience a significant increase in TFP, but this tendency does not increase after their entry into the export market. López (2009) uses plant-level data for Chilean manufacturing plants from 1990-1993 to show that productivity increases in plants that are about the enter export markets, relative to those that do not export. López (2009) finds that in the year before entry and in the year of entry, productivity increases by 10% and 20%, but does not increase thereafter.

The above papers all examine productivity and exports with data from one country. Temouri *et al.* (2013) and ISGEP (2008) examine this relationship with data from multiple countries. Temouri *et al.* (2013) do this by examining data for France, the United Kingdom and Germany from 2003-2007. In support of the self-selection hypothesis, they find prospective exporters already had higher productivity 2 years before they entered into the export market. In contrast, they find no support for the learning-by-exporting hypothesis as they find that the average growth rate of export starters in 2005 is not higher than the average growth rate of matched non-exporters. If it is different, it is actually found to be lower.

ISGEP (2008) uses cross-country evidence to investigate the relationship between exports and productivity, which they measure as sales per worker. They find that exporter premia are present in all countries, although they vary across countries. To test the self-selection hypothesis, the authors take all firms that did not export at time $t-3$ to $t-1$ and compare the average labour productivity at $t-3$ for firms that did not export at time t and those that exported at time t. ISGEP (2008) claims that for some countries, the number of new exporters in the data is small, and it is for those countries that the estimates for ex-ante labour productivity differences are small. In 69% of the investigated cohorts that include enough new exporters to conduct the analysis, the pre-entry productivity premium is found to be positive and significant. To investigate the learning-by-exporting hypothesis, ISGEP (2008) compares firms that did not export at time $t-3$ to $t-1$ and exported at time t, $t+1$ and $t+3$ with firms that did not export

for all 6 years. For China, the paper shows negative ex-post productivity growth. For countries where the numbers of export starters is large enough to investigate the issue, the authors only find evidence in favour of the learning hypothesis in 1 country, namely Italy. ISGEP (2008) thus provides significant evidence for the self-selection hypothesis but only little evidence for the learning-by-exporting hypothesis. However, ISGEP (2008) does conclude by saying that the evidence reached for the learning-by-exporting hypothesis may depend on the methodology used, which implies that the authors don't exclude the possibility of learning-by-exporting completely.

The literature presented above generally finds support for the self-selection hypothesis, but less for the learning-by-exporting hypothesis. This conclusion is also reached by Greenaway and Kneller (2007) and Wagner (2007), who provide a detailed review of the literature on the link between exporting and productivity.

2.3.2.3 Learning-By-Exporting Hypothesis

The literature presented above showed that more productive plants self-select into export markets. Few studies find explicit evidence for learning-by-exporting. More recently, however, evidence in favour of this latter hypothesis has become more prominent.

In fact, De Loecker (2013) and Manjón *et al.* (2013) argue that studies examining the learning-by-exporting hypothesis tend to use an approach that is biased towards the rejection of this hypothesis by assuming that productivity evolves exogenously and that past export experience does not affect productivity. Using firm-level data from 1994-2000 of the Slovenian manufacturing sector, De Loecker (2013) shows that when one accommodates endogenous productivity processes, exporting has a positive productivity effect. Similarly, Manjón *et al.* (2013), using firm-level data from 1990-2008 on Spanish manufacturing firms and firm matching techniques, show that whether one uses an endogenous Markov process or exogenous Markov process to determine the effect of exporting on productivity, i.e. whether one allows productivity to evolve endogenously or whether one assumes it to evolve exogenously, affects the results significantly. When assuming an exogenous Markov process for productivity, Manjón *et al.* (2013) find no extra productivity growth induced by exporting. However, when allowing for an endogenous Markov process, they find that exporting increases yearly productivity rates by 3%. Both De Loecker (2013) and Manjón *et al.* (2013) thus argue that exporting does affect productivity, and that the rejection of this hypothesis in past research is based on a specific construction of productivity.

Indeed, many papers find support for the learning-by-exporting hypothesis. Baldwin and Gu (2004) is such a paper. Interestingly, it provides an explanation for why its results differ from those of Bernard and Jensen (2004), who investigate the impact of exporting of the United States and conclude that exporting does not affect firm-productivity. Baldwin and Gu (2004) examine whether exporting induced by NAFTA, entering into force in 1989, increased productivity growth in Canadian firms, using data from 1984-1996. To determine whether new exporters experience post-entry growth, the authors refer to Baldwin and Gu (2003), and reproduce a table from that paper. They argue that plants with faster growth in labour productivity and TFP during the 1990-93 period were more likely to be exporters in

1993-96, which is consistent with the self-selection hypothesis. However, as a result of entry they also experienced faster productivity growth rates compared to non-exporters, which is consistent with the learning-by-exporting hypothesis. Baldwin and Gu (2004) then examine the possible mechanisms leading to this increased productivity growth. They find that after the trade liberalisation, exporters became more specialised, enabling a greater exploitation of economies of scale. Furthermore, export participation increased the investment in R&D, and the rate of introducing innovation was 8 percentage points higher for new exporters than non-exporters without there being such differences prior to the exporters' entry into the export market. This is consistent with the idea that firms benefit from exporting through foreign ideas and technologies, but need to invest in R&D in order to do so. The third mechanism Baldwin and Gu (2004) identified is increased international competition. Using these results, the authors then present some possible explanations for why their results differ from those of Bernard and Jensen (2004) for the United States, where exporting was not found to have beneficial effects on productivity. Regarding the first mechanism, Baldwin and Gu (2004) argue that while Canada is a small economy, the US is a large economy. US firms were therefore already able to exploit economies of scale prior to the trade liberalisation, while this was not the case for Canadian firms. According to Baldwin and Gu (2004), the second mechanism is also limited in the US, as many US plants are world leaders in technology and will thus not benefit from greater exposure to foreign markets by gaining access to new technologies. The third mechanism is also not likely to apply to the US, as the domestic market competition in the United States has been described as more intense than competition in other markets. Baldwin and Gu (2004) conclude that their findings suggest exports should increase productivity growth in Europe, as European countries are more similar to Canada than the US in relevant characteristics. Furthermore, benefits from exporting are not automatic; they require investing in R&D to learn from foreign buyers and benefit from their technologies.

Somewhat in line with Baldwin and Gu (2004)'s prediction that exports should increase productivity growth in Europe, Girma *et al.* (2004) provides evidence that exporting leads to productivity growth in the United Kingdom, using data from the OneSource database for 1988-1999 and matching analysis and difference-in-difference techniques. They find that in the year of entry, exporting firms experience a TFP growth which is 1.6 percentage points higher than if they had remained non-exporters, and TFP continues to grow at an extra percentage point in the following year. TFP growth was not faster for these firms prior to entry into the export markets than non-exporting firms. The results are similar when labour productivity is used as an alternative productivity measure.

Further insight into how exporting may impact on productivity is provided by Damijan *et al.* (2005), De Loecker (2007) and Trofimenko (2008), who argue that the learning effect of exporting is not associated with exporting per se but depends on the export destination. Damijan *et al.* (2005) use firm-level data for Slovenian firms 1994-2002, differentiating between firms exporting to OECD countries, firms exporting to countries from Central or Eastern European countries and firms exporting to countries of the former Yugoslavia. Damijan *et al.* (2005) find that exporting firms increased their TFP level on average by 2% more than non-exporters in the sample period 1994-2002. The authors break this result down according to export destinations, finding that while for firms exporting the majority of sales to OECD countries trade increases the long-run TFP level by 7%, no such long-run effects exist for firms exporting to Cen-

tral and Eastern European or former Yugoslavian countries. The authors then compare the productivity differential between firms that started exporting recently and non-exporters. In this section, they find no continuous productivity improvements from exporting, but short-run productivity shocks after the firm starts to export. The authors find significant increases in TFP growth rates for firms exporting to OECD countries 1 and 2 years after the year of entry into export markets. No productivity improvements are found for new exporters exporting more to less developed countries. Based on these findings Damijan *et al.* (2005) argue that the heterogeneity of markets matters: exporters can benefit from exporting through learning or competition effects only when serving more advanced markets. "Exporting per se does not warrant such effects".

De Loecker (2007) also examine the effect export destinations have on productivity, arguing that if learning-by-exporting did exist, gains from the interaction with buyers and competitors should be larger from higher income regions. Using firm-level data of Slovenian manufacturing firms from 1994-2000, De Loecker (2007), like previous literature, finds strong and significant productivity premia for new exporters. It is furthermore shown that exporting has a positive and significant impact on productivity, as exporting firms on average become 8.8% more productive once they start exporting. For firms exporting only to high-income regions, this productivity gain is significantly larger, as they experience a 20% increase in productivity. De Loecker (2007) argues that if only self-selection mattered, then export destinations should not play a role. His evidence is thus consistent with a learning-by-exporting explanation.

Trofimenko (2008) investigates whether the destination of exporting matters for learning effects with firm-level manufacturing data from 1981-91. Export destinations are broken down into poor, lower-middle-income, upper-middle-income, rich non-OECD and OECD countries. Trofimenko (2008) finds that within industries trading mostly with similar markets the instantaneous impact of exporting is negative and significant for all productivity levels. Within industries exporting to advanced countries, the instantaneous effect of exporting is positive and highly significant. For firms within industries exporting to upper-middle-income and rich non-OECD countries, exporting appears to lead to a one-time productivity jump. These productivity differentials drop in size for continuing exporters for all firms but the most productive ones. Within industries exporting to OECD countries, productivity effects accumulate over time. Trofimenko (2008) concludes that the effects of exporting vary significantly according to export destinations.

Bustos (2011) also examines the effect of exporting on productivity, but investigates a specific channel through which exporting could affect productivity, namely the adoption of new technology. Bustos (2011) uses the MERCOSUR trade liberalisation episode in Argentina and Brazil to estimate the impact of lower tariffs on technology upgrading by Argentinian firms, using data for 1992-1996. To assess the impact of falling tariffs on technology adoption decisions, Bustos (2011) estimates the change in spending on technology as a function of the change in tariffs. It is shown that where tariffs fall more, firms increase their spending on technology more. Bustos (2011) breaks down this result by dividing the firms according to their export status. Continuing exporters on average had a 0.33 log points higher spending on technology than non-exporting firms in 1992, and they increased their spending by 0.28 log points faster than non-exporters during the liberalisation period. New exporters did not spend much more money on

technology than non-exporters before the liberalisation in 1992, but increased their spending on technology per worker by 0.37 log points faster between 1992 and 1996. Falling tariffs are thus shown to induce firms to take actions that can increase their productivity. According to Bustos (2011), this means that productivity differences between exporters and non-exporters cannot be completely explained by self-selection.

Overall, there thus seems to be increasing evidence that while self-selection into export markets is an important channel through which exporting affects aggregate productivity, exporting itself also contributes to aggregate productivity.

2.3.3 Further Theoretical Models of International Trade and Productivity

Next to the empirical work just presented, theoretical work emerged that built on the seminal work in new trade theory and further investigated the relationship between international trade and productivity.

2.3.3.1 Extensions of Melitz (2003)

The model of Melitz (2003) is frequently extended. Melitz and Ottaviano (2008), for example, do this by including sunk entry costs and incorporating endogenous mark-ups into the basic framework. These mark-ups respond to the toughness of competition in the market and the average productivity of firms competing in that market. In this model there are three channels through which welfare is increased: aggregative productivity gains achieved through selection, lower mark-ups achieved through a pro-competitive effect of trade, and higher product variety.

Bernard *et al.* (2011) provide a different, yet intuitive extension of Melitz (2003) by allowing for firms to produce multiple products and export to multiple destinations. In this general equilibrium model, firms also face sunk entry costs as in Melitz (2003), but then choose to produce several products and to serve many export markets. Firms face fixed export costs for serving each market and supplying each product to that market. According to Bernard *et al.* (2011), this model leads to three core implications: trade liberalisation causes firms to drop their least successful product and to reallocate their resources to high-attribute products, increases the number of exporting firms, and increases the number of countries to which a given product is supplied and the exports of a given product of a given firm.

Further literature extends Melitz (2003)'s framework by allowing firm productivity to change over a firm's lifetime. Impullitti *et al.* (2013) is one example of such a paper. It extends Melitz (2003) in two ways: (1) by assuming that a firm's productivity evolves over its lifetime according to a Brownian motion and (2) by assuming that in order to enter export markets, a firm must pay a sunk entry cost in addition to per-period fixed and variable trade costs. Like in Melitz (2003), firms pay an initial sunk cost to enter the domestic industry and draw their initial productivity from a distribution. However, this productivity can evolve. If a firm's productivity exceeds a certain threshold, it becomes profitable for this firm to enter the export market by paying the sunk entry cost. If its productivity falls below the level with which it started exporting, the firm will nevertheless prefer to continue exporting in order to avoid paying the sunk entry cost again later on, even though this choice comes at the expense of negative export profits.

Impullitti *et al.* (2013) thus show that the sunk entry cost introduces a wedge between the export entry cutoff-level and the export exit cutoff level, referred to as a "band of inaction" or hysteresis. Crucially, this model shows that a firm's efficiency level is not enough to determine its export status: its exporting history is relevant as well.

Most of the papers presented above feature productivity heterogeneity and argue that trade liberalisation increases aggregate productivity via self-selection into export markets, with exporting having no effect on firm-productivity. An exception to this is Costantini and Melitz (2008), where a firm can choose to innovate. Even in this model, however, there is no direct connection between innovation and exporting: innovating and exporting are two distinct decisions. In some models, export market participation explicitly affects productivity. In Yeaple (2005), it does this by inducing firms to switch technology from a low productivity to a high productivity technology. Trade thus increases productivity by inducing firms to change technology.

Bustos (2011) builds on Yeaple (2005), but in this model firms are ex-ante heterogeneous. These firms operate in a monopolistically competitive industry, produce differentiated goods, face sunk entry costs and can choose to increase their productivity by paying a fixed technology adoption cost. For the least productive firms, it is most profitable to not export and to use the old technology. As the cost of the new technology is fixed, its benefit is increasing in productivity. A reduction in trade costs increases the market shares of exporters, inducing more of them to adopt the better technology. This increases expected profits, inducing more firms to enter the industry, which reduces the price index. Non-exporting firms thus lose revenues and the least productive exporting firms exit the industry. This model therefore features aggregate productivity growth through firm selection effects and by having exporting affect the technology adoption decisions of firms.

2.3.3.2 Explaining Empirical Patterns

Several studies further extend seminal theoretical models in order to account for certain empirical features. Thus Helpman *et al.* (2008) attempt to account for the fact that many countries do not trade with each other at all. To account for this the authors build a model of international trade with differentiated products and firm heterogeneity, in which firms face fixed and variable costs of exporting. As in Melitz (2003), only the most productive firms export. The profitability of exporting, however, varies according to destination: it is higher for exports to countries with higher demand levels and lower variable and fixed export costs. As profitability levels can differ, this model makes it possible that no firm in a given country is profitable enough to export to a certain country.

Arkolakis (2010) and Albornoz *et al.* (2012) attempt to explain the empirical pattern that many small firms export. Arkolakis (2010) extends the framework of Melitz (2003) by introducing marketing costs for exporting instead of fixed export entry costs. These marketing costs have two important characteristics: (1) the cost to reach a certain number of consumers in a market decreases with the population size of a market and (2) within a given market, the marginal costs of marketing increases with the number of consumers reached. This modelling has 2 implications. Firstly, it can account for the observed fact that

many small firms export, which is at odds with a fixed cost model. This is because with marketing costs, in larger markets the cost to reach the very first consumer is low, enabling many firms to pay this cost. Due to the increasing cost to reach additional consumers however, the relatively small and unproductive exporters choose to only export small amounts. The second implication is that when trade costs decline, firms with low volumes of trade prior to the trade liberalisation will grow at a faster rate. This is due to the decreasing returns to marketing: firms that exported only little prior to the trade liberalisation find it easier to reach new consumers than firms already reaching many consumers. Arkolakis (2010) quantitatively assesses this model and finds support for the model's predictions and implications.

Albornoz *et al.* (2012) also attempt to explain the finding that many small firms operate in export markets, specifically the finding that there is a lot of entry into export markets with small initial sales coupled with rapid subsequent exit. Their central assumption is that firms face initial uncertainty about export profitability. Firms can only discover this profitability by starting to export. According to Albornoz *et al.* (2012), this model explains why many small firms enter export markets with initially small sales: they are attempting to discover their exporting profitability. Furthermore, it also explains rapid subsequent exit, as those firms that find they are not productive enough exit the market quickly.

2.3.3.3 Analysing Implications of the New Trade Models

The growing theoretical literature on new trade theory prompted literature analysing the implications of these new trade models. Alessandria and Choi (2014) extend the Melitz (2003) framework by allowing firms to face idiosyncratic productivity shocks, sunk export costs in addition to fixed export cost and temporary idiosyncratic shocks to fixed export costs. In this general equilibrium model, entering firms draw from a productivity distribution, and incumbents' productivity evolves according to a Markov process. Alessandria and Choi (2014) show that in this sunk cost model, trade liberalisation has a larger effect than in the fixed cost model. Reducing tariff barriers from 30% to 0% raises the ratio of nominal trade to GDP from 0.5% to 7.4% in the sunk cost model, and only from 1.3% to 5.9% in the fixed cost model. This difference largely arises because the extensive margin is substantially more affected in the sunk-cost model. The welfare effects of such a trade liberalisation in the sunk cost model exceed the welfare gains of the fixed cost model by 18%.

Chaney (2008) and Melitz and Redding (2015) undertake similar comparative analyses, but compare new trade models with productivity heterogeneity such as Melitz (2003) to trade models with homogenous producers, such as Krugman (1979). Chaney (2008) expands Melitz (2003) to a world of multiple asymmetric countries, separated by asymmetric trade barriers, and studies the choice of firms to export. In this model, the subset of exporting firms varies with the characteristics of the foreign market. Chaney (2008) examines the effect the elasticity of substitution has on the response of trade flows to changes in tariff barriers in this model compared to Krugman (1979). In Krugman (1979), when the elasticity of substitution is high, trade barriers have a strong impact on bilateral trade flows, as consumers are less willing to pay a higher price for a certain good and substitute the more expensive foreign good with a cheaper domestic product. Conversely, if it is low, consumers are willing to buy foreign varieties even at a higher cost, so trade barriers have little impact. According to Chaney (2008), in the model with firm

heterogeneity and fixed export costs, a high elasticity of substitution has the opposite effect: it makes trade flows less sensitive to changes in trade barriers as the intensive and extensive trade margins are affected differently.

Melitz and Redding (2015) compare new trade models with homogenous firms to new trade models with heterogeneous firms in terms of the welfare gains from trade they generate. They find that the welfare gains in the latter model in response to a trade liberalisation are substantially larger than the welfare gains in the model with homogenous goods, as a reduction in variable trade costs from $\tau = 1.83$ to $\tau = 1$ results in a 5 percentage point higher welfare gain in the heterogeneous firm model than in the homogenous firm model.

2.3.3.4 Transition Dynamics

Many papers in the literature on international trade further study the dynamic response of the model economy to macroeconomic shocks.

For example, Costantini and Melitz (2008) investigate firm-level transition dynamics in response to a trade liberalisation. They augment the Melitz (2003) framework by incorporating a stochastic evolution of firm productivity and an innovation option for firms. In this model, forward-looking decisions of entry, export market participation and innovation require a sunk cost. The innovation option is a one-time opportunity to innovate that induces a one-time stochastic jump in productivity. A firm can only innovate once, but the productivity gain from this innovation is long lasting. There are thus 4 types of firms: those that are non-innovators and do not export (AD firms), those that are innovators but do not export (BD firms), those that did not innovate but export (AX firms) and those that both innovated and export (BX firms). The ranking of these firm decisions is as follows: AD firms are at the bottom of the productivity distribution and BX firms at the top. Costantini and Melitz (2008) illustrate the response of an industry to a change in trade costs, in terms of shifts of the shares of the four different types of firms. In this model, a trade liberalisation increases the returns to both innovation and exporting. Costantini and Melitz (2008) show that a trade liberalisation leads to fewer firms, as in Melitz (2003), and also leads to a substantial shift from AD firms to BX firms.

A seminal extension of Melitz (2003) was provided by Ghironi and Melitz (2005), who extend the framework by studying the macroeconomic dynamics of aggregate shocks in an international trade model. In order to do this they build a dynamic stochastic general equilibrium model of international trade, in which there are two countries, monopolistic competition, firm heterogeneity and sunk entry costs. In each country, there is a continuum of firms that produce differentiated goods with a single factor of production, namely labour. There is initial uncertainty about productivity, which is resolved upon paying the sunk entry cost to enter the industry, as firms draw their productivity from a productivity distribution. Thereafter this firm-level productivity remains fixed. Fixed production costs arise when a firm wants to export, which gives rise to a selection process into the export market in which only the more productive firms, those with productivity levels above the cut-off level, export. Ghironi and Melitz (2005) use this model to study the response dynamics of the economy to an increase in aggregate productivity and a

decrease in home entry costs, interpreted as deregulation. The shocks generally lead to higher prices in the domestic market, but according to Ghironi and Melitz (2005), this effect is dominated by an increase in product variety, which leads to an aggregate welfare gain.

Several papers build on this model and also examine the macroeconomic dynamics following shocks. Adolfson *et al.* (2007) and Rodriguez-Lopez (2011) explicitly examine the response of the economy to a monetary policy shock. Hereby Adolfson *et al.* (2007) are the first to show that the "conventional wisdom" regarding the effects of monetary policy in a closed economy setting also applies in open economies, while Rodriguez-Lopez (2011) examine how exchange rates have expenditure switching effects in a general equilibrium model with exchange rate pass through and endogenous mark-ups. In this model, exchange rate movements affect the extensive margin of trade by affecting cut-off productivity levels. In response to a monetary shock, movements in the exchange rate affect competition conditions, and thereby change the extensive margin of trade. Firm reallocations increase the persistence of such a shock, as changes in the number of producers dissipates slowly during the transition.

Other papers study the response of the economy to productivity shocks (Cavallari (2013), D'Addona and Cavallari (2020) and Dix-Carneiro *et al.* (2021)). Cavallari (2013) study how the dynamic response of the economy to a TFP shock differs under flexible and sticky prices, showing that sticky prices are important for firm entry decisions, and D'Addona and Cavallari (2020) analyse how the dynamic response of the economy to a productivity shock differs under fixed and flexible exchange rate regimes. The authors show that the extensive margin of trade responds more strongly to a productivity and a demand shock under a fixed exchange rate regime than under a floating regime. Dix-Carneiro *et al.* (2021) examine how the length of the shock affects the dynamic response of the economy in a general equilibrium, multi-country, multi-sector model of trade. They find that the economy responds very differently to a temporary foreign productivity shock, a permanent foreign productivity shock, and a gradual increase in foreign productivity.

Literature also studies the response of the economy to shocks other than productivity shocks. For example, Barthelemy and Cleaud (2018) examine a shock to foreign preferences while Bergholt *et al.* (2019) examine an oil price shock. Barthelemy and Cleaud (2018) assess the importance of fluctuations in trade for the business cycle in a 2-country DSGE model that is estimated for the EA and the rest of the world. They motivate changes in trade openness by shocks to the home bias of the two countries, and find that such shocks are an important driver of short-term business cycles in the euro area, as they significantly contribute to explaining inflation and nominal interest rates. Bergholt *et al.* (2019) analyse the transition dynamics of an oil-producing country's economy to an oil price shock. The authors show that while an increase in oil prices leads to a global recession, it increases economic activity in Norway, the oil-producing country. Following an increase in the price of oil, oil producers increase investment in their production, a process that is slow and therefore highly persistent. The increase in oil investments leads to an increase in the demand for supplies from the oil supply sector, which in turn induces supply firms to increase their own factor inputs. These supply-chain dynamics lead to an overall increase in economic activity.

Cacciatore (2014) considers the response of an economy to a 20% decrease in transport cost, specifically analysing how labour market frictions affect this response. In a 2-country DSGE model with heteroge-

neous firms and endogenous product entry they show that while trade integration is beneficial for welfare as it induces higher productivity, unemployment can temporarily rise in response to such a shock. They also demonstrate that labour market rigidities can mitigate such short run employment losses, but that they also reduce gains from trade. Cacciatore *et al.* (2016) consider the effect of product and labour market deregulation in a 2-country monetary union, specifically analysing their implications for monetary policy. By analysing transition dynamics they argue that reforms that make markets more flexible have three main consequences for monetary policy. These are that the optimal response to such a reform is expansionary, that when the reforms' effects are fully materialised price stability is more desirable in the long-run than prior to the reform and that the international synchronisation of reforms is beneficial.

While many of the above papers focus on the response of the economy to a specific shock, some papers examine the response of their model to many shocks. Van Aarle (2012) does this in a DSGE model with disequilibrium dynamics, in which excess product and labour supply is possible under the disequilibrium regime. In this model they show that the adjustment process of the economy differs fundamentally in response to some shocks relative to a standard DSGE model, and that regime switches can occur often and easily. Van Aarle (2012) argue that the consideration of such regime switches may be therefore helpful in understanding complex adjustments produced by crises. In contrast to the above papers, Millard *et al.* (2021) explicitly focus on the effect of international trade on labour productivity. Hereby they examine the importance of non-trading firms in shaping labour productivity in a DSGE model of international trade with monopolistic competition and heterogeneous firms, allowing firms to endogenously enter and exit the domestic market. Millard *et al.* (2021) show that the entry and exit of non-trading firms can explain the persistence of the response of labour productivity to transitory macroeconomic shocks.

De Walque *et al.* (2017) also study many shocks, as they analyse the response of the economy to a large number of macroeconomic shocks in an international trade model. They build a 2-country new Keynesian model with local currency pricing, distribution costs and demand elasticity that increases with relative price. Their stated objective is to "construct a medium-sized 2 country model for the euro area and the US able to deliver an acceptable empirical fit for a relatively wide set of macro-variables and generate reliable forecasts". To construct this international trade model they extend the well-known closed-economy model of Smets and Wouters (2003) to include international trade in goods and assets. They use this model to simulate the economy to a number of shocks, run forecasts, decompose shocks and analyse the contribution of shocks to economic fluctuations, and to study the model's business cycle statistics.

Albonico *et al.* (2019) study the response of their model economy to many shocks as well. Instead of just including two countries, their model accounts for three: a European Monetary Union (EMU) member country, the rest of the euro area (EA) and the rest of the world (RoW). Like De Walque *et al.* (2017) they estimate their model using Bayesian techniques. In this set-up, Albonico *et al.* (2019) study the dynamic response of the main variables to domestic supply (TFP), domestic demand (private saving and government spending), EA monetary policy, and foreign demand shocks, as well as an exchange rate shock to the euro. They also provide a historical composition of these shocks. The authors argue that they have three main objectives in building this model: to provide a structural interpretation of business cycle dynamics, to contribute to the European Commission's economic forecast and to enable scenario

analysis and policy counterfactuals.

2.3.3.5 The Importance of Endogenous Entry

The last few sections of this literature review presented papers that in general studied how international trade affects the macroeconomy. Another strand of the literature on international trade investigates the extent to which entry into domestic production matters in the international trade context. Cacciatore (2014) builds a 2-country DSGE model with endogenous entry into product markets and labour market frictions, and shows that the model captures important empirical regularities. He then shows that the profitability of producer entry into domestic and export markets varies over the business cycle, and the sluggish adjustment in the number of producers feeds back into employment dynamics. Furthermore, the endogenous response of entry into both domestic and export markets dampens the response of the terms of trade to shocks, which strengthens international co-movement.

Alessandria and Choi (2019) study the relationship between international trade and establishment creation over the business cycle in a general equilibrium model with endogenous entry into domestic production and exporting. To do this they build a 2-country DSGE model with heterogenous firms and 2 factors of production. Firms differ in their productivity, capital stock and export status. To become exporters, firms must pay a sunk cost, and thereafter a smaller fixed export cost. The model thus features exporting hysteresis as exporters continue to export even after they have become relatively unproductive or the aggregate conditions have changed in a way that they would not export if they were not already in the export market. Firms enter the domestic market by incurring a sunk entry cost. Alessandria and Choi (2019) show that this model captures several empirical regularities well. They then examine how international trade affects establishment creation, finding that when international trade in assets is eliminated, the volatility in the stock of establishments falls by 44% relative to the benchmark model, while fluctuations in participation by exporters and importers are cut by 65%. When the ability to trade goods is removed from the model as well, the model predicts acyclical fluctuations in the stock of establishments. When eliminating fixed trade costs and allowing all firms to trade abroad, the establishment rate becomes too procyclical. Alessandria and Choi (2019) thus show that international trade is important in creating fluctuations in the number of firms in the market that resemble those seen in data.

Millard *et al.* (2021) show that the entry and exit of non-trading firms into the domestic market creates higher persistence of the response of labour productivity to transitory macroeconomic shocks. They do this by building a 2-country DSGE model of international trade with monopolistic competition and heterogenous firms that builds on Ghironi and Melitz (2005). To allow for endogenous entry and exit from domestic production they include a fixed cost of domestic production in addition to the standard fixed cost of exporting, which ensures that not all firms are productive enough to produce domestically every period. This creates a mechanism of self-selection into domestic production that is akin to the mechanism of self-selection into exporting, allowing for both endogenous entry and exit out of the domestic market. Millard *et al.* (2021) show that it is variations in firm-level productivities and entry and exit rates that create the higher persistence of labour productivity in response to shocks, and argue that this increased persistence allows the model to better match the behaviour of labour productivity in the US.

This insight that endogenous entry into and exit from the domestic market is important in the international trade literature builds on a growing strand of literature that establishes this importance in closed economy settings (Bilbiie *et al.* (2012), Bergin and Corsetti (2008), Hamano and Zanetti (2017), Lee and Mukoyama (2018), Clementi and Palazzo (2016), Woo (2015), Clementi *et al.* (2015)). The seminal paper in this area is (Bilbiie *et al.* (2012), who build a DSGE model with monopolistic competition that allows for endogenous determination of the number of producers and products. They show that economic expansions induce higher entry rates, and that the sluggish response of the number of producers generates a new and potentially important propagation mechanism for business cycle models. Woo (2015) shows that when accounting for endogenous entry and exit, entry becomes more volatile and exit acyclical, which matches data better.

Clementi *et al.* (2015) and Clementi and Palazzo (2016) build on this insight that firm entry matters. Clementi *et al.* (2015) build a DSGE model with heterogeneous firms, endogenous entry and exit, firm growth and firm-level capital accumulation. They find that firms' entry and exit decisions amplify ordinary business cycles driven by shocks to aggregate productivity and, to a lesser extent, protract them. Clementi and Palazzo (2016) illustrate the amplification effect of firm entry and exit quantitatively. Specifically, they show that a positive 1.5 standard deviations shock to productivity leads to a 2.97% increase in output growth with entry, and only a 2.46% increase in output growth without entry. Put differently, Clementi and Palazzo (2016) show that entry and exit are responsible for almost one fifth of output growth over the ten years following the macroeconomic shock. Hamano and Zanetti (2017) and Lee and Mukoyama (2018) provide empirical evidence that entry into domestic markets is important.

2.3.4 The Gap in the Literature

The previous two sections of the literature review on international trade showed that two main findings emerge from the literature: both international trade and endogenous entry into domestic production matter for the response of the economy to macroeconomic shocks. However, the selection of firms into domestic production is usually studied in a domestic context only, as "much of the recent literature on establishment creation over the cycle (. . .) abstracts entirely from international trade" (Alessandria and Choi (2019)). Those models that do account for endogenous entry into domestic production in an international trade framework usually only use one factor of production, namely labour (Cacciatore (2014), Millard *et al.* (2021)). At the same time, we know that the inclusion of two factors of production can be important. Indeed, Bilbiie *et al.* (2012) originally formulate their model without physical capital stock. However, they argue that the omission of capital "is certainly unrealistic: part of observed investment is accounted for by the need to augment the capital stock used in production of existing goods". They find that including capital "significantly improves the performance of the model". Indeed, to the best of my knowledge the only paper that includes two factors of production, international trade and endogenous entry into production in one framework is Alessandria and Choi (2019), who argue that physical capital is important for the propagation of shocks, and to match cyclicality of trade flows. However, Alessandria and Choi (2019) do not elaborate any further on the importance of including physical capital for the dynamic response of a model economy to a variety of shocks, instead analysing how the existence of

international trade in goods and assets matters for entry margins.

In Chapter 4 of the thesis I therefore analyse how and the extent to which resource allocation affects the transmission of macroeconomic shocks when accounting for endogenous entry into domestic production and international trade, paying special attention to the dynamic response of labour productivity to such shocks. With this analysis I aim to examine whether abstracting from a second factor of production matters, and to what extent such an omission is relevant. This may have important implications for policy makers, as the analysis yields insight into how a variety of macroeconomic variables are affected by different macroeconomic shocks in the short-run and in the long-run when both resource reallocation and selection into domestic production are accounted for.

2.4 Financial Frictions

In this section of the literature review I will present a review of the literature on financial frictions. As this literature is incredibly vast and varied, I will focus on the strand that I contribute to, which is literature that studies how financial frictions affect productivity.

In order to present this review, I will proceed as follows. In Section 2.4.1 I will present a review of the early literature that emphasised the importance of finance for economic growth. While this literature does not examine financial frictions, the main subject of this literature review, this nevertheless matters since without this literature that establishes the importance of finance for economic growth, literature on financial frictions would not have emerged. It is therefore important to briefly examine this literature in order to demonstrate the emergence of early literature on financial frictions. In Section 2.4.2 I will present a review of how the literature on financial frictions developed. Hereby I will present a review of the early work on financial frictions, followed by how financial frictions have been investigated since the inception of this work. I will present a review of the literature on how financial frictions affect the business cycle in Section 2.4.2.2, how financial frictions can explain observed dynamics in Section 2.4.2.3 and the effect of financial frictions on productivity in Section 2.4.2.4. In Section 2.4.3 I will present a review of the literature that examines the link between financial frictions and international trade, before identifying the gap in the literature in Section 2.4.4.

2.4.1 Emerging Literature on Finance and Development

2.4.1.1 Pioneering Work

Two of the earliest economists that commented on the link between finance and economic development were Walter Bagehot and Joseph Schumpeter. In the introduction to his book *Lombard Street: A Description of the Money Market*, which was originally published in 1873, Bagehot establishes the importance of finance for economic development by pointing out that English trade is essentially built on borrowed capital, and by attributing the success of the English economy to its elaborate financial system. In his book *Theory on Economic Development*, first published in German in 1912 and translated into English in 1934, Schumpeter provides an analysis of the economy and establishes the relevance of finance for

economic development.

Following Schumpeter's seminal contribution more work emerged that emphasised the importance of finance for economic development (Gurley and Shaw (1955), Patrick (1966), Cameron (1967)). Cameron (1967) is the first contribution that provides some empirical evidence of the link between finance and economic development by examining the history of several nations' banking systems. Further insight into the relationship between finance and economic development is provided by McKinnon (1973) and Shaw (1973), who investigate the difference between financially developed or liberalised economies and less developed economies.

2.4.1.2 Theoretical Literature

Following this pioneering work on the link between finance and economic development, literature embedding this relationship into theoretical models gradually emerged. These emphasise how financial intermediation can improve economic growth by overcoming informational frictions (Boyd and Prescott (1986), Greenwood and Jovanovic (1990)), by mobilising savings by decreasing the costs of monitoring investors and by changing the social composition of savings by providing liquidity (Boyd and Smith (1992), Greenwood and Smith (1997)), by enabling specialisation (Greenwood and Smith (1997), Cooley and Smith (1998)), and by allocating capital and investment more efficiently (King and Levine (1993*b*), Aghion and Howitt (2009)).

2.4.1.3 Empirical Literature

In parallel to the development of the literature explaining the link between finance and economic development in theoretical terms, empirical literature providing evidence for this theoretically articulated link emerged. The first seminal contribution in this field was Goldsmith (1969), which finds a correlation between economic and financial development. However, Goldsmith (1969) was unable to establish the causality of the link between finance and economic development. The second seminal paper in this area was provided by King and Levine (1993*a*). The authors of this paper extend the analysis of Goldsmith (1969) by investigating a larger sample of countries. They also address the problem of causality, finding that the level of financial development can serve as a predictor of future rates of economic growth.

Later papers build on this attempt to establish a causal effect of finance on economic development. In general these studies find empirical support of a strong link between finance and economic growth, and also evidence of a causal effect of finance on economic growth. [7]

2.4.2 Development of Financial Frictions Literature

The early literature on finance and economic development that was presented in the section above established that finance is growth-enhancing and promotes economic development. Following this insight, literature emerged that studies the flipside of this phenomenon: how imperfections in finance can affect real economic activity. Whereas the former literature largely focused on the development of the entire

[7] For a more extensive and detailed review of both early theoretical and empirical literature on the relationship between finance and economic growth and development, see Levine (2005).

banking system, examining the implication of this for economic growth, this latter literature examines how frictions within that system affect the real economy.

2.4.2.1 Seminal Work on Financial Frictions

Very early literature relating to financial frictions examined how credit rationing, either in terms of rationing of loan size or loan quantity, affect economic development and growth (Hodgman (1960), Jaffee and Modigliani (1969) Keeton (2017)). [8]

In parallel with this literature strand that investigated the microeconomic foundations of credit rationing, literature emerged that stressed the importance of balance sheets for economic growth. This literature dates back to Fisher (1933), who argued that the combination of overindebtness and deflation is the major factor that leads to large crises and recessions.

The importance of balance sheets and shocks to net worth was further emphasised in the seminal works of Bernanke and Gertler (1989), Kiyotaki and Moore (1997) and Bernanke *et al.* (1999). Bernanke and Gertler (1989) develop a theoretical business cycle model in which the condition of the borrower's balance sheets is a source of output dynamics. In this model, financial frictions arise from asymmetrical information between entrepreneurs and savers. This leads to a costly state verification as lenders cannot observe realised returns of borrowers, and thus agency costs that are associated with financial intermediation. Higher net worth reduces these agency costs of external finance. As business upturns improve net worth, they also reduce agency costs. This increases investment and thus amplifies the business cycle. The opposite holds for economic downturns. Shocks to the net worth of borrowers thereby provide an accelerator effect for business cycle fluctuations.

In contrast to Bernanke and Gertler (1989), Kiyotaki and Moore (1997) focus on the effect shocks to net worth have on the value of collateral and show that the interaction between credit limits and asset prices is a powerful transmission mechanism that amplifies shocks. This transmission mechanism works as follows. In an economy where land is used to secure loans and as an input of production, some firms are credit constrained and highly leveraged while other firms are not credit constrained. In period t credit constrained firms experience a temporary productivity shock that reduces their net worth. They are thus unable to borrow more, which leads to a reduction of investment expenditure, including investment in land. They will thus incur less revenue in the next period, which again lowers net worth and investment, leading to persistent effects of the initial shock. For the market to clear, demand by unconstrained firms for land must increase, which requires the price of land in period t to fall. This has an additional effect on the behaviour of constrained firms. They suffer a capital loss, which further lowers their net worth, forcing them to further cut back on investment in land in future periods. To restore equilibrium, land prices must fall further in each of these periods. Persistence and amplification thus reinforce each other.

The perhaps most important seminal contribution to the literature on financial frictions is advanced by Bernanke *et al.* (1999), which builds on Bernanke and Gertler (1989). Bernanke *et al.* (1999) introduce

[8] For a detailed review of this early literature, see Baltensperger and Devinney (1985), Williamson (1987).

financial frictions into a standard dynamic general equilibrium model to explain cyclical fluctuations, showing that these can significantly amplify both real and nominal shocks to the economy. The financial frictions stem from asymmetrical information between borrowers and lenders that requires lenders to pay a cost in order to observe realised returns. The costs associated with this lead to an external finance premium for borrowers that is inversely related to net worth. The premium is thus countercyclical, enhancing swings in borrowing and thus in investment, spending and production. After illustrating the effect of financial frictions qualitatively, Bernanke *et al.* (1999) quantitatively examine how financial frictions affect the response of output to several types of shocks, namely monetary shocks, shocks to technology, a shock to government expenditure and a one-time unanticipated transfer of wealth from households to entrepreneurs. It is shown that financial frictions significantly amplify these shocks, as the response of output and investment to these shocks is greater in the model with financial frictions than in the baseline model without financial frictions.

Further literature builds on the insights of these seminal papers that financial frictions significantly affect the real economy. Some of this literature, like the seminal work, examines the importance of financial frictions in explaining business cycle dynamics, some examines their effect on other macroeconomic variables such as economic growth and volatility, and some examines their effect on productivity. A review of this literature will be presented in the following section.

2.4.2.2 Financial Frictions and the Business Cycle

Much literature focuses on explaining the effect of financial frictions on output, growth and business cycle dynamics. Thereby some literature focuses on showing the significance of financial frictions in accounting for macroeconomic fluctuations, whereas other literature shows different ways in which financial frictions can affect macroeconomic variables. Futher literature examines the importance of financial frictions for monetary and fiscal policy, and whether financial frictions can explain specific observed firm- or macroeconomic dynamics and patterns.

2.4.2.2.1 The Importance of Financial Frictions for Business Cycles

Much literature emphasise the importance of financial frictions for the business cycle. Carlstrom and Fuerst (1997) and Iacoviello (2005), for example, show that they can account for the response of the economy to certain shocks. Both show that financial frictions lead to a more hump-shaped response of output to shocks. Iacoviello (2005) also shows that financial frictions amplify the response of the economy to demand shocks, while they dampen its response to supply shocks.

Gertler and Kiyotaki (2011) quantify the amplification mechanism of financial frictions in a model where the agency problem exists between households and banks, instead of banks and firms. They analyse the effect of a 5% decline in the quality of capital, finding that financial frictions double the response of output in a perfect interbank capital market setting, whereas they increase the response of output by 20% when interbank markets are imperfect. Gertler *et al.* (2015) show how the response of the economy can be amplified in a model where bank runs are possible and Christiano *et al.* (2014) show that both the loan rate that depends on the borrower's net worth as well as the Fisher deflation effect can be important in

amplifying the business cycle. Christiano *et al.* (2010*a*) find that fluctuations in the severity of financial frictions account for substantial portions of business cycle fluctuations in the United States over the past 2.5 decades.

The above papers mainly investigate how financial frictions explain business cycle dynamics by amplifying shocks originating in other sectors. In contrast, Jermann and Quadrini (2012) and Khan and Thomas (2013) show that shocks to financial frictions themselves can drive real activity, as they are important in generating real fluctuations and are necessary for accounting for business cycle dynamics. Iacoviello (2015) builds on this insight and examines how the presence of constrained banks amplifies the response of the economy to a financial shock.

Rather than examining the extent to which financial frictions contribute to explaining business cycle fluctuations as a whole, some papers specifically investigate the importance of financial frictions for crises. In a general manner, Aghion *et al.* (2001) show that credit constraints can lead to currency crises and Brunnermeier and Sannikov (2014) illustrate that financial frictions can cause regular crises by showing that they lead to asymmetry in business cycles. According to the authors, financial frictions only slightly amplify the response of the economy to positive shocks, whereas they significantly amplify the response of the economy to negative shocks. Large negative shocks are then amplified into crises.

Further evidence for the relevance of financial frictions in explaining crises is provided by papers that illustrate their importance for accounting for the 2008 financial crisis (De Ridder (2016), Khan *et al.* (2016) and Arellano *et al.* (2016)) and papers investigating their effect in the context of sudden stops (Caballero and Krishnamurthy (2004), Gertler *et al.* (2007), Durdu *et al.* (2009), Mendoza (2010)).[9]

2.4.2.2.2 The Importance of Financial Frictions for Monetary and Fiscal Policy

Further literature on financial frictions examines the implications they have for monetary and fiscal policies. In this section I will first present a review of literature that addresses the implications of financial frictions for monetary policy, before presenting a brief review of literature that addresses financial frictions' effect on fiscal policy.

In their seminal paper, Bernanke *et al.* (1999) find that credit frictions increase the initial response of output to a monetary policy shock by 50 percent, nearly double the response of investment and substantially increase the persistence of the real effects. In light of these effects, Curdia and Woodford (2010) suggest that modifying a standard Taylor rule for interest rate policy to incorporate adjustments of credit spreads may be desirable. While these papers show that financial frictions can amplify monetary policy, Braggion *et al.* (2009) find that financial frictions can change the direction of the effect of monetary policy in sudden stop economies.

Several papers also study the effect of unconventional monetary policy in the presence of financial frictions (Gertler and Karadi (2011), Gertler and Kiyotaki (2011) and Buera and Nicolini (2017)). Gertler and Karadi (2011) consider the benefits of unconventional monetary policy when financial frictions are

[9] Sudden stops refer to the large financial crises that occurred in several emerging economies in the late 1990s.

present. The central bank does not face a leverage constraint, as it can always commit to honouring its debt. If a negative shock to the quality of capital occurs, intermediaries' balance sheets deteriorate, which induces firesales of assets, which in turn leads to a decline in the market price of capital and a sharp increase in the spread between expected return on capital and the risk-free rate. Aggregate investment and output drop in response, which further tightens the intermediaries' leverage constraints. In this setting, intervention by the central bank dampens the rise in the spread, which dampens the reduction in investment. Like Gertler and Karadi (2011), Gertler and Kiyotaki (2011) show that in the presence of financial frictions, unconventional policy by the central bank can have beneficial effects. Buera and Nicolini (2017) also examine unconventional policy, specifically the policy followed by the FED in the recent financial crisis. In contrast to the previous two papers, they demonstrate a policy trade-off however, as an expansionary monetary policy would ameliorate the output drop at the cost of a slow recovery in their model.

Next to the literature examining the implications of financial frictions for monetary policy, some literature also examines their implications for fiscal policies. Thus Aghion and Bolton (1997) and Garcia-Macia (2017) show that fiscal policy in the presence of credit constraints can be beneficial. Aghion *et al.* (2014) examine a different aspect of fiscal policy as they analyse how the effects of a stabilising fiscal policy on industrial growth depends on the financial constraints in an industry. They find that a countercyclical fiscal policy will have a larger positive effect in industries with a higher fraction of credit constrained firms.

2.4.2.3 Financial Frictions and Observed Dynamics

Another strand of the literature studying financial frictions examines the extent to which they can account for certain observed dynamics.

Thus Cooley and Quadrini (2001) and Albuquerque and Hopenhayn (2004) show that models with financial frictions can replicate certain observed firm dynamics. Akyol and Athreya (2009) investigate whether financial frictions are important in accounting for the fact that self-employment rates are higher and project sizes lower in less developed countries (LDCs) than in the US and other advanced economies. They find that self-employment choices depend on the availability and attractiveness of alternative labour market opportunities and financial frictions. Hereby lower wages relative to the US, can explain the higher rates of self-employment observed in LDCs, whereas financial frictions, by reducing the amount of credit available to entrepreneurs, account for the smaller project size of self-employed people in LDCs.

A further international phenomenon that is addressed in the literature is the role financial frictions play in transition dynamics. To do this Buera and Shin (2013) incorporate two features of so-called miracle economies into a standard growth model, namely the observation that growth accelerations followed large-scale reforms reducing distortions and resource misallocation in the economy, and the observation that the financial markets of miracle economies remained largely underdeveloped until latter stages of their economic transitions. Buera and Shin (2013) implement financial frictions into their model in the form of a collateral constraint, and show that financial frictions can explain observed transition dynamics

in emerging economies.

2.4.2.4 Financial Frictions and Productivity

A recent strand of the literature on financial frictions has emphasised their impact on productivity. A seminal paper in this area was advanced by Buera *et al.* (2011), who attempt to quantify the role financial frictions play in explaining certain empirical regularities in development economics. In order to do this they use data from the 1996 International Comparison Programme of the United Nations and construct sector-level TFP measures for manufacturing and services for 18 OECD countries using the Productivity Level Database of Groningen Growth and Development Centre. They also build a model in which agents can choose to operate an establishment and become an entrepreneur or work for a wage. Agents differ in their levels of entrepreneurial productivity and wealth, and the former evolves stochastically, creating a need for reallocation from previously productive to currently productive users. Financial frictions in the form of collateral constraints arising from imperfect contract enforceability impede this reallocation. For their quantitative analysis Buera *et al.* (2011) calibrate their perfect credit benchmark to the US economy, and then assess to what extent variations in external finance to GDP ratios, or the strength of financial frictions, can explain empirical regularities in development economics. They find that differences in financial frictions can decrease output per worker by 50% relative to the perfect credit benchmark, which explains about 80% of the difference in output per worker between the US and Mexico and almost all of this difference between the US and Malaysia. According to the authors, the majority of this shortfall is accounted for by lower aggregate TFP, as financial frictions can reduce TFP by 36%.

2.4.2.4.1 The Effect of Financial Frictions on Productivity within a Country

Like Buera *et al.* (2011), Erosa and Cabrillana (2008) investigate to what extent financial frictions can explain certain observed characteristics of economic development. To do this Erosa and Cabrillana (2008) build a multi-sector general equilibrium model in which agents choose whether to work or become an entrepreneur, in which case they will operate a technology that requires a fixed cost of operation that varies across sectors. In order to operate this technology, entrepreneurs need to borrow. This borrowing is subject to the following two problems: (i) the ability and productivity of the entrepreneur cannot be observed by the lender and (ii) contracts cannot be enforced perfectly. The degree of enforcement is vital in this model, as it is shown that low enforcement leads to the use of low productivity technology and creates a barrier to factor mobility. Erosa and Cabrillana (2008) show that an increase in the degree of enforcement allows factors to be allocated more efficiently, increasing TFP and output.

Quintin (2008) is similar to Erosa and Cabrillana (2008), as the paper also investigates the effect of different degrees of contract enforceability, in a model in which agents who are heterogeneous in their managerial talent and wealth can choose whether to become a worker or an entrepreneur managing a technology. Quintin (2008) develops a dynamic industrial organisation model with the above characteristics. In order to be an entrepeneur and manage a technology, agents need to finance physical capital and wages. Because of limited contract enforceability, borrowing is limited, a limit that depends on the degree of contract enforceability. Quintin (2008) shows that in economies where enforcement is poor, more agents must be managers in order for the labour market to clear, which means that less productive

technologies must be activated. Furthermore, talented managers who are credit constrained may need to become workers, while untalented managers with access to credit become managers. These effects have an adverse impact on labour productivity.

That financial frictions have large effects on productivity is also shown by Greenwood *et al.* (2010) and Greenwood *et al.* (2013), who study the role of information production in the process of resource misallocation and its effect on productivity. They build a general equilibrium model using costly state verification following Townsend (1979): as the lender cannot costlessly observe the state of the borrower, he must pay a monitoring cost in order to observe it. Greenwood *et al.* (2010) and Greenwood *et al.* (2013) make the outcome of monitoring random: the probability of detecting malfeasance depends on the amount of resources devoted to policing returns to a project and the efficiency of the monitoring technology. In this environment, technological improvements in the financial sector make monitoring more efficient. Greenwood *et al.* (2013) quantifies the effects of such an improvement in intermediation efficiency, using cross-country data from the Penn World Table and Beck et al. (2000), (2001). They first calibrate the model to match stylised facts of the US economy 1974-2004. They then compute at what rate output would have grown had no technological progress occurred in the financial sector within this period, finding that US output would have risen by 1.5%. This compares with an actual rate of growth of 2.0%, meaning that 29% of growth in the US in this period is shown to be due to innovation in the financial sector that reduces informational frictions. By studying a larger set of 45 countries, Greenwood *et al.* (2013) find that on average a country could increase its GDP by 58% and its TFP by 12% if it moved to the best financial practice, which is Luxembourg. The effect of financial frictions in the form of informational asymmetries is thus shown to be large.

The result that financial frictions have a large effect on productivity is supported by Larrain and Stumpner (2017), who use a cross-country dataset from Amadeus to show that capital account liberalisation increased aggregate productivity through a more efficient allocation of capital across firms in 10 Eastern European countries. Specifically, they show that the capital account liberalisation was associated with an increase of TFP of 12%.

2.4.2.4.2 Financial Frictions and Differences in Cross-Country Output and Productivity

While the above papers mainly illustrate the effects of financial frictions on productivity within a country, other papers explicitly study the extent to which financial frictions can account for differences in cross-country output and productivity (Antunes *et al.* (2008), Caselli and Gennaioli (2013), Bah and Fang (2014) and Greenwood *et al.* (2013)).

Antunes *et al.* (2008) do this by assessing the quantitative effects of financial frictions on output per worker and occupational choice. They include two financial frictions in their general equilibrium model: (i) financial repression that is modelled as a deadweight cost to financial intermediation and (ii) limited enforcement, which makes capital dependent on net worth and project profitability. When simulating their model, Antunes *et al.* (2008) find that the effect of financial frictions depends on the interest rate. Overall, they show that when the interest rate is exogenous, financial frictions can explain significant portions of cross-country variations in output per capita. When the interest rate is endogenous, this

portion decreases significantly.

A rather different conclusion is reached by Caselli and Gennaioli (2013) and Bah and Fang (2014), as they document sizeable effects of financial frictions on cross-country productivity. Caselli and Gennaioli (2013) does this by showing how dynastic management, the inter-generational transmission of managerial responsibilities in family firms, affects productivity. In their model, untalented heirs to firms would like to transfer the control or ownership of their companies. Due financial frictions however, it can be difficult for outsiders to obtain the necessary financing to take over incumbent firms. Furthermore, financial frictions hinder capital mobility, allowing untalented managers to remain in the market. Caselli and Gennaioli (2013) quantify these effects, and find that the model can generate $\frac{1}{3}$ of the observed cross-country dispersion in TFP. Regarding levels of TFP, Caselli and Gennaioli (2013) find that the economy with the largest financial frictions has TFP levels as low as 79% of the most efficient economy: financial frictions can thus decrease TFP by 21%.

Bah and Fang (2014) study the interaction between entry costs and financial frictions and find it can account for a substantial portion of cross-country differences in labour productivity and TFP. To reach this result they build a discrete-time model in which establishments are heterogenous in their productivity and face entry costs. Establishments use a technology subject to decreasing returns to scale and a fixed production cost. They finance the entry and fixed cost from the financial markets. However, they are subject to a borrowing constraint and can only borrow up to a fraction of their expected discounted lifetime profits. Bah and Fang (2014) calibrate this model to match statistics of the US economy, finding that it can explain 55% of cross-country variation in output per worker and 46% of cross-country differences in TFP. The authors argue that the results stem from the following mechanisms: (i) higher entry costs protect incumbents, allowing lower productivity firms to survive, (ii) financial frictions limit borrowing, distorting resource allocation towards firms with a large capital stock, and (iii) financial frictions prevent some highly productive entrants from producing, as they cannot finance the required upfront entry cost.

2.4.2.4.3 The Effect of Financial Frictions on Productivity in Specific Countries

The literature presented in the previous section investigates the effect of financial frictions on productivity using cross-country data. Much literature also provides quantitative and empirical evidence for the effect of financial frictions by studying their role in causing productivity losses in specific countries. Manaresi and Pierri (2018) and Doerr *et al.* (2018) do this for Italy, Pratap and Urrutia (2012) and López (2017) for Mexico, Cavalcanti and Vaz (2017) for Brazil and Varela (2018) for Hungary. Generally these papers conclude that financial frictions lead to sizeable productivity losses.

Manaresi and Pierri (2018) and Doerr *et al.* (2018) investigate the extent to which greater credit supply affects productivity in Italy. Manaresi and Pierri (2018) use matched firm-bank data for Italian firms from 1997-2013 to estimate the effect of idiosyncratic changes in the supply of credit faced by Italian firms on their TFP growth rates. They show that a 1% increase in credit raises firm value-added TFP growth by 0.1% and revenue TFP growth by between 0.02% and 0.03%. This may not seem like a large amount prima facie. However, the authors argue that during the 2008 financial crisis credit growth shrank by 12% while value-added TFP fell by more than 8%. Their estimates imply that between 12.5% and 30%

of the average drop in firm TFP experienced by firms during the crisis can be explained by a reduction in credit supply.

Like Manaresi and Pierri (2018), Doerr *et al.* (2018) investigate the effect of credit supply shocks on Italian firms' productivity. Using matched firm-bank syndicated loan data from 2010Q1 to 2012Q2, they show that banks who had significant loan exposure to firms in financially distressed euro area countries during the European debt crisis contracted their loans to Italian firms. Doerr *et al.* (2018) show that a one standard deviation increase in the measure of exposure of firms to banks in financial distress decreased labour productivity by 10.5% and TFP by 5.8%.

Investigating the effect of financial frictions on productivity in Mexico, Pratap and Urrutia (2012) build a dynamic two-sector model of a small open economy with a working capital constraint. They calibrate this model to the Mexican economy prior to its sudden stop in 1994, and introduce a sequence of interest rates observed in Mexico during the sudden stop as an unexpected shock. They find that the model accounts for 52% of the observed decline in TFP and 74% of the observed decline of output per worker.

López (2017) also studies the role of financial frictions in explaining resource misallocation in Mexico. To do this the paper uses a standard model of heterogenous agents subject to borrowing constraints, in which entrepreneurs operate a common technology and can only borrow in proportion to their wealth. López (2017) calibrates this model to Mexico data using establishment-level data from Mexico's 2014 Economic Census and finds that the baseline calibration implies a TFP loss of 10% due to financial frictions.

Cavalcanti and Vaz (2017) demonstrate the effect of financial frictions on productivity in Brazil by exploiting a policy change by the Brazilian Development Bank. This policy change classed more firms as small firms instead of medium-sized companies. This change in classification matters, because small firms paid at least 1.5 percentage points less in interest rates per year than medium firms, a difference that could reach 3 percentage points. Cavalcanti and Vaz (2017) analyse the effect of this change in classification. They show that the mean investment rate for new small firms, so those who were classed as medium firms prior to the 2002 reform and as small firms after it, increased sharply. Furthermore, their conditional labor productivity and TFP increased by 9% and 11%, which shows that a reduction in financial frictions in the form of reduced borrowing costs has substantial effects on productivity levels.

Varela (2018) presents evidence for the importance of financial frictions in affecting productivity in Hungary, by examining the financial liberalisation that took place in that country in 2001. Prior to this reform, domestic firms could only borrow from local markets while foreign firms could borrow internationally, which enabled them to circumvent the low credit availability in Hungary. Effectively domestic firms were therefore credit constrained while foreign firms were not. To guide the empirical analysis of the effect of this reform, Varela (2018) develops a small open economy model in which capital controls create asymmetric access to capital markets. Using this model, Varela (2018) shows that capital controls prior to the reform in 2001 were associated with low levels of capital, worse financing conditions and lower leverage for domestic firms. The reform led to an expansion of credit and improved the financing terms for these companies. After the reform, aggregate productivity grew at 9.6% per year within the

three years after the reform and 8.5% per year within the five years after the reform, compared with 5.8% per year between 1998 and 2000. Varela (2018) controls for other reforms and confirms that it was the financial liberalisation that drove this increase in aggregate productivity.

2.4.2.4.4 Further Empirical Literature on Financial Frictions' Effect on Productivity

Further empirical literature explores the effect of financial frictions on TFP in more general terms. Thus Aghion, Askenazy, Berman, Cette and Eymard (2012) use a French firm-level panel database from 1994-2004 to show the effects of financial frictions on R&D investment and firm-level productivity. They show that R&D investment is countercyclical without credit constraints but turns procyclical with sufficiently tight constraints. Specifically, they find that financial frictions have an asymmetric effect: in the presence of credit constraints; R&D investment decreases during crises but does not increase proportionately during upturns. According to Aghion *et al.* (2012)'s findings, credit constraints raise the sensitivity of productivity to exogenous shocks and reduce the average propensity to invest in R&D projects by preventing firms from investing in them during downturns. Financial frictions thus lead to a lower and more volatile rate of productivity growth at the firm-level.

Further empirical evidence that financial frictions impact on firm-level productivity growth is provided by Ferrando and Ruggieri (2018) and Levine and Warusawitharana (2017). Levine and Warusawitharana (2017) use firm-level data for Italy, France, Spain and the UK from the Amadeus dataset and find that an increase in financial frictions reduces firm-level productivity growth. Furthermore, productivity growth sensitivity to debt growth increases with the severity of financial frictions. Ferrando and Ruggieri (2018) also use euro-area firm-level data from the Amadeus database, but examine eight euro area countries for 1995-2011. They show that more financially constrained countries are likely to have lower productivity. Ferrando and Ruggieri (2018) further conduct a counterfactual experiment to quantify the potential gain in aggregate TFP these countries could experience under free access to finance. They find that Italy, Portugal and Spain would benefit most from such a circumstance, increasing their TFP by 19% - 22%. Finland and the Netherlands would have the smallest gains, increasing their TFP by around 14%.

Midrigan and Xu (2014) also relate financial frictions to aggregate productivity, arguing that financial frictions can cause aggregate TFP losses by distorting entry and technology decisions and by generating differences in returns to capital across individual producers, thus leading to capital misallocation. Using establishment-level data for the manufacturing sectors of South Korea, Colombia and China, Midrigan and Xu (2014) quantitatively evaluate these two channels. They find that financial frictions can reduce levels of TFP, consumption and output by up to 40%.

2.4.3 Financial Frictions and International Trade

A recent and growing body of literature examines the impact of financial frictions on international trade, a review of which will be presented in this section. In Section 2.4.3.1 I will first explain why external finance is important for international trade, which illustrates the importance of examining the effect frictions in the provision of this finance have. In Section 2.4.3.2 I will present a review of the seminal papers that study the effect of financial frictions on international trade, and in Section 2.4.3.3 I will present a review

of empirical and theoretical literature building on this seminal work. In Section 2.4.3.4 I present a review of literature investigating the effect of financial frictions on international trade and productivity.

2.4.3.1 The Importance of External Finance for Trade

Literature examining the impact of financial frictions on international trade is premised on the fact that external finance is important for international trade. Within the literature on international trade finance, 3 major reasons emerge for why external finance is more important for international trade than domestic trade (see for example Schmidt-Eisenlohr (2013), Manova (2013), Ahn (2011)). Firstly, export activities are inherently riskier than domestic activities. Secondly, exporting is associated with additional upfront and fixed costs, which requires firms to obtain more working capital to pay for these. Finally, this need for working capital is magnified by the fact that the time lag between production and receipt of revenues is significantly larger for exporters than domestic producers.

Due to these reasons, much of international trade is financed with external capital. According to Auboin (2009), "some 80% to 90% of world trade relies on some form of trade finance". This finance can take three main forms (Asmundson *et al.* (2011), Schmidt-Eisenlohr (2013), Ahn (2014)). The most frequently used form is Open Account, in which exporters ship their products to importers prior to the importer's payment, and the importer pays upon receipt of the shipment. Hereby the exporter bears the risk of non-payment and is likely to require access to external credit to finance the upfront costs. The second form of finance is cash-in-advance, whereby the importer pays the value of the goods prior to receiving them: the importer bears the risk of non-performance and the upfront payment cost. The third form of trade credit is bank-intermediated credit, whereby the bank issues a letter of credit guaranteeing payment. The risk is thus borne by the banks, but both parties incur a fee for this intermediation.

As trade depends heavily on these different forms of finance, any changes in their availability is likely to affect international trade patterns. Having shown that finance and thus financial frictions are very pertinent to international trade, I will now present the literature that examines the effect of these phenomena on trade, starting with seminal papers in the field.

2.4.3.2 Seminal Papers

The two seminal papers that implement credit constraints into an international trade model are Chaney (2016) and Manova (2013). Both incorporate credit constraints into a Melitz (2003) model with heterogeneous firms, sunk entry costs and labour as the only factor of production. In Chaney (2016), like in Melitz (2003), there are fixed and variable export costs, which ensure that only the most productive firms export. Chaney (2016) incorporates liquidity constraints by positing that firms can obtain external finance for domestic but not for exporting activities: the firm must rely on its own liquidity to cover the entry and fixed cost into foreign markets. Firms can obtain this liquidity either by generating internal liquidity from domestic sales or by pledging assets they inherited. In this context, financial constraints are found to have a negative impact on trade flows, as some firms that are productive enough to export are constrained from doing so by having insufficient liquidity. Easing liquidity constraints thus increases total exports.

Manova (2013) also introduces financial frictions into a Melitz (2003) model, but does so in a very different manner. In this model companies are assumed to finance domestic activities from their cash flows but are required to pay a fraction of their fixed exporting costs upfront, for which they need to borrow external capital. For this, they must provide collateral. Specifically, a fraction of the sunk entry cost is used for tangible assets that can be used as collateral. The fraction of costs that must be covered externally and the tangibility of assets vary across sectors. Equally, countries differ in their level of financial contractibility. Manova (2013) shows that export participation will generally be higher in countries where contracts are more likely to be enforced, and in sectors with lower external finance dependence and higher asset tangibility. In addition to restricting export entry, financial frictions are also shown to decrease the level of exports of credit constrained firms. These effects are more important in financially vulnerable industries, industries with greater external finance needs and lower asset tangibility. Furthermore, Manova (2013) shows that 75% – 80% of the impact of credit constraints on exports is independent of output reductions. Of this effect, 30% – 40% are due to lower export participation and 60%-70% are the result of depressed firm-level exports.

2.4.3.3 Empirical Evidence and Theoretical Evidence for the Impact of Financial Frictions on Trade

Much theoretical and empirical evidence builds on these seminal papers and demonstrates the significant effect of financial frictions on international trade.[10]

2.4.3.3.1 Empirical Evidence

Empirical evidence suggests that less financially constrained firms are both more likely to export and to export more.

Exporters Face less Credit Constraints than Non-Exporters

Some literature finds that exporters face less credit constraints than non-exporters, and investigates whether this is due to self-selection or ex-post effects. Thus Greenaway *et al.* (2007), using a panel of UK manufacturing firms from 1993 to 2003, show that exporters are financially more healthy than non-exporters. They find no evidence for ex-ante health advantages of exporters however, and instead suggest that exporting increases the financial health of firms.

Like Greenaway *et al.* (2007), Manole and Spatareanu (2010), using firm-level data on Czech firms covering 1994-2003, find that exporters face less liquidity constraints than non-exporters. However, in contrast to Greenaway *et al.* (2007), Manole and Spatareanu (2010) argue that this is driven by new exporters, and that less liquidity constrained firms self-select into export markets.

[10] Both Chaney (2016) and Manova (2013) appear to be recent papers, so it may seem odd prima facie that they form the basis of the literature presented in this section. However, both papers circulated for a long time as working papers, and it is these versions that formed the basis of much of the literature presented in this section: Chaney (2016) was frequently cited as Chaney (2005) and Manova (2013) as Manova (2008).

Bellone *et al.* (2010) support the results of Manole and Spatareanu (2010). This paper also investigates the effect of financial well-being on exporting, using a panel of French manufacturing firms from 1993-2005. Bellone *et al.* (2010) find that exporting firms are generally more liquid and have easier access to external finance than non-exporters. In order to examine whether this financial advantage is due to self-selection or ex-post effects, the authors examine the financial health of export starters and non-exporters in one and three years before the new exporters start exporting. They find that future new exporters have better financial health in both years, and are more liquid one year before entry. Bellone *et al.* (2010) find no evidence that exporting increases financial health ex-post, and thus overall find that financially healthy firms self-select into export markets.

The Effect of Financial Frictions on Trade

A related strand of the literature examines how financial frictions affect trade volumes. Minetti and Zhu (2011) use survey data on Italian firms to identify the impact of credit rationing on exports. Using the survey, they build a binary measure of weak and strong credit rationing, and find that rationing has a significant negative effect on export market participation: strong rationing reduces the probability of exporting by 38.6%. Credit rationing is also shown to affect the intensive margin of exports, as weak and strong rationing reduce foreign sales by 30% and 38% respectively.

Evidence from Manova *et al.* (2015) further suggests that less-credit constrained firms export more. This paper does not directly investigate credit constraints, but investigates the extent to which foreign ownership affects export behaviour, using data from the Chinese Customs Office on China's international trade transactions in 2005. The authors show that wholly foreign owned affiliated and joint ventures export 62% and 50% more than domestic firms in sectors highly dependent on external finance relative to financially less sensitive sectors. Furthermore, foreign-owned firms serve more destinations than domestic exporters in financially more vulnerable sectors, and export a broader range of products. According to Manova *et al.* (2015), these patterns are consistent with the idea that foreign-owned firms are less credit constrained due to access to cheaper internal markets and capital markets abroad, and imply that credit constraints restrict the ability of firms to enter more markets, widen their product range and expand trade volumes.

Muûls (2015) also examines the effect of financial frictions on exports. This paper uses the yearly Coface Services Belgium Global Score between 1999 and 2007 as a measure for credit constraints, as it provides information on the credit worthiness of firms. Muûls (2015) shows that credit constraints are correlated with both the number of products and the number of destinations exported to, as well as the intensive margins of exports. The author also investigates the effect of credit constraints on export and import growth rates. She finds that a one standard deviation increase in the log of the credit score is associated with a 2.5% increase in growth of exports and a 2.6% increase in growth of imports.

Schmidt-Eisenlohr (2013) examines the trade flows between countries with differing financing costs, which he uses as proxies of the tightness of financing constraints. To do this, Schmidt-Eisenlohr (2013) builds a model of trade finance and tests its predictions using data on bilateral trade flows from 150 exporting countries 1980-2004. He finds that financial conditions are correlated with trade flows, and that countries

with higher net interest rate margins, so higher repayment rates, trade less with each other. Specifically, a 1% increase in the financing cost in a country is associated with 2% lower exports and 2.3% lower imports by that country.

The studies cited above all study the effect of constraints in the overall credit supply, although they use different measures of credit constraints. In a slightly different approach, Niepmann and Schmidt-Eisenlohr (2017) use US banking data to investigate the effect of constraints to a specific finance supply, namely shocks to the bank-level supply of letters of credit on trade. They find that, controlling for demand effects, a negative supply shock to letters of credit in a country of one standard deviation reduces the export growth of that country by 1.5 percentage points.

Further literature examines the effect of financial frictions on trade balances by decomposing their impact on the extensive and intensive margins of trade. Hereby different papers reach different conclusions. Berman and Héricourt (2010), for example, study the impact of financial constraints, productivity and financial development on international trade, using a cross-country firm-level database of 9 developing and emerging economies, and find that financial frictions only affect the extensive margin of trade. Specifically, Berman and Héricourt (2010) find that a 10% increase in the financial proxies increases the exporting probability by between 0.5% and 1%. Furthermore, Berman and Héricourt (2010) find that productivity only matters for the exporting probability if firms have above-median access to finance. Financial constraints are thus shown to generate a disconnection between firms' productivity and export status, diminishing the importance of productivity for the selection of firms into exporting. According to Berman and Héricourt (2010), financial frictions thus have two major effects: they reduce the number of exporters and affect the selection of firms into exporting by affecting the degree to which productivity matters for exporting decisions. Conversely, financial frictions are found to be uncorrelated with the probability of remaining exporters and the intensive margin of exporting.

Askenazy *et al.* (2015) also provide evidence that financial frictions affect the extensive margin of exports. To do this, they use a firm-level dataset for French firms from 1995-2007, and four different measures of credit constraints. They find that the number of newly served export destinations of a firm is negatively associated with all four measures: credit constraints thus prevent firms from exporting to new destinations. Furthermore, the number of markets a firm exits is positively associated with credit constraints. Askenazy *et al.* (2015) argue that this is likely to reflect the fact that firms facing financing constraints face difficulties refinancing the required exporting fixed cost. Numerically, they find that normalised increases in financial constraints decrease the number of destinations a firm enters by 0.6 - 2.4%, and increase the number of exits from destination markets of a firm by 0.65 - 1.38% annually. The authors argue that if these increases are maintained, the cumulative effects of increases in financial constraints can be quite large.

While the above studies found that credit constraints affect the extensive but not intensive margin of trade, Paravisini *et al.* (2015) reach the opposite conclusion. This paper studies the effect of bank credit shocks on the export behaviour of Peruvian firms during the 2008 crisis by comparing the export growth of the same product to the same destination across firms that borrowed from banks that were differentially

affected by the reversal of capital flows to the country. Paravisini *et al.* (2015) find that negative shocks to credit reduced the volume of exports for firms that continued exporting to a given product-destination market, but had no effect on the probability that a firms entered or exited new product and destination markets. Paravisini *et al.* (2015) do find that when extending the post-crisis period from 12 to 24 months, a credit shock slightly affects the probability of entry. Nevertheless, Paravisini *et al.* (2015) argue that the finding that credit shocks mainly affect the intensive margin of trade suggests that credit shocks principally affect the variable costs of exporting.

2.4.3.3.2 Theoretical Evidence

Next to this empirical literature examining the impact of financial frictions on international trade, some papers also examine their influence in a theoretical setting. Hereby the papers examine slightly different phenomena, namely the impact financial frictions have on export flows, their impact on the gains of trade liberalisation, how they influence the choice between direct and intermediated trade, how they affect firm dynamics in an international trade setting and how they affect international trade fluctuations over the business cycle.

Li and Yu (2009) and Leibovici (2021) examine the effect of financial frictions on the volume of trade flows. Li and Yu (2009) do this in a Melitz (2003)-type model, in which firms draw a random productivity level from a productivity distribution. They face fixed and variable export costs, and the fixed costs need to be financed upfront. Financial intermediaries evaluate export projects according to their probability of success, which is assumed to be an increasing function of a firm's productivity. Based on this probability, financial intermediaries request a level of repayment and require a certain level of collateral. Credit constraints thus affect the intensive margin of exports as more credit constrained firms have higher repayment costs and therefore lower revenues, which constrains their export volumes. They affect the extensive margin of exports as only a subset of firms can raise the necessary funds to cover the required fixed costs. Li and Yu (2009) test this model for a dataset of Chinese manufacturing firms covering 2000-2007 and find support for their predictions.

Leibovici (2021) also considers the effect financial frictions have on export flows. The paper does this in a general equilibrium multi-industry model with credit constraints and occupational choice. Individuals endogenously choose whether to be entrepreneurs or workers, and entrepreneurs decide whether to operate in the capital-intensive or labour-intensive sector. If they choose the former, they must pay a fixed cost of operation, while choosing the latter industry is costless. In this model industries differ in their capital intensity, which leads to differences in their dependence on external capital, capital-intensive industries being more dependent on external finance. International trade is subject to an export entry cost as well as fixed and variable export costs. Leibovici (2021) assumes that the entry and fixed cost of exporting need to be paid upfront. However, debt is limited to a fraction of the value of a firm's capital stock. These financial frictions are shown to distort decisions along three margins. Firstly, they affect the production decisions of exporters, reducing the amount they export. Secondly, they distort export entry decisions, as firms with insufficient net worth are unable to enter export markets. Thirdly, they affect the occupational choice of individuals, as well as the technology choice of entrepreneurs: only individuals

with high net worth will choose to be entrepreneurs, and only entrepreneurs with high net worth will choose the capital-intensive technology.

Kohn *et al.* (2016) examine a different aspect of the impact of financial frictions on international trade, namely their effect on firm dynamics. Using Chilean plant-level data, they document two features of new exporter dynamics: external finance plays a key role in financing working-capital expenditures, and exporters face relatively higher working capital needs than non-exporters. Kohn *et al.* (2016) incorporate these features into an international trade model and assume that exporters must pay the full production cost for the export market and the fixed exporting cost in advance of production. Financial frictions are shown to impact on trade along both the intensive and extensive margins, by forcing firms with low internal funds to produce below their optimal scale and preventing firms with low internal funds from entering the export markets. When firms remain in the export markets, they can accumulate assets and thus relax their constraints, which allows them to expand their production and foreign sales. In order to assess the importance of financial frictions, Kohn *et al.* (2016) calibrate their model and a standard sunk entry cost model to Chilean plant-level data. They find that the model with financial frictions can account for the dynamics of new exporters observed in the data, namely that the majority of new exporters are financially constrained and that as they accumulate internal funds they become less constrained, increase their scale rapidly and decrease their exit probability. Besides considering the effect financial frictions have on firms dynamics, Kohn *et al.* (2016) also examine their impact on the gains of trade liberalisations, showing that the effects of trade liberalisation are decreased in a model with financial frictions. This occurs because with financial frictions, firms with low assets are unable to take advantage of lower tariffs, which means that the share of exporters increases by less.

Chan (2019) takes a slightly different approach in examining the impact of financial frictions on international trade, as he examines the role of financial frictions in shaping patterns of direct and intermediated trade, the latter being trade in which firms sell their goods abroad through 3rd party intermediaries. He finds that financially constrained firms are more likely to export indirectly than non-constrained firms. Chan (2019) empirically tests this prediction with a firm-level dataset of 115 developing countries from 2006-2015, as well as data on bilateral shares of indirect exports in total exports for Hong Kong, and finds support.

Watson (2019) examines a further aspect of financial frictions' effect on the macroeconomy, as this paper assesses their impact on the dynamics of international trade over the business cycle and their role in the great trade collapse of 2008 in a general equilibrium framework. Watson (2019) introduces financing frictions into an international trade model with heterogeneous firms, in which international trade is more dependent on external finance than domestic sales. Domestic retailers and exporters must pay a fixed production cost and a fraction of their variable costs in advance, for which a fraction of the required working capital needs to be financed externally. In each period, a fraction of firms defaults on their loans, which motivates banks to charge premiums on their loans. As the fraction of defaulting firms depends on aggregate macroeconomic conditions, this external finance premium is time-varying, causing firms' marginal costs and prices to also vary over time. As exporters are more dependent on external credit, their prices are more sensitive to such changes than domestic prices. This leads to a procyclical

evolution of the trade to GDP ratio and a countercyclical evolution of the relative price of imported goods relative to domestic goods. Watson (2019) argues that credit frictions can explain a significant part of the fluctuations of international trade over the business cycle, as changes in the external finance premium amplify the impact of demand and productivity shocks on international trade.

2.4.3.4 Financial Frictions, International Trade and Productivity

A recent and still relatively small strand of literature examines the joint link between financial frictions, trade and productivity. These papers thus take their analysis a step further than the literature presented above: they also consider the effect financial frictions have on international trade patterns, but additionally investigate the impact these trade patterns have on aggregate productivity.

Bonfiglioli *et al.* (2018) extend the Melitz (2003) framework by assuming that firms draw a random productivity level from a productivity distribution upon paying a sunk innovation cost. Firms can affect the variance of the probability distribution from which the productivity is drawn by choosing between investment projects upon entry. Larger innovation projects are associated with a more dispersed realisation of productivity. According to the authors, the key insight of this model is that the exit probability insures against bad draws and increases the value of drawing productivity from a more dispersed productivity distribution. Because export opportunities increase expected profits associated with a good productivity draw, they induce firms to draw technology from a more dispersed productivity distribution and thus induce firms to invest in larger projects. According to the authors, this increases average productivity. Bonfiglioli *et al.* (2016) extend this model by introducing financial frictions. Firms are assumed to have no wealth prior to entry, so they must finance the upfront sunk entry cost with external capital. In this model, financial frictions lower the equilibrium degree of productivity heterogeneity in a sector. This is because they increase the cost of investment and thus the cost of entry. This reduces entry and therefore also competition, allowing less productive firms to survive. But a higher survival probability lowers the value of drawing from a more dispersed distribution, which ensures firms are smaller and more homogenous. Financial frictions are thus shown to discourage investment in large-scale projects and the use of advanced technologies, generating more productivity homogeneity within a sector, decreasing exports and allowing less productive firms to survive. Although the authors don't explicitly refer to the impact of these effects on aggregate productivity, it is intuitive that they will adversely affect aggregate productivity relative to a setting without financial frictions.

Caggese and Cuñat (2013) develop an industry model following Melitz (2003), augmenting it with firm dynamics. Firms are heterogeneous in their productivity, produce differentiated goods and face per-period fixed costs and sunk entry costs to enter both the domestic and export markets. Caggese and Cuñat (2013) introduce the following innovations to this set-up: financing constraints, heterogeneity in fixed costs and volatility of firm profits. For the latter, they introduce idiosyncratic profit shocks. To model financing constraints, firms are assumed to be required to pay their fixed production costs in advance. However, they are exposed to absolute borrowing constraints: they cannot borrow. When firms cannot cover their costs, they go bankrupt and are liquidated, which is costly. In order to prevent this, firms accumulate internal funds as precautionary savings. In this setting financial frictions constrain

firms from paying the required costs up-front and self-selecting into the export market, and delay the exporting decision of productive firms. This latter effect occurs because exporting adds volatility to firm profits and initially decreases wealth, increasing the risk of costly bankruptcy. To mitigate this risk, firms build up precautionary savings prior to entering the export market. Finally, financial frictions lead to a competition effect as they allow relatively inefficient firms with low profit volatility to enter the export market, inducing further misallocation. Caggese and Cuñat (2013) quantify this model by calibrating it to Italian manufacturing data covering 1995-2003. They consider three versions of the model and find that the benchmark model is best able to replicate patterns in the data. Quantifying the gains trade liberalisation induces in each of these models, Caggese and Cuñat (2013) find that the presence of both liquidity constraints and costly bankruptcy reduces the gains from trade by 25%.

Kohn *et al.* (2017) is the paper that examines the relationship between trade, financial factors and productivity most directly and most in depth. Specifically, Kohn *et al.* (2017) investigate and quantify two channels through which financial frictions affect productivity, namely by distorting firms' production and exporting decisions and by affecting their entry and exit decisions. To do this they study a small open economy. The international trade decisions are modelled following Melitz (2003): firms face per-period fixed costs to produce domestically and additional entry, fixed and variable costs for exporting. Financial frictions are incorporated into this set-up by assuming that entrepreneurs' borrowing is limited to a fraction of their net worth. Kohn *et al.* (2017) also incorporate occupational choice into their model. Due to credit constraints, only individuals with high productivity and high net worth become entrepreneurs. In this setting, financial frictions lead to three distortions. They force entrepreneurs that are constrained to produce below their optimal scale, which reduces sales and profits. Conditional on a given level of net worth, these distortions are larger among exporters as they typically have a higher optimal scale given the larger markets they face and their higher productivity. Financial frictions also distort the export-entry decision, as productive firms with low net worth are prevented from exporting. Finally, financial frictions affect the allocation of individuals between workers and entrepreneurs, as individuals that would be productive entrepreneurs but have low net worth choose to be workers. This leads to further misallocation and TFP losses. Kohn *et al.* (2017) quantify the importance of these frictions, finding 88% of firms do not operate at their optimal scale due to their presence. Among these firms, average profits are 39% lower than they would be without financial frictions. Furthermore, export participation and the number of entrepreneurs would be significantly higher in the absence of credit constraints. Aggregate TFP is found to be 26% lower than it would be without financial frictions due to their joint impact on production, export and entry decisions. Kohn *et al.* (2017) also consider the effect of a trade liberalisation that reduces variable trade costs by 25%. They find that in the baseline economy with financial frictions, exports increase by almost 50%, whereas domestic sales decrease by 11% as sales are reallocated towards exporting firms. Aggregate consumption increases by 4% , wages by 4.2% and GDP by 3.9%. In an economy with less credit frictions, these effects are reduced. According to Kohn *et al.* (2017), this is because a trade liberalisation increases profits and thus allows firms to accumulate assets, which relaxes their credit constraints. Such a relaxation is particularly valuable in economies where firms are severely credit constrained.

In contrast to Kohn *et al.* (2017), Brooks and Dovis (2020) show that whether financial frictions reduce

gains from trade critically depends on the way they are modelled. They argue that when financing constraints are forward-looking and depend on the future profitability of the firm, the gains from trade liberalisations are the same as in an economy without any financial frictions. In contrast, when financing constraints are backward-looking in the form of collateral constraints, where debt is proportional to a firm's assets, gains from trade liberalisations are lower relative to a frictionless economy. According to Brooks and Dovis (2020), differential changes in TFP are the driver of these differences. In the model with backward-looking constraints, non-exporters are less profitable following a trade liberalisation, meaning they can accumulate less assets. Productive young firms are thus unable to enter export markets, while less productive firms with high net worth can enter. In the model with forward-looking constraints, debt is limited by future profitability. As a trade liberalisation increases the profitability of exporters, these young productive firms that would be prevented from entering export markets in the model with backward-looking constraints are able to enter foreign markets, which reduces misallocation.

2.4.4 The Gap in the Literature

Taken together, the literature described in Sections 3 and 4 of the literature review illustrates three key facts. Firstly, Chapter 2.3 shows that international trade considerably increases aggregate productivity. Secondly, Chapter 2.4 illustrates that financial frictions have a significant impact on productivity. Thirdly, financial frictions have been shown to affect international trade. However, while there is a vast amount of literature examining the impact of financial frictions on productivity, an equally vast amount of literature examining the impact of international trade on productivity, and an increasing amount of literature on the effect of financial frictions on international trade, the link from financial frictions to productivity through international trade remains to be more precisely understood. Notable papers in this area include Caggese and Cuñat (2013) and Brooks and Dovis (2020), who investigate how financial frictions decrease the welfare gains from trade, Bonfiglioli *et al.* (2018), who show that financial frictions decrease the heterogeneity of productivity in a sector, and Kohn *et al.* (2017), who explore the effect of financial frictions on international trade and productivity in most depth by estimating that financial frictions, via three distortions, decrease aggregate TFP by 26% relative to a setting without financial frictions.

However, to the best of my knowledge no paper examines how financial frictions affect the dynamic response of labour productivity to macroeconomic shocks in an international trade model and the implications international trade has for this effect. In Chapter 5 of this thesis I therefore examine how financial frictions amplify the response of the economy and labour productivity to a variety of macroeconomic shocks in an international trade model. I furthermore examine how their effect on macroeconomic variables, especially labour productivity, is impacted by international trade, as I analyse how and to what extent international trade affects the amplification effect of financial frictions. This is important, as the literature implies that both financial frictions and international trade have a significant effect on productivity. If international trade changes the effect of financial frictions on labour productivity, then models that abstract from international trade will either overstate or understate the impact of financial frictions. This in turn has important repercussions for policy-making and -design.

2.5 Conclusion

In this chapter I presented a review of the literature that the three substantive chapters of the thesis build on, and identified my contribution to the respective strands of literature. Below I summarise these contributions.

The literature on macroeconomic puzzles has attempted to create models that can explain four frequently-studied puzzles: the Quantity Puzzle, the Positive Co-movement Puzzle, the Backus-Smith Puzzle and the Terms of Trade Puzzle. Most of this literature, however, uses data from the 1970s-1990s. Even among the recent literature some papers use such old data periods, while others include more recent data. However, to the best of my knowledge for such papers the data period also starts in 1970 or 1980. If any changes in the data patterns underlying the puzzles occured in recent decades, these papers thus would not necessarily be able to capture this change. In Chapter 3 of the thesis, I therefore contribute to the literature by examining whether the data patterns underlying four prominent puzzles in international macroeconomics still exist in recent data, both for the US and for other country-pairs. More specifically, I address the following research question. Using recent data, do we still find that the cross-country correlation of output exceeds the cross-country correlation of consumption, that output, consumption, investment and employment correlate positively across countries, that the real exchange rate and relative consumption are negatively correlated across countries, and that terms of trade are more volatile than output? This research question is important for the following reason. The data patterns underlying the four prominent puzzles addressed in this thesis are frequently used as validation mechanisms for macroeconomic models. If these data patterns no longer exist, then they are no longer useful as a validation mechanism and building models to match them is redundant. If the likelihood the patterns hold depends on certain country characteristics, awareness of this heterogeneity in the data patterns is important, and models should be built that can account for it.

The literature on international trade illustrates very clearly, in both theoretical and empirical terms, that international trade increases productivity. A large strand of this literature analyses the dynamic response of the economy to macroeconomic shocks. Hereby, the literature shows that both international trade and endogenous entry into domestic production matter for the response of the economy to macroeconomic shocks. However, most models that examine endogenous entry in an international trade framework only use one factor of production, namely labour. At the same time, we know that the inclusion of two factors of production can be important. In Chapter 4 of the thesis I therefore address the following research question. How does resource allocation affect the transmission of macroeconomic shocks in an international trade model with endogenous entry into domestic production? Hereby I pay specific attention to the dynamic response of labour productivity to such shocks. I thus contribute to the literature by analysing the extent to which the omission of a 2nd factor of production is important when considering the dynamic response of labour productivity to macreconomic shocks in an international trade framework.

The literature on financial frictions shows that financial frictions have a significant effect on both productivity and international trade. Combined with the literature on international trade, we therefore have three key facts. Firstly, international trade considerably increases aggregate productivity. Secondly,

financial frictions have a significant impact on productivity. Thirdly, financial frictions have been shown to affect international trade. However, while there is a vast amount of literature examining the impact of financial frictions on productivity, an equally vast amount of literature examining the impact of international trade on productivity, and an increasing amount of literature on the effect of financial frictions on international trade, the link from financial frictions to productivity through international trade remains to be understood. Indeed, to the best of my knowledge no paper examines the extent to which international trade affects the effect of financial frictions. In Chapter 5 of this thesis I therefore address the following research question. How and to what extent does international trade affect the amplification effect of financial frictions? Throughout the chapter I pay specific attention to the dynamic response of labour productivity to the macroeconomic shocks I study. I therefore contribute to the literature by examining how the effect of financial frictions is affected by the presence of international trade. This contribution is important, as it shows that models that abstract from international trade either overstate or understate the impact of financial frictions on labour productivity and the economy. This is relevant for policy-makers; my contribution shows that jointly accounting for financial frictions and international trade is important for policy-design, as abstracting from international trade when estimating the effect of a policy when taking financial frictions into account would cause this effect to be over- or underestimated.

Chapter 3

Re-examining Four Puzzles in International Macroeconomics

3.1 Introduction

Macroeconomic models are frequently built to match certain moments in data. If such moments in data occur frequently and are documented extensively, they are referred to as stylised facts. If the model in question matches such stylised facts, then there is a good case to argue that it explains certain aspects of the data well. Stylised facts are thus frequently used as a validation mechanism for economic models.

A problem arises if certain stylised facts are not matched by a certain type of model that is standard in the literature at all. When such a case arises and a standard pattern in the data is not matched or explained by theory, it is referred to as a puzzle. In such an instance, a body of literature tends to emerge trying to adapt these standard models to fit the documented data moments and explain the puzzle. Such literature can exist and be built on over a large period of time. However, a question that is important to ask when considering such literature is: do the patterns that were originally documented in data, which models were unable to match and explain, still persist in the present? In other words, can the data patterns that are considered to be stylised facts still be called such today? This question is important, because if the stylised facts that gave rise to the puzzles no longer exist, then they are no longer useful as a validation mechanism, and building models to explain the puzzles is redundant.

In this chapter I address the following 4 stylised facts on international business cycles that were first documented around the 1990s and that standard international macroeconomic models were historically unable to match. First, cross-country correlations of output exceed cross-country correlations of consumption. Second, investment, employment, consumption and output are positively correlated across countries. Third, the real exchange rate is negatively correlated with relative consumption and fourth, terms of trade exhibit high volatilities relative to output.

Standard models of international trade frequently have problems yielding these international business cycle statistics, as they yield very high cross-country correlations of consumption that exceed those of

output, negative cross-country correlations of investment and employment and sometimes of output, a positive correlation between the real exchange rate and relative consumption, and small volatilities in the terms of trade.

The inability of standard models of international trade to match and therefore explain the stylised facts described above have widely been referred to as puzzles. Specifically, the inability of models to generate and therefore provide an explanation for a cross-country correlation of output that exceeds the cross-country correlation of consumption was termed the Quantity Puzzle, and the inability of models to generate positive co-movement of output, consumption, investment and employment simultaneously was termed the Positive Co-movement Puzzle. The inabibity of models to generate and therefore provide an explanation for the fact that the real exchange rate and relative consumption are negatively correlated in data was called the Backus-Smith Puzzle, after the two academics that first documented this empirical regularity. The inability of models to match and therefore explain the large volatility of the terms of trade is referred to as the Terms of Trade Puzzle in this thesis.

To address these four puzzles, literature emerged that tried to adapt standard international macroeconomic models in a way that enables them to match and therefore explain the patterns found in data. The question I address in this chapter is: do the patterns underlying the four puzzles still exist in current data? In other words, can the data patterns that have widely been considered to be stylised facts still be called such today? 4 main results stand out from the analysis. First, I find that the data pattern underlying the Quantity Puzzle exists for a much smaller percentage of country-pairs in recent data than in older data, as only 65% of country-pairs exhibit a cross-country correlation of output that exceeds the cross-country correlation of consumption. The intuition behind the decrease in the prominence of the pattern is increased globalisation, specifically an increase in financial integration. When proxying financial development with GDP-per-capita, I find that only 31.75% of the financially developed countries exhibit a cross-country correlation of output that exceeds that of consumption, while for 68.25% of the sample the cross-country correlation of consumption exceeds that of output. Second, terms of trade are less volatile than output in recent data for the majority of country-pairs, especially among EU countries. Third, the data pattern underlying the Backus-Smith Puzzle still exists for a large majority of country-pairs that are not part of the European Monetary Union. For country-pairs that are part of the euro area (henceforth EA), this is not the case, as a small majority of country-pairs actually has a positive correlation between their real exchange rate and relative consumption. Fourth, positive co-movement among output, consumption, investment and employment continues to persist in recent data and across many country-pairs.

Overall, positive co-movement of macroeconomic variables is still clearly a stylised fact today. A similar conclusion applies for the data pattern underlying the Backus-Smith Puzzle, namely that the real exchange rate is negatively correlated with relative consumption. This pattern is still a stylised fact for country-pairs that are not part of the euro area. However, for members of the EA it can no longer be considered to be a stylised fact. The same applies to the data pattern underlying the Terms of Trade Puzzle; as just over half of the countries exhibit a volatility of terms of trade that is greater than the volatility of output, this pattern is no longer a stylised fact. Finally, whether the data pattern underlying the Quantity Puzzle holds depends on certain country characteristics, which implies that the pattern can

also no longer be considered a stylised fact in recent data.

The contribution of this chapter to the literature is twofold. First, I illustrate that greater awareness and consideration of the fact that stylised facts can change over time and differ across country groups is important. Since stylised facts are often used as validation mechanisms, such awareness is important to ensure that models yield output in line with up-to-date data. Second, to account for the heterogeneity of data patterns across country-groups, models need to include mechanisms that are appropriate for the countries that are being modelled and calibrated for in order to match the relevant data moments.

The chapter will proceed as follows. Section 3.2 presents a review of the literature. In Section 3.2.1 I summarise the literature and and in Section 3.2.2 I provide a brief overview of the data the literature used and identify the gap in the literature. In Sections 3.3-3.7 I consider whether the empirical regularities that were originally documented in the 1990s and have since then widely been accepted as stylised facts still exist today. More concretely, I examine whether, using recent data, we still find that cross-country correlations of output exceed those of consumption; whether we still find positive co-movement among output, consumption, investment and employment; whether we still find that real bilateral exchange rates are negatively correlated with relative consumption; and whether we still find that terms of trade are more volatile than output. To do this Section 3.3 describes the data used in this chapter, and Sections 3.4-3.7 re-examine the Quantity Puzzle, the Positive Co-movement Puzzle, the Backus-Smith Puzzle and the Terms of Trade Puzzle respectively. Section 3.8 concludes.

3.2 A Review of the Literature

3.2.1 The Literature

There are three seminal papers in the literature on the four macroeconomic puzzles addressed in this chapter. These are Backus *et al.* (1992), Backus and Smith (1993) and Backus *et al.* (1993). Backus *et al.* (1992) first documented that cross-country correlations of output are higher than cross-country correlations of consumption in data, while the opposite is predicted by standard theory.[1] This data pattern was confirmed by Backus *et al.* (1993), who were also the first to point out the Positive Co-movement Puzzle and the Terms of Trade Puzzle.[2] Backus and Smith (1993) is the first paper to illustrate what later became known as the Backus-Smith Puzzle, namely the inability of standard models to explain the observation that in data, a country-pair's real exchange rate and relative consumption tend to be negatively correlated. Since these seminal papers, much literature has emerged seeking to explain one or several of the puzzles they documented.

In order to explain the Quantity Puzzle, that the stylised fact that cross-country correlations of output are higher than cross-country correlations of consumption in data is not explained by standard models, literature has investigated the extent to which international trade costs (Backus *et al.* (1992), Obstfeld

[1] The authors refer to this as the quantity anomaly. In the literature it has been referred to by different names; in this chapter I refer to it as the Quantity Puzzle.

[2] The authors refer to the latter puzzle as the price anomaly. For the sake of name consistency across all puzzles considered in this chapter, I refer to it as the Terms of Trade Puzzle.

and Rogoff (2001), Ghironi and Melitz (2005), Hoffmann (2008), Eaton *et al.* (2016)) or asset market incompleteness (Kollmann (1996), Heathcote and Perri (2002), Kehoe and Perri (2002), Dmitriev and Roberts (2012)) contribute to reducing the puzzle. Bhattarai and Kucheryavyy (2020) show that a model with intermediate trade in goods and negative capital externalities is able to resolve the Quantity Puzzle. Similarly, Ambler *et al.* (2002) show that convex capital adjustment costs are vital in bringing model output closer to data. Other papers have investigated the role that the type of shock driving the business cycle plays in the explanation of this puzzle. Stockman and Tesar (1995) and Jiang (2017) argue that demand shocks are important in this regard and Mandelman *et al.* (2011) investigate the extent to which investment specific technology shocks can explain the puzzle. Gars and Olovsson (2017) include an oil-producing country and oil supply and efficiency shocks in their model, showing that accounting for oil shocks can explain the Quantity Puzzle. Xiao (2004) and McKnight and Povoledo (2017) both address how market expectations rather than shocks themselves affect cross-country correlations of consumption and output. While Xiao (2004) argues that changes in market expectations about shocks are crucial in generating a cross-country consumption correlation that is lower than a cross-country output correlation, McKnight and Povoledo (2017) argue that market expectations themselves are insufficient to solve the puzzle. According to McKnight and Povoledo (2017), it is only when self-fulfilling expectations are allowed to correlate with technology shocks that the Quantity Puzzle is decreased. Some papers have also investigated the extent to which financial frictions are relevant for the puzzle. Thus Faia (2007) study the importance of differences in financial frictions and exchange rate regimes for the Quantity Puzzle, finding that neither substantially contributes to explaining it. In contrast, Yao (2019) argues that financial frictions reduce the consumption correlation, thereby reducing the size of the Quantity Puzzle. Iliopulos *et al.* (2021) agree that financial frictions matter for the puzzle. To illustrate this they build a model that includes financial frictions, learning and departures from uncovered interest rate parity, and show that with monetary and technology shocks the model is able to match the pattern found in the data.

Many of the papers investigating the Quantity Puzzle also examine the Positive Co-movement Puzzle, which refers to the inability of standard models of international trade to explain the positive co-movement of output, consumption, investment and employment observed in data. Thus Backus *et al.* (1992) and Ghironi and Melitz (2005) argue that trade costs are important in explaining both puzzles, while Heathcote and Perri (2002) and Kehoe and Perri (2002) claim that asset market incompleteness contribute to explaining both the Quantity and the Positive Co-movement Puzzles. Faia (2007) shows that both similarity of the degree of financial integration and similarity of monetary policies are important in generating positive co-movement. As with the first puzzle, some papers argue that the way shocks are modelled is important in addressing the discrepancies between data and theory. Thus, Wen (2002) and Jiang (2017) argue demand shocks yield positive co-movement among macroeconomic variables, while Gars and Olovsson (2017) show that accounting for oil shocks is important for resolving the puzzle. De Walque *et al.* (2017) show that their model's match with data improves when risk premium shocks are enabled, arguing that this suggests internationally linked financial sectors may be an interesting avenue for further research into the Positive Co-movement Puzzle. Indeed, Yao (2019) argues that the presence of a collateral constraint is crucial for bringing the model closer to data.

Further literature investigates the role production structure plays in creating international co-movement.

Wong and Eng (2013) argue that including vertical specialisation in modelling helps account for the co-movement of macroeconomic variables in East and southeast Asia, Lambrias (2020) develops a model with non-tradable goods in order to explain the puzzle, and Huo *et al.* (2020) study the role of the global production network in generating output co-movement. Bergholt (2015) argues that trade between firms is important for creating more co-movement among macroeconomic variables in his model, a finding that is echoed by Huang and Liu (2007). Huang and Liu (2007) show that accounting for trade among intermediate inputs and multi-stage processing is crucial for generating positive co-movement in response to a monetary expansion. In contrast, Bhattarai and Kucheryavyy (2020) find that trade in intermediate goods is unimportant in generating positive co-movement, instead arguing that negative capital externalities in production are crucial for resolving the Positive Co-movement Puzzle.

The third puzzle I address in this chapter is the Backus-Smith Puzzle. In 1993, Backus and Smith argued that under perfect purchasing parity, one would assume that the real exchange rate of two countries would be correlated with their relative consumption. This is because as the price of goods rises in one country due to a change in the exchange rate, the consumption of those goods should adapt in both countries to reflect that price change. However, Backus and Smith (1993) found that in data, this is not actually the case, as the real exchange rate and relative consumption appear to be negatively correlated. This puzzle has also attracted much attention in the literature. As for the previous two puzzles I presented, incomplete asset markets have been suggested as a potential explanation (Corsetti *et al.* (2008), Benigno and Thoenissen (2008)). Benigno and Thoenissen (2008) argue that limited international asset trade combined with a non-traded goods sector is important in addressing the puzzle, as shifts in the prices of non tradable goods contribute to generating a negative correlation between the real exchange rate and relative consumption. Raffo (2010) argues that such a negative correlation can be achieved with investment specific technology shocks, Jiang (2017) argues the same result can be obtained with demand shocks, and Itskhoki and Mukhin (2021) argue that it is depreciations induced by financial shocks that explain the Backus-Smith Puzzle. While these papers succeed in yielding the negative correlation between the real exchange rate and relative consumption that is observed in data, other papers that investigate the puzzle fail to generate this correlation. Chari *et al.* (2002) examine the importance of sticky prices for the puzzle and McKnight and Povoledo (2017) investigate whether indeterminacy and self-fulfilling expectations can solve the puzzle. Both papers find that their avenues do not solve the Backus-Smith Puzzle.

Regarding the fourth puzzle I address in this chapter, various avenues have been put forward as a solution. Stockman and Tesar (1995) show that including demand shocks increases the variability of the terms of trade, while Raffo (2010) illustrates that the same result can be achieved by including investment-specific technology shocks. Heathcote and Perri (2002) argue that international asset market incompleteness is necessary to generate a high terms of trade volatility, while McKnight and Povoledo (2017) show that accounting for self-fulfilling expectations generates higher volatilities of terms of trade than output, as seen in data.

3.2.2 The Data used in the Literature & the Gap in the Literature

Since the seminal papers of Backus *et al.* (1992), Backus and Smith (1993) and Backus *et al.* (1993), much literature has attempted to address puzzles in international macroeconomics. As the literature review of the thesis shows, the vast majority of the papers illustrate that in data: (1) the cross-country correlation of output exceeds the cross-country correlation of consumption, (2) there is positive international co-movement for output, consumption, investment and employment, (3) a country-pair's real exchange rate and relative consumption are negatively correlated, and (4) terms of trade exhibit a volatility that is larger than that of output.

However, the data used to draw these conclusions has two major drawbacks.[3] The first drawback is that it is very US-centered. Indeed, only very few papers consider country-pairs that do not include the US at all. As the US economy is not necessarily representative among either industrialised or developing economies in terms of both its size and openness, this US-centered approach makes it difficult to ascertain whether the documented data patterns hold for country-pairs that do not include the US as well. Intuitively, however, in order to consider patterns found in data to be robust stylised facts, they should hold across a large number of country-pairs. The second drawback of the data used in the literature is that it does not tend to include very recent data. Among the more recent papers, some papers simply employ data from older papers, while others still only use data up to the early 2000s. There are also recent papers that include more recent data. However, to the best of my knowledge for such papers the data period starts in 1970 or 1980. If data patterns changed between the late 1900s and early 2000s, such data samples would not necessarily be able to show said change. There are several reasons for why we could expect data patterns to have changed. The continued increase in globalisation, creation of the European Monetary Union and synchronised monetary policy in form of quantitative easing since the 2008 financial crisis all could have implications for the data patterns underlying the four puzzles.

The data limitations presented above raise two questions. Firstly, do the observed patterns persist when using country-pairs that do not include the US? Secondly, has the prominence of the puzzles changed in recent data? These questions are important, as they have implications for the literature. From a policy-making perspective, it is important to know whether the stylised facts apply only to the US, or whether they hold more generally. For the literature, it is important to know whether the stylised facts that underlie and give rise to the puzzles still exist in the data today. Insofar as they do not, they no longer serve as a validation mechanism for economic models.

In order to address the questions formulated above, I will use recent data to analyse whether the four puzzles still exist. In other words, I examine whether the stylised facts underlying four prominent puzzles in international macroeconomics still persist today. Concretely I will:

1. Provide evidence for the data patterns underlying the puzzles in the data period most frequently used in the literature.

[3] A breakdown of the data used in prominent papers in the field is provided in the literature review of the thesis, in Chapter 2.2.2

2. Provide an analysis of the international correlations for a large number of country-pairs using recent data.

3. Provide an analysis of the international business cycle statistics for a large number of individual countries vis-à-vis the US using recent data.

The first exercise ensures that my results for recent data are not driven by my choice of database. The second analysis enables me to examine whether the data still deviates from the predictions of standard international trade models, and therefore whether the puzzles I address in this chapter still exist today. The third analysis allows me to determine whether the prominence of the data patterns underlying the puzzles depends on whether the US is included in the sample.[4] As the literature addressing the macroeconomic puzzles is very US-focused, this allows me to place my findings in the context of the literature and to determine whether a US-focused approach overstates the prominence of the data patterns underlying the macroeconomic puzzles.

I therefore contribute to the literature by examining whether the data patterns that have been documented extensively in literature: (1) hold more generally also for country-pairs that do not include the US and (2) still hold in recent data.

3.3 Data

All data used to calculate the international business cycle statistics in this chapter is taken from the OECD *Main Economic Indicators* database.[5] The only exception are the terms of trade, which are taken from `https://data.oecd.org/trade/terms-of-trade.htm`. For GDP, consumption and investment I used quarterly data, which can be found under "Monthly Economic Indicators - National Accounts". They are, respectively, gross domestic product, private final consumption expenditure, and gross fixed capital formation. I used the index of these variables at constant prices. Data for employment is from the "Civilian Employment Index", found under "Labour - Annual Labour Force Statistics Archives - Population and Labour Force", and is annual. To compute the relevant business cycle moments I took the log of all variables and detrended them using a Hodrick-Prescott filter, following the standard methodology in the literature.

Data for the terms of trade and for the real exchange rates is annual. To construct real exchange rates, I use the nominal exchange rates and Consumer Price Indices (CPIs) from the OECD *Main Economic Indicators* database. As the nominal exchange rates I use are annual, I use annual CPI and consumption data as well.

I use two data periods in order to carry out the analysis. The earlier period is 1970Q1-1995Q4. This period was chosen because it corresponds to much of the data that is used in the existing literature in this field. The second, more recent data period is 1999Q1-2020Q2. The choice of this data period is given

[4] When I refer to prevalence or prominence in this chapter I refer to the proportion of country-pairs for which a data pattern holds.

[5] This database can be found at `https://stats.oecd.org/Index.aspx`.

by the desire to investigate the importance of the euro area for the Puzzles. Since the euro only came into existence in 1999Q1, this conditioned the choice of the data for this study.[6] Henceforth, I will refer to the period 1970Q1-1995Q4 as Period 1 and the period 1999Q1-2020Q2 as Period 2.[7] When data is annual, Period 1 refers to 1970-1995 and Period 2 to 1999-2019.

In Period 2, the *Main Economic Indicators* database provides data on GDP, consumption and investment for 38 countries and data on employment for 33 countries. In Period 1 it provides data on GDP and consumption for 10 countries, data on investment for 9 countries and data on employment for 26 countries.

As far as possible, I followed standard methodology. As Section 2.2.2 showed, the majority of literature employs quarterly data, although some papers use annual data. The choice of data frequency may have implications for results, with shorter-term frequency being the preferred choice. I use quarterly data for the Quantity and Positive Co-movement Puzzles, and annual data to address the Backus-Smith and Terms of Trade Puzzles. The frequency choice for the latter two puzzles was determined by data availability for a large sample of bilateral (not effective) exchange rates and terms of trade. A second issue that may arise concerning comparability of the methodology is the definition of variables. For example, the exact definition of the terms of trade, or the use of effective versus bilateral exchange rates, may affect results. I attempted to mitigate any problems that may arise from the choice of data frequency and variable definitions by using the same variables and methodology,[8] across the two periods I analyse. Any changes that occur in the data patterns are therefore not due to methodological choices, but underlying economic factors.

3.4 The Quantity Puzzle

In this section I will investigate whether the data pattern underlying the Quantity Puzzle still exists in recent data. As a reminder, the Quantity Puzzle refers to the inability of standard models of international trade to generate and thus explain a cross-country correlation of output that exceeds the cross-country correlation of consumption. Standard theory predicts that the ability to share risk internationally produces a large correlation of consumption across countries, one that exceeds the cross-country correlation of output. In data, the cross-country correlation of output was found to be larger than that of consumption. I analyse whether this data pattern still exists and thus whether the data pattern underlying the Quantity Puzzle continues to be a stylised fact in recent data.

First, I will provide evidence for the data pattern that the cross-country correlations of output exceed those of consumption in Period 1. This is to ensure that the results I present are not driven by my choice of database. I then examine a large sample of countries for Period 2 in Section 3.4.2. I analyse the cross-country correlations for each country-pair, which yields 703 observations. Examining the Quantity Puzzle with such a large amount of country-pairs is unprecedented in the literature. The only other study I am aware of that examine the Puzzle over a large number of countries is Ambler *et al.* (2004), who used

[6] I explicitly did not include the most recent years in order to not take account of the impact of the Covid-19 pandemic.
[7] Whenever I refer to recent paper in this chapter, I refer to Period 2.
[8] The methodology I use is standard in the literature.

190 country-pair observations. In Section 3.4.3 I discuss my results and draw out implications for the literature.

3.4.1 Evidence for the Stylised Fact underlying the Quantity Puzzle in Earlier Data

Tables 3.1 and 3.2 describe the cross-country correlations of output and consumption for 45 country-pairs in Period 1. Of the 45 country-pair observations, 37 country-pairs have a correlation of output that exceeds the correlation of consumption. For 8 country-pairs, the cross-country correlation of output is lower than that of consumption.[9] My findings are thus in line with those from the literature (see for example Backus *et al.* (1992), Ambler *et al.* (2004), Kehoe and Perri (2002), Jiang (2017), Iliopulos *et al.* (2021)) as I show that the cross-country correlation of output exceeds that of consumption in the majority of country-pairs in Period 1.

I will now examine whether the prevalence of the pattern changes depending on whether or not the US is included in the sample. First, I consider all country-pairs that include the US, as described in Table 3.3. For all 9 country-pair observations, the cross-country correlation of output exceeds the cross-country correlation of consumption in Period 1.

The next question to consider is whether the stylised fact that the cross-country correlation of output exceeds the cross-country correlation of consumption holds for country-pairs that do not include the US. Out of 36 observations, 27 country-pairs exhibit a cross-country correlation of output that is higher than that of consumption in Period 1, while 9 exhibit a cross-country correlation of consumption that exceeds that of output. The stylised fact that the cross-country correlation of output exceeds that of consumption therefore persists among country-pairs that do not include the US in Period 1 as well. However, it is important to note that ALL country-pairs including the US exhibited this pattern in the first period. For country-pairs not including the US, only 75% of country-pairs exhibit this pattern in the first period. It therefore seems that whether or not the US is included in the country-pair has some relevance for the prevalence of the Quantity Puzzle, even when considering the older data period. The documented data pattern is present for a larger percentage of country-pairs that include the US than for country-pairs that do not include the US.

Overall in this section I provide evidence that the data pattern underlying the Quantity Puzzle is prominent in Period 1. Indeed, the cross-country correlation of output exceeds that of consumption for 100% of the country-pairs that include the US, and 75% of country-pairs that do not include the US. Focusing only on the US, as the literature tends to do, thus leads to an overstatement of the Puzzle.

[9] These country-pairs are Australia-France, Australia-Korea, Canada-Sweden, France-Greece, France-Korea, Greece-Korea, Korea-Sweden and South Africa-UK.

Table 3.1: International Output and Consumption Correlations

Country-Pair	*Output Correlation*	*Consumption Correlation*
Australia - Canada	0.71	0.04
Australia - France	0.22	0.23
Australia - Germany	0.034	-0.41
Australia - Greece	0.22	0.16
Australia - Korea	-0.12	0.03
Australia - South Africa	0.54	0.27
Australia - Sweden	0.28	0.22
Australia - UK	0.31	0.05
Australia - US	0.44	-0.26
Canada - France	0.32	0.2
Canada - Germany	0.23	0.18
Canada - Greece	0.24	0.05
Canada - Korea	0.25	0.03
Canada - South Africa	0.39	0.06
Canada - Sweden	0.33	0.37
Canada - UK	0.5	0.49
Canada - US	0.74	0.55
France - Germany	0.61	0.35
France - Greece	0.35	0.52
France - Korea	0.25	0.32
France - South Africa	0.26	0.08
France - Sweden	0.33	0.29
France - UK	0.59	0.49
France - US	0.37	0.32
Germany - Greece	0.49	0.36
Germany - Korea	0.21	0.18
Germany - South Africa	-0.04	-0.35
Germany - Sweden	0.19	0.09
Germany - UK	0.37	0.22
Germany - US	0.43	0.37

Table 3.2: International Output and Consumption Correlations - Continued

Country-Pair	*Output Correlation*	*Consumption Correlation*
Greece - Korea	0.17	0.37
Greece - South Africa	-0.09	-0.18
Greece - Sweden	0.03	-0.06
Greece - UK	0.4	0.17
Greece - US	0.44	0.37
Korea - South Africa	-0.25	-0.16
Korea - Sweden	0.09	0.1
Korea - UK	0.4	0.22
Korea - US	0.37	0.31
South Africa - Sweden	0.48	0.1
South Africa - UK	-0.03	0.09
South Africa - US	-0.05	-0.36
Sweden - UK	0.29	0.15
Sweden - US	0.12	-0.01
UK - US	0.68	0.49

Table 3.3: International Correlations of US Output and Consumption vis-à-vis Other Countries in Period 1

Country-Pair	*Output Correlation*	*Consumption Correlation*
US - Australia	0.44	-0.26
US - Canada	0.74	0.55
US - France	0.37	0.32
US - Germany	0.43	0.37
US - Greece	0.44	0.37
US - Korea	0.37	0.31
US - South Africa	-0.05	-0.36
US - Sweden	0.12	-0.01
US - UK	0.68	0.49

3.4.2 The Cross-Country Correlations of Output and Consumption in Recent Data

I now examine the relationship between the cross-country correlation of consumption and the cross-country correlation of output in recent data. For this I will first analyse all country-pairs in Section 3.4.2.1. To enable a better comparison with the literature I will then analyse only country-pairs that include the US in Section 3.4.2.2.

3.4.2.1 All Country-Pairs

The OECD *Main Economic Indicators* database has data for 38 countries, which yields cross-country correlation observations for 703 country-pairs. Due to the amount of observations, the tables containing this data have been relegated to the Appendix.[10] Of 703 country-pairs, 247 have a cross-country correlation of consumption that is equal to or greater than the cross-correlation of output and 456 country-pairs have a cross-country correlation of consumption that is smaller than the cross-correlation of output. Therefore, of all country-pairs, 64.86% exhibit the data pattern that underlies the Quantity Puzzle, while 35.14% do not. While the data pattern therefore exists for the majority of country-pairs, it exists for a much smaller percentage of country-pairs than in Period 1, when it held for 87.72% of country-pairs. As just under 65% of country-pairs exhibit a cross-country correlation of output larger than the cross-country correlation of consumption, the question arises regarding the extent to which this data pattern can still be considered a stylised fact and the extent to which it is still a useful validation mechanism for macroeconomic models.

A likely explanation for the decreased prominence of the data pattern underlying the Quantity Puzzle is increased globalisation. Globalisation significantly increased since the early 1990s. This was both in terms of trade in goods and in terms of capital flows: both goods and financial markets became more integrated. When markets are more integrated, we expect business cycles to be more synchronised. This is because a shock in one country will, if it has strong trade and financial ties with another country, also affect macreconomic variables in that foreign country. Specifically in terms of the cross-country correlation of consumption, theory expects that it is high when consumers are able to share risk among countries. This is the case when financial markets are highly integrated. We should therefore expect that among countries with higher financial integration, the cross-country correlation of consumption exceeds the cross-country correlation of output.

To test this prediction, I divide the sample into an EU and a non-EU group. Since the EU is a single market with free movement of capital and goods, we would expect the cross-country correlation of consumption to be higher than that of output among a majority of EU-country pairs. The division of the sample into EU countries and non-EU countries yields a total of 351 country-pair observations; 231 for the EU countries and 120 for the 16 non-EU countries. For 69 of the 231 EU country-pairs, the cross-country correlation of consumption is greater than or equal to that of output, whereas for 162 country pairs the opposite is true. Among non-EU countries, 49 country-pairs have a consumption correlation that exceeds the correlation of GDP while 71 have a cross-country correlation of consumption that is smaller

[10] Appendix A.1 shows the cross-country correlations of output and Appendix A.2 shows the cross-country correlations of consumption.

than that of output. In percentage terms, among EU country-pairs 70.13% exhibit the data pattern that underlies the Quantity Puzzle while this is only true for 59.17% of non-EU country-pairs. Interestingly, it thus seems that being part of the EU slightly increases the likelihood of exhibiting the data pattern that underlies the Quantity Puzzle.

The results presented above suggest that a single market in terms of capital goods is not sufficient to explain why many country-pairs have a cross-country correlation of consumption that exceeds that of output. A potential reason for this is that countries within the EU have quite different levels of GDP and therefore of economic development. Risk sharing is more likely to occur among countries that both have well-developed financial systems. If two countries are similar in the degree of financial development, but their financial markets are not highly developed, then the extent of risk sharing is limited. If, however, two countries are similar in the degree of financial development, and both financial markets are highly developed, international risk sharing should be visible.

To test this intuition, I proxy financial development with GDP-per-capita. I can do this, because the positive correlation between financial development and economic development has been very well established in the literature.[11] Within the EU, many countries have quite different levels of GDP, and therefore also quite different levels of financial development. To test whether it is financial development and similarity in financial development that drives the difference in the ranking of cross-country correlations of consumption and output, I divide the sample into a high-GDP-per-capita and a low-GDP-per-capita group.[12] Both groups consist of 19 countries each and thus of 171 country-pair observations.

The results are as follows. Among the high-GDP-per-capita group, 115 country-pairs, or 68.25% of the sample, have a cross-country correlation of consumption that is either equal to or greater than the cross-country correlation of output, while for 56 country-pairs, or 31.75% of the sample, the opposite is true. Among the low-GDP-per-capita group, only 21 country-pairs have a cross-country correlation of consumption that is either equal to or greater than the cross-country correlation of output, while for 150 country-pairs the cross-country correlation of output exceeds that of consumption. Thus, among the low-GDP-per-capita group 87.72% of country-pairs exhibit the data pattern that underlies the Quantity Puzzle. Among the high-GDP-per-capita group, this is only the case for 31.75% of country-pairs. As among the high-GDP-per-capita group the cross-country correlation of output exceeds that of consumption for only $\frac{1}{3}$ of country-pairs, one can hardly argue that for this group of countries, this data pattern is still a stylised fact. For the low-GDP-per-capita group, the data pattern can still be considered a stylised fact. What these results suggest is that financial development and similarity in financial development are jointly a strong predictor of whether the cross-country correlation of output exceeds that of consumption, or whether it is the other way around.

[11] For a very brief overview of this literature, see Chapter 2.2.4 of the thesis.

[12] The high-GPD-per-capita group consists of Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Iceland, Ireland, Israel, Luxembourg, the Netherlands, New Zealand, Norway, Sweden, Switzerland, the UK and the US. The low-GDP-per-capita group consists of Brazil, Costa Rica, Estonia, Greece, Hungary, Indonesia, Italy, Japan, Korea, Latvia, Lithuania, Mexico, Poland, Portugal, Slovakia, Slovenia, South Africa, Spain and Turkey.

3.4.2.2 Country-Pairs Including the US

Until now, the analysis has examined whether the data pattern underlying the Quantity Puzzle persists in recent data for a large number of country-pairs. This is unprecedented in the literature. While this yields interesting results in itself, it makes comparison to the existing US-focused literature difficult. To enable such a comparison, I consider all available cross-country correlations vis-à-vis the United States for Period 2 in this section. The results are presented in Table 3.4. For these country-pairs, no obvious trend is discernible. Out of 37 country-pairs, 18 country pairs exhibit a cross-country correlation of consumption that is lower than that of output, and 19 countries exhibit a cross-country correlation of consumption that is equal to or higher than that of output. As only half of the country-pairs exhibit the data pattern that the literature tends to find (see for example Backus *et al.* (1992), Kehoe and Perri (2002), Jiang (2017), Iliopulos *et al.* (2021)) , one can hardly refer to this pattern as a stylised fact anymore.
To test whether the intuition that it is the extent of financial development and financial integration that determines the ranking of the cross-country correlations of ouptut and consumption, I again divide the sample into a high-GDP-per-capita and a low-GDP-per-capita group.[13]

The results are as follows. In the high-GDP-per-capita group, only 4 of 18 countries have a cross-country correlation of output that exceeds that of consumption vis-à-vis the US. For all other country-pairs, or 77.8% of the sample, the cross-country consumption correlation is equal to or higher than that of output. For the low-GDP-per-capita group, the opposite is true. The majority of countries, namely 14 out of 19 or 73.7%, have a cross-country correlation of consumption that is lower than that of output. The remaining four countries have a cross-country correlation of consumption that is larger than or equal to the cross-country correlation of output vis-à-vis the US.

For the US, the observation that the cross-country correlation of output exceeds that of consumption is thus no longer a stylised fact either in general terms or for high-income countries, whereas it may still be referred to as such for low-income countries. As in the previous section, my results suggest that financial development and similarity in financial development are jointly a strong predictor of whether the cross-country correlation of output exceeds that of consumption. This is because financial development is required in both countries to allow risk sharing across borders, and therefore for a high cross-country correlation of consumption.

The implication of this result for the literature is profound. As shown in the literature review of the thesis, most of the literature uses a foreign "Rest of the World" (RoW) aggregate composed of the EU15, Japan and Canada, or a different aggregate of largely developed countries (see for example Kehoe and Perri (2002), Mandelman *et al.* (2011), Dmitriev and Roberts (2012), Jiang (2017), Lambrias (2020)). For every RoW country described in the literature review the majority of countries is in the high-GDP-per-capita group. As most of the literature in the field examines the correlations of the US vis-à-vis an aggregate of a majority of developed countries, my findings suggest that developing models that yield

[13]GDP per capita is taken from the World Bank Data page. The high-GDP- per-capita group consists of Luxembourg, Switzerland, Ireland, Norway, Iceland, Denmark, Australia, Netherlands, Sweden, Austria, Finland, Germany, Canada, Belgium Israel, the United Kingdom, New Zealand and France. The low-GDP-per-capita group consists of the rest.

Table 3.4: International Correlations of US Output and Consumption vis-à-vis Other Countries in Period 2

Country	*Cross-Country Output Correlation*	*Cross-Country Consumption Correlation*
Australia	0.75	0.88
Austria	0.86	0.85
Belgium	0.91	0.85
Brazil	0.6	0.51
Canada	0.9	0.9
Costa Rica	0.76	0.7
Denmark	0.87	0.81
Estonia	0.71	0.61
Finland	0.69	0.78
France	0.87	0.87
Germany	0.79	0.87
Greece	0.5	0.32
Hungary	0.9	0.7
Iceland	0.6	0.67
Indonesia	0.74	0.67
Ireland	0.57	0.89
Israel	0.75	0.85
Italy	0.83	0.87
Japan	0.86	0.67
Korea	0.58	0.37
Latvia	0.63	0.69
Lithuania	0.56	0.5
Luxembourg	0.7	0.76
Mexico	0.93	0.93
Netherlands	0.74	0.81
New Zealand	0.75	0.81
Norway	0.73	0.89
Poland	0.72	0.63
Portugal	0.7	0.73
Slovakia	0.69	0.34
Slovenia	0.74	0.61
South Africa	0.88	0.85
Spain	0.79	0.91
Sweden	0.83	0.87
Switzerland	0.85	0.82
Turkey	0.74	0.53
UK	0.9	0.91

a cross-country correlation of consumption that is lower than that of output is no longer necessary or indeed desirable, as such a correlation would, in most cases, not be in line with recent data.

3.4.3 Discussion of Results

In this section I have shown that: (1) the percentage of country-pairs for which the data pattern underlying the Quantity Puzzle holds has decreased in recent years and (2) the stylised fact that the cross-country correlation of output exceeds that of consumption holds among less-developed countries, but not among developed economies. Indeed, the data pattern holds for 87.72% of low-GDP-per-capita country-pairs, whereas among high-GDP-per-capita countries it only holds for 31.75% of country-pairs. The intuition for this result is an increase in financial integration among developed countries.

These results have important implications for the literature investigating the Quantity Puzzle. This literature attempts to create models in which the cross-country correlation of output generally exceeds that of consumption, using the data pattern that the cross-country correlation of output exceeds that of consumption as a validation mechanism for their models. However, as the literature review in Section 2.2.2 of the thesis shows, most of the literature examines the correlations of the US vis-à-vis an aggregate of a majority of developed countries (Backus *et al.* (1992), Kehoe and Perri (2002), Heathcote and Perri (2002), Mandelman *et al.* (2011), Jiang (2017)). As most papers calibrate their models to the US and a RoW aggregate of high-income countries, the data pattern that the cross-country correlation of output should exceed that of consumption can no longer serve as a validation mechanism. In fact, the prediction of the ranking of the cross-country correlation of output and consumption of standard international trade models is correct for high-income countries, the group of countries most models are calibrated to.

Furthermore, my results indicate that whether or not the pattern underlying the Quantity Puzzle holds depends on certain country characteristics. Therefore, future research should focus on explaining exactly what circumstances determine the ranking of the cross-country correlation of output and consumption, and build models that are in line with these results.

3.5 Positive Co-Movement Puzzle

The stylised fact that underlies the Positive Co-movement Puzzle will be investigated in this section. As a brief reminder, standard models generally predict that the cross-country correlations of investment and employment, and sometimes of output, are negative. In data, the opposite was observed. It is the inability of standard models to provide an explanation for this observation that is referred to as the Positive Co-movement Puzzle. In the following section I investigate whether we still observe positive co-movement among output, consumption, investment and employment in recent data, and thus whether this observation can still be considered a stylised fact today.

I will do this in three steps. In Section 3.5.1 I provide evidence for the pattern of positive co-movement among output, consumption, investment and employment with data from Period 1. This ensures that my results are not driven by my choice of database. I analyse the data pattern underlying the Positive

Co-movement Puzzle for a large number of country-pairs for Period 2 in Section 3.5.2. For output and consumption, I have data for 10 countries, for investment for 9 countries and for employment for 26 countries. [14] In Section 3.5.3 I draw out the implications of my results for the literature.

3.5.1 Evidence for Positive International Co-movement in Earlier Data

Tables 3.1 and 3.2 show the cross-country correlations of consumption and output in Period 1 and Table 3.5 shows the cross-country correlations of investment. Due to the large amount of observations I refer the reader to Appendix A.4 for the cross-country correlations of employment.

I will present the general results first. In Period 1, the cross-country correlation of output was positive in 40 of 45 observations, or for 89% of country-pairs. 82% of country-pairs had a positive cross-country correlation of consumption and 86% had a positive cross-country correlation of investment. The positive co-movement was smaller for employment. Out of 325 cross-country correlations, 229, or 70%, were positive. For the majority of country-pairs there was thus positive co-movement across output, consumption, investment and employment in Period 1. This positive co-movement was particularly prevalent for output and investment, and was weakest for employment.

To examine whether the prevalence of positive co-movement depends on whether or not the US is included in the sample I will now divide the sample into a US and non-US group. First, I consider all country-pairs that include the US. For output and consumption, this is described in Table 3.3. For investment, it is described in Table 3.6. For employment correlations, see Appendix A.4. Output correlations are positive for 8 out of 9 country-pairs, or for 88.89% of the sample, and investment correlations are positive for 87.5% of the sample. For consumption, the correlation is positive for 6 of the 9 country-pairs, or for 66.66% of the sample. For employment, the correlation is positive for 21 of 25 country-pairs, or in 84% of cases. The correlations for the non-US sample are as follows. For both output and consumption, cross-country correlations are positive for 31 of 36 country-pairs, or 86.11% of the sample. For investment this is the case for 24 of 28 correlations, or 85.71% of country-pairs. For employment the co-movement is lower, as correlations are positive in 206 of 300 instances, or for 68.67% of country-pairs. The consideration of only US country-pairs does not change the prevalence of positive co-movement much for investment or output, but decreases the co-movement for consumption and increases the co-movement for employment. Overall, a US-focused approach does not seem to affect the prevalence of positive co-movement among macroeconomic variables much.

Overall, this section showed that there is positive co-movement among macroeconomic variables in Period 1, both among US country-pairs and country-pairs that do not include the US. Positive co-movement is strongest for output and investment, and weakest for employment.

[14] The data for all four variables is described in Section 3.3. Data for employment is annual and was only available until 2015. For employment, Period 2 therefore refers to 1999-2015 and Period 1 refers to 1970-1995.

Table 3.5: International Investment Correlations

Country-Pair	*Investment Correlation*
Australia - Canada	0.67
Australia - France	0.41
Australia - Germany	0.05
Australia - Korea	-0.15
Australia - South Africa	0.37
Australia - Sweden	0.28
Australia - UK	0.31
Australia - US	0.41
Canada - France	0.45
Canada - Germany	0.07
Canada - Korea	-0.23
Canada - South Africa	0.37
Canada - Sweden	0.37
Canada - UK	0.15
Canada - US	0.21
France - Germany	0.48
France - Korea	0.01
France - South Africa	0.35
France - Sweden	0.47
France - UK	0.38
France - US	0.17
Germany - Korea	0.22
Germany - South Africa	-0.11
Germany - Sweden	0.17
Germany - UK	0.36
Germany - US	0.41
Korea - South Africa	-0.39
Korea - Sweden	0.05
Korea - UK	0.28
Korea - US	0.35
South Africa - Sweden	0.47
South Africa - UK	0.08
South Africa - US	-0.28
Sweden - UK	0.3
Sweden - US	0.08
UK - US	0.53

Table 3.6: International Investment Correlations of US vis-á-vis Other Countries

Country-Pair	*Investment Correlation*
Australia - US	0.41
Canada - US	0.21
France - US	0.17
Germany - US	0.41
Korea - US	0.35
South Africa - US	-0.28
Sweden - US	0.08
UK - US	0.53

3.5.2 Positive Co-Movement in Recent Data

The analysis of the more recent data confirms the pattern of positive co-movement among macroeconomic variables. For the tables presenting this section's results for Period 2 I refer the reader to the Appendix.[15] The data I have for output, consumption and investment yields a total of 703 country-pairs. The data on employment covers 527 country-pairs. For output, not a single cross-country correlation is negative, and for consumption, there are only 3 negative cross-country correlations, amounting to 0.5% of the sample. Cross-country correlations of investment are positive for 95% of country-pairs and cross-country correlations of employment are positive for 79.23% of country-pairs.

To determine whether the prevalence of positive co-movement is affected by a US-focused approach I examine only country-pairs that include the US. For output and consumption, 100% of correlations are positive. For employment, the proportion of positive correlations is 92% and for investment, the proportion of positive correlations is 91.89%. The prevalence of positive co-movement is therefore the same for output, higher for consumption and employment and slightly lower for investment. Focusing only on the US thus slightly increases positive co-movement overall and leads to an overstatement of the Puzzle.

Overall, positive international co-movement among macroeconomic variables is a common feature in recent data. It is strongest for output and weakest for employment.[16]

3.5.3 Discussion of Results

The stylised fact underlying the Positive Co-movement Puzzle that was first documented in the mid-1990s, namely that output, consumption, investment and employment are all positively correlated, continues to exist today. Indeed, positive international co-movement seems to have increased, which is likely due to an increase in globalisation worldwide. As argued in the previous section, an increase in trade integration and lower barriers to trade create a higher exposure to foreign shocks, which in turn increases positive

[15] See Appendices A1-A4.

[16] I did not subdivide the sample further because positive co-movement is such a strong feature of recent data.

co-movement.

The stylised fact that macroeconomic variables tend to be synchronised internationally has become more robust in recent data and continues to serve as an important validation mechanism for macroeconomic models. Explaining this stylised fact and its underlying drivers furthermore remains an important task for future research in order to ensure models are in line with recent data.

3.6 The Backus-Smith Puzzle

In their 1993 paper, Backus and Smith found that the real exchange rate of two countries is either uncorrelated or negatively correlated with their relative consumption ratio. This is unexpected from a theoretical point of view, as when arbitrage is possible,[17] we expect consumers to buy a product from the country in which it is cheaper at a given point in time. Therefore, we expect that changes in the relative price of a good induce changes in the consumption of that good in the two countries in which the prices are being compared. In more general terms, we thus expect changes in relative consumption to be correlated with changes in relative prices, or in the real exchange rate. However, in data the opposite is the case. The Backus-Smith Puzzle thus refers to the inability of models to provide an explanation for the negative correlation of the real exchange rate and relative consumption.

I investigate whether the stylised fact underlying the Backus-Smith Puzzle, namely that the real exchange rate and relative consumption are negatively correlated, has changed in recent years. As with the previous puzzles I addressed, I do this in three steps. In Section 3.6.1 I provide evidence that the stylised fact underlying the Backus-Smith Puzzle holds for many country-pairs in Period 1. This section is followed by an analysis of whether the real exchange rate is still negatively correlated with relative consumption among a large number of country-pairs in Period 2. In Section 3.6.3 I briefly discuss my results and draw out their implications for the literature.

3.6.1 Data

I calculate the real exchange rate by using the nominal exchange rates and Consumer Price Indices (CPIs) from the OECD *Main Economic Indicators* database. Nominal exchange rates are found under "Prices and Purchasing Power - Purchasing Power Parities Statistics - PPPs and Exchange Rates - Exchange rates, period average". This data is annual.[18] CPIs are found under "Prices and Purchasing Power - Consumer and Producer Prices - Consumer Price Indices (CPIs) Complete Database". To calculate relative consumption I use private final consumption expenditure.[19] As the nominal exchange rates I use are annual, I use annual CPI and consumption data as well. For sake of consistency with the previous sections, Period 1 refers to 1970-1995 and Period 2 to 1999-2019.

[17] Arbitrage is the purchase and sale of an asset in different markets to exploit price differences.

[18] Nominal exchange rates for this range of countries was only available in annual form in this database. For the sake of a large sample size I therefore used annual data.

[19] For more detail on this, see Section 3.3.

I use the bilateral nominal exchange rates of the US with 38 different countries, and the CPIs of the same countries. The database provides data on bilateral exchange rates with the US only. In order to be able to carry out the analysis for other country-pairs as well, I assumed that arbitrage holds and transformed the US rates into all other bilateral exchange rates by dividing the respective rates. This yields a total of 703 bilateral real exchange rates. I examine the correlation of these 703 bilateral real exchange rate with the relative consumption ratio of the countries whose currencies form each of these exchange rates, yielding a total of 703 correlations.

The real exchange rate of country i with country j, $Q_{i,j}$, is defined as follows: $Q_{i,j} = \varepsilon_{i,j} P_j / P_i$, where $\varepsilon_{i,j}$ is the nominal exchange rate of countries i and j defined in terms of units of currency of country i per unit of currency of country j, P_j is the price level in country j and P_i is the price level in country i. I will calculate the correlation of $Q_{i,j}$ with the relative consumption of countries i and j, which is C_i/C_j, where C_i is consumption in country i and C_j is consumption in country j.

3.6.2 Evidence for the Stylised Fact Underlying the Backus-Smith Puzzle in Earlier Data

In Period 1, the average correlation of country-pairs' real exchange rate and relative consumption was -0.27. In this period, 30 of 36 correlations, or 83.33%, were negative and 6 correlations, or 16.66%, were positive. For a large majority of countries, the data pattern underlying the Backus-Smith Puzzle was present in Period 1.

The data pattern underlying the Backus-Smith Puzzle is more prominent for the sample that includes only US-country pairs, as Table 3.8 shows. For this sample, the average correlation of the 8 observations is -0.42 and all correlations are negative. For the 28 country-pairs that do not include the US, the average correlation is -0.27. Of the 28 country-pairs, 22 country-pairs or 78.57% have a negative correlation between their real exchange rate and relative consumptions. 21.43% have a positive correlation. As in the case of the Quantity Puzzle, this analysis shows that focusing only on the US overstates the size of the Backus-Smith Puzzle. If only the US is considered, the data pattern underlying the Backus-Smith Puzzle persists in 100% of the cases. If other countries are included, the proportion of country-pairs for which this is true decreases.

Overall in this section I find that the data pattern underlying the Backus-Smith Puzzle is very prevalent in Period 1, as it exists for 83.33% of the sample. However, focusing only on the US overstates the prevalence of this data pattern.

3.6.3 The Correlation of Real Exchange Rate and Relative Consumption in Recent Data

I will now analyse the prevalence of the stylised fact that the real exchange rate and relative consumption are negatively correlated in recent data.

Table 3.7: Correlation of Real Exchange Rate and Relative Consumption

Country-Pair	*Correlation of Q and Relative Consumption*
Australia - Canada	0.18
Australia - France	-0.48
Australia - Greece	-0.22
Australia - Korea	-0.37
Australia - South Africa	0.08
Australia - Sweden	-0.68
Australia - UK	-0.19
Australia - US	-0.35
Canada - France	0.33
Canada - Greece	0.13
Canada - Korea	-0.36
Canada - South Africa	-0.1
Canada - Sweden	-0.06
Canada - UK	-0.08
Canada - US	-0.48
France - Greece	-0.09
France - Korea	-0.08
France - South Africa	-0.51
France - Sweden	-0.3
France - UK	0.21
France - US	-0.18
Greece - Korea	0.01
Greece - South Africa	-0.46
Greece - Sweden	-0.37
Greece - UK	-0.16
Greece - US	-0.36
Korea - South Africa	-0.27
Korea - Sweden	-0.5
Korea - UK	-0.59
Korea - US	-0.63
South Africa - Sweden	-0.79
South Africa - UK	-0.42
South Africa - US	-0.26
Sweden - UK	-0.38
Sweden - US	-0.59
UK - US	-0.52

Table 3.8: Correlation of Real Exchange Rate and Relative Consumption for US in Period 1

Country-Pair	*Correlation of Q and Relative Consumption*
Australia - US	-0.25
Canada - US	-0.07
France - US	-0.04
Greece - US	0.03
Korea - US	-0.24
Sweden - US	-0.31
UK - US	-0.46

3.6.3.1 All Country-Pairs

My sample consists of 38 countries, yielding a total of 703 observations. The average correlation for the real exchange rate and relative consumption in this sample is -0.21. 203 country-pairs or 28.88% have a correlation that is positive, while 500 country-pairs, or 71.22%, have a correlation that is negative. The proportion of country-pairs with a positive correlation is thus 10% lower than in Period 1.

To gain further insight into this result I subdivided the group into an EU and a non-EU group. We have 24 EU countries, which yields a total of 253 country-pairs. Of these, 116 country-pairs, or 45.85%, have a correlation that is positive, while 137 country-pairs, or 54.15%, have a negative correlation. Splitting the EU-group up further into EA countries and non-EA countries yields the following results. Among the EA group 52.94% of correlations are positive and 64 of the 136 correlations are negative. Among the 15 observations for EU but non-EA countries, 13 correlations, or 86.67%, are negative and only 2 correlations are positive. For the non-EU country group, the average correlation is -0.31 and 31 of 105 country-pairs, or 20%, have a positive correlation while 84 country-pairs, or 80%, have a negative correlation. Among the non-EA group, the group that excludes all EA members, 83.17% of country-pairs have a negative correlation. For the group that excludes only EA country-pairs, this percentage is reduced to 76.94%.

These results show that having a single currency increases the probability of having a positively correlated real exchange rate and relative consumption, as it is the single currency that is driving the result of the decreased prominence of the data pattern underlying the Backus-Smith Puzzle in recent data, not the single market. Country-pairs that are members of the single market but not of the single currency have a similar probability of having a positive correlation between the real exchange rate and relative consumption as country-pairs that are not part of the single market.

There are several potential explanations for this result. Firstly, it is well known that the nominal exchange rate is highly volatile (Dornbusch (1976), Clark *et al.* (2004)) [20] and moves in ways that are unconnected

[20] I calculated the nominal exchange rate volatility for the exchange rates from the database, and also found them to be very volatile.

to economic fundamentals. It is possible that once one removes this highly volatile component of the exchange rate from the equation, the correlation of the real exchange rate and relative consumption is more in line with theoretical predictions. Indeed, this is what Hess and Shin (2010) argue is the case. The second possible explanation is that the removal of the volatile exchange rate exchange rate makes it easier for consumers to perceive and understand movements in relative price, and adapt their consumption basket accordingly. This explanation is in line with the theory of rational inattention, the idea that as economic decision makers cannot absorb all available information, they decide which pieces of available information to process (Sims (2003), Maćkowiak *et al.* (2021)). When nominal exchange rates are highly volatile, consumers rarely know the exact exchange rate at any point in time and therefore do not adapt their consumption accordingly. Futhermore, it is difficult to extract information on relative prices from movements in the nominal exchange rate, as they might be due to movements in the relative price or movements of the nominal exchange rate. Due to the difficulty of interpreting and keeping information on the exchange rate up-to-date, consumers thus do not adapt their consumption basket in line with movements of relative prices. When the information becomes easier to follow and understand, changes in relative consumption correlate more with changes in relative prices, as we would expect based on the idea of rational inattention.

To examine the explanations further I investigated the correlations of the real exchange rate and relative consumption of EA countries and EU-but-non-EA members whose currency is pegged to the euro, and the correlations of EA members with those EU-but-non-EA member states whose currency is free-floating. Effectively a pegged exchange rate also eliminates the highly volatile nominal exchange rate whose behaviour is unrelated to economic fundamentals. If the first explanation is correct, then we would expect the correlation between the real exchange rate and relative consumption of EA members and EU-but-non-EA countries who have a pegged exchange rate to be positive more frequently than the correlations of EA members and EU-but-non-EA countries with a floating exchange rate. Of the 6 countries in my sample that are in the EU but not part of the euro area, two have a currency that is pegged to the euro. These are Denmark and Hungary. The Czeck Republic, Poland, Sweden and the UK have floating exchange rates. In the first group I have 29 observations. Of these, 12 correlations, or 41.38%, are positive and 58.62% are negative. The second group consists of 71 observations. In this group, 40.85% of correlations are positive and 59.15% are negative. The proportion of positive and negative correlations are very similar, which is unexpected if we believe that the nominal exchange rate is the driver of negative real exchange rate and relative consumption correlations. It thus seems that the first explanation may not be the full story.

To further investigate the second explanation, I divide the EA countries into a high-GDP-per-capita and a low-GDP-per-capita group.[21] As before, I use GDP-per-capita to proxy financial development. Examining financial development is important because it allows consumers to adapt their consumption baskets across countries in response to shocks. If it is ease of understanding exchange rate movements that drives the positive correlations between the exchange rate and relative consumption, we would expect that when the ease of understanding exchange rate movements is held constant, as is the case within a single cur-

[21] The high-GDP-per-capita group is composed of Austria, Belgium, Finland, France, Germany, Ireland, Italy, Luxemburg and the Netherlands. The low-GDP-per-capita group is composed of the rest.

rency area, the exchange rate will be more frequently positively correlated with relative consumption in financially developed country-pairs. This is because in those country-pairs, consumers are able to borrow and lend internationally and therefore adapt their consumption basket in both countries. The high-GDP-per-capita group consists of 36 observations. Of these, exactly 50% of the correlations are positive and 50% are negative. The low-GDP-per-capita group consists of 28 observations. Of these, 20 correlations, or 71.43% of observations, are positive and only 8 correlations, or 28.55%, are negative. This is contrary to what we would expect from a theoretical point of view, as we would expect countries that are more financially developed to be more likely to have an exchange rate that is positively correlated with relative consumption. One potential explanation for this result is that within the euro area, all countries are financially developed, and therefore differences in GDP are not relevant for the Backus-Smith Puzzle in this sample of countries. Another possibility is that it is not the ease with which exchange rate movements can be understood that drives the positive correlation between the exchange rate and relative consumption. Like Itskhoki and Mukhin (2021) suggest, it might be the type of shock driving exchange rate movements that determines whether the real exchange rate and relative consumption are positively or negatively correlated. Determining the extent to which this is the case is beyond the scope of this chapter.

Furthermore, given that the percentage of countries that have a positively correlated exchange rate and relative consumption ratio is significantly higher in the euro area than in the rest of the world, I find it difficult to conclude that it is only the type of shock that determines whether the real exchange rate and relative consumption are positively or negatively correlated. Determining which of the explanations described in this section are most important in determining the sign of the correlation between the real exchange rate and relative consumption is a very interesting avenue for further research.

3.6.3.2 Country-Pairs Including the US

In order to enable a comparison with literature, I consider only country-pairs that include the US in this section. The results of this analysis are presented in Table 3.9. The average correlation for country-pairs that include the US is -0.24. In this sample, 8 country-pairs, or 21.62%, have a positive correlation between their real exchange rates and relative consumption, whereas 29 country-pairs, or 78.38% of the sample, have a negative correlation.

These statistics compare to the sample that do not include the US as follows. Among all country-pairs that do not include the US, 29.28% have a positive correlation between their real exchange rates and relative consumption, whereas 70.72% have a negative correlation. However, the previous section showed that EA country-pairs have a larger likelihood of having a positive correlation than other country-pairs. As the group that consists only of country-pairs that include the US necessarily excludes EA country-pairs, we must also exclude EA country-pairs from the non-US sample. In this case, 76.92% of country-pairs have a negative correlation between their real exchange rate and relative consumption. The percentage of country-pairs for which the data pattern underlying the Backus-Smith Puzzle holds therefore does not change much depending on whether or not the US included in the sample; a US-focused approach does not have strong implications for the puzzle.

Table 3.9: Correlation of Exchange Rate and Relative Consumption for US in Period 2

Country-Pair	*Correlation of Q and Relative Consumption*
Australia - US	-0.61
Austria - US	-0.08
Belgium - US	0.09
Brazil - US	-0.57
Canada - US	-0.28
Czekia - US	-0.69
Denmark - US	-0.58
Estonia - US	-0.15
Finland - US	-0.54
France - US	0.06
Germany - US	0.28
Greece - US	-0.37
Hungary - US	-0.38
Iceland - US	-0.82
Indonesia - US	-0.18
Ireland - US	-0.22
Israel - US	-0.63
Italy - US	-0.01
Japan - US	-0.19
Korea - US	0.45
Latvia - US	-0.07
Lithuania - US	-0.23
Luxemburg - US	0.27
Mexico - US	-0.35
Netherlands - US	0.17
New Zealand - US	-0.61
Norway - US	-0.32
Poland - US	-0.2
Portugal - US	-0.06
Slovakia - US	-0.53
Slovenia - US	-0.4
South Africa - US	-0.22
Spain - US	-0.23
Sweden - US	0.08
Switzerland - US	-0.23
Turkey - US	-0.58
UK - US	0.02

3.6.4 Discussion of Results

In this section I showed that the percentage of country-pairs for which the data pattern underlying the Backus Smith Puzzle, namely that the real exchange rate and relative consumption are negatively correlated, has decreased from 80% to 70% in recent decades. This reduction appears to be driven by the creation of the European Monetary Union. For country-pairs for which both countries are EA members, the real exchange rate and relative consumption are negatively correlated in only 47% of the sample. For the sample that does not include country-pairs which are both members of the EA, this is the case for 76.94% of country-pairs. If all EA members are excluded from the analysis, this percentage increases to 83.17%. My results are therefore in line with the literature at the same time as showing a novel contribution. I show that for the US as well as country-pairs that are not part of the euro area, the data pattern of the negative correlation between the exchange rate and relative consumption remains a stylised fact. This finding is in line with the literature that uses older data (see for example Chari *et al.* (2002), Corsetti *et al.* (2008), Benigno and Thoenissen (2008), Lambrias (2020)). For country-pairs that are part of the EA, this is not true; among these country-pairs a small majority actually has a positive correlation between the real exchange rate and relative consumption. This is likely due to the fact that within a single currency area consumers are more easily able to follow movements in relative prices and adapt their consumption accordingly. The source of the shock may also be an important determinant for the sign of the correlation of the real exchange rate and relative consumption.

The implications of my findings for the literature are as follows. The stylised fact that the real exchange rate and relative consumption are negatively correlated remains a validation mechanism for models that are not calibrated to the EA, and more research into the drivers of this negative correlation is important in order to solve the Backus-Smith Puzzle. However, for models that are built for the EA, the pattern that the real exchange rate and relative consumption are negatively correlated cannot serve as a validation mechanism. More research into the drivers of this correlation within the euro area is important to further our understanding of the Puzzle and to yield models that are in line with data.

3.7 Volatility of the Terms of Trade

I next examine the Terms of Trade Puzzle. First I describe the data I use. In Section 3.7.2 I then examine the Terms of Trade Puzzle in Period 1 and Period 2, before discussing my results and drawing out their implications for the literature in Section 3.7.3.

3.7.1 Data

The data for the terms of trade is taken from the OECD at the website `https://data.oecd.org/trade/terms-of-trade.htm`. Terms of trade are defined as the ratio between the index of export prices and the index of import prices. This data is annual, as quarterly terms of trade data was not available for as large a sample as I use. As the terms of trade data is annual, I used annual GDP data in this section as well.[22]

[22] For details on GDP, see Section 3.3.

Table 3.10: Volatility of the Terms of Trade in Period 1

Country	*Volatility Terms of Trade*	*Volatility GDP*	*Relative Volatility Terms of Trade*
Australia	6.35	1.67	3.8
Finland	3.01	2.19	1.37
France	3.38	1.57	2.16
Germany	3.56	1.89	1.88
Greece	2.9	3.09	0.94
Korea	4.7	3.19	1.47
South Africa	6.91	2.11	3.28
Sweden	2.76	2.03	1.36
UK	4.1	2.53	1.62
US	3.66	2.08	1.76

3.7.2 Volatility of the Terms of Trade

3.7.2.1 Evidence for the High Volatility of the Terms of Trade in Earlier Data

Table 3.10 shows the relative volatility of the terms of trade of 10 countries for Period 1. It illustrates that during 1970-1995, the terms of trade were more volatile than output for all countries except for Greece. Even for Greece, however, the terms of trade were not much less volatile than output.

3.7.2.2 The Volatility of the Terms of Trade in Recent Data

Table 3.11 shows the volatility of terms of trade and GDP, as well as the relative volatility of the terms of trade, for 38 countries. Out of 38 countries, 16 countries have a volatility of the terms of trade that exceeds the volatility of GDP, while 22 countries have a volatility of the terms of trade that is smaller than the volatility of GDP. In percentage terms, 42% of countries have terms of trade that are more volatile than output, whereas for 58% of countries terms of trade are less volatile than output. The observation that terms of trade are more volatile than output is thus no longer a stylised fact, and can no longer serve as a validation mechanism for macroeconomic models. As before, I will divide the sample into smaller sub-samples in order to ascertain whether any patterns regarding the relative volatility of terms of trade can be found according to country regions. Dividing the sample into EU and non-EU countries yields a much clearer pattern than the consideration of the whole sample. 19 of 23 EU countries, or 82.61%, have terms of trade that are less volatile than GDP, while 5 countries, or 21.7%, have terms of trade that are more volatile than GDP. For non-EU countries the opposite pattern holds true. Of 15 non-EU countries, only 4 countries have terms of trade that are less volatile than GDP. The remaining 11 countries, 73.3% of the sample, exhibit a larger terms of trade volatility than output volatility. Further sub-dividing the sample into EA countries does not affect the results very much. The percentage of EA countries that have terms of trade that are less volatile than output is virtually the same as for EU countries, namely 82.35%. It thus appears to be the single market rather than the single currency that is driving the results.

Table 3.11: Volatility of the Terms of Trade in Period 2

Country	*Volatility Terms of Trade*	*Volatility GDP*	*Relative Terms of Trade Volatility*
Australia	7.89	0.49	16.27
Austria	1.0	1.49	0.67
Belgium	0.84	1.1	0.76
Canada	3.0	1.35	2.22
Costa Rica	2.89	1.58	1.83
Czech Republic	1.6	3.1	0.52
Denmark	0.82	2.02	0.41
Estonia	1.45	6.16	0.24
Finland	1.52	2.72	0.56
France	1.4	1.21	1.16
Germany	1.67	1.71	1.04
Greece	1.67	5.76	0.29
Hungary	0.84	3.63	0.23
Iceland	3.68	4.4	0.84
Indonesia	2.91	0.8	3.64
Ireland	1.61	6.54	0.25
Israel	2.52	1.82	1.38
Italy	2.22	1.95	1.14
Japan	4.6	1.64	2.8
Korea	3.2	1.29	2.48
Latvia	1.72	6.97	0.25
Lithuania	2.1	5.3	0.4
Luxembourg	0.87	2.47	0.32
Mexico	2.12	1.93	1.1
Netherlands	0.8	1.82	0.44
New Zealand	2.74	1.73	1.58
Norway	7.93	1.26	6.29
Poland	1.84	1.78	1.03
Portugal	1.35	2.47	0.55
Slovakia	4.4	3.13	1.41
Slovenia	1.44	3.7	0.39
South Africa	2.78	1.5	1.85
Spain	1.56	3.14	0.5
Sweden	0.96	1.9	0.51
Switzerland	1.37	1.38	0.99
Turkey	3.28	3.97	0.83
UK	1.52	1.9	0.8
US	1.56	1.62	0.96

The explanation for this finding is that members of the single market face homogenous product standards and higher competition, all of which contribute to higher price convergence.[23] If prices are more homogenous and also have less scope for moving due to strong competition, as is the case within a single market, prices should be less volatile. Furthermore, EU members trade significantly more with each other than with non-EU countries,[24] and most of within EU trade is intra-industry trade (Hellvin (1996), Greenlaw and Taylor (2017)). For such trade, we expect prices to be similar, whereas for inter-industry trade we expect prices to be different and therefore more volatile.

To test this prediction, I again split the sample into a high-GDP-per-capita group and a low-GDP-per-capita group.[25] For the low-GDP-per-capita group, 50% of the 20 countries have terms of trade that are more volatile than output while for the other 50% of countries, terms of trade are less volatile than GDP. For the high-GDP-per-capita group, the pattern is different. For only 6 out of 18 countries the terms of trade are more volatile than output. For the remaining 12 countries or 66.7%, terms of trade are less volatile than output. These results lend some support to the initial intuition provided above that a lower trade volatility is due to greater trade integration and more intra-industry trade. More developed countries are more likely to have stronger trade ties, which leads to higher competition. These competitive effects reduce the scope for price movements, which reduces the volatility of the terms of trade. Developed countries furthermore engage in more intra-industry trade than developing countries (Hellvin (1996), Greenlaw and Taylor (2017)), a type of trade for which we expect prices to be more similar and therefore less volatile. In contrast, developing countries tend to engage more in inter-industry trade and often export commodities (Cavalcanti and Vaz (2017)). As "commodity prices are notoriously volatile" (Larson and Varangis (1996)), we expect the terms of trade of countries that export commodities to be more volatile as well. My results support this intuition. Of the 6 developed countries that have a relative volatility of their terms of trade that exceeds unity, 4 are commodity exporters. These are Australia, Canada and Norway, which all export oil or natural gas, and New Zealand, which heavily exports agricultural products.[26]

My results suggest that it is mainly the extent of intra-industry trade a country engages in that determines the volatility of its terms of trade. The pro-competitive effects of the single market and homogenous product standards also play a role in reducing this volatility.

[23] For evidence on price convergence in the EU, see Dreger *et al.* (2007), Méjean and Schwellnus (2009) and Hałka and Leszczyńska-Paczesna (2019).

[24] For most EU countries, the share of intra-EU exports is between 50% and 70%. This share is only lower than 50% for Cyprus, Ireland and Malta (of these countries, only Ireland is in my sample). For all other countries, intra-EU exports were higher than exports to countries outside of the EU. For more detailed statistics, see `https://ec.europa.eu/eurostat/statistics-explained/index.php?oldid=452727Evolution_of_intra-EU_trade_in_goods`

[25] GDP per capita is from 2019, and is taken the World Bank Data database, available at `https://data.worldbank.org/indicator/NY.GDP.PCAP.CD`

The high-GDP-per-capita group consists of Luxembourg, Switzerland, Ireland, Norway, Iceland, the US, Denmark, australia, Netherlands, Sweden, Austria, Finland, Germany, Canada, Belgium Israel, the United Kingdom, and New Zealand. The low-GDP-per-capita group consists of the remaining countries.

[26] For information on the main exports of Australia see `https://oec.world/en/profile/country/aus,` for information on the main exports of Canada see `https://oec.world/en/profile/country/can`, for information on the main exports of Norway see `https://oec.world/en/profile/country/nor`, for information on the main exports of New Zealand see `https://oec.world/en/profile/country/nzl`.

3.7.3 Discussion of Results

This section has shown that terms of trade have become less volatile than output for the majority of countries. Terms of trade are more volatile than output for only 42% of countries analysed in this chapter. This finding is contrary to the findings in the literature (Corsetti *et al.* (2008), McKnight and Povoledo (2017)), and suggests that the observation that terms of trade are highly volatile relative to output can no longer be considered a stylised fact in recent data. It is therefore no longer a useful validation mechanism for macroeconomic models. The reason for a lower terms of trade volatility is increased globalisation, which leads to stronger competition and lower scope for price movements, as well as strong intra-industry trade ties among developed countries and within the EU.

3.8 Conclusion

Much theoretical literature attempts to match certain moments in data. This makes sense, as we want our models to explain what actually happens in the real economy. When standard theory is consistently unable to explain regular patterns found in data, we refer to this as a puzzle. In such a case literature attempts to explain the puzzle by adapting models to better match the documented empirical regularities, or stylised facts. The danger with contributing to such literature is simply accepting that the stylised facts that give rise to the puzzles continue to persist today. In this chapter, I re-examined whether the data patterns underlying four prominent international macroeconomic puzzles still exist today, and whether they can still be called stylised facts.

Specifically, I re-examined the Quantity Puzzle, the Positive Co-movement Puzzle, the Backus-Smith Puzzle and the Terms of Trade Puzzle. To re-examine these puzzles with contemporary data, I examined whether, using recent data, we still find that cross-country output correlations exceed those of consumption; whether we still find positive co-movement among output, consumption, investment and employment; whether we still find that real exchange rates are negatively correlated with relative consumption; and whether we still find that terms of trade are more volatile than output.

Four main results stand out from my analysis. First, I find that the data pattern that underlies the Quantity Puzzle is a lot less prominent in recent data than in older data, as only 65% of the sample exhibit a cross-country correlation of output that exceeds the cross-country correlation of consumption. The intuition behind the decrease in the prominence of the data pattern is increased globalisation, specifically an increase in financial integration. Furthermore, the data pattern still holds for developing country-pairs, but not among the majority of developed countries. Second, terms of trade are less volatile than output in recent data for the majority of countries, especially among high-income and EU countries. This is driven by increased trade integration and competition, and a high degree of intra-industry trade. Third, the data pattern underlying the Backus-Smith Puzzle has become less frequent in recent data. The reason for this is the creation of the European Monetary Union, as the single currency substantially decreases the likelihood that a country-pair's real exchange rate is negatively correlated with its relative consumption. For countries that are not part of a single currency, the observation that real exchange rates and relative consumptions tend to be negatively correlated remains a stylised fact. Fourth, positive co-movement

among macroeconomic variables continues to persist in recent data and across many country-pairs.

Two key general contributions to the literature follow from these results. First, I illustrate the importance of greater awareness of the fact that stylised facts can change over time and differ across country groups. As stylised facts are frequently used as a validation mechanism for macroeconomic models, such awareness ensures that models are validated using data patterns that are still present in recent data. Second, to account for the heterogeneity of data patterns across country-groups, models need to include mechanisms that are appropriate for the country-group that is being modelled. My results suggest that mechanisms such as different levels of intra-industry trade, financial integration or a lack thereof, or trade in commodities can be important for international trade models in matching the heterogeneity of macroeconomic patterns across country-groups.

Important avenues for further research on puzzles in international macroeconomics remain. Regarding the Quantity Puzzle, using a more rigorous empirical analysis and a wider set of macroeconomic variables to examine precisely what circumstances affect the ranking of the cross-country correlations of output and consumption is important to corroborate my results and make them more nuanced. The same applies to the Terms of Trade Puzzle: it would be insightful to use more rigorous empirical analysis and a wider set of macroeconomic variables to understand precisely what circumstances affect the volatility of terms of trade. Regarding the Backus-Smith Puzzle I showed that more work needs to be done to understand why relative consumption ratios and real exchange rates are negatively correlated. It would furthermore be interesting to understand under what circumstances such a correlation occurs within a monetary union. These avenues for further research are important, as they will yield a deeper insight into the circumstances under which data patterns hold for a certain country-pair or -group. This will allow developing models that match macroeconomic moments that differ according to country-characteristics, which is highly relevant for policy makers.

Chapter 4

The Role of Resource Allocation in the Transmission of Macroeconomic Shocks in an International Trade Model with Endgoenous Entry into Domestic Production

4.1 Introduction

"Productivity isn't everything, but in the long-run it is almost everything" (Krugman (1994)). One of the factors well-known to significantly affect long-run productivity is international trade (Bernard and Jensen (1999), Melitz (2003)). However, while much research examines the drivers of long-run productivity, the dynamic response of labour productivity to macroeconomic shocks is not well-studied in an international trade framework. In this chapter I therefore examine the dynamic response of labour productivity to such shocks in an international trade model. In my analysis, I particularly investigate the role that the allocation of labour and capital plays in the transmission of macroeconomic shocks, as although much research shows that resource allocation can significantly affect productivity (see for example Caggese and Cuñat (2013), Midrigan and Xu (2014), Calligaris (2015), Kohn *et al.* (2017)), many models of international trade include only labour as a factor of production (see for example Melitz (2003), Melitz and Ottaviano (2008), Bernard *et al.* (2011), Impullitti *et al.* (2013)). Therefore, these models cannot take into account the effect of resource allocation on labour productivity, missing an important channel through which labour productivity can be affected by macroeconomic shocks.

The framework developed in this chapter is most closely related to Melitz (2003), Ghironi and Melitz (2005), Fattal-Jaef and Lopez (2014) and Millard *et al.* (2021) (henceforth MNN). Important precursors to these models are Dixit and Stiglitz (1977), Hopenhayn (1992) and Krugman (1979). My theoretical framework allows for firms to use both capital and labour in production, as in Fattal-Jaef and Lopez (2014), enabling us to study the role of resource allocation in the transmission of macroeconomic shocks,

and the endogenous selection of firms into domestic production, as in MNN. DSGE models of international trade that use both capital and labour as factors of production (Fattal-Jaef and Lopez (2014), Kohn *et al.* (2017) and Brooks and Dovis (2020)) tend to miss this endogenous selection into domestic production, thereby omitting an important channel through which labour productivity can be affected by macroeconomic shocks.

Therefore, my model allows us to analyse how the allocation of factors of production and endogenous entry into domestic production jointly determine the dynamic response of labour productivity to a mixture of temporary supply and demand shocks.

Two key results emerge from this analysis. First, allowing firms to adjust their employment of labour and capital in response to macroeconomic shocks overall increases the time macroeconomic variables require to return to their steady state values relative to the model without capital. This introduces an element of persistence into the economy, and creates a more hump-shaped response of output. Second, the dynamic response of labour productivity is driven by the interaction between efficient resource allocation and endogenous selection into domestic production. This leads to the two novel results presented in this chapter. Firstly, in response to most shocks, either the volatility or the magnitude of the response of labour productivity is increased relative to models that do not have endogenous entry into domestic production and two factors of production, such as MNN. Secondly, the response of labour productivity to an aggregate technology shock is reversed. While the first result, that capital introduces persistence to the economy, is well-known, the second set of results have, to the best of my knowledge, not been reported before in the literature before.

The rest of the chapter is structured as follows. In Section 4.2 I present a review of the relevant literature and identify the gap that I address. In Section 4.3 I present the model and in Section 4.4 I present the model calibration. In Section 4.5 I analyse the response of macroeconomic variables to the macroeconomic shocks I consider, analysing the role resource allocation plays in the transmission of these shocks. In Section 4.6 I apply my model to data and examine the extent to which my model captures data on international business cycles relative to similar models. Section 4.7 concludes.

4.2 Literature Review

This chapter builds on two strands of literature. The first strand analyses the dynamic response of the economy to macroeconomic shocks in international trade models and the second analyses the impact of endogenous entry into the domestic market on the dynamic response of the economy to such shocks.

The literature analysing the dynamic response of the economy to macroeconomic shocks in an international trade model was pioneered by Ghironi and Melitz (2005), who build a 2-country dynamic, stochastic general equilibrium model of international trade with initial uncertainty regarding productivity, firm heterogeneity, sunk entry costs and fixed and variable costs of trade. The fixed exporting costs give rise to a selection process into the export market in which only the more productive firms, those with productivity levels above the cut-off level, export. Ghironi and Melitz (2005) use this model to study the response

dynamics of the economy to a permanent increase in aggregate productivity and a permanent decrease in home entry costs.

Several papers build on this model and also examine the macroeconomic dynamics following shocks. Adolfson *et al.* (2007) and Rodriguez-Lopez (2011) explicitly examine the response of the economy to a monetary policy shock. Hereby Adolfson *et al.* (2007) are the first to show that the "conventional wisdom" regarding the effects of monetary policy in a closed economy setting also apply in open economies, and Rodriguez-Lopez (2011) examine how exchange rates have expenditure switching effects in the presence of limited exchange rate pass-through. Dix-Carneiro *et al.* (2021) focus on different types of productivity shocks and examine how the length of the shock affects the dynamic response of the economy, Cavallari (2013) analyse a single productivity shock and study how the dynamic response of the economy to such a TFP shock differs under flexible and sticky prices, and D'Addona and Cavallari (2020) analyse how the dynamic response of the economy to a productivity shock differs under fixed and flexible exchange rate regimes. Barthelemy and Cleaud (2018) examine a shock to foreign preferences and show this shock is vital in driving the business cycle and Bergholt *et al.* (2019) examine the response of the economy to an oil productivity shock. Cacciatore (2014) considers the dynamic response of an economy to a 20% decrease in transport cost and analyses how labour market frictions affect this response, while Cacciatore *et al.* (2016) analyses how the economy responds to market reforms. Van Aarle (2012), Albonico *et al.* (2019) and De Walque *et al.* (2017) analyse the response of the economy to a large number of shocks in an international trade model. I build on this literature by analysing the dynamic response of the economy to a large number of shocks, focusing on how resource allocation affects this response.

The second strand of literature I build on is the literature that demonstrates the importance of entry into domestic markets for the business cycle. A large amount of literature documents this importance in closed economy models (Bilbiie *et al.* (2012), Hamano and Zanetti (2017), Lee and Mukoyama (2018), Clementi and Palazzo (2016), Woo (2015), Clementi *et al.* (2015)). Recently, some papers have also begun examining the importance of entry into domestic production in an international trade setting (Cacciatore (2014), Alessandria and Choi (2019) and Millard *et al.* (2021)), overall finding that entry matters for aggregate business cycle dynamics also in an international trade setting.

We thus have two main findings from the literature: both international trade and endogenous entry into domestic production matter for the response of the economy to macroeconomic shocks. However, most models that examine endogenous entry in an international trade framework only use one factor of production, namley labour (Cacciatore (2014), Millard *et al.* (2021)). At the same time, we know that the inclusion of two factors of production can be important. Indeed, Bilbiie *et al.* (2012) originally formulate their model without physical capital stock. However, they argue that the omission of capital "is certainly unrealistic: part of observed investment is accounted for by the need to augment the capital stock used in production of existing goods". They find that including capital "significantly improves the performance of the model". Indeed, to the best of my knowledge the only paper that includes two factors of production, international trade and endogenous entry into domestic production is Alessandria and Choi (2019), who argue that physical capital is important for the propagation of shocks, and to match cyclicality of trade flows. However, Alessandria and Choi (2019) do not elaborate any

further on the importance of including physical capital for the dynamic response of a model economy to a variety of shocks, instead analysing how international trade in goods and assets matters for entry margins.

In this chapter, I analyse how and the extent to which resource allocation affects the transmission of macroeconomic shocks, and especially the dynamic response of labour productivity to such shocks. With this analysis I aim to examine whether abstracting from a second factor of production matters when jointly allowing for international trade and endogenous selection into domestic production, and to what extent such an omission is relevant. This may have important implications for policy makers, as the analysis yields insight into how a variety of macroeconomic variables are affected by different macroeconomic shocks in the short-run and in the long-run when resource reallocation is accounted for.

The features of my model are most closely related to Alessandria and Choi (2019) as I include international trade, two factors of production and endogenous entry into domestic production. The model implementation is most closely related to Fattal-Jaef and Lopez (2014) and Millard *et al.* (2021)). In contrast to Alessandria and Choi (2019), I also allow for endogenous exit from the domestic market in response to macroeconomic shocks.

4.3 The Model

The model presented in this section is a two-country DSGE model of international trade, with capital and labour as inputs of intermediate production, monopolistic competition, heterogeneous firms, fixed costs of domestic production and fixed and variable costs of exporting. All foreign variables are denoted with a superscript *. Three agents operate in each country: households, final good producers and intermediate good producers. I describe each of their problems in turn.

4.3.1 Household Problem

The representative household is assumed to own the capital stock, real bonds and shares in domestic firms, and is also assumed to supply L_t units of labour. It maximises its intertemporal utility subject to its intertemporal budget constraint:

$$\max_{\substack{w.r.t:C_t,\\ B_t,x_t,C_{t+1}}} U = \left[\sum_{s=t}^{\infty} \beta^{s-t}\varepsilon_s\Big[\frac{C_s^{\mu}(1-L_s)^{1-\mu}}{1-\gamma}\Big]^{1-\gamma}\right],$$

s.t.

$$B_{H,t} + Q_t B_{F,t} + \frac{\eta}{2}(B_{H,t}^2 + Q_t B_{F,t}^2) + \tilde{v}_t N_{H,t} x_t + C_t + I_t$$
$$= (1 + r_{b,t-1})B_{H,t-1} + Q_t(1 + r^*_{b,t-1})B_{F,t-1} + (\tilde{d}_t + \tilde{v}_t)N_{D,t}x_{t-1} + w_t L_t + r_t^k K_{t-1} + T_t,$$

and

$$K_t = (1 - \delta_k)K_{t-1} + I_t,$$

where I_t is investment in new capital at time t, $K_t - 1$ is the amount of capital available at time t, C_t is consumption at time t, $\beta \epsilon(0,1)$ is the subjective discount factor, $\mu \epsilon(0,1)$ is the share of consumption in utility, $\gamma > 0$ is the inverse of the intertemporal elasticity of substitution, ε_t is a term that represents a shock to the discount rate affecting intertemporal substitution, essentially a shock to households' preferences regarding consumption, x_{t-1} is the household's mutual fund holdings at the beginning of period t, chosen during the previous period $t-1$, $\tilde{v}_t$ is the expected post-entry value of firms, $\tilde{d}_t$ is the average total profits of home firms, δ_k is the rate of depreciation of capital and r_t^k is the real rental rate of capital. $N_{H,t}$ is the mass of firms present in the home country at the end of period t, and $N_{D,t}$ is the mass of incumbent and producing firms in the home country during period t. Households can furthermore possess bonds, which can be traded internationally. $B_{H,t-1}$ is the household's holdings of home bonds at the beginning of period t, chosen during the previous period $t-1$, $B_{F,t-1}$ is the household's holdings of real foreign bonds at the beginning of period t, chosen during the previous period $t-1$, $r_{b,t-1}^b$ is the real interest rate on domestic bonds in period t as it is set in the previous period, $r_{b,t-1}^*$ is the real interest rate on foreign bonds in period t as it is set in the previous period. Domestic and foreign bonds, mutual fund holdings, and the capital stock are thus exogenously given at the start of every period, as they are determined at time $t-1$. In order to guarantee stationarity and determinacy of the steady state, I assume that households face a cost for adjusting their bond holdings, equal to $\frac{\eta}{2}(B_{H,t}^2 + Q_t B_{F,t}^2)$, where $\eta > 0$. The adjustment costs are rebated to the domestic households by the financial intermediaries via a lump-sum transfer, T_t, which equals $\frac{\eta}{2}(B_{H,t}^2 + Q_t B_{F,t}^2)$ in equilibrium. I assume throughout that there is no inflation in this economy; hence, the budget constraint and all quantities are expressed in real terms.

In this model, a household thus has four income sources. It enters a period with $B_{H,t-1}$ domestic and $B_{F,t-1}$ foreign bonds, which respectively yield the risk-free real rate of return $r_{b,t-1}$ and $r_{b,t-1}^*$, and x_{t-1} mutual funds, for which the household receives dividend income that is equal to the real average total profits of all home firms producing in that period, $\tilde{d}_t N_{D,t}$. The household can further sell shares, and thus receives the value of selling its initial share position, which is $\tilde{v}_t$. The representative household also earns income from its labour, which it $w_t L_t$, where w_t is the real wage in period t. As in this model capital is owned by households, the representative household additionally earns income from the capital it rents out to firms, $r_t^k K_{t-1}$.

The representative household divides this income between purchases of new bonds and new mutual fund holdings to be carried over into the next period, consumption, and investment in new capital by transforming the final good into capital. The household buys new shares x_t from a mutual fund of $N_{H,t} = N_{D,t} + N_{E,t}$ firms, where $N_{D,t}$ are the incumbent firms and $N_{E,t}$ the entering firms. Only $N_{D,t+1} = [1 - G(z_{D,t+1})]N_{H,t}$ firms will produce and pay dividends at time t, where $G(z_{D,t+1})$ is the average proportion of firms that exits the economy each period.[1] As the household does not know which firms will be able to produce in the next period, it finances the operation of all existing firms and all new entrants during period t.

[1] For a more precise explanation of this proportion, see Sections 4.3.3, 4.3.5 and 4.3.6.

The solution to this problem yields the following Euler equations:

$$C_t^{-1}[C_t^{\mu}(1-L_t)^{1-\mu}]^{1-\gamma}(1+\eta B_{H,t}) = (1+r_{b,t})\beta E_t\Big\{\frac{\varepsilon_{t+1}}{\varepsilon_t}C_{t+1}^{-1}[C_{t+1}^{\mu}(1-L_{t+1})^{1-\mu}]^{1-\gamma}\Big\}, \tag{4.1}$$

$$C_t^{-1}[C_t^{\mu}(1-L_t)^{1-\mu}]^{1-\gamma}(1+\eta B_{F,t}) = (1+r_{t,b}^{*})\beta E_t\Big\{\frac{Q_{t+1}}{Q_t}\frac{\varepsilon_{t+1}}{\varepsilon_t}C_{t+1}^{-1}[C_{t+1}^{\mu}(1-L_{t+1})^{1-\mu}]^{1-\gamma}\Big\}, \tag{4.2}$$

$$C_t^{-1}[C_t^{\mu}(1-L_t)^{1-\mu}]^{1-\gamma} = \beta E_t\Big\{(1-\delta_k+r_{t+1}^{k})\frac{\varepsilon_{t+1}}{\varepsilon_t}C_{t+1}^{-1}[C_{t+1}^{\mu}(1-L_{t+1})^{1-\mu}]^{1-\gamma}\Big\}, \tag{4.3}$$

$$w_t(1-L_t) = \frac{1-\mu}{\mu}C_t \tag{4.4}$$

$$\tilde{v}_t = \beta E_t\Big\{(1-G(z_{D,t+1}))\frac{\varepsilon_{t+1}}{\varepsilon_t}\frac{C_t}{C_{t+1}}\Big[\frac{C_{t+1}^{\mu}(1-L_{t+1})^{1-\mu}}{C_t^{\mu}(1-L_t)^{1-\mu}}\Big]^{1-\gamma}(\tilde{d}_{t+1}+\tilde{v}_{t+1})\Big\}. \tag{4.5}$$

Average firm value in period t is thus discounted by the probability firms will still be in the market in period $t+1$, given by the endogenous rate of firm survival $[1-G(z_{D,t+1})]$.

4.3.2 Final Goods Producers

Final good producers are perfectly competitive and produce a non-traded final good for households, which can either be consumed or invested. In order to produce, final good producers use domestically produced intermediate goods and imported intermediate goods.

Letting z denote the firm-specific productivity level, the final good producers produce according to

$$Y_t = \Big[\int_{z\epsilon\Omega} y_{D,t}(z)^{\frac{\theta-1}{\theta}}dz + \int_{z\epsilon\Omega^*} y_{X,t}^{*}(z)^{\frac{\theta-1}{\theta}}dz\Big]^{\frac{\theta}{\theta-1}}, \tag{4.6}$$

where Y_t is the final good, $y_{D,t}(z)$ is the output of a domestic intermediate good producing firm with productivity level z sold at home, $y_{X,t}^{*}(z)$ is the quantity a foreign intermediate good producing firm with productivity level z exports to the home country, and $\theta > 1$ is the elasticity of substitution across goods.

The representative final good producer solves the following problem:

$$\max_{\substack{w.r.t:\\ Y_t, y_{D,t}, y_{X,t}^{*}}} P_tY_t - \int_{z\epsilon\Omega} p_{D,t}(z)y_{D,t}(z)dz - \int_{z\epsilon\Omega^*} p_{X,t}^{*}(z)y_{X,t}^{*}(z)dz,$$

subject to (4). P_t is the aggregate price level, $p_{D,t}(z)$ is the nominal price an intermediate good producing firm with the productivity level z charges for its good at home and $p_{X,t}^{*}(z)$ is the nominal price a foreign intermediate good producing firm with the productivity level z charges in the home economy.[2] This problem yields the following demand functions:

$$y_{D,t}(z) = \Big(\frac{p_{D,t}(z)}{P_t}\Big)^{-\theta}Y_t, \tag{4.7}$$

$$y_{X,t}^{*}(z) = \Big(\frac{p_{X,t}^{*}(z)}{P_t}\Big)^{-\theta}Y_t. \tag{4.8}$$

[2] $p_{X,t}^{*}(z)$ is thus a domestic currency price; it is the price that domestic final good producers pay for imported goods.

As the foreign final good producers face an identical problem, I can derive the demand function for domestic exporters from equation (6):

$$y_{X,t}(z) = \left(\frac{p_{X,t}(z)}{P_t^*}\right)^{-\theta} Y_t^*. \tag{4.9}$$

I transform these demand functions into relative price terms, by defining:

$$\rho_{D,t}(z) = \frac{p_{D,t}(z)}{P_t} \text{ and } \rho_{X,t}(z) = \frac{p_{X,t}(z)}{P_t^*},$$

where $\rho_{D,t}(z)$ is the price an intermediate good producing firm with the productivity level z charges for its good at home relative to the domestic price level and $\rho_{X,t}(z)$ is the price an exporting domestic intermediate good producing firm with the productivity level z charges for its good in the foreign economy relative to the foreign price level.

4.3.3 Intermediate Goods Producers

Each intermediate good producer produces a differentiated good, $\omega \epsilon \Omega$. Intermediate good firms produce using labour and capital as inputs of production, and produce according to the production function $y_t(z) = Z_t z k_{t-1}(z)^{\alpha} l_{P,t}(z)^{1-\alpha}$, where $\alpha \, \epsilon(0,1)$ is the capital income share, $y_t(z)$ is the amount produced by a firm with the productivity level z, Z_t is the aggregate country-specific technology level, $k_{t-1}(z)$ is the capital employed by a firm with the productivity level z, and $l_{P,t}(z)$ is the labour employed for production by a firm with the productivity level z.

In order to enter the market a firm must pay a sunk entry cost $f_{E,t}$, following Melitz (2003). Upon paying the entry cost, a firm draws its firm-level productivity z from a fixed productivity distribution $G(z)$ with support over (z_{min}, ∞). This firm-level productivity is re-drawn at the end of every period. Firms furthermore pay a fixed cost for domestic production $f_{D,t}$, as well as a fixed exporting cost $f_{X,t}$ and variable trade costs τ_t if they export. The variable costs are modelled as standard iceberg costs, whereby more than one unit of a good has to be shipped in order for one unit of a good to arrive at its destination. The fixed costs and sunk entry costs are defined in terms of effective labour units.[3] To get the costs in units of output, they need to be multiplied by the real wage, w_t, and divided by the aggregate technology level, Z_t.

A representative intermediate good producer maximises its real profit subject to the domestic and foreign demand curves and its production constraint.

$$\max_{\substack{w.r.t:\rho_{D,t},\\ \rho_{X,t}, l_{P,t}(z), k_t^k(z)}} d_t(z) = \rho_{D,t}(z) y_{D,t}(z) + Q_t \rho_{X,t}(z) y_{X,t}(z) - w_t l_{P,t}(z) - r_t^k k_{t-1}(z) - \frac{w_t f_{D,t}}{Z_t} - \frac{w_t f_{X,t}}{Z_t}, \tag{4.10}$$

subject to:

$$y_{D,t}(z) = (\rho_{D,t})^{-\theta} Y_t,$$

$$y_{X,t}(z) = (\rho_{X,t})^{-\theta} Y_t^*,$$

$$y_{D,t}(z) + \tau_t y_{X,t}(z) = Z_t z k_{t-1}(z)^{\alpha} l_{Pp,t}(z)^{1-\alpha},$$

[3] Sunk and fixed costs are specified in terms of labour to proxy real-world costs that tend to be associated with setting up a firm and overhead costs. These costs frequently involve man-power, such as hiring lawyers, marketing, or book-keeping.

where $d_t(z)$ are total profits of the firm with productivity level z in period t, $Q_t = \frac{\epsilon P_t^*}{P_t}$ is the real exchange rate.

Solving this problem, firms set prices as follows:

$$\rho_{D,t}(z) = \frac{\theta}{\theta - 1}\Big(\frac{w_t}{1-\alpha}\Big)^{1-\alpha}\Big(\frac{r_t^k}{\alpha}\Big)^{\alpha}\frac{1}{Z_t z},$$

$$\rho_{X,t}(z) = \frac{\tau_t}{Q_t}\frac{\theta}{\theta - 1}\Big(\frac{w_t}{1-\alpha}\Big)^{1-\alpha}\Big(\frac{r_t^k}{\alpha}\Big)^{\alpha}\frac{1}{Z_t z}.$$

Defining marginal costs as $MC(z) = \Big(\frac{w_t}{1-\alpha}\Big)^{1-\alpha}\Big(\frac{r_t^k}{\alpha}\Big)^{\alpha}\frac{1}{Z_t z}$, firms set their prices according to

$$\rho_{D,t}(z) = \frac{\theta}{\theta - 1}MC(z), \tag{4.11}$$

$$\rho_{X,t}(z) = \frac{\tau_t}{Q_t}\frac{\theta}{\theta - 1}MC(z). \tag{4.12}$$

Note that relative prices depend negatively on the firm-level productivity level. Firms with higher productivity thus set lower prices.

The choice of factors of production is determined by:

$$k_{t-1}(z) = \alpha MC(z)\frac{y_t(z)}{r_t^k(z)},$$

$$l_{P,t}(z) = (1-\alpha)MC(z)\frac{y_t(z)}{w_t}.$$

Expanding these expressions leads to

$$k_{t-1}(z) = \Big(\frac{w_t}{r_t^k}\frac{\alpha}{1-\alpha}\Big)^{1-\alpha}\Big((\frac{w_t}{1-\alpha})^{1-\alpha}(\frac{r_t^k}{\alpha})^{\alpha}\frac{\theta}{\theta-1}\Big)^{-\theta}(Z_t z)^{\theta-1}[Y_t + \tau_t^{1-\theta}Q_t^{\theta}Y_t^*], \tag{4.13}$$

$$l_{P,t}(z) = \Big(\frac{r_t^k}{w_t}\frac{1-\alpha}{\alpha}\Big)^{\alpha}\Big((\frac{w_t}{1-\alpha})^{1-\alpha}(\frac{r_t^k}{\alpha})^{\alpha}\frac{\theta}{\theta-1}\Big)^{-\theta}(Z_t z)^{\theta-1}[Y_t + \tau_t^{1-\theta}Q_t^{\theta}Y_t^*]. \tag{4.14}$$

Total profits are given by the sum of domestic profits and exporting profits. However, due to the presence of fixed costs for domestic production, not all firms are able to produce in any given period. Only firms with a productivity level $z > z_{D,t} = inf\{z : d_{D,t}(z) > 0\}$ are productive enough to enter domestic production, with $d_{D,t}$ defined below. Firms that draw a productivity level below $z_{D,t}$, the productivity cut-off level for domestic production, cannot produce profitably and thus exit the market immediately. It is changes in this productivity cut-off level in response to macroeconomic shocks that cause firms to enter and exit the market endogenously. Similarly, only firms with a productivity level $z > z_{X,t} = inf\{z : d_{X,t}(z) > 0\}$ are productive enough to profitably pay the fixed exporting costs and export, where $d_{X,t}$ is defined below. In every period, only a subsection of firms thus produces, and only the most productive of those firms export. Total profits are given by:

$$d_t(z) = d_{D,t}(z) + d_{X,t}(z),$$

where

$$d_{D,t}(z) = \begin{cases} \frac{1}{\theta}(\rho_{D,t}(z))^{1-\theta}C_t - \frac{w_t f_{D,t}}{Z_t} & \text{if the firm produces,} \\ 0 & \text{otherwise.} \end{cases}$$

$$d_{X,t}(z) = \begin{cases} \frac{Q_t}{\theta}(\rho_{X,t}(z))^{1-\theta}C_t^* - \frac{w_t f_{X,t}}{Z_t} & \text{if the firm exports,} \\ 0 & \text{otherwise.} \end{cases}$$

4.3.4 Firm Averages

In every period, there is a mass of incumbent firms $N_{D,t}$ that produces, given the productivity cut-off level for domestic production, and a mass of firms $N_{X,t}$ that exports, given the productivity cutoff level for exporting.

Following Melitz (2003), I can define average productivities for domestic firms, $\tilde{z}_{D,t}$, and for exporting firms, $\tilde{z}_{X,t}$:

$$\tilde{z}_{D,t} = \Big[\frac{1}{1-G(z_{D,t})}\int_{z_{D,t}}^{\infty} z^{\theta-1}dG(z)\Big]^{\frac{1}{\theta-1}}, \tag{4.15}$$

$$\tilde{z}_{X,t} = \Big[\frac{1}{1-G(z_{X,t})}\int_{z_{X,t}}^{\infty} z^{\theta-1}dG(z)\Big]^{\frac{1}{\theta-1}}. \tag{4.16}$$

Melitz (2003) shows that these average productivities summarize the entire distribution of productivities of all firms and of the subset of exporting firms. Thus the average price in the domestic market is equal to the price of the firm with the average productivity level $\tilde{z}_{D,t}$, $\tilde{\rho}_{D,t} = \rho_{D,t}(\tilde{z}_{D,t})$, and the average price in the exporting market is equal to the price of the firm with the average exporting productivity level $\tilde{z}_{X,t}$, $\tilde{\rho}_{X,t} = \rho_{X,t}(\tilde{z}_{X,t})$. The aggregate price level in the home economy will reflect both the domestic average price and the foreign average exporting price: $P_t = [N_{D,t}(\tilde{p}_{D,t})^{1-\theta} + N^*_{x,t}(\tilde{p}^*_{x,t})^{1-\theta}]^{\frac{1}{1-\theta}}$. Taking both sides to the power of $1-\theta$ and dividing both sides by $P_t^{1-\theta}$ yields the following price index:

$$N_{D,t}(\tilde{\rho}_{D,t})^{1-\theta} + N^*_{X,t}(\tilde{\rho}^*_{X,t})^{1-\theta} = 1.$$

From this aggregation it follows that average profits are given by:

$$\tilde{d}_t = \tilde{d}_{D,t} + \frac{N_{X,t}}{N_{D,t}}\tilde{d}_{X,t}.$$

4.3.5 Firm Entry

Entry occurs until the average firm value is equalised with the entry cost. In each period, $N_{E,t}$ firms pay the sunk entry costs. At the end of the period, along with all other firms, they draw their productivity level for the next period. The shock at the beginning of the next period then decides which firms are productive enough to produce given the productivity cut-off level; some of these firms will have a productivity that is lower. Thus, a proportion of these firms, $G(z_{D,t+1})$, will exit before ever producing. Entry will occur until the average firm value, adjusted by the probability of entering the market, is equal to the sunk entry cost $f_{E,t}$, expressed in effective labour units. Thus,

$$\tilde{v}_t = \frac{w_t f_{E,t}}{Z_t}.$$

Given that firms exit and enter the economy based on whether or not their productivity level enables them to pay the fixed cost of domestic production, the law of motion of firms is given by

$$N_{D,t} = [1 - G(z_{D,t})](N_{D,t-1} + N_{E,t-1}).$$

4.3.6 Parameterisation of Productivity Draws

Next, I parameterise the distribution of productivity draws $G(z)$. I assume that z is Pareto distributed, with a lower bound z_{min} and the shape parameter $j > \theta - 1$. Thus, $G(z) = 1 - \left(\frac{z_{min}}{z}\right)^j$. j indexes the dispersion of productivity draws, and therefore defines the distribution. I define $\nu = \left(\frac{j}{j-(\theta-1)}\right)^{\frac{1}{\theta-1}}$, which allows us to use equations (4.15) and (4.16) to express the average productivities $\tilde{z}_{D,t}$ and $\tilde{z}_{X,t}$ as $\tilde{z}_{D,t} = \nu z_{D,t}$ and $\tilde{z}_{X,t} = \nu z_{X,t}$.

The share of exporting firms is given by $N_{X,t}/N_{D,t} = \frac{1-G(z_{X,t})}{1-G(z_{D,t})}$. Above I defined $G(z) = 1 - \left(\frac{z_{min}}{z}\right)^j$. Thus $N_{X,t}/N_{D,t} = \frac{1-G(z_{X,t})}{1-G(z_{D,t})} = \left(\frac{z_{min}}{z_{X,t}}\frac{z_{D,t}}{z_{min}}\right)^j = \left(\frac{z_{D,t}}{z_{X,t}}\right)^j$. Recall that $\tilde{z}_{X,t} = \nu z_{X,t}$ and $\tilde{z}_{D,t} = \nu z_{D,t}$. Substituting this into the proportion of exporting firms yields

$$\frac{N_{X,t}}{N_{D,t}} = \left(\frac{\tilde{z}_{D,t}}{\tilde{z}_{X,t}}\right)^j. \tag{4.17}$$

Using this parameterisation of productivity I can re-write the law of motion of firms as

$$N_{D,t} = \left(\frac{\nu z_{min}}{\tilde{z}_{D,t}}\right)^j (N_{D,t-1} + N_{E,t-1})$$

and the Euler equation for shares from (4.5) as

$$\tilde{v}_t C_t^{-1}[C_t^{\mu}(1-L_t)^{1-\mu}]^{1-\gamma} = \left(\frac{z_{min}\nu}{\tilde{z}_{D,t}}\right)^j \beta E_t\Big\{\frac{\varepsilon_{t+1}}{\varepsilon_t} C_{t+1}^{-1}[C_{t+1}^{\mu}(1-L_{t+1})^{1-\mu}]^{1-\gamma}(\tilde{d}_{t+1} + \tilde{v}_{t+1})\Big\}. \tag{4.18}$$

The zero-profit cut-off (ZPC) conditions $d_{D,t}(z_{D,t}) = 0$ and $d_{X,t}(z_{X,t}) = 0$ imply that average profits will be determined by

$$\tilde{d}_{D,t} = \frac{w_t f_{D,t}}{Z_t}\frac{j}{j-(\theta-1)}, \tag{4.19}$$

$$\tilde{d}_{X,t} = \frac{w_t f_{X,t}}{Z_t}\frac{j}{j-(\theta-1)}. \tag{4.20}$$

4.3.7 Equilibrium Conditions

Both the capital and labour markets must clear.

$$\begin{aligned} K_{t-1} = K_{P,t-1} = N_{D,t}\Big(\frac{w_t}{r_t^k}\frac{\alpha}{1-\alpha}\Big)^{1-\alpha}\left(\Big(\frac{w_t}{1-\alpha}\Big)^{1-\alpha}\Big(\frac{r_t^k}{\alpha}\Big)^{\alpha}\frac{\theta}{\theta-1}\right)^{-\theta} \\ (Z_t)^{\theta-1}[Y_t\tilde{z}_{D,t}^{\theta-1} + \frac{N_{X,t}}{N_{D,t}}\tau_t^{1-\theta}Q_t^{\theta}Y_t^*\tilde{z}_{X,t}^{\theta-1}], \end{aligned} \tag{4.21}$$

and

$$L_t = L_{P,t} + L_{E,t} + L_{D,t} + L_{X,t}, \tag{4.22}$$

where $L_{P,t}$ is aggregate labour used for production, $L_{E,t}$ is aggregate labour used to pay for the sunk entry cost, $L_{D,t}$ is aggregate labour used to pay the fixed cost of domestic production, and $L_{X,t}$ is aggregate labour used to pay the fixed cost of exporting.

$L_{P,t} = N_{D,t}\Big(\frac{r_t^k}{w_t}\frac{1-\alpha}{\alpha}\Big)^{\alpha}\Big((\frac{w_t}{1-\alpha})^{1-\alpha}(\frac{r_t^k}{\alpha})^{\alpha}\frac{\theta}{\theta-1}\Big)^{-\theta}(Z_t)^{\theta-1}\Big[Y_t\tilde{z}_{D,t}^{\theta-1} + \frac{N_{X,t}}{N_{D,t}}\tau_t^{1-\theta}Q_t^{\theta}Y_t^*\tilde{z}_{X,t}^{\theta-1}\Big]$,

$L_{E,t} = \frac{N_{E,t}f_{E,t}}{Z_t}$,

$L_{D,t} = \frac{N_{D,t} f_{D,t}}{Z_t}$,
$L_{X,t} = \frac{N_{X,t} f_{X,t}}{Z_t}$.

The bond market must also clear, as domestic and foreign assets are in net zero supply:

$$B_t + B^*_{F,t} = 0, \tag{4.23}$$

$$B_{F,t} + B^*_H = 0. \tag{4.24}$$

I furthermore set labour productivity to:

$$LaProd_t = \frac{GDP_t}{L_t}, \tag{4.25}$$

where L_t is as previously defined, and $GDP_t = Y_t + NX_t$, where Y_t is real output of the final goods sector, as in equation (4.6), and NX_t are net exports of intermediate goods. Appendix B.2 provides an overview over all equations. The model was coded and simulated in Dynare.[4]

4.4 Calibration

I interpret one period as three months, and calibrate parameters as follows, assuming symmetrical countries. I set $\gamma = 2$ and $\beta = 0.99$, both standard values in the quarterly business cycle literature. I furthermore set $\alpha = 0.36$ and $\delta_k = 0.025$, again both standard values in the literature.

I set the shape parameter j to 5.65, which complies with the condition $j > \theta - 1$. The fixed costs for domestic production and exporting are set to $f_D = 0.004$ and $f_X = 0.006$. I jointly calibrated the shape parameter j and the fixed costs of production and exporting to match the average annual exit rate of 10% in the UK, and the proportion of firms that export in the UK, which is 9.91%. While the intermediate firm exit rate is determined endogenously in this model, the parameters were calibrated to yield a steady-state exit rate of 0.025 per quarter. Data for the exit rate was obtained from the *ONS Business Demography, UK: 2017* database, and was calculated using data from 2012-2017. Data on the exporting proportion in the UK was obtained from the *ONS Annual Business Survey importers and exporters*. The average proportion of exporting firms was calculated using data from 2015 to 2017.

The per unit iceberg costs τ were set using data from the *World Bank International Trade Costs database*, and the 2018 *ONS Pink Book*. The two countries in the model were set as UK and the rest of the world (RoW). The iceberg costs were calculated as an average of weighted country iceberg costs. Specifically, τ is the sum of the iceberg trade costs of the UK with every country in the world for which both databases contain data, multiplied by the proportion of UK exports going to that country. This yielded an average iceberg cost of $\tau = 1.39$.

I further set $f_E = 1$.[5] I can do this without loss of generality, because changing f_E while maintaining the same ratio f_X/f_E does not affect the firm-level productivity variables and has no effect on impulse

[4] `https://www.dynare.org/`

[5] Note that f_E and τ here are the steady state values for the sunk entry cost and iceberg cost of trade respectively. Below $f_{E,t}$ and τ_t are treasted as exogenous stochastic processes.

responses. For similar reasons, I set $z_{min} = 1$. The means of Z_t and ε_t are also normalised to 1 for both countries. The table in Appendix B.3 summarises all parameter values.

4.5 Macroeconomic Shock Responses

In this section I describe the dynamic response of the economy to temporary shocks, namely a positive 1 percentage point 1 period shock to aggregate technology and preferences, and a negative 1 percentage point 1 period shock to the sunk cost of entry and the variable costs of exporting.

The shocks all follow an AR(1) process:

$$\hat{Z}_t = \rho_Z \hat{Z}_{t-1} + \zeta_t^Z, \tag{4.26}$$

$$\hat{f}_{E,t} = \rho_{f_E} \hat{f}_{E,t-1} + \zeta_t^{f_E}, \tag{4.27}$$

$$\hat{\varepsilon}_t = \rho_\varepsilon \hat{\varepsilon}_{t-1} + \zeta_t^\varepsilon, \tag{4.28}$$

$$\hat{\tau}_t = \rho_\tau \hat{\tau}_{t-1} + \zeta_t^\tau, \tag{4.29}$$

where the hat denotes log-deviations from the steady state, ρ is the persistence of the shock, which I set to 0.9 following Ghironi and Melitz (2005), and ζ_t is the magnitude of the shock in period t.

I compare the response of my model economy to the response of MMN,[6] which uses only labour as a factor of production. My model is identical to MNN, with the additions of physical capital and elastic labour supply. The comparison of my model to MNN will allow me to determine how resource allocation changes the response of an economy in which endogenous entry into domestic production is considered. In order to ascertain whether it is the elasticity of labour or resource re-allocation that drives the differences in results I furthermore include in my analysis both the response of the model described in Section 4.3 with elastic labour, and the response of the same model with inelastic labour supply. I will refer to the former model as my model and to the latter model as the inelastic labour model.[7] In Panel A of the below figures I compare the response of the variables that are common to all three models, whereby the solid lines represent the response of the economy in my model, the dashed lines depict the response of the economy in the inelastic labour model and the dotted lines depict the response of the economy in MNN. In Panel B of the figures I illustrate the response of the new variables in my model, namely of capital stock, investment, the rental rate of capital and aggregate labour.

4.5.1 Shock to Aggregate Technology

The response of the economy to a temporary, but persistent, positive shock to aggregate technology is illustrated in Figure 4.1.

[6] I compare the response of my economy to my replication of MNN. Specifically I replicated the responses in MNN and then adapted the model slightly in line with my own implementation. The most important adjustment is the calibration to the UK instead of the US and different definition of labour productivity. This means that my responses will be slightly different than the ones found in that paper. For details on the differences in modelling, see Appendix B.4.

[7] I will only refer to the results of the inelastic labour model if these differ significantly from my baseline model with elastic labour supply.

Figure 4.1, Panel A: Comparison of Response to a Temporary Shock to Aggregate Technology

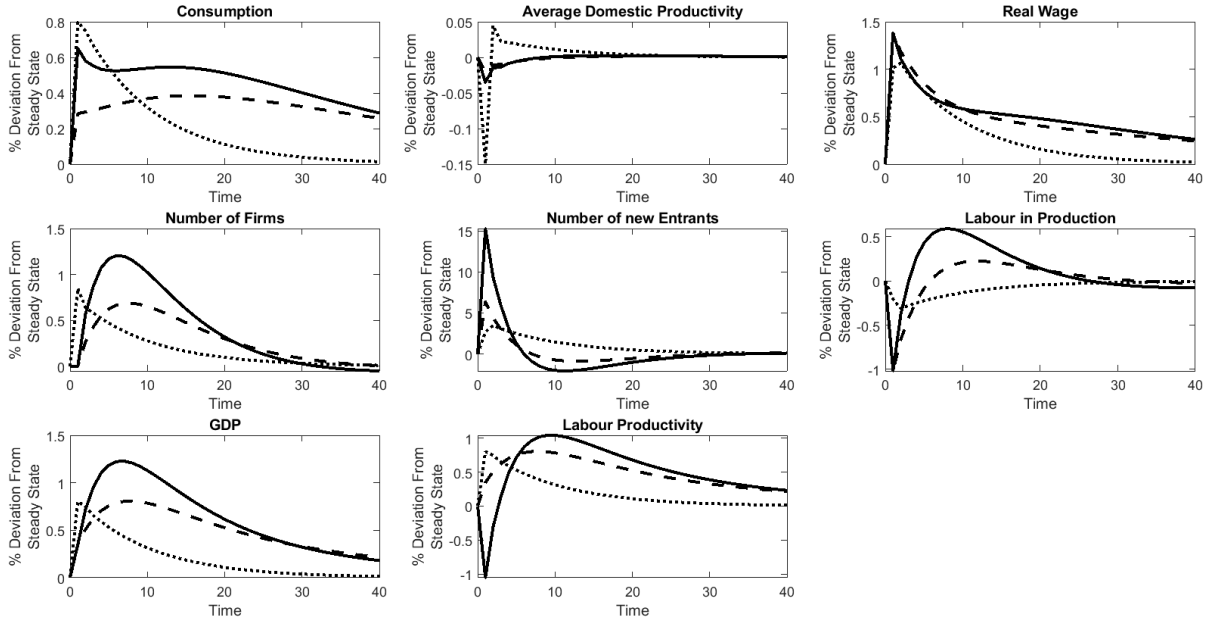
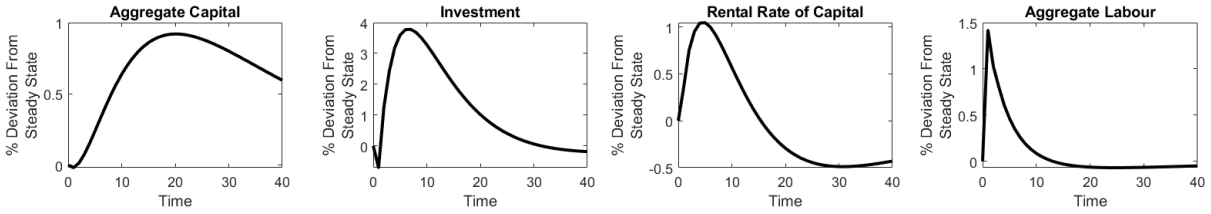


Figure 4.1, Panel B: Response of New Variables



There are two major differences between the responses of my model and MNN to a positive 1 percentage point technological shock. First, in my model labour productivity decreases in the first period in response to a technological shock, whereas it increases in MNN. Second, the dynamic response of output to the shock differs in both models. I will now analyse each of these differences in turn.

First, the difference in the response of labour productivity results from the elasticity of labour supply in my model. In my model, while aggregate labour increases by approximately 1.42% relative to its steady state, aggregate output and GDP increase by only 0.35% in the first period. As labour productivity is defined as $\frac{GDP_t}{L_t}$, it decreases by 1.05% in the first period in my model. In contrast, in MNN aggregate labour is fixed. GDP increases by 0.8% in the first period, causing labour productivity to increase by the same amount. The behaviour of aggregate labour and output in my model occurs due to the presence of sunk and fixed costs and the endogenous selection of firms into domestic production. Figure 4.1 shows that as technology improves following the technological shock, the cut-off productivity for domestic production decreases, allowing firms that were previously too unproductive to produce profitably to enter the domestic market. As the number of new entrants increases by 15.28% in response to this lower pro-

ductivity cut-off level for domestic production, much more labour is demanded to pay for the sunk entry costs. As the number of new entrants also drives up the number of domestic firms by 1.21%, more labour is furthermore used to pay the fixed cost of domestic production. While labour used in production falls in my model in response to the technology shock, as the same amount of output can now be produced with less inputs, the increase in labour required to pay fixed and sunk costs outweighs this decrease in labour used in production, leading to a significant increase in aggregate labour employed. In MNN these dynamics also occur, but to a much lower extent, as the aggregate labour that can be employed is fixed. These dynamics therefore do not affect the response of labour productivity in that model.

The second major difference between the responses of the two models to the technology shock is the dynamic response of output. In MNN, GDP reaches its maximum increase on impact, at which point it increases by 0.8%. In my model, in contrast, it increases by only 0.35% in the first period but continues increasing afterwards. The reason that output increases less on impact in my model lies in the greater reduction in labour employed in production. In both models, labour in production falls in response to the shock as the same output can now be produced with less inputs. In my model, more labour is substituted towards the payment of sunk entry costs and less labour is employed in production. This effect dampens the initial impact of the technological shock on output, causing output to increase less strongly in my model initially. Output continues to increase for a few periods, which it does not do in MNN. This behaviour occurs because of investment in my model, which peaks in period 7. As more inputs get used until this time, GDP increases until this time as well. As aggregate labour returns to its steady state while output continues increasing, labour productivity increases in my model before returning to its steady state level.

The inelastic labour model behaves very similarly to my model with elastic labour supply. The responses are more attenuated as overall labour supply cannot adjust, causing less new entrants to enter the economy. Labour productivity also increases directly for the same reason. However, GDP follows a more hump-shaped response than in MNN. This response seems to be caused by the existence of investment, and it has been largely documented that this is more in line with empirical evidence.

Overall, two major results have emerged from this analysis. In response to a positive technology shock, firms use less inputs in production as the same amount of output can now be produced with less inputs, which is consistent with empirical evidence provided by Basu *et al.* (2006) and Michelacci and Lopez-Salido (2007) who show that a positive technology shock can reduce the use of factor inputs in the short run. The possibility of investment allows output to continue expanding after the initial impact of the shock, causing a more hump-shaped response in GDP. Furthermore, the elasticity of aggregate labour causes labour productivity to decrease in the first period and to increase after this initial impact.

4.5.2 Shock to Preferences

The dynamic response of the economy to a temporary positive 1 percentage point shock to preferences is illustrated in Figure 4.2.

Figure 4.2, Panel A: Comparison of Responses to a Temporary Shock to Preferences

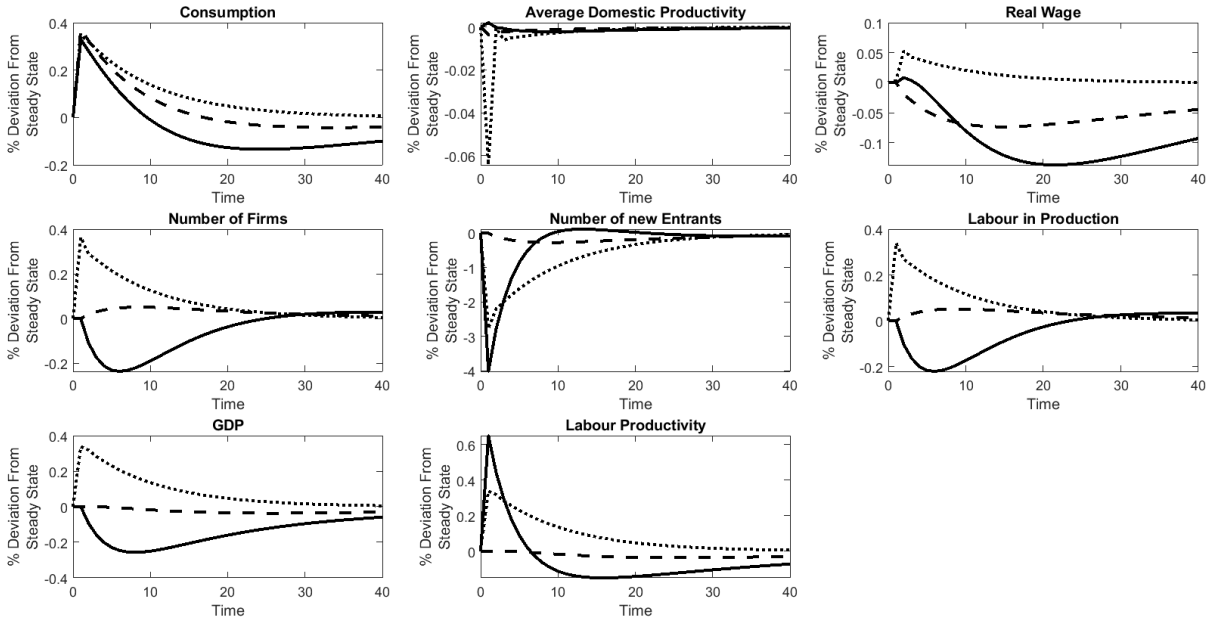
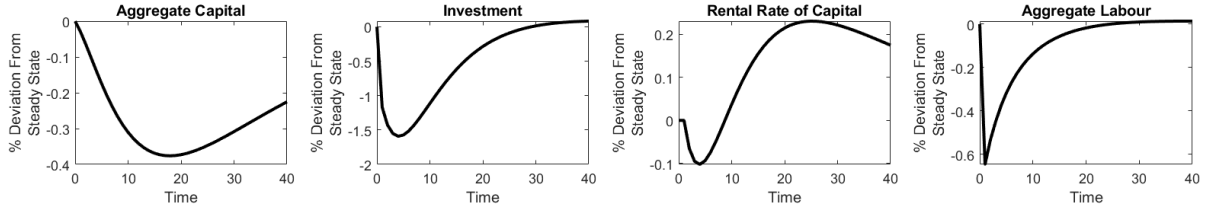


Figure 4.2, Panel B: Response of New Variables



In response to a shock to preferences the future is temporarily discounted by more, which increases present consumption and decreases the present supply of labour. In my model, consumption increases by 0.33% and aggregate labour decreases by 0.65%. In MNN, consumption increases by 0.35% and in the inelastic labour model it increases by 0.37%. Consumption thus increases by very similar amounts in all three models.

Interestingly, however, this simple initial shock leads to quite different dynamics in all three models. The main differences lie in the behaviour of GDP and labour productivity, the use of labour in production, and the number of new entrants and incumbent firms. I will explain these differences in turn.

As the 2nd quadrant of the 3rd line of Figure 4.2, Panel A shows, labour productivity increases by 0.65% in my model, increases by 0.34% in MNN and essentially does not change on impact in the inelastic labour model. The reason for the difference between my model and the inelastic labour model lies in the elasticity of labour supply. In the model with elastic labour supply, aggregate labour decreases in response to the shock as households temporarily favour leisure more, causing less labour to be employed in production and for covering sunk and fixed costs. In the model with inelastic labour supply, over-

all labour cannot change. Indeed, in this model the labour allocation does not change much at all on impact; consumers simply alter their expenditure on investment and consumption in response to the shock. Instead of investing, they consume more on impact. In subsequent periods GDP then slightly falls in response to reduced investment. Thus, while GDP decreases in both models, it falls by much less in the model with inelastic labour supply. In the model with inelastic labour, the decrease in GDP following the decrease in labour used in production also causes a small decrease in labour productivity. In my model, the decrease in GDP, while larger than in the model without elastic labour, is outweighed by the decrease in aggregate labour. Labour productivity therefore expands quite substantially, by 0.65%.

In MNN, the dynamics driving the response of labour productivity are different. In contrast to my model, labour in production expands in response to the shock, causing GDP and therefore labour productivity to increase as well. This is different to my model, where labour in production decreases as consumption can also be increased by substituting for investment. In MNN, the only way to increase consumption is to increase output, which is precisely what happens. The response in labour productivity is therefore driven by very different underlying dynamics in MNN than in my two model variants.

The different response in labour in production further explains the different dynamic in the number of entrants and incumbent firms since sunk and fixed costs are paid in effective labour. In the two models with inelastic labour, labour is re-allocated towards production. In my model with inelastic labour supply labour in production only increases very slightly, as a large increase is not necessary to increase consumption. In MNN, more labour is re-allocated to production in response to the shock, meaning much less labour is available to cover sunk costs. The number of new entrants thus falls by 2.78%. In the inelastic labour model, it only falls by 0.27%. In my model with elastic labour supply, aggregate labour falls, meaning less labour is available in all areas. The number of new entrants therefore falls by more than in both other models, namely by 4.02%.

The number of incumbent firms follows the dynamics of the number of entrants in my baseline model. In MNN and the inelastic labour model, however, the number of incumbents actually increases despite the fall in the number of new entrants. In both models this is induced by a reduced cut-off productivity level for domestic production resulting in a higher rate of firm survival relative to the steady state. In MNN, this decrease in the cut-off level is caused by the increase in consumption and in the inelastic labour model, it is caused by the decrease in factor costs. The intuition for the decrease in the cut-off level in both models is provided by the following equations defining the cut-off productivity level.

In MNN:

$$\tilde{z}_{D,t} = \Big[\Big(\frac{w_t}{Z_t}\Big)^{\theta} f_{D,t} \frac{\theta j}{j-(\theta-1)} \frac{1}{C_t}\Big]^{\frac{1}{\theta-1}} \frac{\theta}{\theta-1}$$

In my model,

$$\tilde{z}_{D,t} = \Big[Z_t^{-\theta} f_{D,t} \frac{\theta j}{j-(\theta-1)} \frac{1}{Y_t}\Big]^{\frac{1}{\theta-1}} \frac{\theta}{\theta-1} w_t^{\frac{\theta-\alpha\theta+\alpha}{\theta-1}} (\alpha-1)^{\alpha-1} \Big(\frac{r^k}{\alpha}\Big)^{\alpha}$$

The factor prices positively influence the cut-off level for domestic productivity and therefore average productivity. This is intuitive, as an increase in the factor prices makes production more expensive, making it more difficult to produce profitably. Consumption and output negatively affect the cut-off

level for domestic production. This is because when consumption of final output increases, there is more demand for the firms' products, making it likely that prices will be higher, and production is overall more profitable.

Overall, the preference shock leads to quite different responses in all three models, and the dynamic response of labour productivity is driven by different underlying forces. In my model, labour decreases in response to the shock, causing the factor inputs and thus aggregate output and GDP to decrease substantially. As the the decrease in labour outweighs the decrease of GDP, labour productivity increases in response to the shock. In the variant of my model with inelastic labour, GDP also falls due to the same dynamics, albeit to a much lesser extent. As labour remains constant, labour productivity falls in response to the shock. In MNN the model economy responds quite differently. In this model households cannot substitute investment for consumption, which means that output must rise to enable higher consumption. To raise output, labour in production increases, which increases GDP and therefore labour productivity on impact.

It is interesting to note that both the elasticity of labour supply and the possibility of investment are vital in driving the response of the economy to this macroeconomic shock. The presence of physical capital changes the response of GDP and labour productivity, and significantly attenuates the response of labour in production, the number of new entrants and the number of incumbent firms relative to the model that only uses labour as a production input. The elasticity of labour supply then reverses the response of labour in production and the number of incumbent firms, and amplifies the response of the number of new entrants and of GDP.

4.5.3 Shock to the Sunk Cost of Entry

The dynamic response of the economy to a temporary, but persistent, negative 1 percentage point shock to the sunk cost of entry is illustrated in Figure 4.3.

As with the preference shock, understanding the response of some variables to this shock requires knowing the determinants of average productivity.

In MNN:

$$\tilde{z}_{D,t} = \Big[\Big(\frac{w_t}{Z_t}\Big)^{\theta} f_{D,t} \frac{\theta j}{j-(\theta-1)} \frac{1}{C_t}\Big]^{\frac{1}{\theta-1}} \frac{\theta}{\theta-1}$$

In my model,

$$\tilde{z}_{D,t} = \Big[Z_t^{-\theta} f_{D,t} \frac{\theta j}{j-(\theta-1)} \frac{1}{Y_t}\Big]^{\frac{1}{\theta-1}} \frac{\theta}{\theta-1} w_t^{\frac{\theta-\alpha\theta+\alpha}{\theta-1}} (\alpha-1)^{\alpha-1} \Big(\frac{r^k}{\alpha}\Big)^{\alpha}$$

The factor prices positively influence the cut-off level for domestic productivity and therefore average productivity, and consumption and output negatively affect the cut-off level for domestic production. The latter effect occurs because when consumption of final output increases, there is more demand for the firms' products, making it likely that prices will be higher, and production is overall more profitable.

Figure 4.3, Panel A: Comparison of Responses to a Temporary Shock to Sunk Entry Cost

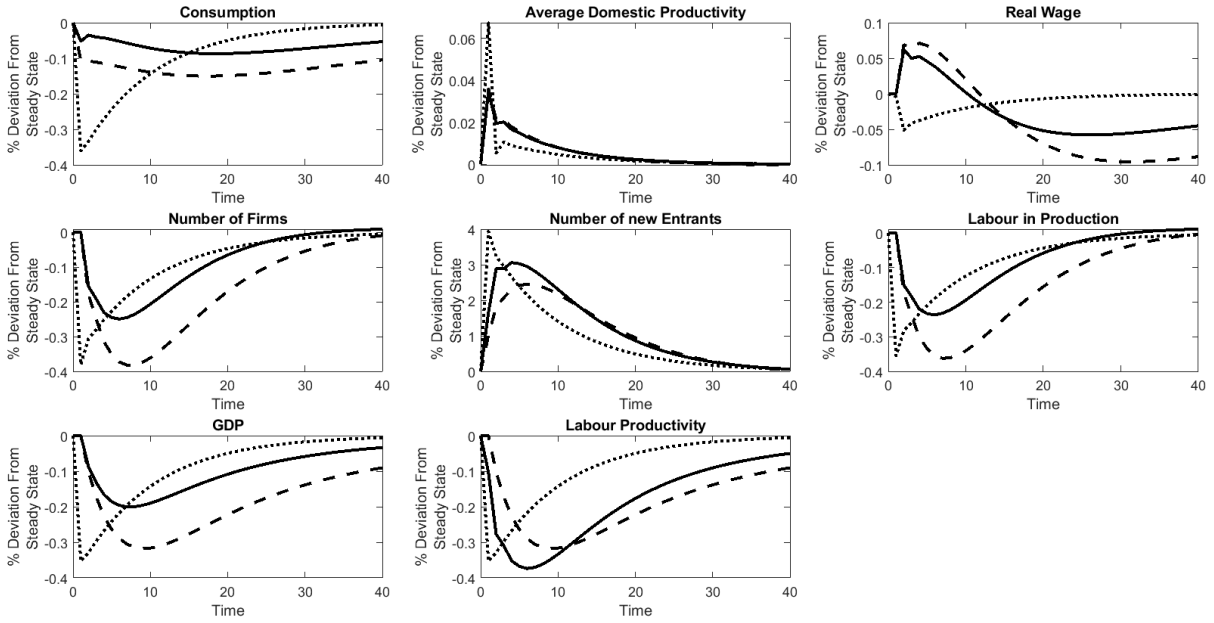
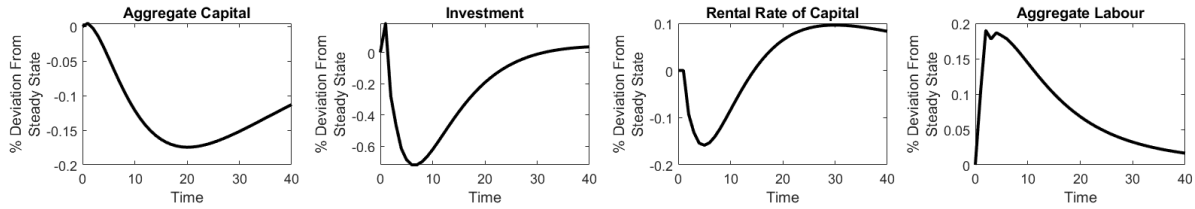


Figure 4.3, Panel B: Response of New Variables



In response to the shock, the sunk entry cost becomes cheaper to finance, inducing labour to be re-allocated towards the payment of the sunk entry cost and thus towards financing the entry of new firms. The number of new entrants therefore increases in all three models. Indeed, the entire response of the economy to this shock is very similar in all three models. The main difference lies in the response of the wage rate, which is reversed in MNN relative to the two variants of my model, and the more hump-shaped response of GDP in my model variants. Besides these differences, the dynamics are quite similar and mainly differ in magnitude.

In my model, as the shock hits the economy capital is kept constant in the first period, but the labour used for production decreases very slightly in the first period. This increase in the factor-of-production ratio has to be matched by am increase in the factor-price ratio, which requires either the rental rate of capital to decrease or the wage rate to increase. The rental rate of capital decreases in response to the shock initially, and does so more than required to match the factor-of-production ratio. The wage rate therefore increases by 0.06% in the first period. The economic intuition for this increase in the wage rate is the following. As less labour is employed in production, labour becomes less productive due to diminishing returns to labour. This increased productivity causes the wage rate to increase on impact.

Similar dynamics apply in the inelastic labour model, although there the wage rate increases slightly more as labour in production decreases by more.[8] In MNN, these dynamics do not occur and the wage rate simply decreases, by 0.05%.

The difference in the behaviour of the wage rate is what causes the number of new entrants to increase by more in MNN than my model. As the wage rate decreases in MNN, the sunk entry cost becomes even cheaper, as it is paid in terms of effective labour. The number of new entrants therefore increases by 3.94%. In the two variants of my model, the wage rate increases, causing the sunk entry cost to decrease by less than in MNN. The number of new entrants therefore also increases by less, by 3.06% in my model with elastic labour supply and by 2.45% in my model with inelastic labour supply.

Despite the increase in the number of new entrants, the number of incumbent firms actually falls in response to the shock in all models. This is due to the increase in average domestic productivity. In my model, the increases in the rental rate of capital and the wage rate make production more expensive, increasing the productivity cut-off level for domestic production. This causes firms with low productivity to endogenously exit the market and also decreases the probability of survival of new entrants. This decreases the number of firms in the domestic market and increases average domestic productivity. In MNN, average domestic productivity also increases despite the decrease in the wage rate. Looking at the equation for average domestic productivity in MNN shows that if $\tilde{z}_{D,t}$ increases despite a decrease in the wage rate, this must be due to a fall in consumption. Consumption indeed falls in MNN in response to the sunk entry cost shock, by 0.36%. This occurs because of the fall in output, which in turn is induced by the fall in labour in production that forces a decrease in consumption at a time when households choose to finance the entry of more firms with their available income. As consumption decreases so do average prices, which increases the cut-off level for domestic production and therefore forces the least productive firms to exit the economy.

Once again, the response of GDP is more hump-shaped in my model than in MNN. The reason for this lies in the presence of physical capital. As shown above, labour in production decreases in all three models as more labour is used for the payment of sunk entry costs. In MNN, the decrease in the only factor of production necessarily causes output to fall as well, and it decreases to its maximum impact straight away. In my model variants, labour is not the only input in production. As labour in production falls capital remains constaint, causing output to fall by much less than in MNN on impact. However, as investment continues to fall in my model until period 7, GDP also continues to decrease until that time. As the factor inputs recover as the shock dissipates, GDP begins to recover as well.

The response of labour productivity follows that of GDP, as can be seen from the 2nd quadrant of the 3rd line of Figure 4.3, Panel A. Its behaviour is driven by the substitution of labour from production towards the payment of sunk entry costs in all three models. In MNN, labour in production falls by 0.36%. As this

[8] This occurs because of inelastic labour supply. As the sunk cost of entry decreases, labour is diverted towards the payment of sunk entry costs. In the baseline model, aggregate labour increases by 1.42% to enable this. In the inelastic labour model, aggregate labour is constant, meaning more labour has to be diverted from production towards the payment of the sunk entry cost.

is the only factor input, GDP also decreases, causing labour productivity to fall by 0.35%. As explained above, in my model GDP decreases by less on impact, causing labour productivity to fall by less on impact as well, namely by 0.1%. However, for the reasons described above, it continues decreasing for a number of periods before returning to its steady state value as the shock dissipates. Labour productivity decreases by more in my model than in the inelastic labour model due to the elasticity of labour supply, which increases to allow more entrants. The response of labour productivity is therefore significantly driven by endogenous entry into domestic production as well as the presence of two factors of production and elastic labour supply in my model. Overall, the presence of physical capital in the model has two major effects, as it reverses the response of the wage rate relative to MNN, and generates a more hump-shaped response of GDP and labour productivity.

4.5.4 Shock to the Variable Costs of Exporting

Figure 4.4, Panel A: Comparison of Responses to a Temporary Shock to Variable Export Costs

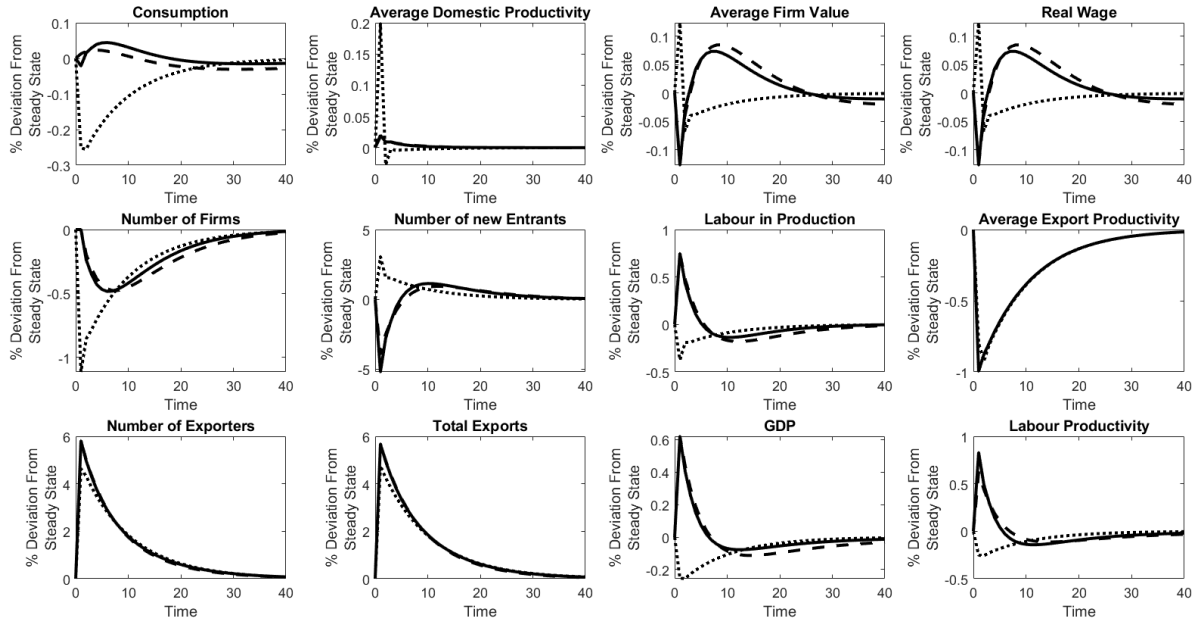
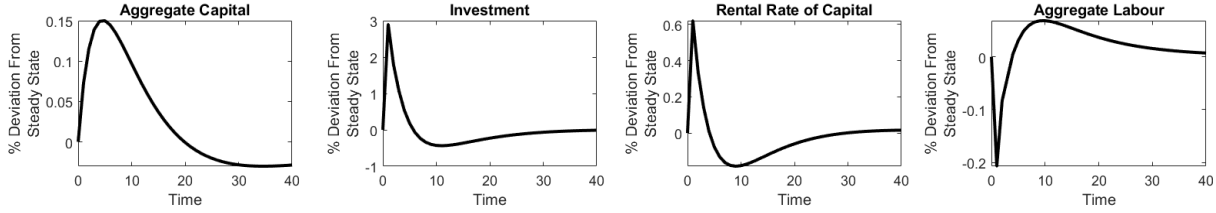


Figure 4.4, Panel B: Response of New Variables



The dynamic response of the economy to a temporary, but persistent, negative 1 percentage point shock to the variable cost of exporting is illustrated in Figure 4.4. In all three models, the cost shock leads to

similar responses in the export sector, as shown by the 8th, 9th and 10th quadrants of Figure 4.4, Panel A. However, the response of many domestic variables, such as labour in production, GDP and labour productivity, differs significantly. To explain this, I will first explain the effect of the variable trade cost shock in my baseline model.

A shock to the variable costs of international trade increases exports. As exporting becomes cheaper, firms that were previously not able to export can now export profitably, inducing less productive firms to enter the export market. This drives up the number of exporters by 5.81% and decreases average exporting productivity by 1%. At the same time, due to the increased competition in the export sector, existing exporters are able to export less. Aggregate exports therefore increase by slightly less than the number of exporters, namely by 5.68%.

Firms that only produce in the domestic market are also affected by this shock. As variable costs of exporting decrease, foreign exporters find it more profitable to enter their export market, increasing competition in the domestic market. This increased competition endogenously causes the least competitive firms to exit the domestic market, marginally increasing average domestic productivity by 0.02% and decreasing the number of firms in the market by 0.48%.

As aggregate demand increases following lower tariffs, firms must increase their production in order to meet this demand. They therefore increase the labour used in production by 0.75% and their investment by 2.9%. This increases aggregate output by 0.62%, causing households to have more income available. In my model, there are now two counteracting pressures on the real wage, which reverses the sign of the initial impact of the shock on the wage rate compared with MNN. Increased competition in the home economy induces wages to increase, while an increase in labour used in production induces them to decrease. Initially, the negative effect of more labour used in production outweighs the positive competitive effect, causing the real wage to fall by 0.13%. This occurs due to the diminishing returns in both factors arising from the presence of two factors of production. As tariffs fall, the equilibrium output increases. As capital is fixed in the first period, more labour must be used in production in order to meet the demand for more exports. In this model, it increases by 0.75%, which decreases the capital-labour ratio by the same amount. As production is shifted away from capital towards labour, capital becomes the scarcer factor of production, requiring the factor price ratio to adjust as well. In response to greater investment, the rental rate of capital increases by 0.62%. However, the rental rate of capital does not increase enough to balance the change in allocation of resources, which requires the wage rate to fall as well.

As both inputs of production increase, aggregate output and GDP increase as well, the latter by 0.62%. As aggregate labour actually decreases slightly, as less labour is used to cover sunk entry costs and fixed costs of domestic production, labour productivity increases by more, namely by 0.83%.

After the initial impact of the shock, resources are re-allocated towards capital following increased investment, causing labour used in production to fall. This increase in the capital-labour ratio decreases the rental rate of capital and increases the wage rate. The large increase in the capital-labour ratio actually causes the rental rate of capital to undershoot its steady state level. As the shock dissipates and export-

ing becomes less profitable again, investment decreases. This causes capital to decrease, re-allocating resources towards labour and decreasing the capital-labour ratio in production, inducing the wage rate to decrease and the rental rate of capital to increase to their steady state levels. As competition decreases again in the economy as foreign exporters exit from the domestic market, the productivity cut-off level for domestic production decreases, inducing firms to enter the market. This endogenous entry of firms with lower productivity into domestic production decreases average domestic productivity, which decreases output and thus labour productivity and consumption, causing all variables to return to their steady state levels.

In MNN the response is different. In this model, the wage rate is only subject to one pressure; labour demand. In response to a shock to the variable trade costs, both domestic and foreign exporters export more.[9] This increases competition in the home market, which in turn drives up the real wage by 0.12% on impact. The higher cost of production increases the domestic productivity cut-off level and forces the least productive firms to exit the market. This self-selection of the less productive firms out of the domestic market increases average productivity by 0.2% and allows the remaining more productive firms to increase their market shares. These dynamics have two implications for prospective new entrants, which work in opposite directions. Firstly, the higher wage increases the sunk entry cost and the higher productivity cut-off level decreases the probability of drawing a productivity large enough to produce. Both these factors have a negative effect on entry. However, the higher productivity cut-off level and subsequent expansion of market shares by higher-productivity firms increases average profits and average firm value; the latter increases by 0.12% on impact. This has a positive influence on entry, as the value of producing if entry is successful increases. In this model, the latter effect outweighs the former and the number of new entrants increases by 3.07%. As both the number of new entrants and the number of exporting firms increase, more labour is demanded to cover sunk and fixed costs. This labour is diverted from labour in production, which decreases by 0.38%. As labour is the only factor in production in MNN, this decreases the amount of output that is produced, reducing GDP and thus labour productivity by 0.25%.

Interestingly, in the model that includes the same self-selection mechanism into domestic production and the exporting market and only one factor of production, the profit-maximising behaviour of each individual firm through the exploitation of cheaper export costs decreases economic activity in the aggregate. Crucial for this result is the denonimation of fixed export costs and sunk entry costs in effective labour; as more firms self-select into the export market in response to cheaper export costs and more firms enter the domestic market in anticipation of higher profits if entry is successful, labour is required to pay these sunk and fixed costs. This labour must be taken from production, which in turn depresses aggregate economic activity.

The reason these dynamics do not occur in the model with two factors of production is the behaviour of factor costs and average firm value, and resulting entry dynamics. In MNN, the main determinant of the wage rate is labour demand. When competition increases due to a decrease in tariffs, the wage rate must

[9] Domestic exports and foreign exports increase by 4.76%.

rise. This leads to the above-described dynamics. In my model with two factors of production, there are two pressures on the wage rate. Increased competition induces it to increase, while diminishing returns to labour induce it to decrease. Importantly, it is not necessary for the wage rate to increase in response to a reduction in the variable costs of trade, which allows my model to yield a more intuitive response to this trade shock. In response to a decrease in variable trade costs firms increase their investment by 3% to meet increased demand and take advantage of the increased exporting profitability. The rental rate of capital increases by 0.62% in response to this rise in investment. As capital is fixed in the first period, this change in the cost of capital requires either the wage rate or labour in production to adapt as well. To ensure the factor-price ratio matches the factor-of-production ratio, the wage rate decreases by 0.13% and labour in production increases by 0.75%. Crucially, this increase is possible because of the adaptation of the factors-of-production ratio and associated factor-price ratio. The increase in the rental rate of capital dominates the decrease in the wage rate, causing factor prices to increase overall. This increase is lower than in MNN however, which means that the domestic productivity cut-off level also increases by less; average domestic productivity increases by 0.02%. The number of low-productivity firms that exit the market is thus lower than in MNN, allowing for a smaller expansion of market shares by the remaining higher-productivity firms. In the presence of tougher competition and higher factor costs, this reduces average profits and thus average firm value, decreasing firm entry. This smaller number of entrants is consistent wth the increased labour used in production.

Overall, the presence of physical capital in the model has profound effects on the response of the economy to a variable trade cost shock when accounting for self-selection into both the domestic and the exporting market. It reverses the effect on the wage rate, which in turn reverses the response of the number of new entrants. Via the mechanism described above, this reverses the response of GDP and labour productivity in MNN relative to my model with two factors of production. Changes in factor costs and self-selection out of the domestic market are the driver of this result; resource re-allocation in response to the shock and resulting changes in factor prices are thus vital in generating a more intuitive response to a decrease in the variable costs of trade.

4.6 International Business Cycle Analysis

In order to gain insight into the validity of my model's predictions, in this section I report on my model's business cycle statistics. I compare these with the business cycle statistics of the United Kingdom. As explained in Section 4.2, my model combines several characteristics that have been shown to influence labour productivity:

- fixed export costs,
- selection of firms into domestic production,
- resource allocation (implemented in this chapter via physical capital and elastic labour supply).

In this section I will compare the business cycle statistics of the model that was used throughout this chapter and incorporates all of these characteristics (my model), the inelastic labour model, the model that includes fixed export costs and selection of firms into domestic production (MNN) and the model that

incorporates fixed export costs, physical capital and elastic capital supply but not endogenous selection of firms into domestic production (I will refer to this as the labour-capital model). This comparison will allow me to determine what characteristics enable my model to match certain aspects from the data well.[10]

I assume that the percentage deviations from the steady state of these variables follow the following process:

$$\begin{pmatrix} Z_t \\ Z_t^* \end{pmatrix} = \begin{pmatrix} \phi_Z & \phi_{ZZ^*} \\ \phi_{Z^*Z} & \phi_{Z^*} \end{pmatrix} \begin{pmatrix} Z_{t-1} \\ Z_{t-1}^* \end{pmatrix} + \begin{pmatrix} \xi_t^Z \\ \xi_t^{Z^*} \end{pmatrix},$$

where ϕ_Z is the persistence of the domestic technology shock in the domestic economy, ϕ_Z^* is the persistence of the foreign technology shock in the foreign economy, ϕ_{Z^*Z} captures the spillover of the domestic technology shock to the foreign economy, ϕ_{ZZ^*}captures the spillover of the foreign technology shock to the domestic economy, and ξ_t^Z and $\xi_t^{Z^*}$ denote the magnitude of the shocks in the domestic and foreign economy respectively. ξ_t^Z and $\xi_t^{Z^*}$ are normally distributed and have a mean of zero.

I follow Ghironi and Melitz (2005) (GM) in the calibration of these parameters, and set

$$\begin{pmatrix} \phi_Z & \phi_{ZZ^*} \\ \phi_{Z^*Z} & \phi_{Z^*} \end{pmatrix} = \begin{pmatrix} 0.906 & 0.088 \\ 0.088 & 0.906. \end{pmatrix}$$

The standard deviation of the technology shocks are set to 0.00852 and the correlation to 0.258, following GM. I report the theoretical moments this process yields for the four models described above in Table 4.1, and compare them with UK data.

All data is taken from the *OECD Main Economics Indicators* database.[11] For GDP, consumption, investment and exports I used quarterly data from 1999Q1-2020Q2, taken from the "National Accounts" under the *Main Economic Indicators* database. For labour I used annual data from 1999-2015, from the "Civilian Employment Index", found under "Labour Force Statistics". As labour data is annual, I also computed annual GDP statistics from the National Accounts. It is these annual figures that are referred to whenever labour is compared to GDP in Table 4.1. For international correlations I compute the correlations between the variables of the UK and those of the US. More information on the data and how I computed the business cycle moments can be found in Appendix B.1

Looking at Table 4.1 shows that my model matches the volatility of UK GDP very well, as it deviates by only 0.25 percentage points. However, MNN and the labour-capital model both match UK consumption data better than my model. My model displays a higher labour and investment volatility than the capital-labour model, thereby better matching the UK volatility of labour and investment. The inelatic labour model, howver, matches the absolute investment volatility of the UK more closely, despite overstating it. When considering relative volatilities, my model best matches the relative volatilities of UK investment and labour, despite understating them. MNN is best at matching relative consumption volatility, followed by the inelastic labour model. All models fare badly at matching the absolute and relative volatility of

[10] The business cycle statistics reported from MNN are derived from my replication of their model.

[11] The link to this database can be found at `https://stats.oecd.org/Index.aspx`.

Table 4.1: Business Cycle Statistics

	UK Data	My Model	Inelastic Labour	MNN	Labour-capital
Volatility					
(*% standard deviation*)					
GDP	2.6	2.85	8.19	2.04	3.1
C	3.06	1.75	6.22	2.04	1.91
I	4.1	2.15	5.57	x	1.42
L	0.97	0.38	x	x	0.28
Exports	4.25	0.28	0.87	0.24	0.37
Relative Volatility					
$(\frac{\text{\% st. dev.}}{\text{GDP \% st. dev.}})$					
C	1.18	0.61	0.76	1	0.62
I	1.58	0.75	0.68	x	0.46
L	0.37	0.13	x	x	0.09
Exports	1.63	0.1	0.11	0.12	0.12
International Correlations					
GDP	0.9	0.17	0.34	0.71	0.32
C	0.91	0.71	0.92	0.7	0.73
I	0.6	-0.03	0.11	x	-0.35
L	0.89	-0.38	x	x	-0.53

exports in data.

I now move on to consider international correlations. The data shows that the cross-country correlation of consumption and output are large, and that they are similar. Hereby the cross-county correlation of consumption is slightly larger than the cross-country correlation of output. Furthermore, there is positive co-movement between output, consumption, investment and labour. The patterns shown here are in line with the findings of Chapter 3, as they show that the cross-country correlation of consumption exceeds that of output for a developed country-pair, and that there is positive co-movmeent among macroeconomic variables. In this section I will examine both patterns, investigating which model best matches the relationship between the cross-country correlation of output and the cross-country correlation of consumption, and which model best matches the positive co-movement of all variables.

When considering the first question, MNN yields the closest relationship between the cross-country correlation of output and consumption, thereby matching the similarity of both values that is seen in the data most closely. At the same time, however, MNN generates a higher correlation of GDP than consumption, which is contrary to what the data shows. All other models succeed in generating the correct ranking of the two correlations. The labour-capital model is the second-best at matching the similarity of the two correlations, followed by my model and then the inelastic-labour model, which yields the largest difference between the two correlations.

The 2nd question is somewhat more difficult to address, as both MNN and the inelastic labour model do not have all four variables. All models generate positive co-movement between output and consumption. The inelastic-labour model best matches the cross-country correlation of consumption as it yields the highest correlation. All other models match this value equally well. MNN best matches the cross-country correlation of output, followed by the labour-capital and inelastic labour models. Neither my model nor the labour-capital model succeed in generating a positive co-movement in investment and labour. However, the international correlations of investment and labour are higher in my model than they are in the labour-capital model, suggesting that it better matches this data overall. Indeed, my model is actually very close to generating a positive co-movement of investment. It thus seems that endogenous selection into domestic production is essential in creating a higher correlation of investment, as the inelastic labour model actually succeeds in yielding positive investment co-movement.

When considering international correlations overall, it cannot be stated conclusively which model best matches data. The labour-capital model and MNN more closely match the relationship between the cross-country correlations of output and of consumption. However, the capital-labour model and my model both include investment and elastic labour, allowing two more variables to be applied to data. MNN and the inelastic labour model cannot account for these two factors, which have been shown extensively to have important effects in reality. For example, in Section 4.5 I showed that resource re-allocation was important in matching the fall in production inputs in response to a positive technology shock that has been documented empirically. When considering the co-movement of all four variables, the labour-capital model better matches output and consumption co-movement slightly, but my model matches investment and labour co-movement more closely. Overall, my model therefore matches the data most closely. It

Table 4.2: Business Cycle Statistics - Robustness Analysis

	UK Data	US Data	EA Data	My Model	Inelastic Labour	MNN	Labour-capital
Volatility (% st. dev.)							
GDP	2.6	1.5	2.03	2.85	8.19	2.04	3.1
C	3.06	1.5	1.86	1.75	6.22	2.04	1.91
I	4.1	3.59	3.57	2.15	5.57	x	1.42
L	0.97	1.69	1.5	0.38	x	x	0.28
Exports	4.25	4.5	4.37	0.28	0.87	0.24	0.37
Relative Volatility ($\frac{\%\text{ st. dev.}}{\text{GDP }\%\text{ st. dev.}}$)							
C	1.18	1	0.89	0.61	0.76	1	0.62
I	1.58	2.39	1.75	0.76	0.68	x	0.46
L	0.37	1.13	0.74	0.13	x	x	0.09
Exports	1.63	3.0	2.15	0.1	0.11	0.12	0.12
International (Correlations)							
GDP	0.9	0.86	0.91	0.17	0.34	0.71	0.32
C	0.91	0.91	0.93	0.71	0.92	0.7	0.73
I	0.6	0.58	0.77	-0.03	0.11	x	-0.35
L	0.89	0.66	0.62	-0.38	x	x	-0.53

matches the relative volatilities of UK macroeconomic variables the most closely overall, and performs as well as other models when applied to international correlations.

The aim of this chapter is to ascertain how and the extent to which the inclusion of capital alters the behaviour of an international trade model with endogenous selection into domestic production. I therefore now consider the business cyle statistics from this point of view. The inclusion of physical capital increases the absolute volatility of all variables. When labour supply is made elastic, this is attenuated again and the majority of variables is brought closer to data, both relative to MNN and the inelastic labour model. To match domestic business cycle statistics well, it thus seems that the addition of elastic labour supply and physical capital is necessary. Regarding international correlations, the addition of physical capital increases the cross-country correlation of consumption and decreases the cross-country correlation of output. It thereby brings the consumption correlation closer to data and moves the output correlation further away from data. It succeeds in yielding the correct ranking between the two correlations, but the similiarity between them is reduced.

Robustness Analysis

To check the robustness of my results I compared the business cycle statistics of the four models to UK, US and EA data in Table 4.2. This analysis shows that the extent to which a model best matches absolute volatilities depends on which country the model is being applied to. For example, while my model best matches the output volatility of the UK, MNN best matches the output volatility of the EA. Equally, my model best matches the volatility of US consumption, while MNN best matches the volatility of UK consumption. However, the qualitative results discussed above regarding relative volatilities and international correlations remain unaffected.

The result from the robustness check creates a slightly more nuanced picture. While my model best matches relative volatilities for investment and labour and MNN best matches the volatilities of relative consumption, my model does not match international correlations better than other models. It is worse at matching the cross-country correlations of output and consumption than MNN and the labour-capital model, but better at matching the cross-country correlations of investment and labour. Overall, it is therefore not significantly worse at replicating the patterns of international correlations. Overall, my model therefore seems to yield the closest match to macroeconomic data, at the same time as providing a more detailed and nuanced framework of the macroeconomy.

4.7 Conclusion

In this chapter I developed a two-country DSGE model of international trade with monopolistic competition, heterogeneous firms using both capital and labour in production, and endogenous selection into domestic production. While analysing the role of resource allocation and capital in the transmission of macroeconomic shocks, two main results stood out. First, as firms can adjust their employment of capital and labour in response to macroeconomic shocks, the time it takes for macroeconomic variables to return to their steady state levels increases. Capital thus introduces an element of persistence into the economy that is greater than in models that use only labour in production, such as MNN, which allows the model to better match macroeconomic data.

Second, when firms can adjust their employment of labour and capital in response to macroeconomic shocks and enter and exit the domestic market endogenously, the dynamic response of labour productivity is driven by the interaction between efficient resource allocation and endogenous selection into domestic production. This reverses the initial response of labour productivity to an aggregate technology shock and trade shock relative to MNN. These findings have not been reported before in the literature, and may have important implications for policy makers, as they yield insight into how a variety of macroeconomic variables are affected by a variety of shocks in the short-run and in the long-run.

Chapter 5

Financial Frictions, International Trade, and their Impact on Labour Productivity

5.1 Introduction

The 2008 financial crisis made us aware yet again of the large extent to which finance and international trade matter for output and labour productivity. The credit crunch following the collapse of Lehman Brothers led to a global decline in international trade and output; in the UK, output and labour productivity both fell and labour productivity growth has still not recovered. The fact that the credit crunch and fall in international trade occurred simultaneously suggests that both factors may have played a joint role in affecting output and labour productivity. Indeed, the facts that financial frictions and international trade affect output and productivity are well established in the literature. A growing amount of literature also illustrates the distorting effect financial frictions have on international trade. However, very few papers investigate how financial frictions and international trade together affect productivity, and none of them addresses the question of the extent to which both factors jointly play a role in impacting the dynamic response of labour productivity to shocks.

In this chapter I address this question by examining the extent to which financial frictions and international trade jointly affect the dynamic response of labour productivity to macroeconomic shocks. In most literature examining the role of financial frictions, their effect on productivity is studied only in a closed economy. As financial frictions have been shown to also affect international trade, which in turn has an effect on productivity, it stands to reason that international trade can play a role for the way in which financial frictions affect labour productivity. This chapter studies this link in more detail, examining how financial frictions affect the response of labour productivity to a variety of macroeconomic shocks in an international trade framework, and analysing the extent to which international trade changes their amplification effect.

In order to do this, I build a two-country DSGE model of international trade with monopolistic competition, heterogeneous firms and fixed and variable export costs based on Ghironi and Melitz (2005), capital and elastic labour in the style of Fattal-Jaef and Lopez (2014), endogenous entry and exit from

the domestic economy following Millard *et al.* (2021) and credit constraints modelled in the form of the well-known financial accelerator of Bernanke *et al.* (1999). I assume that entrepreneurs, who are subject to financing constraints, are not involved in the production of goods, thereby differentiating between intermediate good producing firms and entrepreneurs. Herewith I follow the implementation of the financial accelerator of Christiano *et al.* (2010*b*). As in Christiano *et al.* (2010*b*), entrepreneurs have a unique ability to operate capital, which they acquire from capital producers and rent out to intermediate good producing firms, a subset of which engages in international trade. The purchase of capital is undertaken with net worth. However, entrepreneurs need to finance a fraction of their capital purchases with external funds, for which they face borrowing constraints.

Two findings stand out from my analysis. Firstly, financial frictions amplify the response of the economy to macroeconomic shocks in an open economy setting. Secondly, international trade dampens the amplification effect of financial frictions. Thus, I show that the well-known effect of the financial accelerator of amplifying the response of the economy, which has been well-established in a closed economy setting, also holds in an open economy setting. I furthermore show that international trade dampens this effect. In the case of a positive technology shock to the economy, the decrease in the terms of trade and the resulting self-selection of less productive firms into the foreign export market decrease the profitability of home producers. This allows the net worth of entrepreneurs and therefore their level of borrowing to expand by less relative to the closed economy, leading to a dampened financial accelerator effect. In the case of a negative sunk entry cost shock and a positive preference shock the opposite applies: the terms of trade effect and the competitive effect increase the profitability of home producers, leading to a lower fall in net worth and therefore borrowing, which in turn dampens the amplified downturn of the economy and labour productivity.

After presenting these results I apply my model to the UK Productivity Puzzle to examine the extent to which financial frictions help explain stagnant labour productivity in the UK since the 2008 financial crisis. I find that financial frictions can explain around 2% of the productivity shortfall that was still seen in 2019Q2, and that therefore financial frictions are not driving the UK Productivity Puzzle.

This chapter will proceed as follows. Section 5.2 will present a review of the literature and place my contribution in that literature. Section 5.3 presents the model and Section 5.4 the model calibration. In Section 5.5 I present the results, in Section 5.6 I apply the model to the UK Productivity Puzzle and Section 5.7 concludes.

5.2 Literature Review

5.2.1 Finanial Frictions, International Trade and Labour Productivity

I build on three strands of literature that investigate the interactions between financial frictions, international trade and productivity. Most of the literature only investigates the link between two of the three factors, examining either how financial frictions affect productivity, how international trade affects productivity, or what effect financial frictions have on trade. In contrast to this approach, I will examine

the link between all three at the same time.

Before presenting the review of the three strands of literature that I build on I first refer to the vast literature on financial frictions and the way they are modelled. This literature dates back to Schumpeter (1961)[1] and Fisher (1933), who demonstrated the importance of finance for the real economy. In the vast literature on financial frictions, these frictions are mainly modelled in four ways: as limited enforcement (Erosa and Cabrillana (2008), Quintin (2008), Monge-Naranjo (2009), Jermann and Quadrini (2012)), moral hazard (Aghion and Howitt (2009), Gertler *et al.* (2015)), cash-in-advance constraints (Arellano *et al.* (2016), Hill and Perez-Reyna (2017)), or collateral constraints (Bernanke (1983), Kiyotaki and Moore (1997), Garcia-Macia (2017)). In papers studying the dynamic effect of credit constraints, financial frictions are frequently thought of as a financial accelerator, as they amplify and propagate the response of the economy to macroeocnomic shocks. In this chapter I implement the well-known financial accelerator of Bernanke *et al.* (1999), which is in effect a type of collateral constraint. The financial accelerator models financial frictions via an external finance premium that is inversely related to entrepreneurs' net worth, which causes the amount entrepreneurs can borrow to be limited by their level of net worth. This collateral constraint is endogenously derived from an asymmetric information problem between the lender and borrowers that requires the lender to pay an auditing cost to observe the borrower's actual returns.

The first strand of literature I build on studies the effect of financial frictions on productivity and was pioneered by Buera *et al.* (2011), who quantify the role financial frictions play in explaining certain empirical regularities in development economics. They find that financial frictions can decrease output per worker by 50% relative to the perfect credit benchmark, which explains about 80% of the difference in output per worker between the US and Mexico. Subsequent theoretical literature builds on this work. Erosa and Cabrillana (2008) and Quintin (2008) show that a higher degree of enforcement of financial contracts, and thus lower financial frictions, allows factors of production to be allocated more efficiently, thus increasing TFP. That financial frictions have large effects on productivity is also shown by Greenwood *et al.* (2010) and Greenwood *et al.* (2013), who study the role of information production in the process of resource misallocation and its effect on productivity. These theoretical findings are supported by a range of empirical papers that each study how financial frictions decrease productivity within a specific country (Calligaris (2015), Manaresi and Pierri (2018), Doerr *et al.* (2018), Pratap and Urrutia (2012), López (2009), Gopinath *et al.* (2017), Varela (2018)).

The second strand of literature I build on illustrates how international trade affects productivity. Pioneers of this literature are Krugman (1980) and Melitz (2003). Krugman (1980) addresses the inability of models of comparative advantage to explain intra-industry trade, arguing that such trade arises due to economies of scale and product differentiation, and that it increases output and welfare. Melitz (2003) builds on Krugman (1980) and explains the empirically stylised fact that only the most productive firms export by introducing firm heterogeneity and fixed trade costs. In this model, opening up to trade induces only the most productive firms to self-select into the export market. This process reallocates

[1] This book was originally published in 1912.

profits and market shares to productive firms, and increases aggregate productivity. Much theoretical work in recent years builds on Melitz (2003). For example, Ghironi and Melitz (2005) extend this framework to a dynamic setting, and analyse the economy's transition dynamics in response to macroeconomic shocks. Much empirical evidence further supports the proposition that international trade increases aggregate productivity, either via (i) self-selection into the export market, and/or (ii) learning-by-exporting (Bernard and Jensen (1999), Baldwin and Gu (2004), Alcalà and Ciccone (2004) Lileeva and Trefler (2010), Bustos (2011), De Loecker (2013), Manjón *et al.* (2013)).[2]

The third strand of literature I build on examines the impact of financial frictions on international trade. This literature establishes that finance is important for exporters, and more so than for domestic producers (Auboin (2009), Ahn (2011), Amiti and Weinstein (2011)), as export activities are inherently riskier than domestic activities, exporting is associated with additional upfront and fixed costs, and the need for working capital is magnified by the higher time lag between production and receipt of revenues for exporters. Since finance is shown to be highly significant for international trade in this literature, much further literature investigates the extent to which constraints to finance for international trade affect trade patterns. Seminal papers in this area include Manova (2013) and Chaney (2016), who incorporate credit constraints into a Melitz (2003) model and show that they decrease exporting both along the intensive and extensive margins. The majority of the literature examining the impact of financial frictions on international trade support the findings of these two papers, showing that they decrease exports and international trade overall (Minetti and Zhu (2011), Schmidt-Eisenlohr (2013), Berman and Héricourt (2010), Paravisini *et al.* (2015), Ferrando and Ruggieri (2018)).

Taken together, the literature described above illustrates three key facts. Firstly, financial frictions have a significant impact on productivity. Secondly, international trade considerably increases aggregate productivity. Thirdly, financial frictions have been shown to affect international trade. However, while there is a vast amount of literature examining the impact of financial frictions on productivity, an equally vast amount of literature examining the impact of international trade on productivity, and an increasing amount of literature on the effect of financial frictions on international trade, the link from financial frictions to productivity through international trade remains to be understood. Notable papers in this area include Caggese and Cuñat (2013) and Brooks and Dovis (2020), who investigate how financial frictions decrease the welfare gains from trade, Bonfiglioli *et al.* (2018), who show that financial frictions decrease the heterogeneity of productivity in a sector, and Kohn *et al.* (2017), who explore the effect of financial frictions on international trade and productivity in most depth by estimating that financial frictions, via three distortions, decrease aggregate TFP by 26% relative to a setting without financial frictions.

However, to the best of my knowledge no paper examines how financial frictions affect the dynamic response of labour productivity to macroeconomic shocks in an international trade model and how international trade affects the effect of financial frictions. In this chapter I examine how financial frictions amplify and propagate the response of the economy and labour productivity to a variety of macroeconomic shocks in an international trade model. I furthermore examine how their effect on labour productivity

[2]See Wagner (2007) and Wagner (2012) for surveys.

is impacted by international trade, as I analyse how and to what extent international trade affects the amplification effect of financial frictions.

5.2.2 The UK Productivity Puzzle

I also apply my model to the UK Productivity Puzzle, thereby contributing to the vast literature that examines this puzzle. The UK Productivity Puzzle refers to the observation that labour productivity remains significantly lower than it would have been had labour productivity growth recovered its pre-2008-crisis rates. Several explanations have been put forward to explain this labour productivity shortfall: 1) mismeasurement issues, 2) cyclical factors, and 3) more persistent supply-side factors.

Regarding the first category of explanations, the literature generally agrees that measurement errors, such as an overstatement of GDP prior to the crisis (Oulton (2013)), an understatement of current GDP due to the omission of intangibles (Goodridge *et al.* (2013), Corrado *et al.* (2018)) or the inability of official statistics to accurately capture the effect of new technologies (Hatzius *et al.* (2016)) cannot account for a significant portion of the puzzle (Burgess (2011), Oulton (2013), Goodridge *et al.* (2018)). Regarding the second explanation, a reduction in consumer demand could have led to labour hoarding by businesses (Martin and Rowthorn (2012)), or the diversion of labour to business-winning activities (King and Millard (2014), Barnett, Chiu, Franklin and Sebastia-Barriel (2014)). Again, however, the literature overall seems to agree that due to the length of the protracted productivity weakness, cyclical factors are unlikely to explain the puzzle (Barnett, Chiu, Franklin and Sebastia-Barriel (2014), Barnett *et al.* (2014b), Patterson *et al.* (2016)).

The literature on non-cyclical factors examined whether (i) the labour productivity weakness is caused by capital shallowing during the crisis (Pessoa and Van Reenen (2014), Harris and Moffat (2017), Oulton and Wallis (2016)) and (ii) the labour productivity weakness is the result of a weakness in TFP. Regarding the latter explanation, it has mainly been argued that the Productivity Puzzle can be explained by resource misallocation (Arrowsmith *et al.* (2013), Barnett, Broadbent, Chiu and Miller (2014), Barnett *et al.* (2014b), Broadbent (2012), Harris and Moffat (2016)). In this context, Riley *et al.* (2014*a*), Riley *et al.* (2014*b*) Franklin *et al.* (2015), Chadha *et al.* (2017), Besley *et al.* (2020) have investigated the extent to which financial frictions can explain the labour productivity weakness. While Riley *et al.* (2014*a*) and Riley *et al.* (2014*b*) argue that they are not a major factor for the UK Productivity Puzzle, Chadha *et al.* (2017), Franklin *et al.* (2015) and Besley *et al.* (2020) argue that they do substantially contribute to explaining the puzzle.

Riley *et al.* (2014*b*) examine the claim that financial frictions might be able to account for the UK Productivity Puzzle with an empirical analysis. They do indeed find clear evidence that the financial crisis affected credit supply to businesses and caused bank lending to decline. According to the authors, if this decline in credit had been a key factor in weakening productivity growth, one would expect a heterogeneity in productivity performance among industries or firms that reflects heterogeneity in banking dependence. However, the regressions show no such clear relationship between the productivity growth and bank dependence of a sector. Riley *et al.* (2014*b*) also examine productivity performances at the firm-

level, decomposing productivity growth and finding that the decrease in labour productivity is mainly the result of within-firm productivity changes. This suggests that the main driver of the productivity weakness is due to within-business productivity changes rather than reallocations between businesses, as would be expected if decreases in bank credit were the main factor driving the productivity puzzle. This result is supported by findings from Riley *et al.* (2014*a*) and Riley *et al.* (2015), who also find that the majority of the productivity fall can be attributed to within-firm productivity reductions.

Franklin *et al.* (2015), in contrast, provide empirical evidence that financial frictions in the form of a contraction in credit supply contribute significantly to explaining the UK Productivity Puzzle. They use a large firm-level data set of UK companies and information on the pre-crisis lending to identify the effects of changes in credit supply in the 2008 financial crisis on the real economy, specifically on the level of capital per capita, labour productivity and wages. They find that a 10% reduction in borrowing caused by a contraction in credit supply led to a 5-8% fall in labour productivity. Franklin *et al.* (2015) use these micro-level results to estimate aggregate effects. They find that the credit supply shock in the UK could have lowered the level of labour productivity by 1-2% by 2009, and 5-8% by 2013. This compares to observed measures of an aggregate shortfall of 10% by 2009 and 17% by 2013, which suggests that the reduction in credit supply may explain substantial portions of the UK Productivity Puzzle.

In addition to this empirical paper examining the effect of financial frictions on labour productivity during the crisis, two papers provide theoretical insight into the effect of financial frictions on UK productivity (Chadha *et al.* (2017), Besley *et al.* (2020)). Chadha *et al.* (2017) examine how a productivity shock in the financial sector might have amplified a whole-economy shock. They model financial frictions as external finance premia that arise due to asymmetric information requiring banks to impose monitoring and insurance costs and request collateral. The main feature of their banking sector is that it includes an attenuator effect: as consumption and lending increase, monitoring effort is drawn into the banking sector, raising the marginal costs of loans and the external finance premium. If a productivity shock occurs within the banking sector at the same time as a productivity shock hits the real economy, banks can provide more loans at a given amount of monitoring labour and collateral. This shifts loan supply outwards, lowering the external finance premium and amplifying the normal business cycle. Conversely, if there is lower aggregate productivity growth in the economy at the same time as the financial sector becomes less productive, this leads to a higher external finance premium, which further lowers consumption and real wages. Chadha *et al.* (2017) argue that the finance sector is likely to have amplified the business cycle prior to and after the crisis and therefore the overall productivity slowdown in such a way in the UK.

Besley *et al.* (2020) also study the effect financial frictions had on aggregate productivity, both theoretically and quantitatively. In order to do this, Besley *et al.* (2020) build a model of default risk in the presence of moral hazard. They model financial frictions as limited contract enforceability that enables firms to default, motivating a requirement for firms to pledge collateral in order to borrow. A bank's expected profit is determined by the size of this collateral and the probability of default. In order to apply their model to the data, Besley *et al.* (2020) estimate firms' default probabilities using data from the ORBIS dataset and the probability of default model of Standard and Poor's. They show that by eliminating financial frictions, productivity would increase by 38%. Applying their results to the 2008

financial crisis, Besley *et al.* (2020) estimate that credit market frictions are responsible for half of the fall of labour productivity witnessed in the Great Recession.

5.3 The Model

I present my two-country DSGE model of international trade, with monopolistic competition, heterogeneous firms, fixed and variable costs of exporting, capital and labour as inputs of production, and imperfect credit markets. All foreign variables are denoted with a superscript *. Six agents operate in each country: capital producers, entrepreneurs, a bank, households, intermediate good producers, and final good producers.

At the beginning of each period, households make deposits at the bank. The bank then extends loans to entrepreneurs, who buy capital from capital producers.[3] After purchasing the capital stock for the period, the entrepreneurs rent it out to intermediate good producing firms, who combine it with labour supplied by households to produce intermediate goods. These are sold to the perfectly competitive final good producer, who combines them into a final good that is used for consumption and investment, or is used up in monitoring costs. I describe this model in more detail below, describing the problem of each agent in turn.

5.3.1 Capital Producers

I follow Bernanke *et al.* (1999) and assume that capital is produced in a sector by perfectly competitive capital-producing firms. Towards the end of the period, these firms purchase the un-depreciated capital stock from the entrepreneurs at the price q_t, and combine it with investment goods purchased from final good producers, I_t, to make new capital. Following the production of new capital, the capital producers sell the entire capital stock K_t to the entrepreneurs at the same price q_t. Hereby the evolution of the capital stock is given by

$$K_t = \phi\Big(\frac{I_t}{K_{t-1}}\Big)K_{t-1} + (1-\delta^k)K_{t-1}, \tag{5.1}$$

where δ^k is the depreciation rate of capital and $\phi\Big(\frac{I_t}{K_{t-1}}\Big)K_{t-1}$ denotes the production function for capital-producing firms and reflects the costs associated with transforming investment goods into new capital goods.

Capital producers maximise their profit each period:

$$\max q_t K_t - q_t(1-\delta^k)K_{t-1} - I_t,$$

s.t. (5.1).

The solution to this problem implies

[3] This separate, perfectly competitive market that produces capital goods was introduced to require the entire capital stock to be re-purchased every period. This ensures that the financing constraints apply to the entire capital stock and not just investment.

Model Timing

	Period t-1	*Period t*			
	End of Period	**Shock hits**	**Production 1**	**Production 2**	**Entry & Productivity Draw**
Households	Have x_{t-1} shares and D_{t-1} deposits		Provide labour	> Receive wages $w_t L_t$ > Receive dividends $d_t x_{t-1} N_{D,t}$	
Capital Producers					
Entrepreneurs	> In possession of capital stock for next period, K_{t-1} > Net worth of N_{t-1}		Rent capital to intermediate good producing firms	Receive rent on capital, $r^k_t K_{t-1}$	
Banks					
Intermediate Good Producing Firms	$N_{H,t-1} = N_{D,t-1} + N_{E,t-1}$ firms	> Shock may affect cut-off productivity level; those firms with a productivity level $z < z_{D,t}$ exit the market. > Remaining firms: $N_{D,t} = (z_{min}/z_{D,t})^j (N_{D,t-1} + N_{E,t-1})$	> Hire workers > Rent capital > Produce output > Make export decision	> Pay rents > Pay wages > Sell intermediate good	> New firms pay sunk entry cost $f_{E,t}$ and enter the market > All firms draw their productivity level z_{t+1} for the following period
Final Good Producing Firms				> Buy intermediate good > Make final good Y_t	

	Period t	
	Consumption, Capital Production and Loan Repayment	**End of Period**
Households	> Buy final good C_t > Make deposits D_t > Buy shares $v_t x_t N_{H,t}$	Have x_t shares and D_t deposits
Capital Producers	> Buy final good for investment, I_t > Buy undepreciated capital, $(1-\delta^k) K_{t-1}$, from entrepreneurs at price q_t > Create new capital, K_t, and sell it to entrepreneurs at price q_t	
Entrepreneurs	1. Sell their undepreciated capital, $(1-\delta^k)K_{t-1}$, to capital producers at price q_t 2. Decide on whether to default or pay back loan 3. Decide on how much capital to buy for nex period and take out new loans, B_t, from bank 4. Buy their capital stock for the next period from the capital producer, K_t, at price q_t	> In possession of capital stock for next period, K_t > Net worth of N_t
Banks	> Are paid back loans or pay monitoring cost and seize remaining assets > Make new laons to entrepreneurs, B_t, based on their net worth N_t	
Intermediate Good Producing Firms		$N_{H,t} = N_{D,t} + N_{E,t}$ firms
Final Good Producing Firms	Sell output to households, capital producers, and banks for monitoring costs	

$$q_t = \left[\phi'\left(\frac{I_t}{K_{t-1}}\right)\right]^{-1}.$$

5.3.2 Entrepreneurs, Banks and the Demand for Capital

5.3.2.1 Entrepreneurs

Entrepreneurs possess a unique ability to operate physical capital. In this model, each entrepreneur comes into period t with an amount of physical capital, K_{t-1}, which is financed by outstanding loans owed to the banks and net worth, N_{t-1}. They then rent out this capital to intermediate-goods-producing firms at the rental rate r_t^k. Once production has been completed, they either pay back the loans to the banks with interest or default. In either case, the non-depreciated remainder of their capital stock is sold back to capital producers, who produce more capital as described in Section 5.3.1. Surviving entrepreneurs then buy capital from the capital producers, financing their purchases with net worth and bank loans.

The balance sheet identity for entrepreneur h implies:

$$B_t^h = q_t K_t^h - N_t^h, \tag{5.2}$$

where K_t^h denotes the capital stock held by entrepreneur h at time t, B_t^h denotes the amount of loans entrepreneur h has outstanding during period $t+1$, decided at the end of period t, and N_t^h denotes the end-of-period net worth of entrepreneur h.

After purchasing the capital, the entrepreneur experiences an idiosyncratic shock ω. The ex-post return on her capital is thus $R_{t+1}^k \omega^h q_t K_t^h$, where R_{t+1}^k is the return on capital in the next period and ω^h is the idiosyncratic shock to the entrepreneur's return. I assume that the return to capital R_{t+1}^k is known in advance.

The entrepreneur chooses the value of the firm capital, $q_t K_t^h$ and thus the value of its borrowings, B_t^h, prior to the realisation of the idiosyncratic shock. The loan contract is governed by a loan rate Z_t, and a threshold value $\bar{\omega}$, such that for values $\omega^h \geq \bar{\omega}$, the entrepreneur repays the loan at the rate Z_t^h. For values $\omega^h \leq \bar{\omega}$, the entrepreneur defaults. $\bar{\omega}$ is defined by:

$$\bar{\omega} R_{t+1}^k q_t K_t^h = Z_t^h B_t^h. \tag{5.3}$$

When $\omega^h \geq \bar{\omega}$, the entrepreneur repays $Z_t^h B_t^h$ and keeps the difference, $R_{t+1}^k q_t K_t^h \omega^h - \bar{\omega} R_{t+1}^k q_t K_t^h$. When $\omega^h \leq \bar{\omega}$, the entrepreneur defaults. In this case, the bank pays the auditing cost and keeps what it finds. The bank's receipts are: $(1-\mu) R_{t+1}^k q_t K_t^h \omega^h$. The defaulting entrepreneur receives nothing.

The entrepreneur chooses how much capital to buy today and how many loans to take out based on her profit maximisation problem:

$$\max E_t\Big\{\pi_t^h\Big\} = E_t\Big\{r_{t+1}^k K_t^h + (1-\delta^k) K_t^h q_{t+1} - R_{t+1}^k \bar{\omega} q_t K_t^h\Big\},$$

where $R_{t+1}^k \bar{\omega} q_t K_t^h$ is the amount to be repaid on the loan as given by equation (5.3), $r_{t+1}^k K_t^h$ is the income she receives from renting out her capital to intermediate good producing firms during the period $t+1$ and $(1-\delta^k) K_t^h q_{t+1}$ is the income she receives by selling her un-depreciated capital back to capital producers at the end of period $t+1$.

The solution to this problem implies that the expected gross return to holding a unit of capital from t to $t+1$ is

$$R^k_{t+1} = E_t\Big\{\frac{r^k_{t+1} + (1-\delta^k)q_{t+1}}{q_t}\Big\}.^4$$

5.3.2.2 Banks

Banks hold deposits from households and provide loans to entrepreneurs. Thus, $D_t = B_t$, where D_t are deposits made by households at the end of period t and B_t are loans extended to entrepreneurs at the end of period t.

The bank has the opportunity cost of funds equal to the economy's riskless gross rate of return, R_t, as its loan risk is perfectly diversifiable. The bank faces a problem of costly state verification: it has to pay a fixed monitoring cost in order to observe a borrower's return, equal to proportion μ of the realised payoff to the entrepreneur's capital: $\mu\omega^h R^k_{t+1} q_t K^h_t$.

Free entry into the market implies zero profits, so the bank must have an expected return equal to the opportunity cost of its funds. Therefore,

$$[1 - F(\bar{\omega})]Z^h_t B^h_t + (1-\mu)\int_0^{\bar{\omega}} \omega R^k_{t+1} q_t K^h_t dF(\omega) = R_t B^h_t, \tag{5.4}$$

where $F(\bar{\omega})$ gives the probability of default, Z_t is the loan rate. The left-hand side of equation (5.4) is the bank's expected return on the loan and the right-side is the bank's opportunity cost of lending.

5.3.2.3 The Demand for Capital

Combining the problems of the banks and entrepreneurs allows us to derive the rules according to which loans are extended.

Combining equations (5.2), (5.3), and (5.4) yields

$$[1 - F(\bar{\omega})]\bar{\omega} R^k_{t+1} q_t K^h_t + (1-\mu)\int_0^{\bar{\omega}} \omega R^k_{t+1} q_t K^h_t dF(\omega) = R_t(q_t K^h_t - N^h_t). \tag{5.5}$$

An increase in the cut-off level of the idiosyncratic shock has two effects. Firstly, it increases the pay-off in case of non-default. Secondly, it increases the probability of default, which lowers the expected return.

The entrepreneur's expected return is:

$$\int_{\bar{\omega}}^{\infty} \omega dF(\omega) R^k_{t+1} q_t K^h_t - (1 - F(\bar{\omega}))\bar{\omega} R^k_{t+1} q_t K^h_t. \tag{5.6}$$

Recall equation (5.5), and solve it for $[1 - F(\bar{\omega})]\bar{\omega} R^k_{t+1} q_t K^h_t$:

$$-[1 - F(\bar{\omega})]\bar{\omega} R^k_{t+1} q_t K^h_t = (1-\mu)\int_0^{\bar{\omega}} \omega R^k_{t+1} q_t K^h_t dF(\omega) - R_t(q_t K^h_t - N^h_t).$$

[4] In the aggregation ω is normalised to 1.

Combining this with equation (5.6) allows re-writing the entrepreneur's expected return as

$$(1-\mu)\int_0^{\bar{\omega}} \omega dF(\omega) R_{t+1}^k q_t K_t^h - R_t(q_t K_t^h - N_t^h) + \int_{\bar{\omega}}^{\infty} \omega dF(\omega) R_{t+1}^k q_t K_t^h. \tag{5.7}$$

The entrepreneur maximises equation (5.7) subject to (5.4). The solution to this problem yields:[5]

$$q_t K_t^h = N_t^h \psi\Big(\frac{R_{t+1}^k}{R_t}\Big). \tag{5.8}$$

This equation illustrates the link between capital expenditures of the firm and financial conditions, described by the wedge between the amount of capital that can be acquired and net worth. Capital expenditures are proportional to the net worth of the entrepreneur, with the proportionality factor being increasing in the spread on loans, $\frac{R_{t+1}^k}{R_t}$. Everything else being equal, a rise in the expected spread reduces the expected default probability. As a consequence, the entrepreneur can take on more debt and expand the size of her firm. She is constrained from raising the size of her borrowing and thus the size of the firm indefinitely by the fact that expected default costs also rise as the ratio of borrowing to net worth increases.

By inverting equation (5.8) it can also be expressed as

$$R_{t+1}^k = \psi\Big(\frac{N_t^h}{q_t K_t^h}\Big) R_t. \tag{5.9}$$

This equation states that the external finance premium, $R_{t+1}^k - R_t$ is dependent on the capital-net worth ratio. This is the main ingredient of the financial accelerator: the external finance premium, and therefore the amount which an entrepreneur can borrow, depends on the extent to which the entrepreneur is leveraged. When an entrepreneur is more highly leveraged, or when the capital-net-worth ratio is higher, the external finance premium increases. Conversely, a less highly leveraged entrepreneur with a low capital-net-worth ratio faces a lower external finance premium.

Next, I define net worth. Letting V_t be the entrepreneurial equity towards the end of period t, and N_t the net worth of entrepreneurs at the end of period t, I define

$$N_t = (1-\delta)V_t, \tag{5.10}$$

where $(1-\delta)V_t$ is the equity held by the entrepreneurs at the end of period $t-1$ who survive into period t. I thus assume that δ is the proportion of entrepreneurs that declare bankruptcy in each period. Those entrepreneurs who default consume the residual equity: $C_t^e = \delta V_t$. Hereby,

$$V_t = R_t^k q_{t-1} K_{t-1} - \Big(R_{t-1} + \frac{\mu \int_0^{\bar{\omega}} \omega R_t^k q_{t-1} K_{t-1} dF(\omega)}{q_{t-1} K_{t-1} - N_{t-1}}\Big)(q_{t-1} K_{t-1} - N_{t-1}). \tag{5.11}$$

Entrepreneurial equity equals gross earnings on holdings of equity from $t-1$ to t less repayment of borrowings, where $\frac{\mu \int_0^{\bar{\omega}} \omega R_t^k q_{t-1} K_{t-1} dF(\omega)}{q_{t-1} K_{t-1} - N_{t-1}}$ is the external finance premium.

Combining equations (5.10) and (5.11) yields:

[5] See Appendix C.1 for details.

$$N_t = (1-\delta)\Big[R_t^k q_{t-1}K_{t-1} - \Big(R_{t-1} + \frac{\mu \int_0^{\bar{\omega}} \omega R_t^k q_{t-1}K_{t-1}dF(\omega)}{q_{t-1}K_{t-1} - N_{t-1}}\Big)(q_{t-1}K_{t-1} - N_{t-1})\Big]. \tag{5.12}$$

Equations (5.9) and (5.12) are the basic ingredients of the financial accelerator. Equation (5.9) describes how movements in net worth affect the cost of borrowing. Equation (5.12) characterises endogenous variation in net worth.

5.3.3 Household Problem

The representative household maximises its intertemporal utility subject to its intertemporal budget constraint:

$$\max_{\substack{w.r.t:C_t,\\ B_t,x_t,C_{t+1},L_t}} U = \left[\sum_{s=t}^{\infty} \beta^{s-t}\varepsilon_s \Big(\frac{C_s^{\mu}(1-L_s)^{1-\mu}}{1-\gamma}\Big)^{1-\gamma}\right],$$

s.t.

$$\tilde{v}_t N_{H,t} x_t + C_t = (\tilde{d}_t + \tilde{v}_t)N_{D,t}x_{t-1} + w_t L_t + R_{t-1}D_{t-1} - D_t,$$

where C_t is consumption at time t, β is the subjective discount factor, μ is the share of consumption in utility, $\gamma > 0$ is the inverse of the intertemporal elasticity of substitution, ε_t is a term that represents a shock to the discount rate affecting intertemporal substitution, essentially a shock to households' preferences regarding consumption, x_{t-1} is the household's mutual fund holdings at the beginning of period t, chosen during the previous period $t-1$, $\tilde{v}_t$ is the expected post-entry value of firms, $\tilde{d}_t$ is the average total profits of home firms. $N_{H,t}$ is the mass of firms present in the home country at the end of period t, and $N_{D,t}$ is the mass of incumbent and producing firms in the home country during period t. Households make deposits at a financial intermediary at the end of the period, D_{t-1},[6] which yield the pre-determined gross interest rate R_{t-1}. I assume throughout that there is no inflation in this economy; hence, the budget constraint and all quantities are expressed in real terms.

In this model, a household thus has four income sources. It enters a period with x_{t-1} mutual funds, for which the household receives dividend income that is equal to the real average total profits of all home firms producing in that period, $\tilde{d}_t N_{D,t}$. The household can further sell shares, and thus receives the value of selling its initial share position, which is $\tilde{v}_t$. The representative household also earns income from its labour, which it $w_t L_t$, where w_t is the real wage in period t and L_t is labour supply, and interest on its deposits, equal to $R_{t-1}D_{t-1}$.

The representative household divides this income between purchases of mutual fund holdings to be carried over into the next period x_t, consumption C_t, and new deposits D_t. The household buys new shares x_t from a mutual fund of $N_{H,t} = N_{D,t} + N_{E,t}$ firms, where $N_{D,t}$ are the incumbent firms and $N_{E,t}$ the entering firms. Only $N_{D,t+1} = (1 - G(z_{D,t+1}))N_{H,t}$ firms will produce and pay dividends at time $t+1$,

[6] To rule out Ponzi schemes, D_t is assumed to be non-negative.

where $G(z_{D,t+1})$ is the average proportion of firms that exits the economy each period.[7] As the household does not know which firms will be able to produce in the next period, it finances the operation of all existing firms and all new entrants during period t.

The solution to this problem yields the following Euler Equations:

$$C_t^{-1}\Big(C_t^{\mu}(1-L_t^{1-\mu})\Big)^{1-\gamma} = \beta E_t\Big\{C_{t+1}^{-1}\frac{\varepsilon_{t+1}}{\varepsilon_t}\Big(C_{t+1}^{\mu}(1-L_{t+1}^{1-\mu})\Big)^{1-\gamma}\Big\}R_t.$$

$$\tilde{v}_t = \beta E_t\Big\{(1-G(z_{D,t+1}))\frac{\varepsilon_{t+1}}{\varepsilon_t}\frac{C_t}{C_{t+1}}\Big[\frac{C_{t+1}^{\mu}(1-L_{t+1})^{1-\mu}}{C_t^{\mu}(1-L_t)^{1-\mu}}\Big]^{1-\gamma}(\tilde{d}_{t+1}+\tilde{v}_{t+1})\Big\}. \tag{5.13}$$

$$(1-L_t)w_t = \frac{1-\mu}{\mu}C_t.$$

5.3.4 Final Good Producing Firm Problem

In this economy, there are final good producers and intermediate good producers. The representative final good producer is perfectly competitive and produces its final good using the products produced by domestic intermediate good producing firms and foreign exporting intermediate good producing firms. Specifically, it produces according to:

$$Y_t = \Big[\int_{z\epsilon\Omega} y_{D,t}(z)d(z)^{\frac{\theta-1}{\theta}} + \int_{z\epsilon\Omega^*} y^*_{X,t}(z)d(z)^{\frac{\theta-1}{\theta}}\Big]^{\frac{\theta}{\theta-1}}, \tag{5.14}$$

where z denotes firm-level productivity, $y_{D,t}(z)$ is the quantity the domestic intermediate good producing firm with productivity level z produces, $y_{X,t}(z)$ is the quantity the foreign exporting intermediate good producing firm with productivity level z produces, Y_t is the quantity produced by the final good producer, and $\theta > 1$ is the elasticity of substitution across goods. The representative final good producer solves the following problem:

$$\max_{\substack{w.r.t:\\ Y_t, y_{D,t}, y^*_{X,t}}} P_tY_t - \int_{z\epsilon\Omega} p_{D,t}(z)y_{D,t}(z)dz - \int_{z\epsilon\Omega^*} p^*_{X,t}(z)y^*_{X,t}(z)dz,$$

s.t (5.14), where $p_{D,t}(z)$ denotes the price the domestic intermediate good producing firm with productivity level z charges for its product, $p_{X,t}(z)$ denotes the price the foreign exporting intermediate-good-producing firm with productivity level z charges for its product in the domestic market, and P_t is the price charged by the final good producer.

Solving this problem yields the following demand functions:

$$y_{D,t}(z) = \Big(\frac{p_{D,t}(z)}{P_t}\Big)^{-\theta}Y_t \equiv (\rho_{D,t}(z))^{-\theta}Y_t \tag{5.15}$$

$$y^*_{X,t}(z) = \Big(\frac{p^*_{X,t}(z)}{P_t}\Big)^{-\theta}Y_t \equiv (\rho^*_{X,t}(z))^{-\theta}Y_t.$$

[7] For a more precise explanation of this proportion, see Sections 5.3.7 and 5.3.8.

As the foreign problem is symmetrical, the domestic demand function is:

$$y_{X,t}(z) = \Big(\frac{p_{X,t}(z)}{P_t^*}\Big)^{-\theta} Y_t^* \equiv (\rho_{X,t}(z))^{-\theta} Y_t^*. \tag{5.16}$$

5.3.5 Intermediate Good Producing Firm's Problem

Each intermediate good producer produces a differentiated good, $\omega \epsilon \Omega$. Intermediate good firms produce using labour and capital as inputs of production, and produce according to the production function $y_t(z) = Z_t z k_{t-1}(z)^{\alpha} l_{P,t}(z)^{1-\alpha}$, where $\alpha \ \epsilon(0,1)$ is the capital income share, $y_t(z)$ is the amount produced by a firm with the productivity level z, Z_t is the aggregate country-specific technology level, $k_t(z)$ is the capital employed by a firm with the productivity level z, and $l_{P,t}(z)$ is the labour employed for production by a firm with the productivity level z.

In order to enter the market a firm must pay a sunk entry cost $f_{E,t}$, following Ghironi and Melitz (2005). Upon paying the entry cost, a firm draws its firm-level productivity z from a productivity distribution $G(z)$ with support over (z_{min}, ∞). This firm-level productivity is re-drawn at the end of every period. Firms furthermore pay a fixed cost for domestic production $f_{D,t}$, as well as a fixed exporting cost $f_{X,t}$ and variable trade costs τ_t if they export. The variable costs are modelled as standard iceberg costs, whereby more than one unit of a good has to be shipped in order for one unit of a good to arrive at its destination. The fixed costs and sunk entry costs are defined in terms of effective labour units. To get the costs in units of output, they need to be multiplied by the real wage, w_t, and divided by the aggregate technology level, Z_t.

A representative intermediate good producer maximises its real profit subject to the domestic and foreign demand curves and its production constraint.

$$\max_{\substack{w.r.t: \rho_{D,t}, \\ \rho_{X,t}, l_{P,t}(z), k_{t-1}^k(z)}} \quad d_t(z) = \rho_{D,t}(z) y_{D,t}(z) + Q_t \rho_{X,t}(z) y_{X,t}(z) - w_t l_{P,t}(z) - r_t^k k_{t-1}(z) - \frac{w_t f_{D,t}}{Z_t} - \frac{w_t f_{X,t}}{Z_t}, \tag{5.17}$$

subject to:

$$y_{D,t}(z) = (\rho_{D,t})^{-\theta} Y_t,$$

$$y_{X,t}(z) = (\rho_{X,t})^{-\theta} Y_t^*,$$

$$y_{D,t}(z) + \tau_t y_{X,t}(z) = Z_t z k_{t-1}(z)^{\alpha} l_{P,t}(z)^{1-\alpha},$$

where $d_t(z)$ are total profits of the firm with productivity level z in period t, $Q_t = \frac{\epsilon P_t^*}{P_t}$ is the real exchange rate.

Solving this problem, firms set prices as follows:

$$\rho_{D,t}(z) = \frac{\theta}{\theta - 1} \Big(\frac{w_t}{1-\alpha}\Big)^{1-\alpha} \Big(\frac{r_t^k}{\alpha}\Big)^{\alpha} \frac{1}{Z_t z},$$

$$\rho_{X,t}(z) = \frac{\tau_t}{Q_t} \frac{\theta}{\theta - 1} \Big(\frac{w_t}{1-\alpha}\Big)^{1-\alpha} \Big(\frac{r_t^k}{\alpha}\Big)^{\alpha} \frac{1}{Z_t z}.$$

Defining marginal costs as $MC_t = \left(\frac{w_t}{1-\alpha}\right)^{1-\alpha}\left(\frac{r_t^k}{\alpha}\right)^{\alpha}\frac{1}{Z_t z}$, firms set their prices according to

$$\rho_{D,t}(z) = \frac{\theta}{\theta-1}MC_t, \tag{5.18}$$

$$\rho_{X,t}(z) = \frac{\tau_t}{Q_t}\frac{\theta}{\theta-1}MC_t. \tag{5.19}$$

Note that relative prices depend negatively on the firm-level productivity level. Firms with higher productivity thus set lower prices.

The remuneration of the factors of production is determined by:

$$k_{t-1}(z) = \alpha MC(z)\frac{y_t(z)}{r_{k,t}(z)},$$

$$l_{P,t}(z) = (1-\alpha)MC(z)\frac{y_t(z)}{w_t}.$$

Expanding these expressions leads to

$$k_{t-1}(z) = \left(\frac{w_t}{r_t^k}\frac{\alpha}{1-\alpha}\right)^{1-\alpha}\left[\left(\frac{w_t}{1-\alpha}\right)^{1-\alpha}\left(\frac{r_t^k}{\alpha}\right)^{\alpha}\frac{\theta}{\theta-1}\right]^{-\theta}(Z_t z)^{\theta-1}[Y_t + \tau_t^{1-\theta}Q_t^{\theta}Y_t^*], \tag{5.20}$$

$$l_{P,t}(z) = \left(\frac{r_t^k}{w_t}\frac{1-\alpha}{\alpha}\right)^{\alpha}\left[\left(\frac{w_t}{1-\alpha}\right)^{1-\alpha}\left(\frac{r_t^k}{\alpha}\right)^{\alpha}\frac{\theta}{\theta-1}\right]^{-\theta}(Z_t z)^{\theta-1}[Y_t + \tau_t^{1-\theta}Q_t^{\theta}Y_t^*], \tag{5.21}$$

whereby

$$\frac{k_{t-1}}{l_{P,t}} = \frac{w_t}{r_t^k}\frac{\alpha}{1-\alpha}. \tag{5.22}$$

Total profits are given by the sum of domestic profits and exporting profits. However, due to the presence of fixed costs for domestic production, not all firms are able to produce in any given period. Only firms with a productivity level $z > z_{D,t} = inf\{z : d_{D,t}(z) > 0\}$ are productive enough to enter domestic production, with $d_{D,t}$ defined below. Firms that draw a productivity level below $z_{D,t}$, the productivity cut-off level for domestic production, cannot produce profitably and thus exit the market immediately. It is changes in this productivity cut-off level in response to macroeconomic shocks that cause firms to enter and exit the market endogenously. Similarly, only firms with a productivity level $z > z_{X,t} = inf\{z : d_{X,t}(z) > 0\}$ are productive enough to profitably pay the fixed exporting costs and export. In every period, only a subsection of firms thus produces, and only the most productive of those firms export. Total profits are given by:

$$d_t(z) = d_{D,t}(z) + d_{X,t}(z),$$

where

$$d_{D,t}(z) = \max\begin{cases} \frac{1}{\theta}(\rho_{D,t}(z))^{1-\theta}Y_t - \frac{w_t f_{D,t}}{Z_t} & \text{if the firm produces,} \\ 0 & \text{otherwise.} \end{cases}$$

$$d_{X,t}(z) = \max\begin{cases} \frac{Q_t}{\theta}(\rho_{X,t}(z))^{1-\theta}Y_t^* - \frac{w_t f_{X,t}}{Z_t} & \text{if the firm exports,} \\ 0 & \text{otherwise.} \end{cases}$$

5.3.6 Firm Averages and Aggregation

In every period, a mass $N_{D,t}$ of firms produces in the home country, with the productivity distribution over (z_{min}, ∞), as given by $G(z)$. Of these firms, $N_{X,t} = [1 - G(z_{X,t})]N_{D,t}$ are exporters.

Following Melitz (2003), I define the average productivity levels of all home producing firms ($\tilde{z}_D$) and home exporting firms ($\tilde{z}_{X,t}$):

$$\tilde{z}_{D,t} = \Big[\frac{1}{1 - G(z_{D,t})} \int_{z_{D,t}}^{\infty} z^{\theta-1} dG(z)\Big]^{\frac{1}{\theta-1}};$$

$$\tilde{z}_{X,t} = \Big[\frac{1}{1 - G(z_{X,t})} \int_{z_{X,t}}^{\infty} z^{\theta-1} dG(z)\Big]^{\frac{1}{\theta-1}}.$$

Further define $\tilde{p}_{D,t} = p_{D,t}(\tilde{z}_D)$ as the average nominal price of home firms in the domestic market and $\tilde{p}_{X,t} = p_{X,t}(\tilde{z}_{X,t})$ as the average nominal price of home exporters in the export market.

The price index at home thus reflects the prices of home firms ($N_{D,t}$ firms) for the domestic market, and the prices of foreign exporting firms ($N^*_{X,t}$) for their export market (the home market). The home price index is thus: $P_t = [N_{D,t}(\tilde{p}_{D,t})^{1-\theta} + N^*_{X,t}(\tilde{p}^*_{X,t})^{1-\theta}]^{\frac{1}{1-\theta}}$, which is equivalent to $1 = N_{D,t}(\tilde{\rho}_{D,t})^{1-\theta} + N^*_{X,t}(\tilde{\rho}^*_{X,t})^{1-\theta}$.

The productivity averages $\tilde{z}_{D,t}$, $\tilde{z}_{X,t}$ and $\tilde{z}^*_{X,t}$ are constructed in such a way that $\tilde{d}_{D,t} = d_{D,t}(\tilde{z}_D)$ represents the average profit earned from domestic sales by all home firms and $\tilde{d}_{X,t} = d_{X,t}(\tilde{z}_{X,t})$ is the average profit earned by all home exporters on their foreign sales. Thus $\tilde{d}_t = \tilde{d}_{D,t} + (1 - G(z_{X,t}))\tilde{d}_{X,t}$ represents the average total profits of home firms.

From this aggregation it follows that factor demand is as follows:

$$L_{P,t} = N_{D,t}\Big(\frac{r^k_t}{w_t}\frac{1-\alpha}{\alpha}\Big)^{\alpha}\Big[\Big(\frac{w_t}{1-\alpha}\Big)^{1-\alpha}\Big(\frac{r^k_t}{\alpha}\Big)^{\alpha}\frac{\theta}{\theta-1}\Big]^{-\theta}(Z_t)^{\theta-1}\Big[Y_t\tilde{z}^{\theta-1}_{D,t} + \frac{N_{X,t}}{N_{D,t}}\tau_t^{1-\theta}Q_t^{\theta}Y^*_t\tilde{z}^{\theta-1}_{X,t}\Big]$$

$$K_{t-1} = N_{D,t}\Big(\frac{w_t}{r^k_t}\frac{\alpha}{1-\alpha}\Big)^{1-\alpha}\Big[\Big(\frac{w_t}{1-\alpha}\Big)^{1-\alpha}\Big(\frac{r^k_t}{\alpha}\Big)^{\alpha}\frac{\theta}{\theta-1}\Big]^{-\theta}(Z_t)^{\theta-1}[Y_t\tilde{z}^{\theta-1}_{D,t} + \frac{N_{X,t}}{N_{D,t}}\tau_t^{1-\theta}Q_t^{\theta}Y^*_t\tilde{z}^{\theta-1}_{X,t}].$$

5.3.7 Firm Entry

Entry occurs until the average firm value is equalised with the entry cost. In each period, $N_{E,t}$ firms pay the sunk entry costs. At the end of the period, along with all other firms, they draw their productivity level for the next period. The shock at the beginning of the next period then decides which firms are productive enough to produce given the productivity cut-off level; some of these firms will have a productivity that is lower. Thus, a proportion of these firms, $G(z_{D,t+1})$, will exit before ever producing. Entry will occur until the average firm value, adjusted by the probability of entering the market, is equal to the sunk entry cost $f_{E,t}$, expressed in effective labour units. Thus,

$$\tilde{v}_t = \frac{w_t f_{E,t}}{Z_t}.$$

Given that firms exit and enter the economy based on whether or not their productivity level enables them to pay the fixed cost of domestic production, the law of motion of firms is given by

$$N_{D,t} = (1 - G(z_{D,t}))(N_{D,t-1} + N_{E,t-1}).$$

5.3.8 Parameterisation of Productivity Draws

Next, I parameterise the distribution of productivity draws $G(z)$. I assume that z is Pareto distributed, with a lower bound z_{min} and the shape parameter $j > \theta - 1$. Thus, $G(z) = 1 - \left(\frac{z_{min}}{z}\right)^j$. j indexes the dispersion of productivity draws, and therefore defines the distribution. I define $\nu = \left(\frac{j}{j-(\theta-1)}\right)^{\frac{1}{\theta-1}}$, which allows us to define the average productivities $\tilde{z}_{D,t}$ and $\tilde{z}_{X,t}$ as $\tilde{z}_{D,t} = \nu z_{D,t}$ and $\tilde{z}_{X,t} = \nu z_{X,t}$.

The share of exporting firms is given by $N_{X,t}/N_{D,t} = \frac{1-G(z_{X,t})}{1-G(z_{D,t})}$. Above I defined $G(z) = 1 - \left(\frac{z_{min}}{z}\right)^j$. Thus $N_{X,t}/N_{D,t} = \frac{1-G(z_{X,t})}{1-G(z_{D,t})} = \left(\frac{z_{min}}{z_{X,t}}\frac{z_{D,t}}{z_{min}}\right)^j = \left(\frac{z_{D,t}}{z_{X,t}}\right)^j$. Recall that $\tilde{z}_{X,t} = v z_{X,t}$ and $\tilde{z}_{D,t} = v z_{D,t}$. Substituting this into the proportion of exporting firms yields

$$\frac{N_{X,t}}{N_{D,t}} = \left(\frac{\tilde{z}_{D,t}}{\tilde{z}_{X,t}}\right)^j. \tag{5.23}$$

Using this parameterisation of productivity I can re-write the law of motion of firms as

$$N_{D,t} = \left(\frac{\nu z_{min}}{\tilde{z}_{D,t}}\right)^j (N_{D,t-1} + N_{E,t-1})$$

and the Euler equation for shares from (5.13) as

$$\tilde{v}_t C_t^{-1}[C_t^{\mu}(1-L_t)^{1-\mu}]^{1-\gamma} = \left(\frac{z_{min}\nu}{\tilde{z}_{D,t}}\right)^j \beta E_t\Big\{\frac{\varepsilon_{t+1}}{\varepsilon_t} C_{t+1}^{-1}[C_{t+1}^{\mu}(1-L_{t+1})^{1-\mu}]^{1-\gamma}(\tilde{d}_{t+1} + \tilde{v}_{t+1})\Big\}. \tag{5.24}$$

The zero-profit cut-off (ZPC) conditions $d_{D,t}(z_{D,t}) = 0$ and $d_{X,t}(z_{X,t}) = 0$ imply that average profits will be determined by

$$\tilde{d}_{D,t} = \frac{w_t f_{D,t}}{Z_t}\frac{j}{j-(\theta-1)}, \tag{5.25}$$

$$\tilde{d}_{X,t} = \frac{w_t f_{X,t}}{Z_t}\frac{j}{j-(\theta-1)}. \tag{5.26}$$

5.3.9 Market Clearing and Equilibrium

For markets to clear, the following conditions must hold:

$K_{t-1} = K_{P,t-1}$, where

$$K_{t-1} = N_{D,t}\Big(\frac{w_t}{r_t^k}\frac{\alpha}{1-\alpha}\Big)^{1-\alpha}\Big[\Big(\frac{w_t}{1-\alpha}\Big)^{1-\alpha}\Big(\frac{r_t^k}{\alpha}\Big)^{\alpha}\frac{\theta}{\theta-1}\Big]^{-\theta}(Z_t)^{\theta-1}[Y_t\tilde{z}_{D,t}^{\theta-1} + \frac{N_{X,t}}{N_{D,t}}\tau_t^{1-\theta}Q_t^{\theta}Y_t^*\tilde{z}_{X,t}^{\theta-1}].$$

$$L_t = L_{P,t} + L_{E,t} + L_{X,t} + L_{D,t},$$

where $L_{P,t}$ is aggregate labour used for production, $L_{E,t}$ is aggregate labour used to pay for the sunk entry cost, $L_{D,t}$ is aggregate labour used to pay the fixed cost of domestic production, and $L_{X,t}$ is aggregate labour used to pay the fixed cost of exporting. Hereby,

$$L_{P,t} = N_{D,t}\Big(\frac{r_t^k}{w_t}\frac{1-\alpha}{\alpha}\Big)^{\alpha}\Big[\Big(\frac{w_t}{1-\alpha}\Big)^{1-\alpha}\Big(\frac{r_t^k}{\alpha}\Big)^{\alpha}\frac{\theta}{\theta-1}\Big]^{-\theta}(Z_t)^{\theta-1}\Big[Y_t\tilde{z}_{D,t}^{\theta-1} + \frac{N_{X,t}}{N_{D,t}}\tau_t^{1-\theta}Q_t^{\theta}Y_t^*\tilde{z}_{X,t}^{\theta-1}\Big],$$

$$L_{E,t} = \frac{N_{E,t}f_{E,t}}{Z_t},$$

$$L_{D,t} = \frac{N_{D,t}f_{D,t}}{Z_t}.$$

$$L_{X,t} = \frac{N_{X,t}f_{X,t}}{Z_t}.$$

In equilibrium, I furthermore assume balanced trade. Therefore, the trade balance equation is

$$Q_t N_{X,t}(\tilde{p}_{X,t})^{1-\theta}Y_t^* = N_{X,t}^*(\tilde{p}_{X,t}^*)^{1-\theta}Y_t.$$

This assumption was made to ensure simplicity and tractability because including bonds in this model was complicated and would require a number of further assumptions about who is able to trade financially. I thus only address one aspect of globalisation, namely trade in goods, and not trade in financial assets.[8]

Aggregate output is used to cover consumption, investment, entrepreneurial consumption and monitoring costs. The monitoring costs effects are marginal, as shown by Bernanke *et al.* (1999), and therefore not included. This yields the following expression for aggregate output

$$Y_t = C_t + I_t + C_t^e,$$

where C_t^e has been defined as δV_t.

Labour productivity will be defined as output per worker, so $LaProd_t = \frac{Y_t}{L_t}$, where Y_t and L_t are as previously defined. The model was log-linearised around the steady state and simulated using Dynare.[9]

5.4 Calibration

I interpret one period as three months, and calibrate parameters as follows, assuming symmetrical countries. I set the inverse of the intertemporal elasticity of substitution, γ, to 2 and the subjective discount factor β to 0.99, both standard values in the quarterly business cycle literature. I furthermore set the capital share α to 0.36 and the depreciation rate of capital δ_k to 0.025, again both standard values in the literature.

[8] This may affect results. Relaxing this assumption and considering whether trade in financial assets has implications for the financial accelerator would therefore be an interesting avenue for future research.

[9] For the full log-linearised model, see Appendix C.2. For more information on the program, see `https://www.dynare.org/`

The elasticity of substitution across goods θ is set to 6, to match average firm mark-ups in the UK of 1.2, as calculated by Macallan *et al.* (2008). I set the shape parameter j to 5.65, which complies with the condition $j > \theta - 1$. The fixed costs for domestic production and exporting are set to $f_D = 0.004$ and $f_X = 0.006$. I jointly calibrated the shape parameter j and the fixed costs of production and exporting to match the average yearly exit rate of 10% in the UK, and the proportion of firms that export in the UK, which is 9.91%. While the intermediate firm exit rate is determined endogenously in this model, the parameters were calibrated to yield a steady-state exit rate of 0.025 per quarter. Data for the exit rate was obtained from the *ONS Business Demography, UK: 2017* database, and was calculated using data from 2012-2017. For simplicity and data availability reasons, I assume that the average death rate of entrepreneurs and intermediate firms is identical. Data on the exporting proportion in the UK was obtained from the *ONS Annual Business Survey importers and exporters*. The average proportion of exporting firms was calculated using data from 2015 to 2017.

The per unit iceberg costs τ were set using data from the *World Bank International Trade Costs database*, and the 2018 *ONS Pink Book*. The two countries in the model were set as UK and the rest of the world. The iceberg costs were calculated as an average of weighted country iceberg costs. Specifically, τ is the sum of the iceberg trade costs of the UK with every country in the world for which both databases contain data, multiplied by the proportion of UK exports going to that country. This yielded an average iceberg cost of $\tau = 1.39$.

I further normalise the sunk entry cost f_E to 1. I can do this without loss of generality, because changing f_E while maintaining the same ratio f_X/f_E does not affect the firm-level productivity variables and has no effect on impulse responses. For similar reasons, I set the minimum productivity level z_{min} to 1. The means of Z_t and ε_t are also normalised to 1 for both countries.

For the financial accelerator parameters I follow the calibration of Bernanke *et al.* (1999). I set the elasticity of the price of capital with respect to the investment capital ratio ϕ to 0.25 and the ratio of capital to net worth to 2. Due to the log-linearisation of the model I further need to set some steady state values. I set the rate of return to capital to yield a risk spread of 50 basis points and set the steady state of labour to 0.33, a standard value in the literature.[10]

5.5 Results

I analyse the dynamic response of the economy to temporary shocks to aggregate technology, Z, the sunk cost of entry, f_E, and preferences, ε.

The shocks follow an AR(1) process:

$$\hat{Z}_t = \rho_Z \hat{Z}_{t-1} + \eta_t^Z, \tag{5.27}$$

$$\hat{f}_{E,t} = \rho_{f_E} \hat{f}_{E,t-1} + \eta_t^{f_E}, \tag{5.28}$$

[10] Table C.4.1 in Appendix C.4 summarises all parameter values and Table C.4.2 in Appendix C.4 summarises all steady state values.

$$\hat{\varepsilon}_t = \rho_\varepsilon \hat{\varepsilon}_{t-1} + \eta_t^\varepsilon, \tag{5.29}$$

where the hat denotes log-deviations from the steady state, ρ is the persistence of the shock, which I set to 0.9 following Ghironi and Melitz (2005), and η_t is the magnitude of the shock in period t.

In Section 5.5.1 I analyse how the financial accelerator effect operates in an open economy. I analyse the effect of financial frictions on the response of the main macroeconomic variables to these shocks by comparing the responses of the model without financial frictions to that of the model with financial frictions. The frictionless economy is generated by turning off the financial accelerator and the external finance premium. To do this, in equation (5.9) I set $s = 1$, and the steady state external finance premium to 0. In Section 5.5.2 I examine how international trade affects the amplification effect of the financial accelerator on the response of the model economy to macroeconomic shocks.

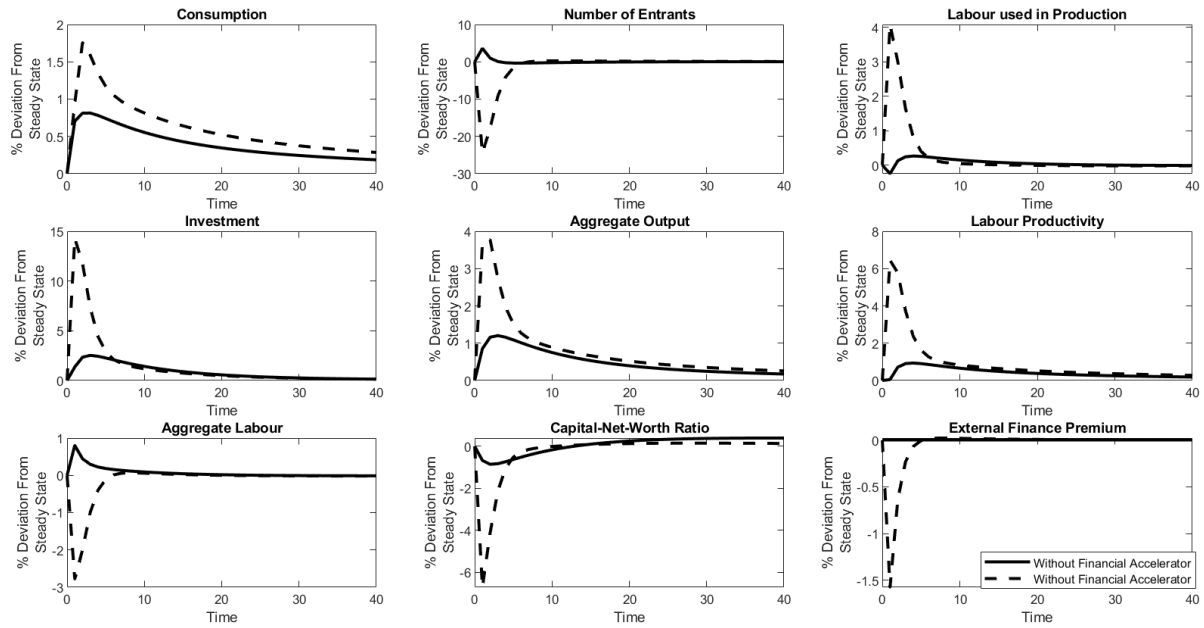
5.5.1 The Effect of the Financial Accelerator

In this section I describe the impulse responses of the economy without and with the financial accelerator. Hereby the solid line shows the impulse responses of the model without financial frictions and the dashed line shows the impulse responses for the model that includes the financial accelerator.

5.5.1.1 Shock to Aggregate Technology

Figure 5.1 illustrates the response of the main macroeconomic variables to a temporary positive 1% shock to aggregate technology.

Figure 5.1: Response to a Temporary Shock to Aggregate Technology



I will first describe the response of the main macroeconomic variables without the financial accelerator. In this set-up, a positive technology shock makes firms more productive. This higher profitability induces more firms to enter the market, causing the number of entrants to increase by 2.99% and the number of domestic firms in the market to increase by 1.13%. As more firms enter the market, more labour is used to pay for the sunk entry costs expressed in effective labour, causing aggregate labour to increase. However, as more labour has to be used to pay for the sunk entry cost, labour used in production decreases slightly on impact, by 0.25%.[11] Due to higher profitability following the technology shock, the demand for capital also increases, leading to an increase of investment of 1.36% relative to the steady state in the first period. In response to a higher demand for capital and for labour, the wage rate and rental rate of capital both increase.[12] This increase in factor prices decreases profitability again, causing the number of entrants to decrease sharply. The labour used to cover sunk entry costs decreases, allowing more labour to be re-allocated to the production of intermediate goods again. All factors return to their steady state levels as the shock dissipates.

In the model with financial frictions the dynamics change. The external finance premium thus now varies with the capital-net worth ratio, affecting the amount individual entrepreneurs are able to borrow. This, in turn, affects the amount of capital they can purchase and then rent out to intermediate good producing firms. When entrepreneurs are less leveraged, they face a lower external finance premium and can take out more loans, and vice versa.

The financial accelerator enhances the above-described effects. As above, an improvement in aggregate technology increases the profitability of firms, which leads to an increase in investment to take advantage of the improved technology. At the same time, the increase in the rental rate of capital increases the net worth of entrepreneurs. As firms are now less leveraged, they face a lower external finance premium, which further increases the amount of investment. Investment and capital thus increase by more than in the frictionless environment due to the additional positive influence of net worth on investment. The main effect of the financial accelerator is thus to increase investment in the first instance. This can be observed from the 3rd quadrant on the 1st line of Figure 5.1: investment increases by 14.29% instead of only 1.36%. At its peak, capital increases by 1.02% relative to the steady state, compared to 0.53% in the frictionless environment.

In line with relatively more capital being available, more labour is used in production relative to the frictionless environment in order to properly take advantage of the increased factors of production, as the factors are not perfectly substitutable. The increase in the factors of production relative to the frictionless economy allows aggregate output to expand by more, namely by 3.78% relative to 1.2% in the frictionless economy.

[11] This occurs due to the following mechanism. Labour supply in the economy is elastic, with households choosing between labour and leisure. As the wage rate increases due to the higher demand for labour, more labour is provided in the aggregate. However, the remuneration does not increase enough to cause a greater increase in aggregate labour; in response to the shock labour is substituted towards paying the sunk entry cost and away from labour used in production.

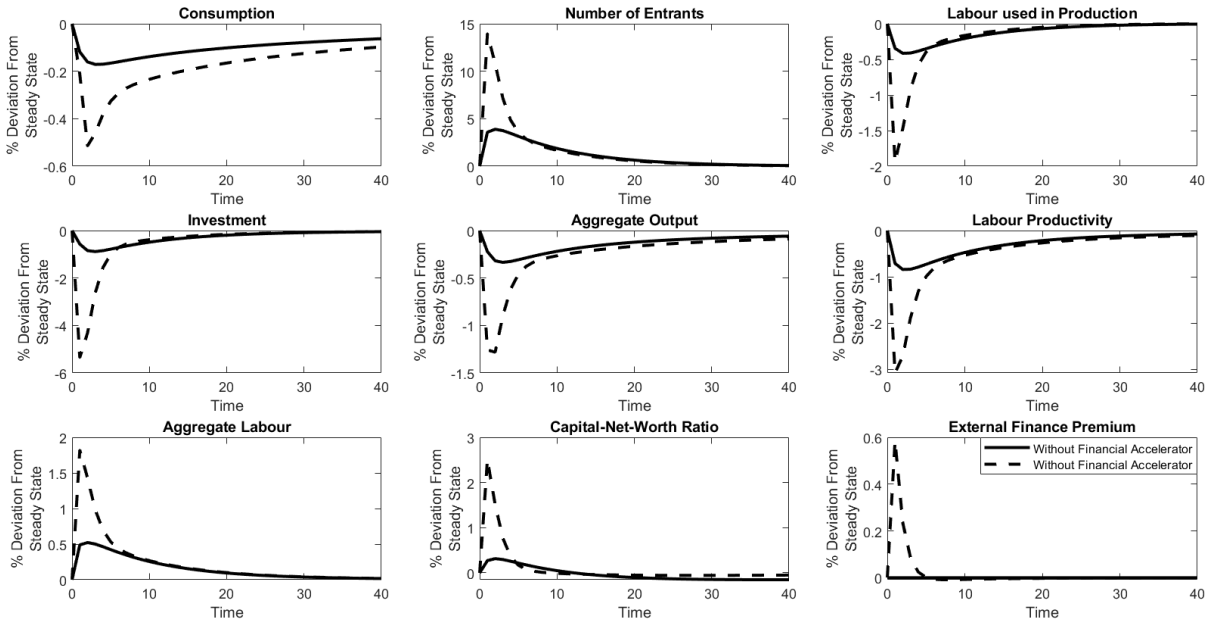
[12] In this model, there are two pressures that influence the wage rate. A higher demand for labour to pay for sunk and fixed costs puts upward pressure on wages. Furthermore, due to diminishing returns to labour, less labour used in production also puts upward pressure on wages as the remaining labour is more productive.

The response of labour productivity is also amplified by the financial accelerator, as can be seen from the 2nd quadrant on the 2nd line of Figure 5.1. As output increases by more in the economy with financial frictions, labour productivity also increases by more, namely by 6.44% relative to 0.93% in the frictionless economy. The financial accelerator thus more than quintuples the magnitude of the response of labour productivity to this shock. The response of labour productivity to this shock is amplified to a larger extent than that of output because of the behaviour of aggregate labour. When the financial accelerator is present, aggregate labour actually falls instead of increasing as in the frictionless environment. As explained above, in the frictionless economy this increase in aggregate labour occurs as more labour is used to pay for sunk entry costs. When the financial accelerator is active, less firms enter the market, causing aggregate labour to decrease. It seems that instead of creating new firms to take advantage of the productivity shock, resources are instead used by intermediate firms taking advantage of the more cheaply available capital. This dynamic causes the response of labour productivity to be amplified considerably.

5.5.1.2 Shock to Sunk Entry Cost

Figure 5.2 illustrates the response of the economy to a temporary one-period negative 1% shock to the sunk cost of entry.

Figure 5.2: Response to a Temporary Shock to Sunk Entry Cost



I will first explain the response of the economy without the financial accelerator to facilitate understanding of the role played by financial frictions. In response to a temporary decrease in the sunk cost of entry, more firms enter the market, causing the number of entering firms to increase by 3.14%.

A change in the cost of entry predominantly impacts entering firms; incumbent firms are impacted mainly indirectly via the effect on the prices of factor inputs. As the financing of new firms becomes cheaper, households pay for the entry of more firms, causing labour to be diverted from labour used in production to labour used to pay for the sunk entry costs. Labour used in production therefore falls by 0.34%. The reasoning behind this fall is the same as in the case of the aggregate technology shock. Labour supply in the economy is elastic, with households choosing between labour and leisure. As the wage rate increases due to the higher demand for labour, more labour is provided in the aggregate. However, the remuneration does not increase enough to cause a greater increase in aggregate labour; in response to the shock labour is substituted towards paying the sunk entry cost and away from labour used in production. Both lower labour used in production and higher demand for labour to pay for sunk costs lead to an increase in the wage rate of 0.12%. As less labour is employed in production, output falls by 0.22% on impact. The lower availability of the final good decreases investment by 0.57% on impact and 0.89% at its trough. As output falls at the same time as more labour is employed to cover sunk costs, labour productivity also decreases, by 0.84%.

As the shock dissipates and the sunk cost of entry increases to its previous level, the number of entering firms decreases again. The sunk cost of entry returns to its steady state level more quickly than the wage rate, thereby increasing the effective cost of entry and causing the number of new entrants to return to its steady state level. Other domestic variables follow and also return to their steady state levels.

Financial frictions change the model dynamics slightly. The loan rate and thus amount entrepreneurs are able to borrow from the bank depends on the capital-net worth ratio; a higher net worth, and thereby lower capital-ne -worth ratio, enables entrepreneurs to borrow more and thus buy more capital.

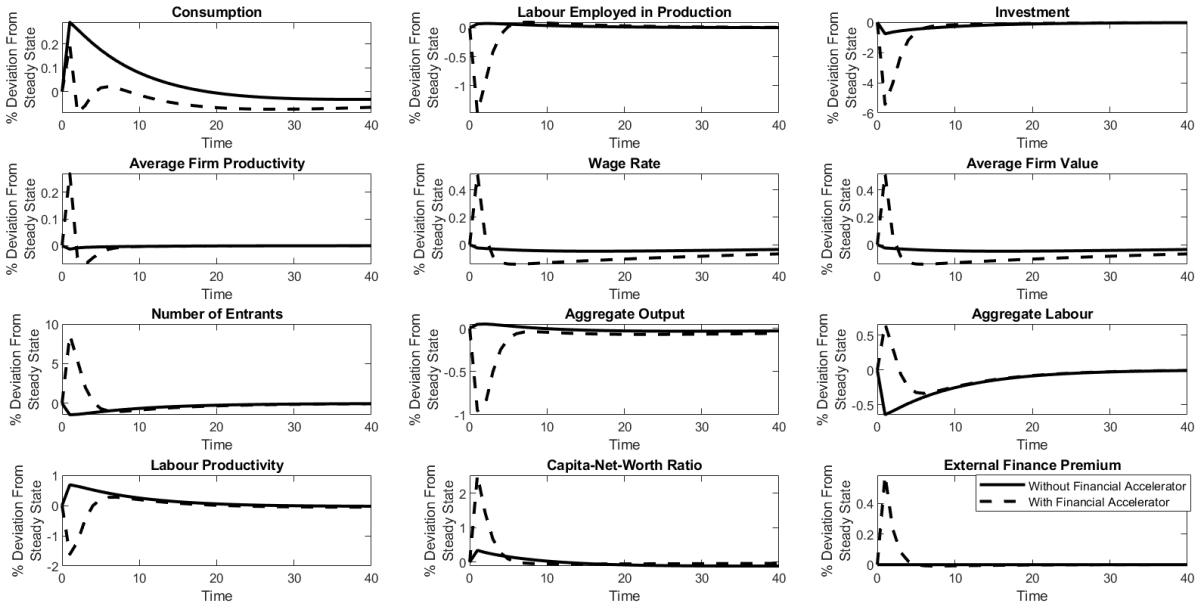
The sunk entry cost shock lowers net worth by reducing the rental rate of capital. This rate changes in response to the shock because of the change in the factor-of-production ratio: as capital is fixed in the first period and labour used in production falls, capital becomes the relatively more abundant factor of production, requiring the rental rate of capital to fall. When the financial accelerator is active, labour used in production decreases by more, which induces a larger adaptation in the wage rate and the rental rate of capital. The rental rate of capital and thus the return to capital falls by more than in the frictionless economy, which causes net worth to fall by more. As net worth falls, entrepreneurs are more highly leveraged, which induces the external finance premium to increase. This, in turn, amplifies the reduction in investment; investment falls by 5.34%. As less labour and capital are used in production, aggregate output also falls by more, namely by 1.28%. In line with the rest of the economy, the response of labour productivity is also amplified, as it decreases 3.08% relative to the steady state. The response of labour productivity is thus tripled in response to this shock.

Allowing for financial frictions therefore mainly amplifies the response of the economy, through the mechanism described above. As in the case of the aggregate technology shock these effects are as expected from Bernanke *et al.* (1999): financial frictions act as an accelerator and amplify the initial response of the economy to the shock to the sunk entry cost.

5.5.1.3 Shock to Preferences

Figure 5.3 illustrates the response of the economy to a temporary positive 1% shock to preferences.

Figure 5.3: Response to a Temporary Shock to Preferences



I will first explain the response of the economy without the financial accelerator to facilitate understanding of the role played by financial frictions. In response to a temporary increase in the preference parameter, the future is temporarily discounted by more. This means that households increase their consumption by 0.29% and decrease the supply of labour by 0.64% to enjoy more leisure time. In order to meet the increased demand, firms re-direct labour towards production, away from sunk entry costs. This causes the number of entering firms in the market to fall, by 1.43%. As labour is re-directed towards production, labour in production increases by 0.07% on impact.

As more labour is used in production, aggregate output increases slightly initially, by 0.05%. As consumption demand increased, more of this final good is spent on consumption, decreasing investment by 0.77%. This decreases the amount of capital available for production in the next period, decreasing aggregate output, which reaches its trough at -0.03% relative to the steady state. Despite the only very small initial increase of output in response to the preference shock, labour productivity increases substantially on impact due to the large decrease in labour, namely by 0.69% .

In response to this shock, current net worth falls as the price of capital decreases due to lower demand for capital, causing entrepreneurs to be more leveraged. When the financial accelerator is active, the price of capital falls by more, which causes net worth to decrease and the capital-net worth ratio to increase by more as well. As the decrease in investment is much higher in response to the shock, labour in production

also decreases. This decrease in labour in production leads to a shift in the factor-of-production ratio, which requires a shift in the factor-price ratio as well, decreasing the rental rate of capital in addition to the price of capital, which further amplifies the response of net worth. In response to lower net worth and a higher capital-net worth ratio, the external finance premium increases, which further decreases the ability of entrepreneurs to take out loans. Investment therefore falls by more than when financial frictions are not active, namely by 5.44%, and the response of output is also amplified, as it decreases by 0.95% relative to the steady state.

Interestingly, the response of labour productivity is reversed by the financial accelerator. While aggregate output falls by significantly more in response to this shock, aggregate labour actually increases, as more labour is used to pay for the sunk entry cost of entering firms. This occurs due to the following dynamics. As labour in production decreases the remaining labour becomes more expensive due to diminishing returns to labour, which increases the wage rate. This, in turn, increases the domestic productivity cut-off level; as the 1st quadrant on the 2nd line of Figure 5.3 shows, average productivity increases when the financial accelerator is active. This is because as the cut-off level increases, the least productive firms are forced out of the market. As the more productive firms remain they increase their market shares, leading to an increase in average profits and the average firm value. When deciding whether to enter the market, firms assess whether the sunk entry cost paid in effective labour is equal to or greater than the average discounted value of running a firm. The above-described dynamics have two major effects on this decision, which work in opposing directions. As the wage rate increases, the sunk entry cost becomes more expensive to finance and the probability of drawing a productivity level large enough to produce decreases, which has a negative effect on the decision to enter. At the same time, the value of producing if having drawn a high enough productivity level increases. It seems that here, the latter effect outweighs the former, and more firms enter the market. This increase in the number of new entrants causes aggregate labour to increase by 0.66%. As output decreases as aggregate labour increases, labour productivity falls by 1.62% on impact, instead of increasing by 0.69% as in the frictionless environment.

5.5.2 The Importance of International Trade for the Amplification Effect

I next analyse the extent to which international trade affects the amplification effect of financial frictions on the macroeconomy, with a focus on the amplification of the response of labour productivity. To do this I compare the responses of aggregate capital, investment, labour used in production, aggregate output, labour productivity and the external finance premium of the following four models: the closed economy version of the frictionless model presented in Section 5.3, the closed economy version of the model with the financial accelerator,[13] the frictionless open economy model, and the open economy model with the financial accelerator. Hereby the lines plot the following. The solid black line plots the frictionless open economy model, the dashed black line plots the open economy model with the financial accelerator, the dash-dotted red line plots the frictionless closed economy version of the model presented in this chapter, and the dotted red line plots the closed economy version of the model presented in this chapter with the financial accelerator.

[13] For the closed economy setting, see Appendix C.3.

5.5.2.1 Shock to Aggregate Technology

Figure 5.4 shows the responses of capital, investment, labour used in production, aggregate output, labour productivity and the external finance premium to a temporary positive 1% shock to aggregate technology. Table 5.1 quantifies these responses, showing numerically how much the relevant variables increase or decrease on impact and at their peak response. Table 5.2 illustrates the effect the financial accelerator (FA) has on the response of these variables by describing the amplification of the response of these variables both in the closed economy and open economy model.

Figure 5.4: Amplification in a Closed and Open Economy in Response to a Temporary Shock to Aggregate Technology

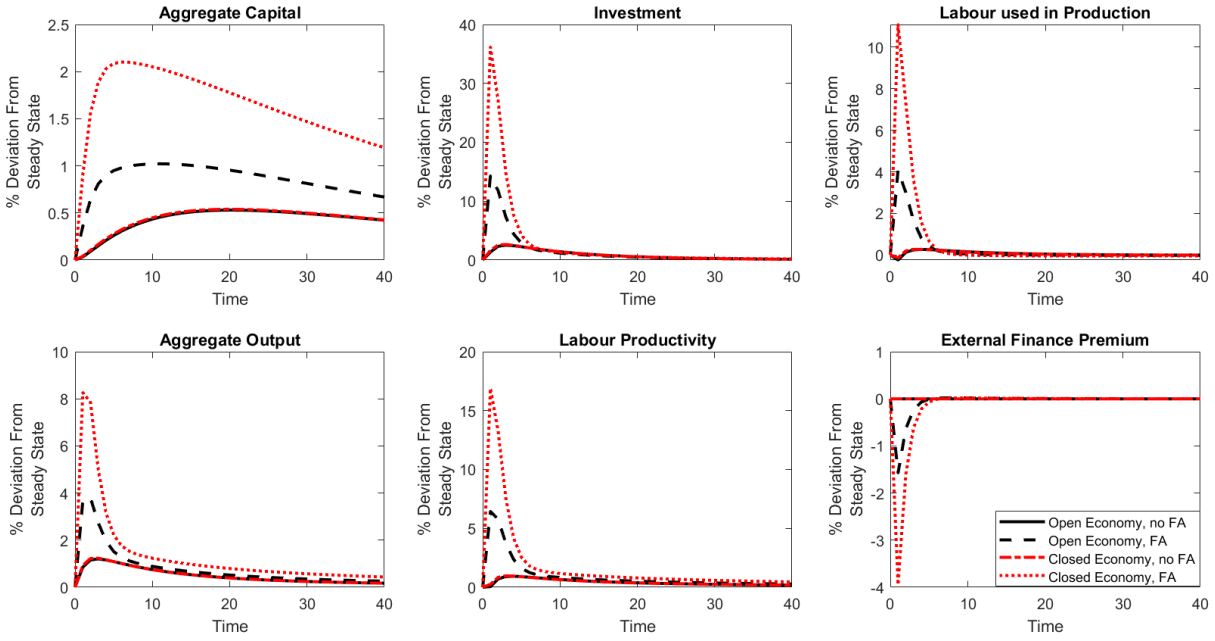


Table 5.2 shows that all variables are amplified by less in the open economy than in the closed economy, both in absolute and in relative terms. The only exception for this is labour productivity: the response of labour productivity is amplified more in the open economy by the financial accelerator than in the closed economy in relative terms on impact. This is because fixed costs are covered by effective labour. A shock to aggregate technology allows more firms to enter the export market, requiring more labour to be used to pay the fixed export costs and causing aggregate labour to decrease by less when the financial accelerator is present. The lower amplification of labour due to the greater demand for labour outweighs the lower amplification of output, causing labour productivity to be amplified by more in relative terms on impact.

The dampening of the financial accelerator in the open economy is driven by two effects: a terms of trade effect and a competitive effect. As the economy becomes more productive, it is possible to produce intermediate goods at a lower cost than in the foreign economy, which decreases prices domestically relative

Table 5.1: Response of Aggregate Capital, Investment, Labour in Production, Output, Labour Productivity and the Finance Premium to Aggregate Technology Shock

	Closed Frictionless Economy	*Closed Economy with FA*	*Open Frictionless Economy*	*Open Economy with FA*
Aggregate Capital	On impact, K=0.04	On impact, K=0.9	On impact, K=0.03	On impact, K=0.36
(K)	At peak, K=0.54	At peak, K=2.1	At peak, K=0.53	At peak, K=1.02
Investment	On impact, I=1.62	On impact, I=36.19	On impact, I=1.36	On impact, I=14.29
(I)	At peak, I=2.65	At peak, I=36.19	At peak, I=2.52	At peak, I=14.29
Labour in Production	On impact, L_P=-0.14	On impact, L_P=11.09	On impact, L_P=-0.25	On impact, L_P=4.08
(L_P)	At peak, L_P=0.27	At peak, L_P=11.09	At peak, L_P=0.27	At peak, L_P=4.08
Output	On impact, Y=0.93	On impact, Y=8.27	On impact, Y=0.85	On impact, Y=3.66
(Y)	At peak, Y=1.23	At peak, Y=8.27	At peak, Y=1.2	At peak, Y=3.78
Labour Productivity	On impact,$LaProd$=0.24	On impact, $LaProd$=16.88	On impact, $LaProd$=0.05	On impact, $LaProd$=6.44
($LaProd$)	At peak, $LaProd$=0.97	At peak, $LaProd$=16.88	At peak, $LaProd$=0.93	At peak, $LaProd$=6.44
Finance Premium	On impact, $Prem$=0	On impact, $Prem$=-3.95	On impact, $Prem$=0	On impact, $Prem$=-1.57

[1] The 1st line describes the response of the variables when the shock hits and the 2nd line the peak impact. When the peak impact occurs in the first period, the values in both lines are the same;

[2] K denotes capital stock, I denotes investment, L_P denotes labour used in production, Y denotes output and $LaProd$ denotes labour productivity.

Table 5.2: Amplification of Responses of Aggregate Capital, Investment, Labour in Production, Output and Labour Productivity to Aggregate Technology Shock

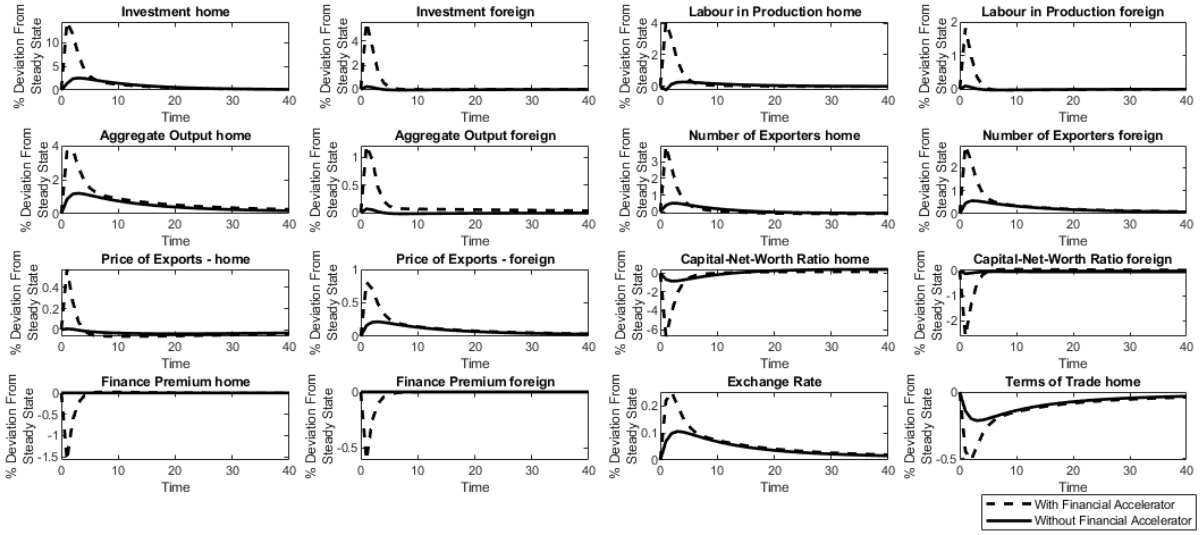
	Closed Economy	*Open Economy*
Aggregate Capital	On impact, 0.86 or *21.5	On impact, 0.33 or *11
(K)	At peak, 1.56 or *2.89	At peak, 0.49 or *0.92
Investment	On impact, 34.57 or *21.33	On impact, 12.93 or *9.51
(I)	At peak, 33.54 or *12.66	At peak, 11.77 or *4.67
Labour in Production	On impact, response is reversed	On impact, response is reversed
(L_P)	At peak, 10.82 or *40.07	At peak, 3.81 or *14.11
Output	On impact, 7.34 or *7.89	On impact, 2.81 or *3.31
(Y)	At peak, 7.04 or *5.72	At peak, 2.58 or *2.15
Labour Productivity	On impact, 16.64 or *69	On impact, 6.39 or *127
($LaProd$)	At peak, 15.91 or *16.4	At peak, 5.51 or *5.92

This table shows the amplification of the response of the variables by the financial accelerator. The 1st line describes the amplification on impact and the 2nd line the amplification of the response of the variables at their peak impact.

to the foreign economy. This causes the exchange rate to depreciate, as can be seen in Figure 5.5.[14]

[14]Note that my formulation of the exchange rate means that a depreciation of the exchange rate signifies an increase in Q_t.

Figure 5.5: The Domestic and Foreign Response to a Temporary Shock to Aggregate Technology



Due to the depreciation, exports become cheaper and the price of imports increases: the terms of trade deteriorate. The increased price of imports decreases the competitiveness of home producers.

In the foreign economy, labour in production increases in response to an improvement of the terms of trade. This is because the increase in the terms of trade means that imports are cheaper relative to exports, which enables an expansion of production. Due to diminishing returns to labour, the wage rate decreases in response to more labour being used in production, decreasing the fixed cost of exporting paid in effective labour. This allows firms that were previously too unproductive to export to enter the export market. The rising number of foreign exporters increases competition in the domestic market, which decreases market shares and therefore the profitability of home producers.

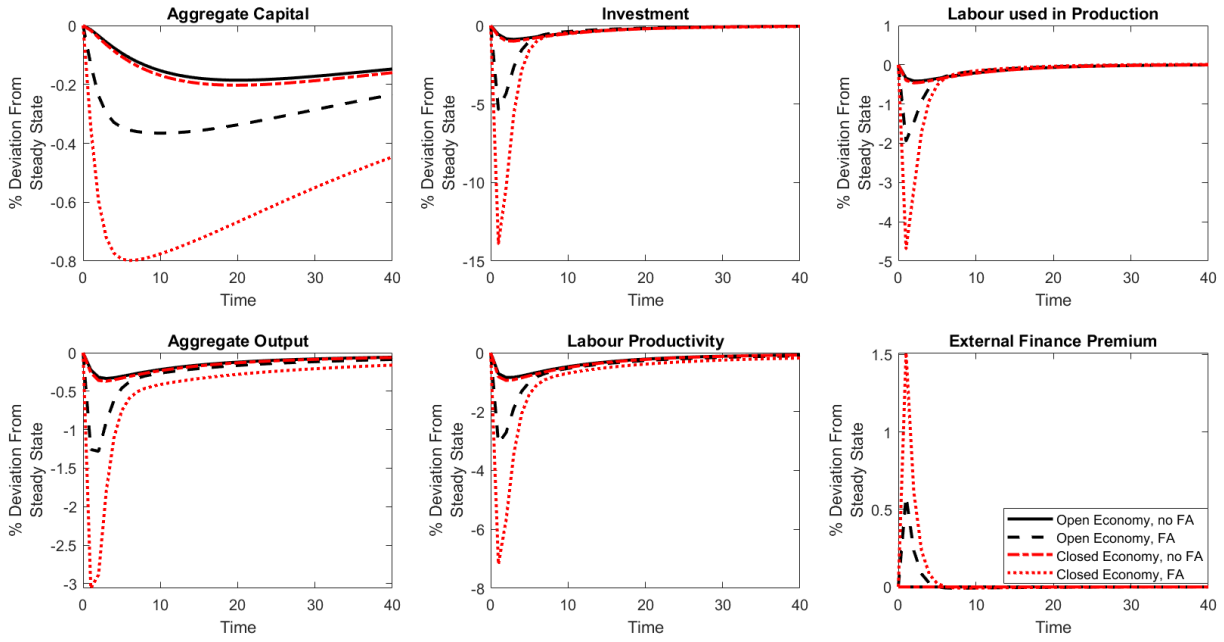
Both the terms of trade effect and the competitive effect decrease the profitability of firms producing at home, causing net worth to rise by less than in the closed ecomomy, where neither effect occurs. This in turn means that the external finance premium decreases by less, allowing entrepreneurs to increase their borrowing by less. These effects lead to a dampened financial accelerator effect in the open economy.

5.5.2.2 Shock to Sunk Entry Cost

Figure 5.6 shows the responses of capital, investment, labour used in production, aggregate output, labour productivity and the external finance premium to a temporary negative 1% shock to the sunk entry cost. Table 5.3 quantifies these responses, showing numerically how much the relevant variables increase or decrease on impact and at their peak response. Table 5.4 illustrates the effect the financial accelerator (FA) has on the response of these variables by describing the amplification of the response of these variables both in the closed economy and open economy model.

Table 5.4 shows that in response to a shock to the sunk cost of entry, the response of all variables is amplified by more in the closed economy than in the open economy. Like in the case of the aggregate technology shock, the presence of international trade thus dampens the amplification effect of the financial accelerator.

Figure 5.6: Amplification in a Closed and Open Economy in Response to a Temporary Shock to the Sunk Entry Cost



As Figure 5.7 shows, both the domestic and the foreign economy contract in response to the shock to the sunk entry cost, which drives the dampening effect of international trade on the financial accelerator. As the sunk entry cost becomes cheaper at home, labour is diverted from production to the payment of sunk entry costs, which induces a contraction in the economy.[15]. As less output is produced, less of the intermediate input from abroad is demanded. As the demand for foreign goods decreases, the value of the foreign currency also decreases, meaning that the home currency appreciates. The appreciation of the home currency makes exports less competitive and increases the terms of trade. As exports become more expensive, imports become relatively cheaper. This allows home foreign-good producers to produce goods more cheaply, increasing the competitiveness of home producers.

Abroad, the exchange rate dynamics lead to a decrease in the foreign terms of trade, which decreases the competitiveness of foreign producers as imports become relatively more expensive. This leads to a contraction in the foreign economy. As labour in production decreases, the wage rate increases due to diminishing returns to labour. This increases the fixed cost of exporting paid in effective labour, forcing firms that can no longer afford to pay this cost to exit the export market. The falling number of foreign

[15]For more information on the mechanisms behind this, see Section 5.5.1.2.

Table 5.3: Response of Aggregate Capital, Investment, Labour in Production, Output, Labour Productivity and the Finance Premium to Sunk Entry Cost Shock

	Closed Frictionless Economy	*Closed Economy with FA*	*Open Frictionless Economy*	*Open Economy with FA*
Aggregate Capital	On impact, K=-0.02	On impact, K=-0.35	On impact, K=-0.01	On impact, K=-0.13
(K)	At peak, K=-0.2	At peak, K=-0.8	At peak, K=-0.19	At peak, K=-0.37
Investment	On impact, I=-0.69	On impact, I=-13.89	On impact, I=-0.57	On impact, I=-5.34
(I)	At peak, I=-0.99	At peak, I=-13.89	At peak, I=-0.89	At peak, I=-5.34
Labour in Production	On impact, L_P=-0.4	On impact, L_P=-4.69	On impact, L_P=-0.34	On impact, L_P=-1.94
(L_P)	At peak, L_P=-0.46	At peak, L_P=-4.69	At peak, L_P=-0.41	At peak, L_P=-1.94
Output	On impact, Y=-0.26	On impact, Y=-3.06	On impact, Y=-0.22	On impact, Y=-1.26
(Y)	At peak, Y=-0.37	At peak, Y=-3.06	At peak, Y=-0.34	At peak, Y=-1.28
Labour Productivity	On impact, $LaProd$=-0.82	On impact, $LaProd$=-7.18	On impact, $LaProd$=-0.71	On impact, $LaProd$=-3.08
($LaProd$)	At peak, $LaProd$=-0.94	At peak, $LaProd$=-7.18	At peak, $LaProd$=-0.84	At peak, $LaProd$=-3.08
Finance Premium	On impact, $Prem$=0	On impact, $Prem$=1.51	On impact, $Prem$=0	On impact, $Prem$=0.58

[1] The 1st line describes the response of the variables when the shock hits and the 2nd line the peak impact. When the peak impact occurs in the first period, the values in both lines are the same;

[2] K denotes capital stock, I denotes investment, L_P denotes labour used in production, Y denotes output and $LaProd$ denotes labour productivity.

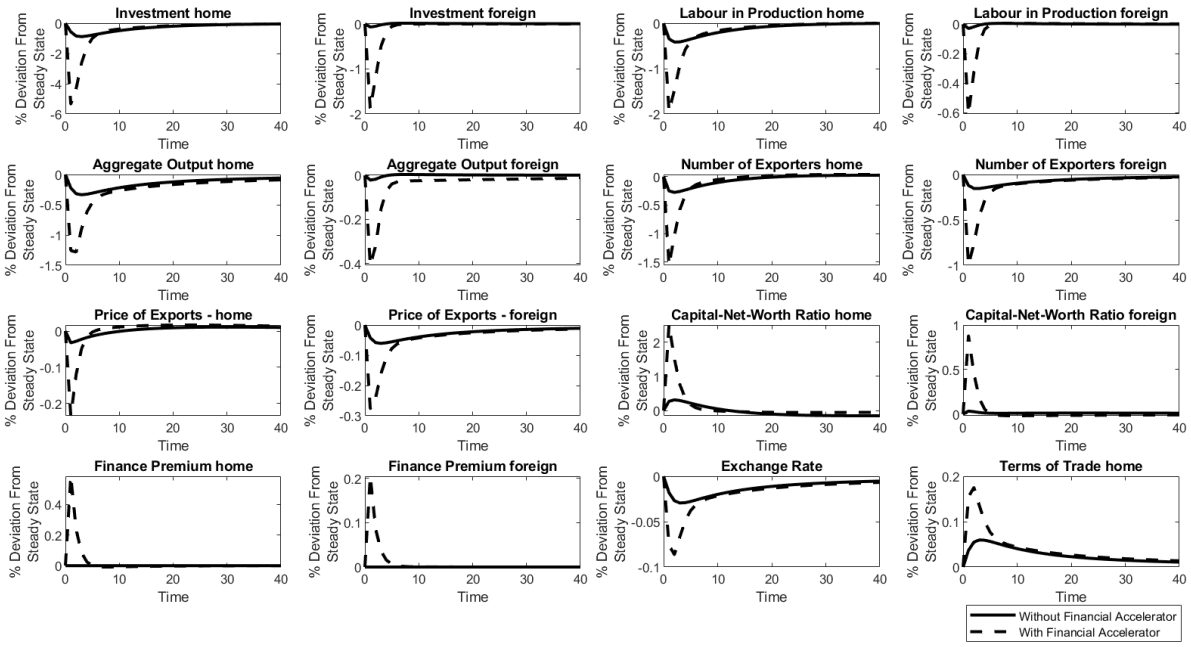
Table 5.4: Amplification of Responses of Aggregate Capital, Investment, Output and Labour Productivity to Sunk Entry Cost Shock

	Closed Economy	*Open Economy*
Aggregate Capital	On impact, 0.33 or *16.5	On impact, 0.12 or *12
(K)	At peak, 0.62 or *3	At peak, 0.18 or *0.95
Investment	On impact 13.2 or *19.1	On impact 4.77 or *8.37
(I)	At peak, 12.9 or *13.03	At peak, 4.45 or *5
Labour in Production	On impact 4.29 or *10.73	On impact 1.6 or *4.7
(L_P)	At peak, 4.23 or *9.2	At peak, 1.53 or *3.73
Output	On impact 2.8 or *910.77	On impact 1.04 or *4.73
(Y)	At peak, 2.69 or *7.27	At peak, 0.94 or *2.76
Labour Productivity	On impact, 6.36 or *7.76	On impact 2.37 or *3.34
($LaProd$)	At peak, 6.24 or *6.64	At peak, 2.24 or *2.67

This table shows the amplification of the response of the variables in the closed and open economy. The 1st line describes the amplification on impact and the 2nd line the amplification at the peak response of the respective variables. Each line shows both the absolute percentage points by which the response increased and the relative increase of the response.

exporters in the domestic market decreases competition in the home market, thereby increasing home profitability.

Figure 5.7: The Domestic and Foreign Response a Temporary Shock to Sunk Entry Cost



Both the terms of trade effect and the competitive effect increase the profitability of firms producing at home, causing net worth to fall by less than in the closed ecomomy, where neither effect occurs. This in turn means that the external finance premium increases by less, allowing entrepreneurs to maintain a higher level of borrowing. These effects lead to a dampened financial accelerator effect in the open economy.

5.5.2.3 Shock to Preferences

Figure 5.8 shows the responses of capital, investment, labour used in production, aggregate output, labour productivity and the external finance premium to a temporary positive 1% shock to preferences, whereby the future is temporarily discounted by more. Table 5.5 quantifies these responses, showing numerically how much the relevant variables increase or decrease on impact and at their peak response. Table 5.6 illustrates the effect the financial accelerator (FA) has on the response of these variables by describing the amplification of the response of these variables both in the closed economy and open economy model. The effect of international trade on the amplification effect of financial frictions is a little bit harder to describe for a preference shock, as the financial accelerator does not simply amplify the magnitude of responses, but actually reverses the response of many variables. Out of all the variables shown in Figure 5.8, this applies to labour in production, aggregate output and labour productivity. For investment and aggregate capital, the response is simply amplified by financial frictions. As in the case with previous shocks, it is more amplified in the closed economy setting, meaning that international trade decreases the amplification effect of financial frictions in response to a preference shock.

Figure 5.8: Amplification in a Closed and Open Economy in Response to a Temporary Shock to Preferences

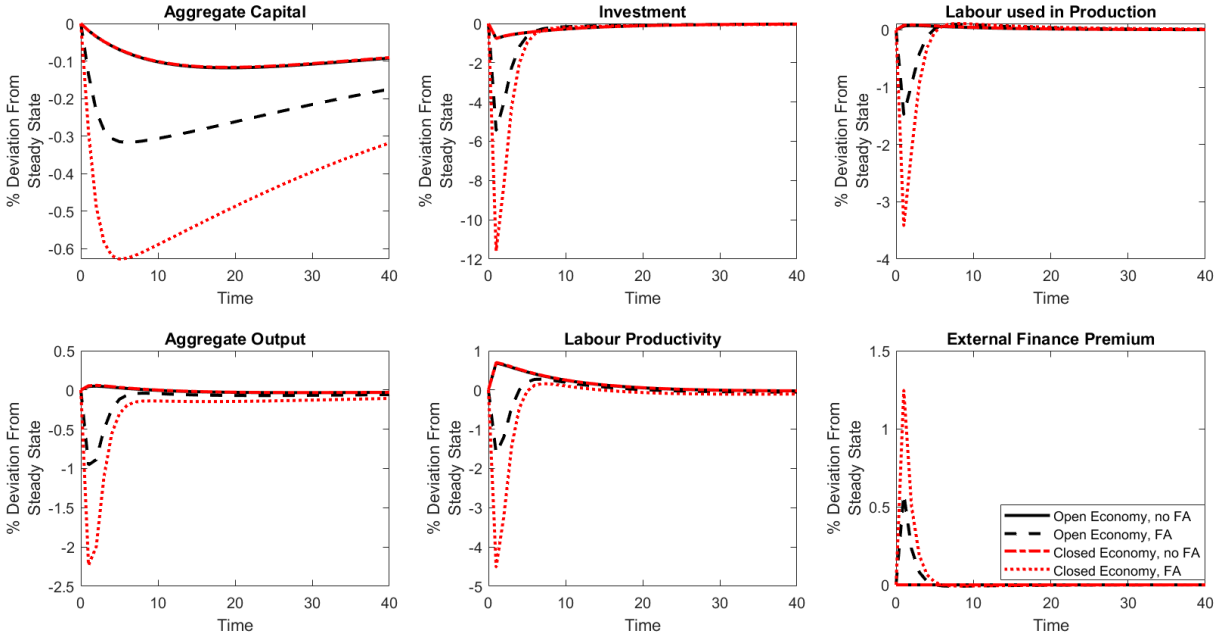
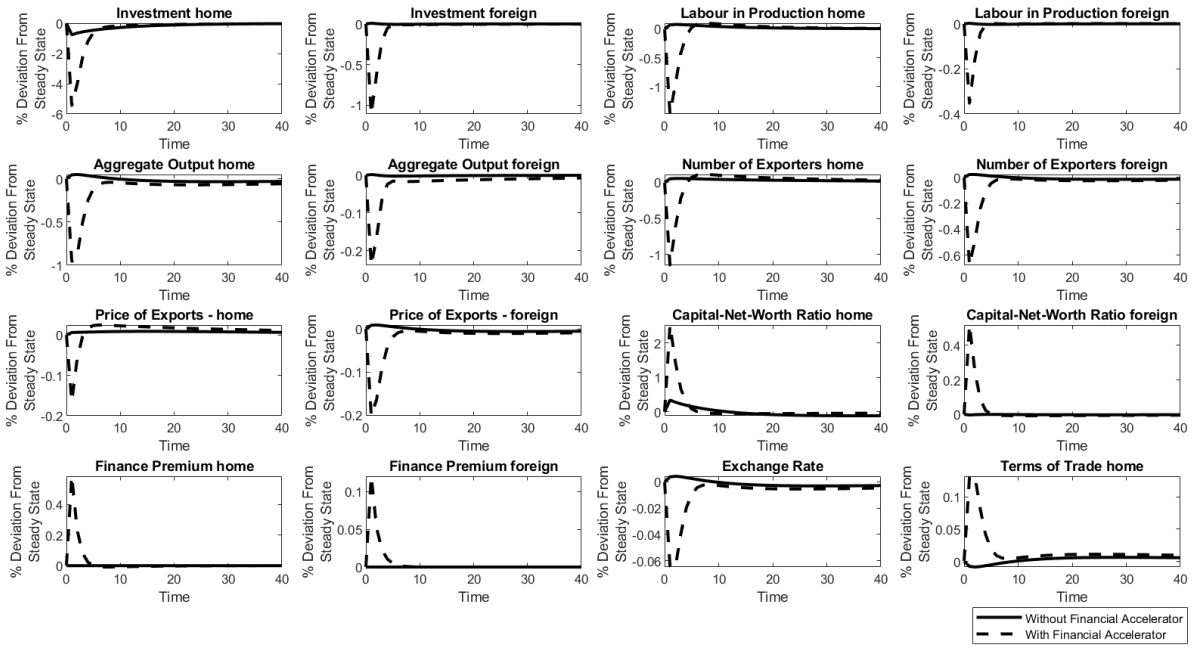


Figure 5.9: The Domestic and Foreign Response to a Temporary Shock to Preferences



For labour in production and output, Table 5.6 shows that financial frictions reverse the direction of the initial response, and also amplify it. Again, international trade dampens this amplification effect. In the

Table 5.5: Response of Aggregate Capital, Investment, Labour in Production, Output, Labour Productivity and the Finance Premium to Preference Shock

	Closed Frictionless Economy	*Closed Economy with FA*	*Open Frictionless Economy*	*Open Economy with FA*
Aggregate Capital (K)	On impact, K=-0.02 At peak, K=-0.12	On impact, K=-0.29 At peak, K=-0.63	On impact, K=-0.02 At peak, K=-0.12	On impact, K=-0.14 At peak, K=-0.32
Investment (I)	On impact, I=-0.76 At peak, I=-0.76	On impact, I=-11.58 At peak, I=-11.58	On impact, I=-0.77 At peak, I=-0.77	On impact, I=-5.44 At peak, I=-5.44
Labour in Production (L_P)	On impact, L_P=0.08 At peak, L_P=0.09	On impact, L_P=-3.42 At peak, L_P=-3.42	On impact, L_P=0.07 At peak, L_P=0.08	On impact, L_P=-1.47 At peak, L_P=-1.47
Output (Y)	On impact, Y=0.05 At peak, Y=0.06	On impact, Y=-2.23 /	On impact, Y=0.04 At peak, Y=0.05	On impact, Y=-0.95 /
(Y)	At undershooting trough, Y=-0.03	At trough, Y=-2.23	At undershooting trough, Y=-0.03	At trough, Y=-0.95
Labour Productivity ($LaProd$)	On impact, $LaProd$=0.7 At peak, $LaProd$=0.7	On impact, $LaProd$=-4.51 At trough, $LaProd$=-4.51	On impact, $LaProd$=0.69 At peak, $LaProd$=0.69	On impact, $LaProd$=-1.62 At trough, $LaProd$=-1.62
Finance Premium	On impact, $Prem$=0	On impact, $Prem$=1.25	On impact, $Prem$=0	On impact, $Prem$=0.58

[1] The 1st line describes the response of the variables when the shock hits and the 2nd line the peak impact. When the peak impact occurs in the first period, the values in both lines are the same;

[2] K denotes capital stock, I denotes investment, L_P denotes labour used in production, Y denotes output and $LaProd$ denotes labour productivity.

case of labour productivity, financial frictions also reverse and amplify the direction of the initial response. This macroeconomic variable either undershoots or overshoots its steady state level as the shock dissipates in all four cases. Table 5.6 shows that financial frictions amplify this over-/undershooting response, and that this amplification is decreased in an open economy.

Similarly to the other shocks, international trade therefore dampens the amplification effect of financial frictions. This occurs because of a terms of trade and a competitive effect. As preferences change and consumers temporarily prefer to consume more and work less, less output is produced and the economy contracts.[16]. As less output is produced, final good producers require less of the intermediate good from abroad. The decrease in the demand for foreign goods causes the value of the foreign currency to decrease, meaning that the home currency appreciates. This can be seen from Figure 5.9, as the exchange rate falls when the financial accelerator is active.[17] The appreciation of the home currency makes exports less competitive, increasing the terms of trade. As exports become more expensive, imports become relatively cheaper. This allows home foreign-good producers to produce goods more cheaply, increasing the competitiveness of home producers.

In the foreign economy, the fall in Q_t leads to a decrease in the foreign terms of trade, causing imports to

[16] For more information on the mechanisms behind this, see Section 5.5.1.3.

[17] Note that my formulation of the exchange rate means that a depreciation of the exchange rate signifies an increase in Q_t.

Table 5.6: Amplification of Responses of Aggregate Capital, Investment, Output and Labour Productivity to Preference Shock

	Closed Economy	*Open Economy*
Aggregate Capital (K)	On impact, 0.27 or *13.5 At peak, 0.51 or *4.25	On impact, 0.12 or *6 At peak, 0.2 or *1.67
Investment (I)	On impact, 10.82 or *14.24 At peak, 10.82 or *14.24	On impact, 4.67 or *6.06 At peak, 4.67 or *6.06
Labour in Production (LP)	On impact response is reversed, initial response *41.75	On impact response is reversed, initial response *20
Output (Y)	On impact response is reversed, initial response *43.6	On impact response is reversed, initial response *22.75
Labour Productivity	On impact response is reversed, initial response *6.44	On impact response is reversed, initial response *2.35

This table shows the amplification of the response of the variables in the closed and open economy. The 1st line describes the amplification on impact and the 2nd line the amplification at the peak response or the overshooting/undershooting response of the respective variables. Where the response was only amplified and not reversed by financial frictions, each line shows both the absolute percentage points by which the response increased and the relative increase of the response. Where the response was reversed by financial frictions, only the relative increase of the magnitude of the response is shown.

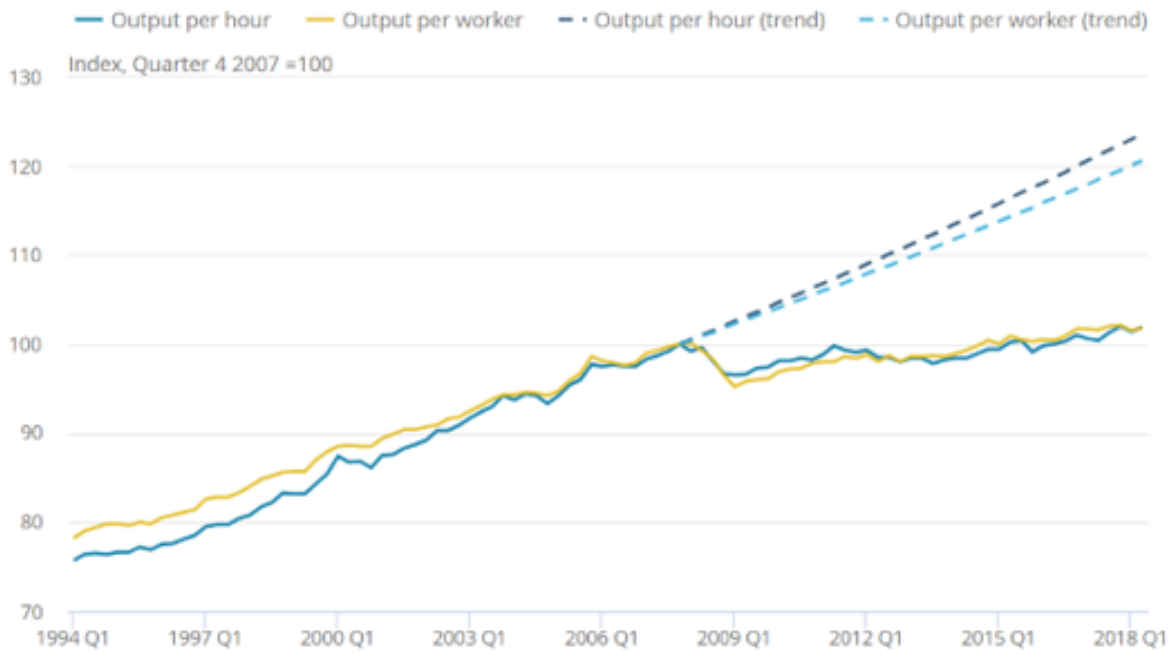
become relatively more expensive. Due to the relative increase in the price of imports, less is imported and output in the foreign economy falls. As labour in production decreases as a result, the wage rate increases due to diminishing returns to labour, increasing the fixed exporting cost paid in effective labour. The increase in this cost forces firms that were previously productive enough to export to exit the export market. The falling number of foreign exporters in the domestic market decreases competition in the home market, thereby increasing the profitability of home producers.

As the terms of trade effect and the competitive effect increase the profitability of firms producing at home, net worth falls by less than in the closed ecomomy, where neither effect occurs. This in turn means that the capital-to-net worth ratio and therefore the external finance premium increase by less, allowing entrepreneurs to borrow more relative to the closed economy. These effects lead to a dampened financial accelerator effect in the open economy.

5.6 Application to the UK Productivity Puzzle

In this section I analyse the extent to which financial frictions can explain the UK Productivity Puzzle. I hereby contribute to the literature attempting to provide an explanation for the protracted labour productivity weakness observed in the United Kingdom since the 2008 financial crisis, referred to in the

Figure 5.10: The UK Productivity Puzzle



literature as the UK Productivity Puzzle. This weakness in UK labour productivity is illustrated in the graph below.

The graph in Figure 5.10 shows that labour productivity, measured both as output per worker and as output per hour, dropped sharply in 2008, at the start of the financial crisis, and has remained sluggish since. In the three business cycles preceding the crisis, labour productivity grew at an average yearly rate of 1.61%, 2.47% and 2.22% respectively. Since the second quarter of 2009, it has only grown at an average of 0.56% per year.[18]

In this chapter, I contribute to the literature seeking to explain the UK Productivity Puzzle by examining the extent to which financial frictions can help explain the protracted labour productivity weakness that was witnessed in the UK. Labour productivity started decreasing in the UK in 2008Q2 and continued to fall until 2009Q1, at which point it had fallen by 4.2% relative to the start of the crisis. This constitutes a level relative to trend of -5.4%.[19] Labour productivity started to recover in 2009Q2, but never reached

[18]These figures arise from the author's own calculations. I used data on labour productivity growth from the ONS, available at `https://www.ons.gov.uk/employmentandlabourmarket/peopleinwork/labourproductivity/timeseries/txbb/prdy`, to calculate peak-to-peak average growth rates over the last three business cycles. The motivation for using my own estimates is that growth figures vary slightly across papers. Hughes and Saleheen (2012), for example argue that the pre-crisis average annual growth rate of labour productivity was 2.4%, while the average annual growth rate since the crisis was 0.5%. According to Abel *et al.* (2016), the pre-crisis average annual growth rate of labour productivity was 2.2%, and the average annual growth rate since the crisis was merely 0.2%. Regardless of what precise figures are used, the substantial labour productivity weakness is evident.

[19]To calculate these statistics I used data from ONS, available at `https://www.ons.gov.uk/employmentandlabourmarket/peopleinwork/labourproductivity/datasets/labourproductivity`. To calculate a trend path for labour productivity and

its pre-crisis trend. In 2019Q2 labour producivity was still 15.05% lower than it would have been had it continued growing at its pre-crisis trend.

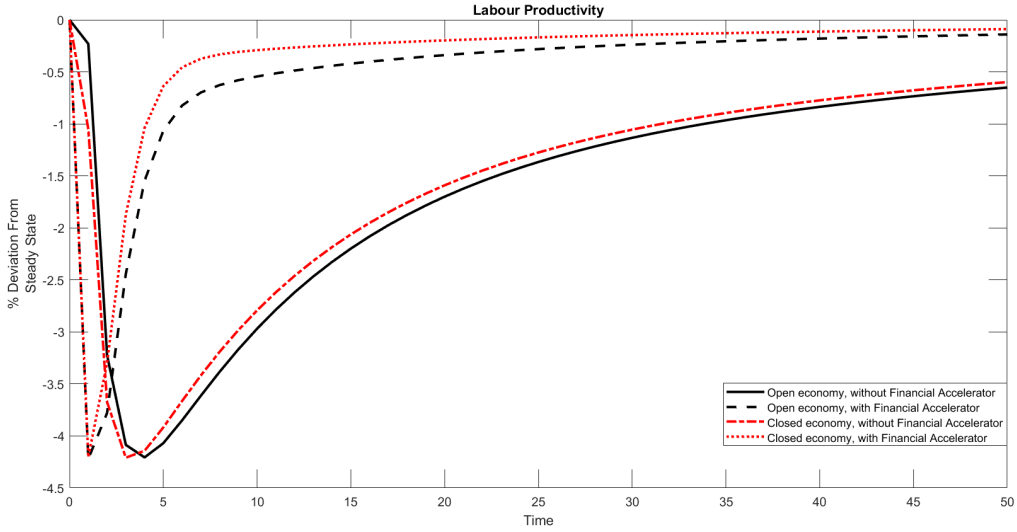
In order to examine whether financial frictions can help explain the protracted productivity weakness in the UK since the crisis, I calibrated a productivity shock in my four model economies to yield a decrease in labour productivity that is equivalent to the fall in UK labour productivity during the crisis. Hereby the productivity shock is a proxy for the demand shock that was witnessed. I calibrated and simulated this shock for the closed economy without financial frictions, the closed economy with financial frictions, the open economy without financial frictions, and the open economy with financial frictions. Each time I calibrated the shock to yield a decrease in labour productivity of 4.2%, the maximum decrease in labour productivity that was observed in the UK during the financial crisis. Since labour productivity started falling in 2008Q2, that is what I interpret as period 1, the period the shock hits. As Figure 5.11 shows, the maximum impact is reached instantaneously in the economies with financial frictions, whereas it is reached only in period 4 in the frictionless economies. I calibrate the shocks to the maximum decrease and not decrease on impact because I am interested in examining whether financial frictions can help explain why labour productivity did not recover after its maximum decrease. To do this I need to compare the behaviour of labour productivity after the shock in the economies with and without the financial accelerator following the same maximum decrease. It is interesting to note that the size of the shock required to yield the maximum decrease is much lower in the economy with financial frictions than in the frictionless economy. This prediction is in line with research that indicates that financial frictions can create a deeper crisis. However, here we are interested in the role financial frictions play for the recovery of the economy after a given decrease in labour productivity, not the size of the initial shock.

In Figure 5.11, the solid black line denotes the response of the open economy without financial frictions, the dashed black line denotes the response of the open economy with financial frictions, the red dash-dotted line plots the response of the closed economy without financial frictions and the red dotted line plots the response of the closed economy with financial frictions.

Figure 5.11 shows that financial frictions do not contribute much to explaining the UK Prductivity Puzzle, as the black dashed line and the red dotted line return to the steady state much more quickly than the black solid and the red dot-dashed lines. When financial frictions are present, in response to a negative aggregate technology shock entrepreneurs find it harder to borrow money as their net worth decreases. This induces investment and thereby output and labour productivity to decrease. However, as the shock dissipates, net worth increases again rapidly, thereby loosening the credit constraints and allowing entrepreneurs to increase their borrowing again. Due to this, the economy recovers more quickly than when financial frictions are not present. Figure 5.11 therefore shows that the economy without financial frictions more closely replicates the behaviour of labour productivity in the UK following the financial crisis, as the decrease in labour productivity is more persistent.

deviations from trend I calculated and extrapolated the average growth rate of labour productivity from 1990Q2-2008Q1. The trend path was calculated by assuming that labour productivity grew at the average rate every quarter since 1990Q2. Deviations from trend are differences between these values and observed values.

Figure 5.11: Application to the UK Productivity Puzzle



My model incorporates a similar mechanism to that of Chadha *et al.* (2017), as financial frictions amplify the response of labour productivity to shocks. However, this does not necessarily mean that they also lead to a higher persistence. Chadha *et al.* (2017) do not apply their model to the UK Productivity Puzzle, but simply argue that it is conceivable that financial frictions, by amplifying the response of productivity, may help explain the Puzzle. My model shows that this is not the case. While in response to a negative aggregate technology shock banks do decrease their lending, thereby decreasing investment, output and productivity, they increase their lending again after the shock passed. This allows firms to recover more quickly than if such a loosening of credit constraints did not occur.

More specifically, labour productivity is still at -0.15% relative to the steady state in the open economy with financial frictions after 45 periods, which I interpret as 2019Q2. In the closed economy with financial frictions, labour productivity is at -0.73% relative to its steady state level after 45 periods. These figures compare to an actual labour productivity shortfall of 15.05% in 2019Q2. Financial frictions can therefore explain around 1% of the productivity shortfall that was still seen in 2019Q2. This is considerably lower than the estimates of Franklin *et al.* (2015) and Besley *et al.* (2020), but is in line with the argument of Riley *et al.* (2014*a*) and Riley *et al.* (2014*b*) that financial frictions are not the driving factor of the Productivity Puzzle in the UK.

My modelling of the UK Productivity Puzzle is relatively crude, and my result that financial frictions do not play a large role in explaining the puzzle may rest on the assumption that banks, once the shock passed, are willing to once again lend. During the 2008 financial crisis we saw that banks were unwilling to lend to increase their own liquidity. Incorporating such a mechanism into my model would allow me to capture such dynamics, and would conceivably cause more persistence in the response of labour productivity when financial frictions are present. However, while my model lacks these more specific dynamics, it does show that in response to a shock leading to a large decline in trade and productivity,

it is vital to increase lending again as quickly as possible. This substantially decreases the time it takes firms to recover, thereby decreasing the time it takes for labour productivity to return to its pre-crisis trend.

5.7 Conclusion

The 2008 financial crisis was characterised by both a dramatic fall in global trade and a substantial credit crunch, highlighting the significance of both these factors for output and productivity. This importance has also been well-established in the literature, and a growing amount of literature shows that financial frictions can also distort international trade. Despite important advances in this field, the joint effect of financial frictions and trade on productivity is not well understood.

It stands to reason that if financial frictions negatively affect productivity, international trade positively affects productivity and financial frictions distort international trade, then international trade may change the way in which financial frictions affect the response of macroeconomic variables to macroeconomic shocks. In this chapter I provided a framework to study and quantify the joint effect of financial frictions and trade on productivity, and the extent to which international trade affects the amplification effect of financial frictions. I implemented the standard and well-known financial accelerator from Bernanke *et al.* (1999) into a 2-country DSGE model of international trade model that is based on Ghironi and Melitz (2005). Two main findings stand out from my analysis. Firstly, I show that the well-known financial accelerator effect of amplifying the response of the economy to macroeconomic shocks also holds in an international trade model. Secondly, I show that the amplification of the response of the economy is dampened by the presence of international trade. Like Caggese and Cuñat (2013), Brooks and Dovis (2020) and Kohn *et al.* (2017) I thus show that the joint consideration of international trade and financial frictions is highly important for productivity. Models that consider the effect of financial frictions on productivity in a closed economy model overstate the impact of financial frictions on the dynamic response of labour productivity.

There are several avenues for further research. In the first instance, in this model financial frictions affect international trade and domestic production by the same mechanism; international trade thus simply dampens the effect of financial frictions. As exporting is more dependent on external finance than domestic production, extending the model to incorporate differential levels of financial frictions for the domestic and exporting sector could be useful. Furthermore, the model could be extended to include financing frictions between the bank and households in addition to the financing frictions between the bank and firms. This would put a greater emphasis on the importance of the banking sector, and could further help explain why credit collapsed during the 2008 crisis.

Chapter 6

Conclusion

In this thesis I addressed three distinct areas of international macroeconomics. In Chapter 3 I empirically re-considered four prominent puzzles in international macroeconomics with contemporary data, in Chapter 4 I analysed how resource allocation and endogenous entry into domestic production affect the dynamic response of labour productivity to a variety of macroeconomic shocks in an international trade framework, and in Chapter 5 I examined the extent to which international trade affects the amplifying effect of financial frictions.

In Chapter 3 I addressed four prominent puzzles in international macroeconomics. These were the Quantity Puzzle, which refers to the inability of standard models of international trade to match and thereby explain that the cross-country correlation of output exceeds the cross-country correlation of consumption in data, the Positive Co-movement Puzzle, which describes the inability of standard models to match and thereby explain the simultaneous positive co-movement of output, consumption, investment and employment, the Backus-Smith Puzzle, which refers to the inability of standard models to generate and therefore explain the negative correlation between real exchange rates and relative consumption ratios that is found in data, and the Terms of Trade Puzzle, which describes the inability of standard models of international trade to replicate and therefore explain a high volatility of the terms of trade relative to output. The four data patterns that underlie these puzzles are frequently used as validation mechanisms for international trade models, and many papers attempt to build models that resolve the puzzles. However, the vast majority of this literature uses very US-focused and relatively old data. In Chapter 3 I re-examined the four puzzles with recent data and investigated whether the data patterns underlying the puzzles still exist in recent data. In other words, I examined whether the stylised facts that have been addressed in the literature still persist today. Four main results stand out from this analysis. First, I find that the data pattern that underlies the Quantity Puzzle is less prominent in recent data than in older data, as only 65% of the sample exhibits a cross-country correlation of output that exceeds the cross-country correlation of consumption. Furthermore, this data pattern continues to hold for developing countries, but no longer holds for high-income countries. The intuition behind the decrease in the prominence of the data pattern and the heterogeneity of the pattern across country groups is increased globalisation, specifically an increase in financial integration. Second, terms of trade are less volatile than output in recent data for the majority of countries, especially for high-income and EU countries. This is driven by increased

trade integration and competition, and a high degree of intra-industry trade. Third, the data pattern underlying the Backus-Smith Puzzle has become less frequent in recent data. The reason for this is the creation of the European Monetary Union, as the single currency substantially decreases the likelihood that a country-pair's real exchange rate and relative consumption are negatively correlated. For countries that are not part of a single currency, the observation that real exchange rates and relative consumptions tend to be negatively correlated remains a stylised fact. Fourth, positive co-movement among macroeconomic variables continues to persist in recent data and across many country-pairs. The implications of these results for the literature are as follows. First, I show that stylised facts can change over time and differ across country groups. As stylised facts are frequently used as a validation mechanism for macroeconomic models, a greater awareness of this fact is important to ensure that models are validated using data patterns that are still present in recent data. Second, to account for the heterogeneity of data patterns across country-groups, models need to include mechanisms that are appropriate for the country-group that is being modelled and calibrated for. My results suggest that features such as different levels of intra-industry trade and financial integration, as well as trade in commodities can be important for international trade models in matching the heterogeneity of macroeconomic patterns across country-groups.

In Chapter 4 I addressed the importance of resource allocation and endogenous entry into domestic production in an international trade model. This analysis was motivated by the fact that international trade models tend to abstract from endogenous entry, and models that account for endogenous entry tend to abstract from international trade, despite both factors having been shown to be important for the business cycle. Furthermore, insofar as endogenous entry and international trade are combined in a unified framework, usually only one factor of production is considered. However, we also know that resource allocation can have important implications for the economy. In Chapter 4 I therefore analysed how resource allocation changes the response of the economy to macroeconomic shocks relative to a model with only one factor of production while accounting for endogenous entry into domestic production. The results are as follows. First, capital introduces an element of persistence into the economy, as the time it takes for the variables to return to their steady state levels increases. Second, the interaction of resource allocation and endogenous selection of firms into domestic production reverses the initial response of labour productivity to an aggregate technology shock relative to MNN. These results on one hand confirm what is well-known, namely that capital introduces persistence into the response of the economy. On the other hand, my results pertaining to the response of labour productivity are novel, and show that the omission of a second factor of production does indeed significantly affect the response of the economy, especially the response of labour productivity.

In Chapter 5 I studied the extent to which international trade affects the effect of financial frictions. To carry out this analysis I first replicated the well-known amplification effect of financial frictions and showed that financial frictions also amplify the response of the economy to macroeconomic shocks in an open economy setting. I then showed that international trade dampens this amplification effect. This occurs because of a terms of trade and a competitive effect. In the case of an expansionary technology shock to the economy, the exchange rate depreciates, inducing a deterioration in the terms of trade. In the foreign economy, the improvement in the foreign terms of trade leads to a decrease in the wage rate, which decreases the fixed cost of exporting and allows more foreign firms to enter their export market,

thereby increasing competition in the home market. Both the terms of trade and competitive effect decrease the profitability of home firms. This means that net worth increases by less relative to the closed economy, allowing entrepreneurs to increase their borrowing by less. These dynamics create a dampened financial accelerator effect relative to the closed economy. In the case of a negative sunk entry cost shock and a positive preference shock the opposite applies: the terms of trade and competitive effect increase the profitability of home producers, causing net worth to fall by less relative to the closed economy. This allows entrepreneurs to maintain a higher level of borrowing, leading to a dampened financial accelerator effect. The implication of these results is that models that abstract from international trade either overstate or understate the impact of financial frictions on labour productivity and the economy.

Important avenues for further research remain in the areas addressed in this thesis. For the literature on macroeconomic puzzles, my results suggest that it continues to be important to find explanations that resolve the Positive Co-movement Puzzle and the Backus-Smith Puzzle. To build on my novel results it would be useful to employ a more rigorous empirical analysis and a wider set of macroeconomic variables to examine precisely what circumstances affect the ranking of the cross-country correlations of output and consumption, as well as the volatility of the terms of trade. This would provide us with a greater understanding of what drives the heterogeneity of the data patterns underlying the Quantity Puzzle and the Terms of Trade Puzzle across country-groups. Regarding the Backus-Smith Puzzle, more research into what macroeconomic variables affect the sign of the correlation of the real exchange and relative consumption within a monetary union would be important to better understand the drivers of the puzzle. To corroborate the results presented in Chapter 4 it would be useful to contrast them with UK data, for example data on the volatility of labour productivity or entry patterns over the business cycle. In the area of international trade, financial frictions and productivity, possible further research avenues are as follows. As exporting is more dependent on external finance than domestic production, differential levels of financial frictions for the domestic and export sectors could be incorporated into my model. It would be useful to consider whether such an extension has implications for the results presented in this thesis. Furthermore, the model could be extended to include financing frictions between the bank and households in addition to the financing frictions between the bank and firms. This would put a greater emphasis on the importance of the banking sector, and could further help explain why credit collapsed during the 2008 crisis.

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Appendix A

Chapter 3 Appendices

A.1 Cross-Country Output Correlations

	Australia	Austria	Belgium	Brazil	Canada	Costa Rica	Denmark	Estonia	Finland	France	Germany	Greece	Hungary	Iceland	Indonesia	Ireland	Israel	Italy	Japan	Korea
Australia																				
Austria	0.803																			
Belgium	0.823	0.944																		
Brazil	0.517	0.651	0.656																	
Canada	0.780	0.916	0.907	0.734																
Costa Rica	0.762	0.883	0.842	0.489	0.750															
Denmark	0.594	0.854	0.839	0.501	0.814	0.793														
Estonia	0.435	0.678	0.575	0.434	0.654	0.687	0.778													
Finland	0.479	0.799	0.710	0.497	0.683	0.794	0.809	0.776												
France	0.826	0.952	0.966	0.668	0.930	0.813	0.811	0.552	0.679											
Germany	0.655	0.913	0.858	0.599	0.844	0.883	0.866	0.748	0.873	0.860										
Greece	0.526	0.538	0.611	0.273	0.466	0.575	0.425	0.143	0.315	0.577	0.420									
Hungary	0.736	0.873	0.873	0.585	0.894	0.755	0.833	0.666	0.664	0.865	0.804	0.624								
Iceland	0.527	0.649	0.602	0.292	0.566	0.689	0.686	0.548	0.656	0.591	0.613	0.488	0.613							
Indonesia	0.765	0.840	0.849	0.680	0.818	0.706	0.640	0.424	0.523	0.872	0.678	0.499	0.747	0.513						
Ireland	0.358	0.450	0.540	0.067	0.401	0.478	0.556	0.413	0.427	0.462	0.475	0.470	0.556	0.442	0.276					
Israel	0.500	0.775	0.791	0.632	0.767	0.644	0.772	0.513	0.686	0.765	0.746	0.446	0.643	0.575	0.630	0.397				
Italy	0.737	0.940	0.956	0.590	0.871	0.832	0.841	0.566	0.757	0.958	0.904	0.577	0.847	0.584	0.815	0.527	0.768			
Japan	0.626	0.795	0.815	0.641	0.819	0.758	0.794	0.733	0.752	0.781	0.815	0.393	0.790	0.557	0.676	0.463	0.689	0.780		
Korea	0.486	0.647	0.681	0.539	0.620	0.609	0.636	0.500	0.639	0.620	0.733	0.291	0.537	0.304	0.397	0.424	0.639	0.687	0.633	
Latvia	0.488	0.614	0.502	0.280	0.573	0.693	0.682	0.887	0.655	0.494	0.645	0.254	0.630	0.655	0.372	0.417	0.420	0.462	0.608	0.314
Lithuania	0.418	0.573	0.440	0.366	0.537	0.677	0.604	0.846	0.714	0.429	0.627	0.241	0.615	0.653	0.375	0.314	0.331	0.414	0.619	0.295
Luxembur	0.512	0.711	0.733	0.427	0.650	0.746	0.776	0.669	0.765	0.659	0.793	0.498	0.658	0.565	0.482	0.623	0.710	0.725	0.717	0.736
Mexico	0.763	0.915	0.930	0.614	0.925	0.831	0.874	0.673	0.743	0.910	0.874	0.487	0.872	0.622	0.801	0.506	0.774	0.894	0.856	0.617
Netherlan	0.636	0.906	0.860	0.527	0.793	0.856	0.836	0.574	0.810	0.854	0.904	0.622	0.787	0.695	0.679	0.540	0.810	0.904	0.688	0.659
New Zeala	0.831	0.734	0.821	0.383	0.728	0.724	0.617	0.434	0.461	0.794	0.631	0.606	0.740	0.513	0.712	0.471	0.471	0.759	0.666	0.501
Norway	0.675	0.697	0.695	0.417	0.717	0.683	0.662	0.599	0.572	0.692	0.654	0.455	0.678	0.618	0.526	0.482	0.590	0.616	0.613	0.440
Poland	0.686	0.843	0.841	0.535	0.718	0.745	0.688	0.423	0.630	0.822	0.722	0.594	0.699	0.494	0.706	0.446	0.766	0.824	0.597	0.550
Portugal	0.696	0.838	0.883	0.535	0.761	0.727	0.711	0.308	0.615	0.883	0.764	0.715	0.765	0.533	0.760	0.506	0.707	0.916	0.623	0.620
Slovakia	0.618	0.779	0.732	0.442	0.666	0.848	0.716	0.638	0.752	0.708	0.764	0.585	0.755	0.735	0.644	0.525	0.492	0.728	0.678	0.443
Slovenia	0.667	0.895	0.834	0.523	0.768	0.879	0.806	0.661	0.822	0.823	0.868	0.646	0.830	0.705	0.687	0.519	0.685	0.865	0.705	0.598
South Afri	0.833	0.926	0.920	0.671	0.930	0.827	0.812	0.613	0.655	0.921	0.831	0.602	0.907	0.662	0.865	0.460	0.729	0.862	0.775	0.533
Spain	0.774	0.887	0.926	0.452	0.805	0.807	0.767	0.425	0.626	0.921	0.787	0.750	0.846	0.619	0.807	0.578	0.683	0.939	0.663	0.547
Sweden	0.557	0.802	0.815	0.491	0.765	0.763	0.870	0.773	0.810	0.751	0.873	0.380	0.788	0.518	0.582	0.644	0.712	0.829	0.812	0.721
Switzerlar	0.692	0.900	0.894	0.652	0.855	0.846	0.872	0.651	0.776	0.879	0.892	0.588	0.824	0.673	0.728	0.515	0.866	0.881	0.773	0.687
Turkey	0.466	0.576	0.598	0.505	0.641	0.557	0.662	0.712	0.616	0.534	0.586	0.158	0.627	0.487	0.492	0.406	0.564	0.534	0.765	0.462
UK	0.854	0.897	0.936	0.579	0.909	0.812	0.801	0.571	0.604	0.935	0.812	0.626	0.918	0.599	0.840	0.506	0.672	0.891	0.798	0.574
US	0.748	0.858	0.905	0.603	0.900	0.758	0.870	0.708	0.691	0.868	0.787	0.502	0.897	0.603	0.744	0.570	0.754	0.829	0.863	0.583

	Latvia	Lithuania	Luxemburg	Mexico	Netherlands	New Zealand	Norway	Poland	Portugal	Slovakia	Slovenia	South Africa	Spain	Sweden	Switzerland	Turkey	UK
Australia																	
Austria																	
Belgium																	
Brazil																	
Canada																	
Costa Rica																	
Denmark																	
Estonia																	
Finland																	
France																	
Germany																	
Greece																	
Hungary																	
Iceland																	
Indonesia																	
Ireland																	
Israel																	
Italy																	
Japan																	
Korea																	
Latvia																	
Lithuania	0.879																
Luxembur	0.581	0.552															
Mexico	0.583	0.549	0.695														
Netherlan	0.539	0.505	0.760	0.823													
New Zeala	0.466	0.382	0.550	0.771	0.598												
Norway	0.681	0.541	0.586	0.705	0.668	0.631											
Poland	0.405	0.306	0.596	0.755	0.818	0.644	0.579										
Portugal	0.251	0.228	0.654	0.760	0.875	0.702	0.558	0.797									
Slovakia	0.663	0.748	0.634	0.733	0.769	0.648	0.590	0.620	0.673								
Slovenia	0.648	0.659	0.730	0.780	0.910	0.645	0.622	0.763	0.816	0.875							
South Afri	0.611	0.572	0.668	0.905	0.833	0.762	0.723	0.758	0.797	0.758	0.823						
Spain	0.412	0.357	0.659	0.841	0.879	0.804	0.619	0.810	0.944	0.759	0.858	0.871					
Sweden	0.616	0.571	0.789	0.837	0.775	0.620	0.603	0.675	0.682	0.701	0.771	0.744	0.723				
Switzerlar	0.601	0.532	0.804	0.865	0.925	0.631	0.735	0.789	0.821	0.725	0.863	0.876	0.833	0.788			
Turkey	0.604	0.599	0.528	0.695	0.429	0.515	0.500	0.460	0.313	0.511	0.481	0.586	0.406	0.719	0.551		
UK	0.551	0.508	0.670	0.909	0.787	0.851	0.689	0.745	0.819	0.718	0.783	0.943	0.904	0.756	0.838	0.571	
US	0.632	0.561	0.696	0.930	0.740	0.754	0.727	0.719	0.700	0.689	0.738	0.878	0.788	0.832	0.851	0.743	0.902

A.2 Cross-Country Consumption Correlations

	Australia	Austria	Belgium	Brazil	Canada	Costa Rica	Denmark	Estonia	Finland	France	Germany	Greece
Australia												
Austria	0.881											
Belgium	0.880	0.921										
Brazil	0.585	0.599	0.640									
Canada	0.926	0.902	0.940	0.657								
Costa Rica	0.847	0.739	0.763	0.431	0.859							
Denmark	0.764	0.696	0.673	0.406	0.738	0.698						
Estonia	0.463	0.303	0.283	0.180	0.470	0.588	0.633					
Finland	0.782	0.695	0.662	0.322	0.739	0.788	0.756	0.605				
France	0.884	0.914	0.962	0.597	0.945	0.739	0.672	0.315	0.673			
Germany	0.842	0.922	0.896	0.551	0.879	0.736	0.651	0.393	0.661	0.906		
Greece	0.396	0.355	0.409	0.162	0.467	0.389	0.343	0.031	0.210	0.459	0.261	
Hungary	0.691	0.579	0.544	0.167	0.689	0.747	0.655	0.619	0.718	0.590	0.568	0.413
Iceland	0.552	0.456	0.399	0.230	0.520	0.557	0.784	0.763	0.658	0.398	0.417	0.069
Indonesia	0.814	0.768	0.789	0.500	0.793	0.731	0.599	0.246	0.542	0.758	0.746	0.495
Ireland	0.810	0.801	0.838	0.527	0.893	0.768	0.722	0.565	0.677	0.880	0.828	0.495
Israel	0.811	0.819	0.874	0.596	0.863	0.688	0.640	0.398	0.645	0.889	0.827	0.341
Italy	0.851	0.891	0.908	0.484	0.883	0.702	0.678	0.285	0.725	0.945	0.858	0.430
Japan	0.716	0.730	0.762	0.586	0.736	0.624	0.577	0.388	0.565	0.688	0.685	0.144
Korea	0.329	0.346	0.455	0.343	0.477	0.368	0.253	0.247	0.339	0.496	0.332	0.118
Latvia	0.594	0.440	0.441	0.344	0.584	0.639	0.700	0.918	0.681	0.453	0.492	0.076
Lithuania	0.378	0.234	0.197	0.147	0.392	0.547	0.591	0.873	0.554	0.209	0.273	0.141
Luxembur	0.812	0.828	0.880	0.558	0.875	0.752	0.549	0.281	0.586	0.877	0.826	0.466
Mexico	0.866	0.836	0.850	0.580	0.895	0.814	0.791	0.594	0.794	0.828	0.836	0.241
Netherlan	0.831	0.858	0.890	0.576	0.900	0.757	0.582	0.282	0.649	0.919	0.857	0.487
New Zeala	0.865	0.785	0.745	0.328	0.803	0.790	0.783	0.514	0.765	0.732	0.715	0.406
Norway	0.887	0.832	0.858	0.617	0.906	0.797	0.820	0.597	0.732	0.847	0.812	0.363
Poland	0.787	0.787	0.803	0.521	0.798	0.690	0.480	0.104	0.578	0.818	0.750	0.570
Portugal	0.743	0.726	0.778	0.462	0.805	0.575	0.572	0.168	0.579	0.848	0.682	0.655
Slovakia	0.446	0.394	0.412	0.217	0.494	0.515	0.423	0.256	0.359	0.436	0.362	0.620
Slovenia	0.741	0.739	0.752	0.346	0.724	0.651	0.524	0.087	0.630	0.785	0.681	0.547
South Afri	0.803	0.718	0.688	0.595	0.801	0.781	0.757	0.778	0.748	0.700	0.775	0.109
Spain	0.901	0.887	0.903	0.481	0.937	0.794	0.756	0.419	0.752	0.948	0.869	0.561
Sweden	0.810	0.778	0.827	0.504	0.843	0.656	0.690	0.395	0.660	0.866	0.769	0.342
Switzerlar	0.839	0.882	0.946	0.622	0.910	0.729	0.645	0.319	0.586	0.936	0.888	0.449
Turkey	0.497	0.382	0.341	0.214	0.414	0.429	0.536	0.481	0.574	0.317	0.327	-0.147
UK	0.918	0.882	0.919	0.537	0.944	0.827	0.724	0.462	0.705	0.917	0.887	0.457
US	0.883	0.853	0.845	0.506	0.896	0.769	0.814	0.610	0.778	0.875	0.872	0.318

	Hungary	Iceland	Indonesia	Ireland	Israel	Italy	Japan	Korea	Latvia	Lithuania	Luxemburg	Mexico	Netherlands	New Zealand	Norway
Australia															
Austria															
Belgium															
Brazil															
Canada															
Costa Rica															
Denmark															
Estonia															
Finland															
France															
Germany															
Greece															
Hungary															
Iceland	0.546														
Indonesia	0.602	0.248													
Ireland	0.626	0.557	0.632												
Israel	0.441	0.487	0.597	0.868											
Italy	0.587	0.440	0.664	0.832	0.859										
Japan	0.435	0.458	0.616	0.625	0.643	0.596									
Korea	0.185	0.233	0.065	0.501	0.524	0.457	0.379								
Latvia	0.602	0.773	0.350	0.627	0.522	0.424	0.567	0.320							
Lithuania	0.571	0.739	0.244	0.499	0.325	0.197	0.266	0.126	0.793						
Luxemburg	0.612	0.226	0.823	0.781	0.766	0.778	0.687	0.424	0.391	0.193					
Mexico	0.657	0.673	0.642	0.851	0.857	0.805	0.736	0.409	0.692	0.518	0.740				
Netherlands	0.590	0.326	0.714	0.863	0.842	0.893	0.588	0.499	0.365	0.260	0.852	0.802			
New Zealand	0.773	0.652	0.774	0.680	0.622	0.716	0.681	0.122	0.622	0.467	0.661	0.792	0.631		
Norway	0.609	0.660	0.726	0.854	0.809	0.782	0.763	0.423	0.717	0.505	0.735	0.878	0.756	0.795	
Poland	0.522	0.137	0.732	0.705	0.709	0.821	0.450	0.340	0.231	0.116	0.788	0.623	0.868	0.580	0.629
Portugal	0.501	0.286	0.591	0.805	0.774	0.865	0.449	0.382	0.274	0.161	0.706	0.672	0.848	0.581	0.660
Slovakia	0.338	0.206	0.432	0.544	0.466	0.453	0.182	0.209	0.232	0.329	0.398	0.373	0.547	0.345	0.391
Slovenia	0.565	0.196	0.714	0.602	0.649	0.820	0.436	0.288	0.197	0.084	0.735	0.547	0.774	0.627	0.572
South Africa	0.623	0.701	0.562	0.795	0.733	0.653	0.680	0.350	0.858	0.658	0.617	0.875	0.665	0.711	0.839
Spain	0.684	0.509	0.737	0.903	0.861	0.948	0.637	0.443	0.530	0.342	0.831	0.846	0.910	0.797	0.850
Sweden	0.502	0.572	0.508	0.835	0.844	0.879	0.571	0.539	0.500	0.292	0.674	0.803	0.806	0.640	0.809
Switzerland	0.499	0.341	0.832	0.847	0.858	0.832	0.754	0.416	0.446	0.252	0.892	0.799	0.870	0.699	0.856
Turkey	0.471	0.680	0.270	0.295	0.298	0.366	0.370	-0.005	0.534	0.471	0.154	0.533	0.230	0.602	0.481
UK	0.714	0.485	0.840	0.875	0.837	0.841	0.755	0.338	0.561	0.369	0.894	0.889	0.859	0.837	0.877
US	0.697	0.674	0.666	0.885	0.849	0.866	0.673	0.366	0.690	0.500	0.762	0.926	0.813	0.808	0.891

	Poland	Portugal	Slovakia	Slovenia	South Africa	Spain	Sweden	Switzerland	Turkey	UK
Australia										
Austria										
Belgium										
Brazil										
Canada										
Costa Rica										
Denmark										
Estonia										
Finland										
France										
Germany										
Greece										
Hungary										
Iceland										
Indonesia										
Ireland										
Israel										
Italy										
Japan										
Korea										
Latvia										
Lithuania										
Luxemburg										
Mexico										
Netherlands										
New Zealand										
Norway										
Poland										
Portugal	0.799									
Slovakia	0.623	0.593								
Slovenia	0.856	0.759	0.558							
South Africa	0.527	0.498	0.355	0.408						
Spain	0.826	0.891	0.565	0.805	0.731					
Sweden	0.650	0.799	0.336	0.596	0.687	0.871				
Switzerland	0.759	0.747	0.439	0.709	0.685	0.877	0.764			
Turkey	0.116	0.193	-0.068	0.138	0.531	0.334	0.450	0.221		
UK	0.735	0.763	0.413	0.694	0.768	0.915	0.791	0.920	0.380	
US	0.635	0.734	0.341	0.607	0.853	0.909	0.872	0.822	0.534	0.914

A.3 Cross-Country Investment Correlations

	Australia	Austria	Belgium	Brazil	Canada	Costa Rica	Denmark	Estonia	Finland	France	Germany
Australia											
Austria	0.263										
Belgium	0.090	0.663									
Brazil	0.237	0.220	0.265								
Canada	0.434	0.447	0.552	0.603							
Costa Rica	0.355	0.400	0.263	-0.048	0.199						
Denmark	0.173	0.576	0.487	-0.027	0.460	0.453					
Estonia	0.470	0.569	0.347	0.202	0.602	0.446	0.567				
Finland	0.245	0.691	0.577	0.162	0.477	0.448	0.493	0.536			
France	0.267	0.783	0.804	0.356	0.647	0.348	0.555	0.521	0.631		
Germany	0.159	0.690	0.625	0.334	0.644	0.378	0.667	0.665	0.694	0.770	
Greece	-0.133	0.191	0.146	-0.158	-0.124	0.230	0.254	-0.041	0.202	0.207	0.144
Hungary	0.197	0.377	0.365	0.352	0.376	0.137	0.285	0.233	0.014	0.451	0.249
Iceland	0.183	0.426	0.518	0.039	0.611	0.308	0.654	0.594	0.564	0.485	0.616
Indonesia	0.090	0.510	0.609	0.410	0.389	-0.031	0.211	0.108	0.394	0.538	0.339
Ireland	-0.039	0.225	0.389	-0.082	0.087	0.102	0.220	0.224	0.097	0.320	0.219
Israel	0.245	0.653	0.577	0.287	0.478	0.368	0.495	0.486	0.731	0.721	0.743
Italy	0.132	0.551	0.673	0.162	0.414	0.257	0.398	0.309	0.545	0.830	0.658
Japan	0.173	0.548	0.488	0.239	0.666	0.274	0.660	0.661	0.408	0.524	0.605
Korea	0.086	0.021	0.038	-0.199	0.014	0.237	0.123	0.009	0.287	0.126	0.184
Latvia	0.366	0.669	0.558	0.230	0.635	0.463	0.643	0.767	0.601	0.559	0.638
Lithuania	0.375	0.580	0.484	0.202	0.629	0.603	0.617	0.812	0.592	0.590	0.694
Luxemburg	0.226	0.371	0.377	0.237	0.352	0.453	0.227	0.425	0.333	0.470	0.380
Mexico	0.352	0.710	0.788	0.210	0.626	0.416	0.613	0.485	0.573	0.851	0.714
Netherlands	-0.045	0.283	0.129	-0.053	0.055	0.289	0.285	0.132	0.226	0.257	0.302
New Zealand	0.514	0.526	0.558	0.134	0.595	0.404	0.438	0.511	0.338	0.614	0.385
Norway	0.326	0.523	0.477	0.294	0.514	0.336	0.596	0.612	0.426	0.503	0.486
Poland	0.049	0.584	0.607	0.313	0.370	0.332	0.513	0.327	0.387	0.570	0.630
Portugal	-0.339	0.141	0.373	0.020	-0.008	0.070	0.163	-0.272	0.223	0.363	0.252
Slovakia	-0.040	0.367	0.464	0.121	0.408	0.251	0.382	0.451	0.353	0.482	0.503
Slovenia	0.230	0.678	0.550	0.279	0.419	0.569	0.588	0.481	0.486	0.658	0.566
South Africa	0.256	0.707	0.658	0.200	0.450	0.430	0.601	0.437	0.366	0.722	0.519
Spain	0.146	0.633	0.738	0.116	0.525	0.406	0.655	0.420	0.524	0.846	0.674
Sweden	0.075	0.576	0.599	0.104	0.541	0.428	0.680	0.610	0.719	0.648	0.822
Switzerland	0.233	0.670	0.703	0.349	0.758	0.372	0.653	0.604	0.709	0.780	0.810
Turkey	0.414	0.380	0.335	0.132	0.579	0.143	0.399	0.474	0.458	0.350	0.446
UK	0.216	0.524	0.673	0.176	0.577	0.357	0.586	0.505	0.421	0.751	0.608
US	0.342	0.574	0.599	0.265	0.822	0.302	0.662	0.687	0.551	0.595	0.644

	Hungary	Iceland	Indonesia	Ireland	Israel	Italy	Japan	Korea	Latvia	Lithuania	Luxemburg	Mexico	Netherlands	New Zealand	Norway
Australia															
Austria															
Belgium															
Brazil															
Canada															
Costa Rica															
Denmark															
Estonia															
Finland															
France															
Germany															
Greece															
Hungary															
Iceland	0.168														
Indonesia	0.292	0.222													
Ireland	0.122	0.289	0.156												
Israel	0.045	0.397	0.428	0.121											
Italy	0.239	0.356	0.356	0.283	0.648										
Japan	0.449	0.747	0.357	0.194	0.350	0.221									
Korea	-0.230	0.205	-0.125	0.027	0.252	0.350	-0.033								
Latvia	0.396	0.657	0.369	0.166	0.495	0.224	0.746	-0.141							
Lithuania	0.373	0.655	0.096	0.181	0.474	0.410	0.673	0.058	0.789						
Luxemburg	0.224	0.264	0.114	0.191	0.365	0.349	0.370	0.062	0.350	0.417					
Mexico	0.356	0.592	0.519	0.341	0.634	0.737	0.504	0.179	0.555	0.551	0.353				
Netherlands	0.237	0.206	0.118	0.127	0.202	0.288	0.146	0.142	0.252	0.275	-0.051	0.318			
New Zealand	0.519	0.475	0.228	0.257	0.343	0.450	0.499	0.121	0.520	0.652	0.334	0.653	0.160		
Norway	0.393	0.576	0.331	0.192	0.450	0.187	0.652	-0.175	0.718	0.603	0.341	0.446	0.186	0.411	
Poland	0.611	0.364	0.386	0.209	0.410	0.391	0.466	-0.103	0.566	0.477	0.236	0.587	0.332	0.329	0.465
Portugal	0.285	0.021	0.147	0.088	0.216	0.573	-0.115	0.306	-0.142	0.015	0.012	0.279	0.296	0.056	-0.093
Slovakia	0.312	0.424	0.301	0.197	0.340	0.467	0.442	-0.039	0.434	0.544	0.216	0.463	0.348	0.322	0.318
Slovenia	0.679	0.417	0.277	0.157	0.420	0.440	0.543	0.018	0.615	0.664	0.414	0.580	0.287	0.541	0.587
South Africa	0.648	0.467	0.459	0.316	0.390	0.449	0.643	-0.080	0.603	0.591	0.471	0.722	0.273	0.614	0.615
Spain	0.551	0.570	0.348	0.351	0.486	0.797	0.541	0.203	0.477	0.616	0.332	0.814	0.370	0.635	0.436
Sweden	0.199	0.718	0.264	0.213	0.614	0.587	0.588	0.346	0.625	0.747	0.258	0.656	0.362	0.411	0.435
Switzerland	0.293	0.743	0.533	0.273	0.667	0.618	0.679	0.238	0.679	0.673	0.393	0.802	0.305	0.550	0.554
Turkey	0.126	0.674	0.252	0.078	0.302	0.291	0.565	0.323	0.441	0.504	0.108	0.508	0.092	0.528	0.323
UK	0.403	0.556	0.322	0.374	0.474	0.683	0.564	0.257	0.430	0.602	0.319	0.747	0.272	0.679	0.451
US	0.340	0.833	0.411	0.237	0.418	0.313	0.846	-0.004	0.798	0.706	0.267	0.676	0.165	0.640	0.618

	Poland	Portugal	Slovakia	Slovenia	South Africa	Spain	Sweden	Switzerland	Turkey	UK
Australia										
Austria										
Belgium										
Brazil										
Canada										
Costa Rica										
Denmark										
Estonia										
Finland										
France										
Germany										
Greece										
Hungary										
Iceland										
Indonesia										
Ireland										
Israel										
Italy										
Japan										
Korea										
Latvia										
Lithuania										
Luxemburg										
Mexico										
Netherlands										
New Zealand										
Norway										
Poland										
Portugal	0.361									
Slovakia	0.481	0.254								
Slovenia	0.732	0.347	0.414							
South Africa	0.682	0.211	0.438	0.789						
Spain	0.633	0.530	0.547	0.732	0.758					
Sweden	0.556	0.340	0.582	0.527	0.492	0.704				
Switzerland	0.565	0.214	0.532	0.527	0.611	0.722	0.780			
Turkey	0.244	-0.132	0.173	0.219	0.307	0.376	0.513	0.634		
UK	0.443	0.288	0.487	0.547	0.631	0.827	0.668	0.682	0.421	
US	0.459	-0.112	0.425	0.471	0.563	0.579	0.640	0.796	0.722	0.601

A.4 Cross-Country Labour Correlations

Period 1:

	Australia	Austria	Belgium	Canada	Denmark	Finland	France	Germany	Greece	Iceland	Ireland	Italy
Australia												
Austria	-0.131											
Belgium	0.599	0.082										
Canada	0.797	-0.154	0.624									
Denmark	0.469	-0.044	0.348	0.409								
Finland	0.713	-0.366	0.312	0.487	0.356							
France	0.226	0.059	0.712	0.204	-0.037	0.243						
Germany	-0.347	0.313	0.312	-0.261	-0.121	-0.311	0.525					
Greece	0.314	0.031	-0.305	0.227	-0.102	0.252	-0.260	-0.449				
Iceland	-0.143	0.061	-0.221	-0.190	0.078	-0.104	-0.266	0.306	-0.099			
Ireland	-0.089	0.347	0.137	0.103	-0.143	-0.193	0.303	0.153	0.182	-0.246		
Italy	0.207	-0.128	0.540	0.267	0.217	0.453	0.641	0.440	-0.223	-0.054	-0.073	
Japan	-0.070	0.111	0.391	-0.084	0.051	0.085	0.668	0.626	-0.212	-0.203	0.061	0.605
Korea	0.405	-0.195	0.684	0.559	-0.031	0.094	0.574	0.165	-0.297	-0.086	0.077	0.329
Luxemburg	0.338	0.124	0.763	0.256	-0.063	-0.004	0.610	0.415	-0.381	0.006	0.000	0.212
Netherlands	0.435	-0.083	0.544	0.497	0.209	0.183	0.392	0.234	0.009	0.112	0.057	0.462
New Zealand	0.442	-0.086	0.079	0.416	0.492	0.131	-0.311	-0.397	0.018	0.337	-0.224	-0.162
Norway	0.271	-0.200	-0.161	0.352	0.369	-0.021	-0.429	-0.456	0.115	0.306	-0.188	-0.427
Poland	0.663	-0.152	0.203	0.692	0.504	0.393	-0.302	-0.670	0.341	-0.093	-0.060	-0.201
Portugal	0.242	-0.189	0.537	0.275	-0.086	0.495	0.586	0.083	-0.245	-0.281	-0.035	0.672
Spain	0.603	-0.215	0.837	0.512	0.229	0.422	0.692	0.187	-0.345	-0.147	-0.096	0.521
Sweden	0.639	-0.421	0.566	0.577	0.370	0.842	0.493	-0.059	-0.047	-0.176	-0.114	0.736
Switzerland	0.270	0.248	0.469	0.023	0.297	0.256	0.496	0.589	-0.063	0.235	-0.092	0.445
Turkey	0.375	0.149	0.430	0.344	0.186	0.321	0.411	0.184	-0.167	0.075	0.221	0.325
UK	0.774	-0.177	0.817	0.790	0.534	0.542	0.445	-0.137	-0.154	-0.411	-0.036	0.434
US	0.512	0.128	0.437	0.725	0.535	0.166	0.100	-0.254	0.056	-0.303	0.160	0.048

	Japan	Korea	Luxemburg	Netherlands	New Zealand	Norway	Poland	Portugal	Spain	Sweden	Switzerland	Turkey	UK
Australia													
Austria													
Belgium													
Canada													
Denmark													
Finland													
France													
Germany													
Greece													
Iceland													
Ireland													
Italy													
Japan													
Korea	0.169												
Luxemburg	0.186	0.635											
Netherlands	0.356	0.504	0.333										
New Zealand	-0.554	0.211	0.032	0.047									
Norway	-0.651	0.178	-0.120	-0.028	0.709								
Poland	-0.410	0.158	-0.085	0.116	0.524	0.572							
Portugal	0.263	0.371	0.396	0.274	-0.123	-0.442	-0.124						
Spain	0.382	0.793	0.733	0.576	0.110	-0.055	0.162	0.570					
Sweden	0.228	0.406	0.199	0.422	0.063	-0.059	0.281	0.648	0.666				
Switzerland	0.693	0.080	0.362	0.466	-0.218	-0.357	-0.150	0.139	0.440	0.267			
Turkey	0.038	0.482	0.370	0.174	0.144	0.172	0.117	0.204	0.512	0.500	0.158		
UK	0.194	0.596	0.427	0.473	0.243	0.101	0.508	0.441	0.772	0.733	0.213	0.416	
US	0.048	0.413	-0.010	0.317	0.317	0.420	0.641	-0.075	0.321	0.277	0.023	0.280	0.691

Period 2:

	Australia	Austria	Belgium	Canada	Czekia	Denmark	Estonia	Finland	France	Germany	Greece	Hungary	Iceland
Australia													
Austria	0.586												
Belgium	0.876	0.428											
Canada	0.242	-0.003	0.086										
Czekia	0.615	0.641	0.553	0.283									
Denmark	0.477	0.173	0.392	0.581	0.795								
Estonia	0.221	0.081	0.134	0.804	0.451	0.713							
Finland	0.731	0.587	0.614	0.532	0.747	0.705	0.628						
France	0.150	0.257	0.023	0.566	0.342	0.444	0.486	0.676					
Germany	0.652	0.695	0.765	-0.111	0.751	0.421	0.158	0.639	0.121				
Greece	0.567	0.166	0.344	0.190	0.464	0.538	-0.001	0.364	0.241	0.179			
Hungary	-0.466	-0.322	-0.424	0.532	0.005	0.354	0.626	0.031	0.419	-0.279	-0.171		
Iceland	0.505	0.411	0.491	0.593	0.788	0.817	0.784	0.797	0.523	0.643	0.281	0.397	
Ireland	0.447	0.115	0.331	0.743	0.669	0.909	0.767	0.692	0.571	0.289	0.562	0.474	0.858
Israel	-0.061	0.113	0.158	0.016	-0.001	-0.048	0.286	0.190	0.012	0.338	-0.693	0.156	0.246
Italy	0.340	0.011	0.062	0.717	0.366	0.691	0.551	0.602	0.700	-0.093	0.659	0.325	0.459
Japan	0.463	0.190	0.594	0.414	0.665	0.731	0.680	0.580	0.160		0.194	0.340	0.888
Korea	-0.386	-0.289	-0.358	0.521	-0.092	0.219	0.437	0.173	0.748	-0.334	-0.155	0.730	0.221
Luxemburg	0.430	0.528	0.288	0.269	0.535	0.426	0.190	0.759	0.839	0.427	0.437	-0.037	0.458
Mexico	0.154	0.051	0.271	0.000	-0.288	-0.357	-0.117	0.004	-0.174	0.090	-0.398	-0.312	-0.142
Netherlands	0.430	0.494	0.232	0.270	0.609	0.549	0.197	0.674	0.721	0.398	0.581	-0.023	0.472
New Zealand	0.080	-0.300	-0.021	0.729	0.319	0.719	0.691	0.292	0.360	-0.179	0.450	0.655	0.550
Norway	0.655	0.784	0.692	-0.005	0.774	0.427	0.203	0.709	0.184	0.921	0.135	-0.326	0.573
Poland	0.736	0.532	0.816	-0.121	0.727	0.493	0.141	0.532	-0.150	0.884	0.340	-0.378	0.534
Portugal	0.411	0.200	0.237	0.343	0.526	0.641	0.174	0.512	0.612	0.204	0.879	0.157	0.456
Slovakia	0.698	0.459	0.557	0.434	0.860	0.861	0.585	0.716	0.195	0.617	0.572	0.063	0.803
Slovenia	0.569	0.076	0.534	0.287	0.670	0.783	0.252	0.567	0.303	0.425	0.796	-0.043	0.555
Spain	0.475	-0.014	0.272	0.718	0.467	0.775	0.607	0.574	0.518	0.041	0.733	0.342	0.619
Sweden	0.486	0.694	0.488	0.369	0.732	0.502	0.490	0.847	0.684	0.710	0.151	0.131	0.764
Switzerland	0.335	0.753	0.391	-0.121	0.683	0.294	0.146	0.593	0.322	0.795	-0.043	-0.161	0.460
Turkey	-0.097	0.513	0.002	-0.422	-0.077	-0.519	-0.219	-0.056	-0.145	0.291	-0.644	-0.244	-0.167
UK	0.020	-0.151	-0.044	0.800	0.319	0.692	0.816	0.393	0.475	-0.074	0.207	0.827	0.659
US	0.175	-0.072	0.188	0.771	0.403	0.737	0.915	0.555	0.511	0.173	0.088	0.734	0.824

	Ireland	Israel	Italy	Japan	Korea	Luxemburg	Mexico	Netherlands	New Zealand	Norway	Poland	Portugal	Slovakia	Slovenia	Spain	Sweden	Switzerland	Turkey	UK
Australia																			
Austria																			
Belgium																			
Canada																			
Czekia																			
Denmark																			
Estonia																			
Finland																			
France																			
Germany																			
Greece																			
Hungary																			
Iceland																			
Ireland																			
Israel	-0.087																		
Italy	0.768	-0.362																	
Japan	0.726	0.276	0.208																
Korea	0.349	0.108	0.457	-0.008															
Luxemburrg	0.439	-0.058	0.571	0.121	0.332														
Mexico	-0.371	0.390	-0.290	-0.095	-0.093	-0.193													
Netherlands	0.545	-0.118	0.632	0.136	0.235	0.888	-0.396												
New Zealand	0.839	-0.300	0.721	0.513	0.448	0.051	-0.379	0.155											
Norway	0.243	0.359	0.007	0.502	-0.319	0.511	0.098	0.500	-0.241										
Poland	0.314	0.176	-0.043	0.662	-0.580	0.207	-0.048	0.289	-0.066	0.838									
Portugal	0.685	-0.540	0.775	0.258	0.256	0.683	-0.432	0.743	0.534	0.166	0.193								
Slovakia	0.782	-0.011	0.501	0.760	-0.225	0.341	-0.265	0.489	0.495	0.631	0.746	0.515							
Slovenia	0.731	-0.276	0.634	0.520	-0.011	0.457	-0.268	0.587	0.543	0.373	0.541	0.763	0.718						
Spain	0.906	-0.378	0.886	0.488	0.309	0.377	-0.315	0.471	0.871	0.002	0.142	0.766	0.647	0.735					
Sweden	0.511	0.258	0.329	0.551	0.214	0.753	-0.050	0.632	0.096	0.767	0.482	0.404	0.535	0.348	0.289				
Switzerland	0.101	0.344	-0.063	0.329	-0.106	0.588	-0.052	0.511	-0.328	0.895	0.607	0.124	0.399	0.168	-0.175	0.807			
Turkey	-0.609	0.421	-0.657	-0.180	-0.202	-0.046	0.429	-0.283	-0.725	0.332	0.047	-0.564	-0.328	-0.667	-0.735	0.233	0.504		
UK	0.799	0.008	0.629	0.602	0.528	0.155	-0.321	0.168	0.861	-0.084	-0.050	0.426	0.498	0.327	0.705	0.304	-0.105	-0.471	
US	0.848	0.293	0.542	0.765	0.537	0.186	-0.144	0.212	0.777	0.106	0.126	0.308	0.546	0.378	0.679	0.438	0.022	-0.386	0.882

Appendix B

Chapter 4 Appendices

B.1 Data for Chapter 4

The data for the business cycle statistics is taken from the OECD Main Economics Indicators database.[1] For GDP, consumption, investment, exports and imports I used quarterly data from 199Q1-2020Q2, taken from the *National Accounts* under the *Monthly Economic Indicators - Main Economic Indicators* database. They are, respectively, gross domestic product, private final consumption expenditure, gross fixed capital formation, exports of goods and services and imports of goods and services. I used the index of these variables at constant prices. I calculate the standard deviation of the above variables as well as their standard deviation relative to output.

For data on labour, I used annual data from 1999-2015 (the latest available date) from the *Civilian Employment Index*, found under *Labour - Annual Labour Force Statistics Archives - Population and Labour Force*. As direct data for the euro area was not available, I constructed an employment index out of the available data. The constructed employment index is the average of all euro area countries excluding Malta, Cyprus, Latvia and Lithuania. [2] In order to compute relative labour volatility statistics I also derived annual GDP volatilities for the time period 1999-2015 from the *National Accounts*. The relative labour volatilities stated in Table 4.1 are $\frac{\%\text{standard deviation of annual labour data 1999-2015}}{\%\text{standard deviation of annual GDP data 1999-2015}}$. It is therefore possible that the relative volatility for labour stated in Table 4.1 deviates slightly from the percentage deviation of labour stated in the table divided by the percentage deviation of GDP as stated in the table.

To compute business cycle moments I took the log of all variables and detrended them using a Hodrick-Prescott filter.

[1] The link to this database can be found at `https://stats.oecd.org/Index.aspx`.

[2] Data for these countries was not available.

B.2 Complete Model

B.2.1 Model Equations

Price Level

$$1 = N_{D,t}\tilde{\rho}_{D,t}^{1-\theta} + N_{X,t}^{*}(\tilde{\rho}_{X,t}^{*})^{1-\theta}$$
$$1 = N_{D,t}^{*}(\tilde{\rho}_{D,t}^{*})^{1-\theta} + N_{X,t}\tilde{\rho}_{X,t}^{1-\theta}$$

Average Prices

$$\tilde{\rho}_{D,t} = \frac{\theta}{\theta-1}\left(\frac{w_t}{1-\alpha}\right)^{1-\alpha}\left(\frac{r_t^k}{\alpha}\right)^{\alpha}\frac{1}{Z_t z_{\tilde{D},t}}$$
$$\tilde{\rho}_{D,t}^{*} = \frac{\theta}{\theta-1}\left(\frac{w_t^*}{1-\alpha}\right)^{1-\alpha}\left(\frac{(r_t^k)^*}{\alpha}\right)^{\alpha}\frac{1}{Z_t^* z_{\tilde{D},t}^*}$$
$$\tilde{\rho}_{X,t} = \frac{\tau_t}{Q_t}\frac{\theta}{\theta-1}\left(\frac{w_t}{1-\alpha}\right)^{1-\alpha}\left(\frac{r_t^k}{\alpha}\right)^{\alpha}\frac{1}{Z_t z_{\tilde{X},t}}$$
$$\tilde{\rho}_{X,t}^{*} = \tau_t Q_t\frac{\theta}{\theta-1}\left(\frac{w_t^*}{1-\alpha}\right)^{1-\alpha}\left(\frac{(r_t^k)^*}{\alpha}\right)^{\alpha}\frac{1}{Z_t^* z_{\tilde{X},t}^*}$$

Average Profits

$$\tilde{d}_t = \tilde{d}_{D,t} + \frac{N_{X,t}}{N_{D,t}}\tilde{d}_{X,t}$$
$$\tilde{d}_t^{*} = \tilde{d}_{D,t}^{*} + \frac{N_{X,t}^{*}}{N_{D,t}^{*}}\tilde{d}_{X,t}^{*}$$
$$\tilde{d}_{D,t} = \frac{1}{\theta}\tilde{\rho}_{D,t}^{1-\theta}Y_t - \frac{w_t f_{D,t}}{Z_t}$$
$$\tilde{d}_{D,t}^{*} = \frac{1}{\theta}(\tilde{\rho}_{D,t}^{*})^{1-\theta}Y_t^{*} - \frac{w_t^* f_{D,t}^*}{Z_t^*}$$
$$\tilde{d}_{X,t} = \frac{Q_t}{\theta}\tilde{\rho}_{X,t}^{1-\theta}Y_t^{*} - \frac{w_t f_{X,t}}{Z_t}$$
$$\tilde{d}_{X,t}^{*} = \frac{1}{Q_t\theta}(\tilde{\rho}_{X,t}^{*})^{1-\theta}Y_t^{-}\frac{w_t^* f_{X,t}^*}{Z_t^*}$$

Zero Profit Cut-off Conditions

$$\tilde{d}_{D,t} = \frac{j}{j-\theta-1}\frac{w_t f_{D,t}}{Z_t}$$
$$\tilde{d}_{D,t}^{*} = \frac{j}{j-\theta-1}\frac{w_t^* f_{D,t}^*}{Z_t^*}$$
$$\tilde{d}_{X,t} = \frac{j}{j-\theta-1}\frac{w_t f_{X,t}}{Z_t}$$
$$\tilde{d}_{X,t}^{*} = \frac{j}{j-\theta-1}\frac{w_t^* f_{X,t}^*}{Z_t^*}$$

Free Entry Condition

$$\tilde{v}_t = \frac{w_t f_{E,t}}{Z_t}\ \ \tilde{v}_t^{*} = \frac{w_t^* f_{E,t}^*}{Z_t^*}$$

Euler Equations

Euler Equations for Domestic Bonds

$$C_t^{-1}[C_t^{\mu}(1-L_t)^{1-\mu}]^{1-\gamma}(1+\eta B_{H,t}) = (1+r_{b,t})\beta\frac{\varepsilon_{t+1}}{\varepsilon_t}C_{t+1}^{-1}[C_{t+1}^{\mu}(1-L_{t+1})^{1-\mu}]^{1-\gamma}$$
$$(C_t^{-1})^{*}[(C_t^{*})^{\mu}(1-L_t^{*})^{1-\mu}]^{1-\gamma}(1+\eta B_{H,t}^{*}) = (1+r_{b,t}^{*})\beta\frac{\varepsilon_{t+1}^{*}}{\varepsilon_t^{*}}(C_{t+1}^{*})^{-1}[(C_{t+1}^{*})^{\mu}(1-L_{t+1}^{*})^{1-\mu}]^{1-\gamma}$$

Euler Equations for Foreign Bonds

$$C_t^{-1}[C_t^{\mu}(1-L_t)^{1-\mu}]^{1-\gamma}(1+\eta B_{F,t}) = (1+r_{t,b}^{*})\beta\frac{Q_{t+1}}{Q_t}\frac{\varepsilon_{t+1}}{\varepsilon_t}C_{t+1}^{-1}[C_{t+1}^{\mu}(1-L_{t+1})^{1-\mu}]^{1-\gamma}$$
$$(C_t^{-1})^{*}[(C_t^{*})^{\mu}(1-L_t^{*})^{1-\mu}]^{1-\gamma}(1+\eta B_{F,t}) = (1+r_{t,b}^{*})\beta\frac{Q_t}{Q_{t+1}}\frac{\varepsilon_{t+1}^{*}}{\varepsilon_t^{*}}(C_{t+1}^{*})^{-1}[(C_{t+1}^{*})^{\mu}(1-L_{t+1}^{*})^{1-\mu}]^{1-\gamma}$$

Euler Equations for Capital

$C_t^{-1}[C_t^{\mu}(1-L_t)^{1-\mu}]^{1-\gamma} = \beta(1-\delta_k+r_{t+1}^k)\frac{\varepsilon_{t+1}}{\varepsilon_t}C_{t+1}^{-1}[C_{t+1}^{\mu}(1-L_{t+1})^{1-\mu}]^{1-\gamma}$

$(C_t^{-1})^*[(C_t^*)^{\mu}(1-L_t^*)^{1-\mu}]^{1-\gamma} = \beta(1-\delta_k+r_{t+1}^k)\frac{\varepsilon_{t+1}^*}{\varepsilon_t^*}(C_{t+1}^*)^{-1}[(C_{t+1}^*)^{\mu}(1-L_{t+1}^*)^{1-\mu}]^{1-\gamma}$

Euler Equations for Shares

$\tilde{v}_t C_t^{-1}[C_t^{\mu}(1-L_t)^{1-\mu}]^{1-\gamma} = \beta\Big(\frac{z_{min}\nu}{\tilde{z}_{D,t}}\Big)^j\frac{\varepsilon_{t+1}}{\varepsilon_t}C_{t+1}^{-1}[C_{t+1}^{\mu}(1-L_{t+1})^{1-\mu}]^{1-\gamma}(\tilde{d}_{t+1}+\tilde{v}_{t+1})$

$\tilde{v}_t^*(C_t^{-1})^*[(C_t^*)^{\mu}(1-L_t^*)^{1-\mu}]^{1-\gamma} = \beta\Big(\frac{z_{min}^*\nu}{\tilde{z}_{D,t}^*}\Big)^j\frac{\varepsilon_{t+1}^*}{\varepsilon_t^*}(C_{t+1}^*)^{-1}[(C_{t+1}^*)^{\mu}(1-L_{t+1}^*)^{1-\mu}]^{1-\gamma}(\tilde{d}_{t+1}^*+\tilde{v}_{t+1}^*)$

Labour-Leisure Condition

$(1-L_t)w_t = \frac{1-\mu}{\mu}C_t$

$(1-L_t^*)w_t^* = \frac{1-\mu}{\mu}C_t^*$

Number of Firms

$N_{D,t} = \Big(\frac{\nu z_{min}}{\tilde{z}_{D,t}}\Big)^j(N_{D,t-1}+N_{E,t-1})$

$N_{D,t}^* = \Big(\frac{\nu z_{min}^*}{\tilde{z}_{D,t}^*}\Big)^j(N_{D,t-1}^*+N_{E,t-1}^*)$

$N_{X,t} = \Big(\frac{\tilde{z}_{D,t}}{\tilde{z}_{X,t}}\Big)^j N_{D,t}$

$N_{X,t}^* = \Big(\frac{\tilde{z}_{D,t}^*}{\tilde{z}_{X,t}^*}\Big)^j N_{D,t}^*$

Factors of Production $K_{t-1} = N_{D,t}\Big(\frac{w_t}{r_t^k}\frac{\alpha}{1-\alpha}\Big)^{1-\alpha}\Big[\frac{\theta}{\theta-1}\Big(\frac{w_t}{1-\alpha}\Big)^{1-\alpha}\Big(\frac{r_t^k}{\alpha}\Big)^{\alpha}\Big]^{-\theta}(Z_t)^{\theta-1}\Big[Y_t\tilde{z}_{D,t}^{\theta-1}+\frac{N_{X,t}}{N_{D,t}}\tau_t^{1-\theta}Q_t^{\theta}Y_t^*\tilde{z}_{X,t}^{\theta-1}\Big]$

$L_{P,t} = N_{D,t}\Big(\frac{r_t^k}{w_t}\frac{1-\alpha}{\alpha}\Big)^{\alpha}\Big[\frac{\theta}{\theta-1}\Big(\frac{w_t}{1-\alpha}\Big)^{1-\alpha}\Big(\frac{r_t^k}{\alpha}\Big)^{\alpha}\Big]^{-\theta}(Z_t)^{\theta-1}\Big[Y_t\tilde{z}_{D,t}^{\theta-1}+\frac{N_{X,t}}{N_{D,t}}\tau_t^{1-\theta}Q_t^{\theta}Y_t^*\tilde{z}_{X,t}^{\theta-1}\Big]$

$K_{t-1}^* = N_{D,t}^*\Big(\frac{w_t^*}{(r_t^k)^*}\frac{\alpha}{1-\alpha}\Big)^{1-\alpha}\Big[\frac{\theta}{\theta-1}\Big(\frac{w_t^*}{1-\alpha}\Big)^{1-\alpha}\Big(\frac{(r_t^k)^*}{\alpha}\Big)^{\alpha}\Big]^{-\theta}(Z_t^*)^{\theta-1}\Big[Y_t^*(\tilde{z}_{D,t}^*)^{\theta-1}+\frac{N_{X,t}^*}{N_{D,t}^*}\tau_t^{1-\theta}Q_t^{-\theta}Y_t(\tilde{z}_{X,t}^*)^{\theta-1}\Big]$

$L_{P,t}^* = N_{D,t}^*\Big(\frac{(r_t^k)^*}{w_t^*}\frac{1-\alpha}{\alpha}\Big)^{\alpha}\Big[\frac{\theta}{\theta-1}\Big(\frac{w_t^*}{1-\alpha}\Big)^{1-\alpha}\Big(\frac{(r_t^k)^*}{\alpha}\Big)^{\alpha}\Big]^{-\theta}(Z_t^*)^{\theta-1}\Big[Y_t^*(\tilde{z}_{D,t}^*)^{\theta-1}+\frac{N_{X,t}^*}{N_{D,t}^*}\tau_t^{1-\theta}Q_t^{-\theta}Y_t(\tilde{z}_{X,t}^*)^{\theta-1}\Big]$

Capital Law of Motion

$K_t = (1-\delta_k)K_{t-1}+I_t,$

$K_t^* = (1-\delta_k)K_{t-1}^*+I_t^*,$

Market Clearing Conditions

$Y_t = C_t + I_t$

$Y_t^* = C_t^* + I_t^*$

Trade Balance Equation

$B_{H,t}+\frac{B_{F,t}^*}{Q_t}-(1+r_{t-1})B_{H,t-1}-(1+r_{t-1})\frac{B_{F,t-1}^*}{Q_t} = Q_t(N_{X,t}\tilde{\rho}_{X,t}^{1-\theta})Y_t^* - N_{X,t}^*(\tilde{\rho}_{X,t}^*)^{1-\theta}Y_t.$

Labour Market Clearing

$L_t = L_{P,t}+L_{E,t}+L_{D,t}+L_{X,t},$

$L_t^* = L_{P,t}^*+L_{E,t}^*+L_{D,t}^*+L_{X,t}^*,$

where

$L_{E,t} = \frac{N_{E,t} f_{E,t}}{Z_t}$,
$L^*_{E,t} = \frac{N^*_{E,t} f^*_{E,t}}{Z^*_t}$
$L_{D,t} = \frac{N_{D,t} f_{D,t}}{Z_t}$
$L^*_{D,t} = \frac{N^*_{D,t} f^*_{D,t}}{Z^*_t}$
$L_{X,t} = \frac{N_{X,t} f_{X,t}}{Z_t}$
$L^*_{X,t} = \frac{N^*_{X,t} f^*_{X,t}}{Z^*_t}$.

Bond Market Clearing
$B_t + B^*_{F,t} = 0$,
$B_{F,t} + B^*_H = 0$.

Further Variables
Exports
$Ex_t = Y^*_t N_{X,t} \tilde{\rho}^{1-\theta}_{X,t}$
$Ex^*_t = Y_t N^*_{X,t} (\tilde{\rho}^*_{X,t})^{1-\theta}$

Trade Balance
$TB_t = Ex_t - Ex^*_t$
$TB^*_t = Ex^*_t - Ex_t$.

GDP
$GDP_t = w_t L_t + r^k_t K_{t-1} + N_{D,t} \tilde{d}_t - N_{E,t} \tilde{v}_t + TB_t$
$GDP^*_t = w^*_t L^*_t + (r^k_t)^* K^*_{t-1} + N^*_{D,t} \tilde{d}^*_t - N^*_{E,t} \tilde{v}^*_t + TB^*_t$

Labour Productivity
$LaProd_t = \frac{GDP_t}{L_t}$,
$LaProd^*_t = \frac{GDP^*_t}{L^*_t}$,

B.2.2 Steady State Model

Assume that $f_E = f^*_E$, $f_X = f^*_X$.

For the initval block in Dynare I set $B_H = B{*}_H = B_F = B^*_F = 0$, $Z = Z^* = 1$, $Q = 1$ and used the following guess values:

$\tilde{z}_X = 3$
$\tilde{z}^*_X = 3$
$\tilde{z}_D = 2$
$\tilde{z}^*_D = 2$
$w = 5$
$w^* = 5$

Interest Rates

$r = \frac{1}{\beta} - 1$

$r^* = \frac{1}{\beta} - 1$

Return on Capital

$r^k = \frac{1}{\beta} + \delta^k - 1$

$(r^k)^* = \frac{1}{\beta} + \delta^k - 1$

Average Prices $\tilde{\rho}_D = \frac{\theta}{\theta-1}\left(\frac{w}{1-\alpha}\right)^{1-\alpha}\left(\frac{r^k}{\alpha}\right)^{\alpha}\frac{1}{\tilde{z_D}}$

$\tilde{\rho}_D^* = \frac{\theta}{\theta-1}\left(\frac{w^*}{1-\alpha}\right)^{1-\alpha}\left(\frac{(r^k)^*}{\alpha}\right)^{\alpha}\frac{1}{\tilde{z}_D^*}$

$\tilde{\rho}_X = \tau\frac{\theta}{\theta-1}\left(\frac{w}{1-\alpha}\right)^{1-\alpha}\left(\frac{r^k}{\alpha}\right)^{\alpha}\frac{1}{\tilde{z_X}}$

$\tilde{\rho}_X^* = \tau\frac{\theta}{\theta-1}\left(\frac{w^*}{1-\alpha}\right)^{1-\alpha}\left(\frac{(r^k)^*}{\alpha}\right)^{\alpha}\frac{1}{\tilde{z}_X^*}$

Number of Firms

$N_D = \frac{1}{\tilde{\rho}_D^{1-\theta}+0.1\tilde{\rho}_X^{1-\theta}}$

$N_D^* = \frac{1}{(\tilde{\rho}_D^*)^{1-\theta}+0.1(\tilde{\rho}_X^*)^{1-\theta}}$

$N_E = \frac{1-\left(\frac{z_{min}{}^{\nu}}{\tilde{z_D}}\right)^j}{\left(\frac{z_{min}{}^{\nu}}{\tilde{z_D}}\right)^j}$

$N_E^* = \frac{1-\left(\frac{z^*_{min}{}^{\nu}}{\tilde{z_D}^*}\right)^j}{\left(\frac{z^*_{min}{}^{\nu}}{\tilde{z_D}^*}\right)^j}$

$N_X = \left(\frac{\tilde{z}_D}{\tilde{z}_X}\right)^j$

$N_X^* = \left(\frac{\tilde{z}_D^*}{\tilde{z}_X^*}\right)^j$

Firm Value:

$\tilde{v} = wf_E.$

$\tilde{v}^* = w^*f_E^*.$

Factors of Production

$K = N_D\left(\frac{w\alpha}{r^k(1-\alpha)}\right)^{1-\alpha}\left[\left(\frac{w}{1-\alpha}\right)^{1-\alpha}\left(\frac{r^k}{\alpha}\right)^{\alpha}\frac{\theta}{\theta-1}\right]^{-\theta}[Y\tilde{z}_D^{\theta-1} + \frac{N_X}{N_D}Y^*\tau^{1-\theta}\tilde{z}_X^{\theta-1}]$

$K^* = N_D^*\left(\frac{w^*\alpha}{(r^k)^*(1-\alpha)}\right)^{1-\alpha}\left[\left(\frac{w^*}{1-\alpha}\right)^{1-\alpha}\left(\frac{(r^k)^*}{\alpha}\right)^{\alpha}\frac{\theta}{\theta-1}\right]^{-\theta}Y^*[(\tilde{z}_D^*)^{\theta-1} + \frac{N_X^*}{N_D^*)}Y\tau^{1-\theta}(\tilde{z}_X^*)^{\theta-1}]$

$L_P = N_D\left(\frac{r^k(1-\alpha)}{w\alpha}\right)^{\alpha}\left[\left(\frac{w}{1-\alpha}\right)^{1-\alpha}\left(\frac{r^k}{\alpha}\right)^{\alpha}\frac{\theta}{\theta-1}\right]^{-\theta}[Y\tilde{z}_D^{\theta-1} + \frac{N_X}{N_D}Y^*\tau^{1-\theta}\tilde{z}_X^{\theta-1}]$

$L_P^* = N_D^*\left(\frac{(r^k)^*(1-\alpha)}{w^*\alpha}\right)^{\alpha}\left[\left(\frac{w^*}{1-\alpha}\right)^{1-\alpha}\left(\frac{(r^k)^*}{\alpha}\right)^{\alpha}\frac{\theta}{\theta-1}\right]^{-\theta}[Y^*(\tilde{z}_D^*)^{\theta-1} + \frac{N_X^*}{N_D^*)}Y\tau^{1-\theta}(\tilde{z}_X^*)^{\theta-1}]$

$I = \delta^k K$

$I^* = \delta^k K^*$

Consumption

$$C = wL + r^k K + N_D \tilde{v} \frac{1-\beta}{\left(\frac{z_{min}\nu}{z_D}\right)^j \beta}$$

$$C^* = w^* L^* + (r^k)^* K^* + N_D^* \tilde{v}^* \frac{1-\beta}{\left(\frac{z^*_{min}\nu}{z_D^*}\right)^j \beta}$$

Labour Market Clearing

$$L = L_P + f_E N_E + f_X N_X + f_D N_D$$

$$L^* = L_P^* + f_E^* N_E^* + f_X^* N_X^* + f_D^* N_D^*$$

Profits

$$\tilde{d}_D = \tfrac{1}{\theta}(\tilde{\rho}_D)^{1-\theta} Y - w f_D$$

$$\tilde{d}_D^* = \tfrac{1}{\theta}(\tilde{\rho}_D^*)^{1-\theta} Y^* - w^* f_D^*$$

$$\tilde{d}_X = \tfrac{1}{\theta}(\tilde{\rho}_X)^{1-\theta} Y^* - w f_X$$

$$\tilde{d}_X^* = \tfrac{1}{\theta}(\tilde{\rho}_X^*)^{1-\theta} Y - w^* f_X^*$$

$$\tilde{d} = \tilde{d}_D + \tfrac{N_X}{N_D}\tilde{d}_X$$

$$\tilde{d}^* = \tilde{d}_D^* + \tfrac{N_X^*}{N_D^*}\tilde{d}_X^*$$

Output

$$Y = C + I.$$

$$Y^* = C^* + I^*$$

Other Variables *Exports* $Ex = Y^* N_X \tilde{\rho}_X^{1-\theta}$

$$Ex = Y N_X^* (\tilde{\rho}_X^*)^{1-\theta}$$

Trade Balance

$$TB = Ex - Ex^*$$

$$TB^* = Ex^* - Ex.$$

GDP

$$GDP = wL + r^k K + N_D \tilde{d} - N_E \tilde{v} + TB$$

$$GDP_t^* = w^* L^* + (r^k)^* K^* + N_D^* \tilde{d}^* - N_E^* \tilde{v}^* + TB^*$$

Labour Productivity

$$LaProd = \tfrac{GDP}{L},$$

$$LaProd^* = \tfrac{GDP^*}{L^*},$$

This model was solved and simulated using Dynare.[3]

[3] `https://www.dynare.org/`

B.3 Parameter Values

Table B: Parameter Values

Parameter	Value	Description
θ	6	Elasticity of substitution across goods
j	5.65	Shape parameter
z_{min}	1	Minimum relative productivity for producing - home economy
$z^{\star}_{min}$	1	Minimum relative productivity for producing - foreign economy
γ	2	Relative risk aversion
β	0.99	Discount factor
α	0.36	Factor Intensity
δ_k	0.025	Depreciation rate of capital
f_E	1	Sunk cost of entry - home
$f^{\star}_E$	1	Sunk cost of entry - foreign
f_D	0.004	Fixed cost of domestic production - home
$f^{\star}_D$	0.004	Fixed cost of domestic production - foreign
f_X	0.006	Fixed cost of exporting - home
$f^{\star}_X$	0.006	Fixed cost of exporting - foreign
τ	1.39	Variable cost of exporting
ρ_Z	0.9	Aggregate Technology AR process parameter - home
$\rho^{\star}_Z$	0.9	Aggregate Technology AR process parameter - foreign
ρ_{fe}	0.9	Sunk entry cost AR process parameter - home
$\rho^{\star}_{fe}$	0.9	Sunk entry cost AR process parameter - foreign
ρ_τ	0.9	Variable iceberg cost AR process parameter
ρ_ε	0.9	Preference AR process parameter - home
$\rho^{\star}_\varepsilon$	0.9	Preference AR process parameter - foreign

B.4 Differences in My Replication of MNN

I replicated the figures MNN use in their paper, which means that the baseline replication of their models is correct. When using this replication in my analysis, I depart from the original model in five ways:

1. I define labour productivity differently to MNN,
2. I change the free entry condition from the formulation in MNN,
3. I do not allow for an exogenous death shock,
4. I allow for international trade in bonds and thus unbalanced trade,
5. I calibrate the model to the UK and not the US.

I define labour productivity differently to MNN, who define labour productivity as $LaProd_t = \frac{GDP_t}{L - \left(\frac{\tilde{z}_{D,t}}{z_{min}}\right)^j N_e \frac{f_{E,t}}{Z}}$, while I define it as $LaProd_t = \frac{GDP_t}{L_t}$. I therefore include the labour that is used to cover sunk costs in my definition.

I do not allow for an exogenous death shock in my analysis. Instead I completely endogenise the firm exit rate and calibrate it to the average firm exit rate of the UK.

I also change the definition of the free entry condition, which states that the average firm value must equal the sunk cost of entry. In MNN this is adapted to account for the probability of drawing a productivity large enough to produce in the next period. However, this is already accounted for in the Euler equation that pins down the average firm value, which is why I remove the relevant term from the free entry condition.

All modifications have been thought about carefully. It is important to be aware of them, as it means that the business cycle statistics I report on for my replication of the model may differ from those presented in either of the papers. Furthermore, my IRFs for MNN will differ from the ones found in their paper as a result of these modifications.

Appendix C

Chapter 5 Appendices

C.1 Demand for Capital

Recall equation (5.5):

$$[1 - F(\bar{\omega})]\bar{\omega}R^k_{t+1}q_tK^j_t + (1-\mu)\int_0^{\bar{\omega}} \omega R^k_{t+1}q_tK^j_t dF(\omega) = R_{t+1}(q_tK^j_t - N^j_t)$$

Define as $r(\bar{\omega})$ the expected gross share of profits going to the lender: $r(\bar{\omega}) = \int_0^{\bar{\omega}} \omega f(\omega)d\omega + \bar{\omega}\int_{\bar{\omega}}^{\infty} f(\omega)d\omega$, where the first term is the second term of the above equation, expected receipts in case of default, and the 2nd term is the first term of the above equation, i.e.$[1 - F(\bar{\omega})]\bar{\omega}R^k_{t+1}q_tK^j_t$.

If $\omega^j \leq \bar{\omega}$, then the lender receives the return ω, multiplied by function of returns. If $\omega^j \geq \bar{\omega}$, the FI receives the return $\bar{\omega}$ multiplied by the function governing returns to capital.

Define monitoring costs as: $\mu G(\bar{\omega}) = \mu\int_0^{\bar{\omega}} \omega f(\omega)d\omega$.

The net share of profits going to the lender are then $r(\bar{\omega}) - \mu G(\bar{\omega})$, and the share going to the entrepreneur is $1 - r(\bar{\omega})$.

The problem for the entrepreneur, when simplified by dropping time subscripts, is:

$$\max_{w.r.t:R^k\bar{\omega},k,\lambda} [1 - r(\bar{\omega})]R^kqK$$

s.t.

$$[r(\bar{\omega}) - \mu G(\bar{\omega})]R^kKq = R(qK - N).$$

The Langrangian corresponding to this problem is:

$$\mathcal{L} = [1 - r(\bar{\omega})]R^kqK + \lambda\Big[[r(\bar{\omega}) - \mu G(\bar{\omega})]R^kKq - R(qK - N)\Big]$$

Divide by RN:

$$\mathcal{L} = [1 - r(\bar{\omega})]\frac{R^k}{R}\frac{qK}{N} + \lambda\Big[[r(\bar{\omega}) - \mu G(\bar{\omega})]\frac{R^k}{R}\frac{Kq}{N} - \Big(\frac{qK}{N} - 1\Big)\Big].$$

Next, define $\frac{R^k}{R} = s$ and $k = \frac{KQ}{N}$:

$$\mathcal{L} = [1 - r(\bar{\omega})]sk + \lambda\Big[[r(\bar{\omega}) - \mu G(\bar{\omega})]sk - (k-1)\Big].$$

The FOCs are:
$\bar{\omega} : r'(\bar{\omega}) - \lambda[r'(\bar{\omega}) - \mu G'(\bar{\omega})] = 0.$

$k : [(1 - r(\bar{\omega})) + \lambda(r(\bar{\omega}) - \mu G(\bar{\omega}))]s - \lambda = 0.$

$\lambda : [r(\bar{\omega}) - \mu G(\bar{\omega})]sk] - (k-1) = 0.$

Solve the FOC for capital for s:

$$\lambda = \Big[1 - r(\bar{\omega}) + \lambda\Big(r(\bar{\omega}) - \mu G(\bar{\omega})\Big)\Big]s.$$

$$\updownarrow$$

$$s = \tfrac{\lambda}{1 - r(\bar{\omega}) + \lambda[r(\bar{\omega}) - \mu G(\bar{\omega})]}.$$

Substitute the above expression for s into the FOC for λ:

$$[r(\bar{\omega}) - \mu G(\bar{\omega})]\tfrac{\lambda}{1 - r(\bar{\omega}) + \lambda[r(\bar{\omega}) - \mu G(\bar{\omega})]} = \tfrac{k-1}{k}.$$

$$\updownarrow$$

$$1 + \tfrac{\lambda[r(\bar{\omega}) - \mu G(\bar{\omega})]}{1 - r(\bar{\omega})} = k.$$

Next, define $\psi = 1 + \frac{\lambda[r(\bar{\omega}) - \mu G(\bar{\omega})]}{1 - r(\bar{\omega})} =.$

Thus,

$$k = \psi(\bar{\omega}).$$

Recalling that $k = \frac{q_t K_t^j}{N t^j}$,

$$q_t K_t^j = N_t^j \psi\Big(\frac{R_{t+1}^k}{R_t}\Big).$$

C.2 Full log-linearised Model

Pricing Equations

$$0 = A^{-1}\Big(\frac{\tau z_{min}}{\tilde{z}_X}\Big)^{\theta-1}\Big(\frac{j}{j-(\theta-1)}\Big)(\hat{N}_{D,t} + \hat{\rho}_{D,t}) + \Big(\frac{z_{min}}{\tilde{z}_X}\Big)^{j}\Big(\frac{j}{j-(\theta-1)}\Big)^{\frac{j}{\theta-1}} A^{-1}(\hat{N}^*_{X,t} + \hat{\rho}^*_{X,t}).$$

$$\hat{\tilde{\rho}}_{D,t} = (1-\alpha)\hat{w}_t + \alpha\widehat{r^k}_t - \hat{Z}_t - \tilde{z}_{D,t}.$$

$$\hat{\tilde{\rho}}_{X,t} = (1-\alpha)\hat{w}_t + \alpha\widehat{r^k}_t + \hat{\tau}_t - \hat{Q}_t - \hat{Z}_t - \hat{\tilde{z}}_{X,t}.$$

Profits

$$\hat{d}_{D,t} = \frac{j}{(\theta-1)}\Big((1-\theta)\hat{\rho}_{D,t} + \hat{Y}_{f,t}\Big) - \frac{j-(\theta-1)}{\theta-1}(\hat{w}_t + \hat{f}_{D,t} - \hat{Z}_t).$$

$$\hat{d}_{X,t} = \frac{j}{(\theta-1)}\Big(\hat{Q}_t + (1-\theta)\hat{\rho}_{X,t} + \hat{Y}^*_{f,t}\Big) - \frac{j-(\theta-1)}{\theta-1}(\hat{w}_t + \hat{f}_{X,t} - \hat{Z}_t).$$

$$\hat{d}_t \;=\; \frac{\theta-1}{j-(\theta-1)}\frac{\left(\frac{z_{min}\nu}{\tilde{z}_{D,t}}\right)^j\beta}{1-\left(\frac{z_{min}\nu}{\tilde{z}_{D,t}}\right)^j\beta}\frac{f_D}{f_E}\hat{d}_{D,t} + \frac{N_X}{N_D}\frac{\theta-1}{j-(\theta-1)}\frac{\left(\frac{z_{min}\nu}{\tilde{z}_{D,t}}\right)^j\beta}{1-\left(\frac{z_{min}\nu}{\tilde{z}_{D,t}}\right)^j\beta}\frac{f_X}{f_E}[\hat{N}_{X,t} + \hat{d}_{X,t} - \hat{N}_{D,t}].$$

ZPC and FE Condition

$$\hat{d}_{D,t} = \hat{w}_t + \hat{f}_{D,t} - \hat{Z}_t.$$

$$\hat{d}_{X,t} = \hat{w}_t + \hat{f}_{X,t} - \hat{Z}_t.$$

$$\hat{v}_t = \hat{w}_t + \hat{f}_{e,t} - \hat{Z}_t.$$

Number of Firms

$$\hat{N}_{D,t} = -j\hat{z}_{D,t} + \left(\frac{z_{min}\nu}{\tilde{z}_D}\right)^j\hat{N}_{D,t-1} + \Big[1-\left(\frac{z_{min}\nu}{\tilde{z}_D}\right)^j\Big]\delta\hat{N}_{E,t-1}.$$

$$\hat{N}_{X,t} = \hat{N}_{D,t} + j\hat{z}_{D,t} - j\hat{z}_{X,t}.$$

Euler Equations

$$[1-(1-\gamma)\mu)]\hat{C}_{t+1} = \frac{R}{1+R}\widehat{R}_t + [1-(1-\gamma)\mu)]\hat{C}_t + \hat{\varepsilon}_{t+1} - \hat{\varepsilon}_t + (1-\gamma)(1-\mu)\frac{L}{(1-L)}[\hat{L}_{t+1} - \hat{L}_t].$$

$$\begin{aligned}\hat{v}_t = {} & [1-(1-\gamma)\mu]\hat{C}_t + [(1-\gamma)\mu - 1]\hat{C}_{t+1} + \hat{\varepsilon}_{t+1} - \hat{\varepsilon}_t \\ & + (1-\gamma)(1-\mu)\frac{L}{(1-L)}[\hat{L}_{t+1} - \hat{L}_t] + \Big[1-\left(\frac{z_{min}\nu}{\tilde{z}_D}\right)^j\beta\Big]\hat{d}_{t+1} + \left(\frac{z_{min}\nu}{\tilde{z}_D}\right)^j\beta\hat{v}_{t+1}.\end{aligned}$$

$$\hat{C}_t = \hat{w}_t - \frac{L}{(1-L)}\hat{L}_t.$$

Factors of Production

$$\begin{aligned}\hat{L}_{P,t} = {} & \alpha\hat{r^k}_t - \alpha\hat{w}_t - \hat{Z}_t + \tau^\theta\tilde{z}_D^{\theta-1}\tilde{z}_X^{-\theta}\frac{1}{B}\Big[\hat{Y}_{f,t} + \hat{N}_{D,t} - \theta\hat{\rho}_{D,t} - \hat{z}_{D,t}\Big] + \\ & \frac{N_X}{N_D}\tau\tilde{z}_X^{-1}\frac{1}{B}\Big[\hat{N}_{X,t} + \hat{\tau}_t + \hat{Y}^*_{f,t} - \theta\hat{\rho}_{X,t} - \hat{z}_{X,t}\Big].\end{aligned}$$

$$\begin{aligned}\hat{K}_t = {} & (1-\alpha)\hat{w}_t - (1-\alpha)\hat{r^k}_t - \hat{Z}_t + \tau^\theta\tilde{z}_D^{\theta-1}\tilde{z}_X^{-\theta}\frac{1}{B}\Big[\hat{Y}_{f,t} + \hat{N}_{D,t} - \theta\hat{\rho}_{D,t} - \hat{z}_{D,t}\Big] + \\ & \frac{N_X}{N_D}\tau\tilde{z}_X^{-1}\frac{1}{B}\Big[\hat{N}_{X,t} + \hat{\tau}_t + \hat{Y}^*_{f,t} - \theta\hat{\rho}_{X,t} - \hat{z}_{X,t}\Big].\end{aligned}$$

$$\hat{K}_t = (1-\delta^k)\hat{K}_{t-1} + \delta^k\hat{I}_t.$$

Entrepreneur Equations

$$\hat{C}_t^e = \hat{N}_t.$$

$$\hat{R^k}_{t+1} = \frac{r^k}{r^k + (1-\delta^k)}\hat{r^k}_t + \frac{(1-\delta^k)}{r^k + (1-\delta^k)}\hat{q}_{t+1} - \hat{q}_t.$$

$$\hat{N}_t = (1-\delta)\frac{K(R^k - R)}{N}[\hat{K}_{t-1} + \hat{q}_{t-1}] + (1-\delta)\frac{R^k K}{N}\hat{R}_t^k - \Big((1-\delta)\frac{RK}{N} - (1-\delta)R\Big)\hat{R}_{t-1} + (1-\delta)R\hat{N}_{t-1}.$$

$$\hat{q}_t = \phi(\hat{I}_t - \hat{K}_{t-1}),$$

$$E\Big\{\hat{R^k}_{t+1}\Big\} - \hat{R}_t = -\psi[\hat{N}_t - \hat{q}_t - \hat{K}_t],$$

where $-\psi = \frac{s'(\frac{N}{K})}{s(\frac{N}{K})}\frac{N}{K}$.

Market Clearing Conditions

$$\hat{L}_t = \frac{L_P}{L}\hat{L}_{P,t} + \frac{N_E f_E}{L}(\hat{N}_{E,t} + \hat{f}_{E,t} - \hat{Z}_t) + \frac{N_X f_X}{L}(\hat{N}_{X,t} + \hat{f}_{X,t} - \hat{Z}_t) + \frac{N_D f_D}{L}(\hat{N}_{D,t} + \hat{f}_{D,t} - \hat{Z}_t),$$

where $L = 0.33$, $N_D = \tilde{\rho}_X^{\theta-1}A^{-1}$, $N_X = \left(\frac{\tilde{z}_D}{\tilde{z}_X}\right)^j N_D$, $N_E = \frac{1-\left(\frac{z_{min}{}^\nu}{\tilde{z}_D}\right)^j}{\left(\frac{z_{min}{}^\nu}{\tilde{z}_D}\right)^j}$.

$$\hat{Y_t^f} = \frac{C}{Y^f}\hat{C}_t + \frac{C^e}{Y^f}\hat{C}_t^e + \frac{I}{Y^f}\hat{I}_t.$$

$$\hat{Q}_t = \hat{N}_{X,t}^* + (1-\theta)\hat{\rho}_{X,t}^* + \hat{Y}_{f,t} - \hat{N}_{X,t} - (1-\theta)\hat{\rho}_{X,t} - \hat{Y}_{f,t}^*.$$

C.3 Closed Economy Model

Pricing Equations

$$0 = \hat{N}_{D,t} + \hat{\rho}_{D,t}.$$

$$\hat{\tilde{\rho}}_{D,t} = (1-\alpha)\hat{w}_t + \alpha\widehat{r^k}_t - \hat{Z}_t - \hat{z}_{D,t}.$$

Profits and FE Condition

$$\hat{d}_{D,t} = \frac{j}{\theta-1}((1-\theta)\hat{\rho}_{D,t} + \hat{Y}_{f,t}) - \frac{j-(\theta-1)}{\theta-1}(\hat{w}_t + \hat{f}_{D,t} - \hat{Z}_t).$$

$$\hat{d}_{D,t} = \hat{w}_t + \hat{f}_{D,t} - \hat{Z}_t.$$

$$\hat{v}_t = \hat{w}_t + \hat{f}_{e,t} - \hat{Z}_t.$$

Number of Firms

$$\hat{N}_{D,t} = -j\hat{z}_{D,t} + \left(\frac{z_{min}{}^\nu}{\tilde{z}_D}\right)^j \hat{N}_{D,t-1} + \Big[1 - \left(\frac{z_{min}{}^\nu}{\tilde{z}_D}\right)^j\Big]\delta\hat{N}_{E,t-1}.$$

Euler Equations

$$[1-(1-\gamma)\mu)]\hat{C}_{t+1} = \frac{R}{1+R}\widehat{R}_t + [1-(1-\gamma)\mu)]\hat{C}_t + \hat{\varepsilon}_{t+1} - \hat{\varepsilon}_t + (1-\gamma)(1-\mu)\frac{L}{(1-L)}[\hat{L}_{t+1} - \hat{L}_t].$$

$$\begin{aligned}\hat{v}_t = {} & [1-(1-\gamma)\mu]\hat{C}_t + [(1-\gamma)\mu - 1]\hat{C}_{t+1} + \hat{\varepsilon}_{t+1} - \hat{\varepsilon}_t \\ & + (1-\gamma)(1-\mu)\frac{L}{(1-L)}[\hat{L}_{t+1} - \hat{L}_t] + \Big[1 - \left(\frac{z_{min}{}^\nu}{\tilde{z}_D}\right)^j\beta\Big]\hat{d}_{t+1} + \left(\frac{z_{min}{}^\nu}{\tilde{z}_D}\right)^j\beta\hat{v}_{t+1}.\end{aligned}$$

$$\hat{C}_t = \hat{w}_t - \frac{L}{(1-L)}\hat{L}_t.$$

Factors of Production

$$\hat{L}_{P,t} = \alpha \hat{r^k}_t - \alpha\hat{w}_t - \hat{Z}_t - \hat{z}_{D,t} - \theta\hat{\rho}_{D,t} + \hat{Y}_t.$$

$$\hat{K}_t = (1-\alpha)\hat{w}_t - (1-\alpha)\hat{r^k}_t - \hat{Z}_t - \hat{z}_{D,t} - \theta\hat{\rho}_{D,t} + \hat{Y}_t.$$

$$\hat{K}_t = (1-\delta^k)\hat{K}_{t-1} + \delta^k\hat{I}_t.$$

Entrepreneur Equations

$$\hat{C}^e_t = \hat{N}_t.$$

$$\hat{R^k}_{t+1} = \frac{r^k}{r^k + (1-\delta^k)}\hat{r^k}_t + \frac{(1-\delta^k)}{r^k + (1-\delta^k)}\hat{q}_{t+1} - \hat{q}_t.$$

$$\hat{N}_t = (1-\delta)\frac{K(R^k - R)}{N}[\hat{K}_{t-1} + \hat{q}_{t-1}] + (1-\delta)\frac{R^k K}{N}\hat{R}^k_t - \Big((1-\delta)\frac{RK}{N} - (1-\delta)R\Big)\hat{R}_{t-1} + (1-\delta)R\hat{N}_{t-1}.$$

$$\hat{q}_t = \phi(\hat{I}_t - \hat{K}_{t-1}),$$

$$E\Big\{\hat{R^k}_{t+1}\Big\} - \hat{R}_t = -\psi[\hat{N}_t - \hat{q}_t - \hat{K}_t],$$

where $-\psi = \frac{s'(\frac{N}{K})}{s(\frac{N}{K})}\frac{N}{K}$.

Market Clearing Conditions

$$\hat{L}_t = \frac{L_P}{L}\hat{L}_{P,t} + \frac{N_E f_E}{L}(\hat{N}_{E,t} + \hat{f}_{E,t} - \hat{Z}_t) + \frac{N_D f_D}{L}(\hat{N}_{D,t} + \hat{f}_{D,t} - \hat{Z}_t),$$

where $L = 0.33$, $N_D = \tilde{\rho}_D^{\theta-1}$, $N_E = \frac{1 - \left(\frac{z_{min}{}^{\nu}}{z_D}\right)^j}{\left(\frac{z_{min}{}^{\nu}}{z_D}\right)^j} N_D$, $L_P = \left(\frac{r^k(1-\alpha)}{w\alpha}\right)^{\alpha}\left[\frac{\theta}{\theta-1}\left(\frac{w}{1-\alpha}\right)^{1-\alpha}\left(\frac{r^k}{\alpha}\right)^{\alpha}\right]^{-\theta} Y\tilde{z}_D^{\theta-1}$

$$\hat{Y^f_t} = \frac{C}{Y^f}\hat{C}_t + \frac{C^e}{Y^f}\hat{C}^e_t + \frac{I}{Y^f}\hat{I}_t.$$

C.4 Parameter Values

Given the model parameterisation described in tables C.4.1 and C.4.2, I solve for and set the steady state of the following variables:
$\tilde{\rho}_X$, $\tilde{\rho}^{\star}_X$, w, $w^{\star}$, K, $K^{\star}$, L_P, $L^{\star}_P$, N_D, $N^{\star}_D$, N_E, $N^{\star}_E$ I, $I^{\star}$, Y, $Y^{\star}$, $\frac{I}{Y}$, $\left(\frac{I}{Y}\right)^{\star}$, $\frac{C}{Y}$, $\left(\frac{C}{Y}\right)^{\star}$

I set
$\frac{\mu}{1-\mu} - \frac{1}{1-\mu}L = \tilde{\rho}_X^{\theta-1}A^{-1}\frac{1-\beta}{\left(\frac{z_{min}\nu}{\tilde{z}_D}\right)^j\beta}f_E + \frac{R-1}{1-\alpha}\left(\frac{1}{\tilde{z}_X}\frac{\theta\tau}{\theta-1}\right)^{\frac{1}{1-\alpha}}\left(\frac{r^k}{\alpha}\right)^{\frac{\alpha}{1-\alpha}}\tilde{\rho}_X^{\frac{1}{\alpha-1}}$.;
$w = (1-\alpha)\Big[\rfloor\tilde{\rho}_X\tilde{z}_X\frac{\theta-1}{\theta\tau}\left(\frac{\alpha}{r^k}\right)^{\alpha}\Big]^{\frac{1}{1-\alpha}}$;
$N_D = \tilde{\rho}_X^{\theta-1}A^{-1}$, where $A = \tau^{\theta-1}\left(\frac{z_{min}}{\tilde{z}_X}\right)^{\theta-1}\frac{j}{j-(\theta-1)} + \left(\frac{z_{min}}{\tilde{z}_X}\right)^j\left(\frac{j}{j-(\theta-1)}\right)^{\frac{j}{\theta-1}}$;
$N_E = \frac{1-\left(\frac{z_{min}\nu}{\tilde{z}_{D,t}}\right)^j}{\left(\frac{z_{min}\nu}{\tilde{z}_{D,t}}\right)^j}N_D$;
$Y = wf_X\tilde{\rho}_X^{\theta-1}\frac{j\theta}{j-(\theta-1)}$
$K = N_D\left(\frac{w\alpha}{r^k(1-\alpha)}\right)^{1-\alpha}\left[\left(\frac{w}{1-\alpha}\right)^{1-\alpha}\left(\frac{r^k}{\alpha}\right)^{\alpha}\frac{\theta}{\theta-1}\right]^{-\theta}Y[\tilde{z}_D^{\theta-1} + \frac{N_X}{N_D}\tau^{1-\theta}\tilde{z}_X^{\theta-1}]$;
$L_P = N_D\left(\frac{r^k(1-\alpha)}{w\alpha}\right)^{\alpha}\left[\left(\frac{w}{1-\alpha}\right)^{1-\alpha}\left(\frac{r^k}{\alpha}\right)^{\alpha}\frac{\theta}{\theta-1}\right]^{-\theta}Y[\tilde{z}_D^{\theta-1} + \frac{N_X}{N_D}\tau^{1-\theta}\tilde{z}_X^{\theta-1}]$;
$I = \delta_k K$;
$\frac{I}{Y} = \frac{I}{Y}$;
$\frac{C}{Y} = 1 - \frac{C^e}{Y} - \frac{I}{Y}$.

In the closed economy model I set:

$\frac{\mu}{1-\mu} - \frac{1}{1-\mu}L = \tilde{\rho}_D^{\theta-1}\frac{1-\beta}{\left(\frac{z_{min}\nu}{\tilde{z}_D}\right)^j\beta}f_E + \frac{R-1}{1-\alpha}\left(\frac{1}{\tilde{z}_D}\frac{\theta}{\theta-1}\right)^{\frac{1}{1-\alpha}}\left(\frac{r^k}{\alpha}\right)^{\frac{\alpha}{1-\alpha}}\tilde{\rho}_D^{\frac{1}{\alpha-1}}$,
$N_D = \tilde{\rho}_D^{\theta-1}$,
$N_E = \frac{1-\left(\frac{z_{min}\nu}{\tilde{z}_{D,t}}\right)^j}{\left(\frac{z_{min}\nu}{\tilde{z}_{D,t}}\right)^j}N_D$;
$Y = wf_D\tilde{\rho}_D^{\theta-1}\frac{j\theta}{j-(\theta-1)}$
$K = N_D\left(\frac{w\alpha}{r^k(1-\alpha)}\right)^{1-\alpha}\left[\left(\frac{w}{1-\alpha}\right)^{1-\alpha}\left(\frac{r^k}{\alpha}\right)^{\alpha}\frac{\theta}{\theta-1}\right]^{-\theta}Y\tilde{z}_D^{\theta-1}$;
$L_P = N_D\left(\frac{r^k(1-\alpha)}{w\alpha}\right)^{\alpha}\left[\left(\frac{w}{1-\alpha}\right)^{1-\alpha}\left(\frac{r^k}{\alpha}\right)^{\alpha}\frac{\theta}{\theta-1}\right]^{-\theta}Y\tilde{z}_D^{\theta-1}$;
$I = \delta_k K$;
$\frac{I}{Y} = \frac{I}{Y}$;
$\frac{C}{Y} = 1 - \frac{C^e}{Y} - \frac{I}{Y}$. The other parameters are set identically to the open economy model, as set out in tables C.4.1 and C.4.2.

Table C.4.1: Calibrated Parameter Values

Parameter	Value	Description
θ	6	Elasticity of substitution across goods
j	5.65	Shape parameter
z_{min}	1	Minimum relative productivity for producing - home
$z^{\star}_{min}$	1	Minimum relative productivity for producing - foreign
δ	0.025	Exit rate
γ	2	Relative risk aversion
β	0.99	Discount factor
τ	1.39	Iceberg cost
μ	0.38	Share of consumption in utility
ν	1.541	Productivity parameter
α	0.37	Capital share
δ^k	0.025	Depreciation rate of capital
f_E	1	Sunk entry cost - home
$f^{\star}_E$	1	Sunk entry cost - foreign
f_X	0.006	Fixed exporting costs - home
$f^{\star}_X$	0.006	Fixed exporting costs - foreign
f_D	0.004	Fixed cost of domestic production - home
$f^{\star}_D$	0.004	Fixed cost of domestic production - foreign
Z	1	Aggregate technology - home
ρ_Z	0.9	Productivity AR process parameter - home
$\rho^{\star}_Z$	0.9	Productivity AR process parameter - foreign
ρ_{fe}	0.9	Sunk entry cost AR process parameter - home
$\rho^{\star}_{fe}$	0.9	Sunk entry cost AR process parameter - foreign
ρ_{ε}	0.9	Preferences AR process parameter - home
$\rho^{\star}_{\varepsilon}$	0.9	Preferences AR process parameter - foreign
ϕ	0.25	Elasticity of price of capital with respect to capital-investment-ratio
υ	0 if the FA is off 0.5 if the FA is on	Leverage ratio

Table C.4.2: Steady State Parameter Values

Parameter	Value	Description
$\tilde{z}_D$	1.548	Steady state average domestic productivity level - home
$\tilde{z}_D^\star$	1.548	Steady state average domestic productivity level - foreign
$\tilde{z}_X$	2.33	Steady state average exporting productivity level - home
$\tilde{z}_X^\star$	2.33	Steady state average exporting productivity level - foreign
Z	1	Steady state aggregate technology level - home economy
$Z^\star$	1	Steady state aggregate technology level - foreign
Q	1	Steady state exchange rate
ε	1	Steady state preference parameter - home
$\varepsilon^\star$	1	Steady state preference parameter - foreign
L	0.33	Steady state value of aggregate labour - home
$L^\star$	0.33	Steady state value of aggregate labour - foreign
$\frac{N_X}{N_D}$	0.099	Steady state proportion of exporting firms - home
$(\frac{N_X}{N_D})^\star$	0.099	Steady state proportion of exporting firms - foreign
r	$\frac{1}{\beta}$	Steady state interest rate - home
$r^\star$	$\frac{1}{\beta}$	Steady state interest rate - foreign
R^k	r if the FA is off $r + 0.005$ if the FA is on	Steady state return to capital - home
$(R^k)^\star$	r if the FA is off $r + 0.005$ if the FA is on	Steady state return to capital - foreign
r^k	$R^k - (1 - \delta^k)$	Steady state rental rate of capital - home
$(r^k)^\star$	$R^k - (1 - \delta^k)$	Steady state rental rate of capital - foreign
$\frac{K}{N}$	2	Steady state ratio of capital to net worth - home
$\left(\frac{K}{N}\right)^\star$	2	Steady state ratio of capital to net worth - foreign
$\frac{C^e}{Y_f}$	0.01	Steady state entrepreneurial consumption to output ratio - home
$\left(\frac{C^e}{Y_f}\right)^\star$	0.01	Steady state entrepreneurial consumption to output ratio - foreign
q	1	Steady state price of capital - home
$q^\star$	1	Steady state price of capital - home