

The Role of Trade Costs in the Surge of Trade Imbalances*

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Abstract

This paper shows that the decline in trade costs that underlies the increase in observed bilateral gross trade flows in the world has notably contributed to the surge in net trade imbalances over the past four decades. To show this, I propose a framework that embeds a quantitative multi-country general equilibrium model of international trade based on Ricardian comparative advantages into a dynamic framework in which trade imbalances arise endogenously. By exploiting the information in bilateral trade flows, among other data, I calibrate the model and provide a decomposition that shows that 69 percent of the increase in world trade imbalances can be explained by the decline in trade costs across countries. In other words, lower trade costs have not only allowed for more trade across countries in a particular point in time, but also for more trade over time. Moreover, the effect of lower trade costs on trade imbalances is very heterogeneous across countries. In particular, trade imbalances in countries like the U.S. and China have been significantly affected by the fact that trade costs have declined.

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1 Introduction

Trade costs affect all forms of trade. Bilateral trade flows at a particular point in time are shaped by the costs associated with shipping goods across countries. Similarly, trade across time periods in the form of trade imbalances, the difference between a country's total exports and imports, also depends on the levels of these costs at different points in time. Hence, a comprehensive understanding of the forces driving increases in trade imbalances and the risks that they might entail, hinges on identifying how changes in trade costs affect them.¹ Even though this fact is self evident, there is little work exploring the effect of these costs on trade imbalances, or what might be called intertemporal trade.²

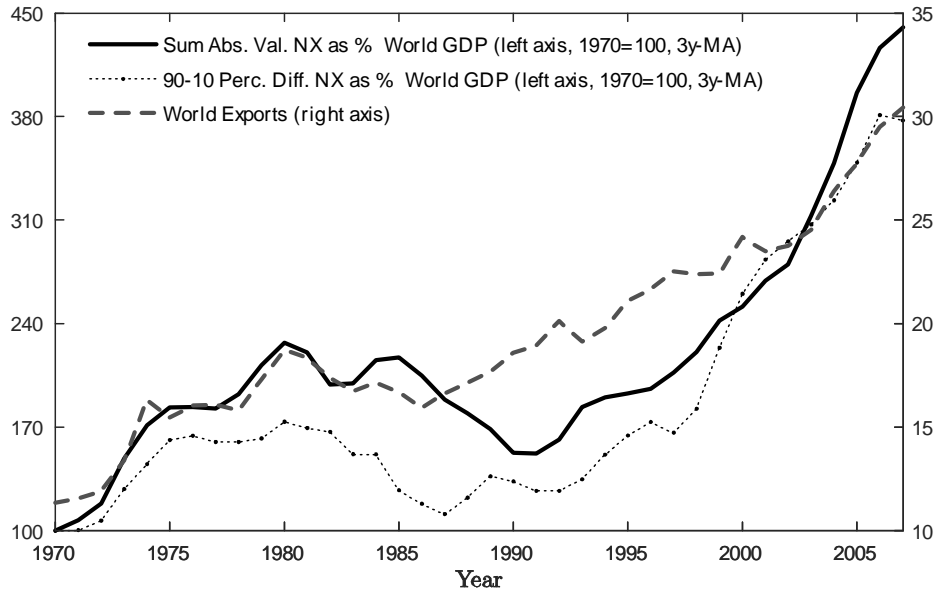
This paper provides a quantitative assessment of the contribution of declining trade costs to the increase in trade imbalances in recent decades. As can be observed in Figure 1, there was a steady and sizable increase in bilateral trade flows as well as in the size of trade imbalances, both as a share of world GDP, over the period spanning from 1970 to 2007. I argue in this paper that the decline in trade costs that underlies the increase in observed bilateral trade flows notably contributed to the steady increase in trade imbalances over this period. Specifically, I show that 69 percent of the increase in trade imbalances from 1970 to 2007 can be attributed to lower trade costs in goods markets.

In order to quantify the effects of bilateral trade costs on trade imbalances I propose a theoretical framework that incorporates the main mechanisms driving bilateral trade flows as well as trade imbalances. Specifically, I embed a quantitative multi-country general equilibrium model of international trade into a dynamic framework in which trade imbalances arise endogenously from optimal consumption-saving decisions by economic agents. This model has two main components. First, a static component that builds on the new quantitative multi-country and sector general equilibrium models of international trade based on Ricardian comparative advantages [*e.g.* Eaton and Kortum (2002), and Caliendo and Parro (2015)]. This part of the model delivers a multi-sector gravity structure of bilateral trade that provides a parsimonious framework to recover the bilateral trade costs that underlie observed bilateral trade flows in the cross section of countries in each year. Second, a dynamic component that gives rise to endogenous trade imbalances based on optimal intertemporal consumption-saving decisions. This part of the model considers a perfect-foresight dynamic framework in which economic agents are able to smooth consumption over time by means of buying and selling one-period bonds in international financial markets. In an equilibrium of the

¹For example, the literature has pointed out the risks associated with rebalancing current accounts around the world [see Blanchard *et al.* (2005), and Obstfeld and Rogoff (2005)]. For a perspective on the relevance of imbalances after the recent financial crisis, see Blanchard and Miles-Ferretti (2009) and Obstfeld (2012).

²One contribution that stands out is the work of Obstfeld and Rogoff (2000).

Figure 1: Gross Trade Flows and Trade Imbalances (Percent of World GDP)



Notes: The figure plots the evolution of bilateral trade flows aggregated up into world exports as a percentage of world GDP (right axis). The figure also plots the evolution of two measures of trade imbalances normalized to one in 1970 (left axis). The first measure of imbalances is the sum over countries' absolute values of net exports as a percentage of world GDP. The second measure is the 90-10 percentile difference of net exports in the cross section of countries. The increase in the second measure implies that the increase in imbalances is not being driven by the tails of the cross section distribution of imbalances. All series plotted are the 3-year moving averages (3y-MA) of the original series.

world economy in this model, trade imbalances that arise from optimal intertemporal decisions by countries have to be consistent with those based on optimal intratemporal trade across countries.

In the model, bilateral trade costs affect equilibrium trade imbalances through two effects. The first effect is a *level effect*. Uniformly lower levels of trade costs over all time periods lead to equilibrium goods and factor prices that increase trade imbalances. Intuitively, high bilateral trade costs act as a tax on intertemporal trade due to the fact that this is realized through intratemporal trade of goods and services in different time periods. The seminal work of Obstfeld and Rogoff (2000) points out this mechanism. The authors show how the level effect translates into differences in countries' real interest rates depending on their trade balance positions: borrowing countries that run trade deficits pay high real interest rates, while lending countries running trade surpluses get paid low real interest rates, thus, leading to smaller trade imbalances.

The second effect is associated with the fact that trade costs decline over time, which I refer to as the *tilting effect*. This is a general equilibrium effect that arises from the fact that lower trade costs in the future imply that the world economy becomes richer. This implies that, compared to the case of constant trade costs, equilibrium world real interest rates under declining trade costs are high in initial periods. Therefore, equilibrium imbalances in initial periods are dampened relative

to those in the future. Countries that borrow in initial periods borrow less due to high real interest rates, while countries that lend in initial periods lend less because of the positive income effect due to higher interest rates.

In order to quantify the effects of trade costs on trade imbalances, I map the model to observed data for the period 1970-2007 by exploiting the information in bilateral trade flows as well as sectoral and aggregate data on production and prices for a set of 26 countries (including the Rest of the World). Specifically, following Eaton *et al.* (2011), I rely on the structure of the model's equilibrium conditions to recover time series of structural residuals, which I refer to as disturbances, that decompose the forces driving the evolution of the data. The set of disturbances consist of: (i) sector-specific bilateral trade costs, (ii) country and sector-specific productivities, (iii) country and sector-specific demand shifters, and (iv) country-specific intertemporal preference shifters. This set of disturbances accounts for all changes in bilateral trade flows, country and sector-specific prices, country and sector-specific expenditures, and trade imbalances. This procedure allows me to disentangle the effects of bilateral trade costs from various other forces that affect the realization of trade imbalances. For instance, frictions in international financial markets are captured by the disturbances to intertemporal preferences, *i.e.* wedges in countries' Euler equations.³

Relying on this decomposition, I conduct counterfactual exercises to quantify the consequences of changes in trade costs. My focus is on the contribution of declining trade costs to the surge in trade imbalances. Hence, in the main counterfactual exercise I assume that bilateral trade costs are held fixed at their 1970's levels and solve for the competitive equilibrium of the world economy. The counterfactual equilibrium is pinned down by the initial net foreign asset distribution of the world economy. Solving for counterfactual equilibria in this fashion is key to provide a quantification that incorporates both the level and tilting effects.⁴

The results of the main counterfactual exercise show that, if trade costs had remained at their 1970's levels, the increase in world trade imbalances from 1970 to 2007 would have been 69 percent smaller than in the data, which implies that this share of the increase in world trade imbalances is explained by the decline in trade costs across countries. This difference is the result of a decrease in

³As it will become clear when I describe the model, it incorporates the effects of those financial frictions that manifest themselves as wedges in a country's Euler equation. Many models with frictions in international financial markets map to this kind of wedges. For example, in Mendoza *et al.* (2009) frictions show up as wedges in Euler equations.

⁴An alternative would be to solve a planner's problem. In this case, we could either assign Pareto weights to countries and recover all disturbances based on the planner's optimality conditions [Eaton *et al.* (2015)], or abstract from disturbances to intertemporal preferences and recover time-varying weights using the data [Fitzgerald (2012)]. However, the issue that arises when conducting counterfactual exercises is that the weights that decentralize the counterfactual equilibrium are unknown. If we were to keep the Pareto weights unchanged in the counterfactual, then we would be ignoring the differential effects across countries due to the ownership of assets. On the other hand, if we were to take a stand on the Pareto weights in the counterfactual, we would not be considering the effects of trade costs in isolation.

imbalances in 2007 of 41 percent and an increase in 1970 of 28 percent of the overall change in the data. The fact that equilibrium imbalances are greater in the initial years even when trade costs in the counterfactual are the same or similar to the ones in the data is a result of the tilting effect; in the counterfactual, not only do the levels of trade costs change, but also their entire dynamic path. I confirm this result by conducting an additional exercise in which I isolate the level effect by comparing trade imbalances fixing trade costs at their 1970's and 2007's levels. These results highlight the importance of solving for counterfactual competitive equilibria that are pinned down by the initial net foreign asset distribution in the world economy.

In an additional exercise I consider the counterfactual scenario in which agents arrive to the year 1986 and realize that trade costs will remain constant in all subsequent periods. This exercise is aimed to quantify the effect of the trade liberalizations that came after 1986. In this counterfactual, there is basically no increase in trade imbalances between 1986 and 2007.⁵

In the main counterfactual exercise, I also find that the effects of lower trade costs on trade imbalances are heterogeneous across countries. In particular, trade imbalances in the U.S. and China have been shaped significantly by the fact that trade costs have declined. For example, if trade costs had not decreased, the U.S. would have not experienced the observed increase in its trade deficit from 1970 to 2007. In the case of China, it would have experienced trade surpluses from 1970 until the early 1990s, and deficits afterwards. Namely, exactly the opposite to what we observe in the data. In contrast to these examples, there are other countries whose trade imbalances are mainly driven by forces other than declines in trade costs and therefore do not change significantly in the counterfactual. This is the case of countries like Japan and Greece.

The reduction in trade costs has important welfare consequences. I compute the welfare gains from lower trade costs in terms of the consumption-equivalent variation in each country. Hence, these measures do not only include the static gains from lower trade costs that are usually computed using static models, but also the additional gains due to the ability to trade intertemporally more efficiently. My results show that, with the exception of two countries of a sample of 26, all countries benefited from lower trade costs. Furthermore, these gains vary significantly across countries. The median gain is 2 percent of additional consumption per year. While Venezuela and Finland suffer welfare losses in the order to 2 percent, countries like Belgium, China and Korea gain additional consumption in the order of 10 percent per year.

These findings highlight the quantitative relevance of lower trade costs for countries' intertemporal trade decisions. Moreover, they point to the fact that the key for a better understanding

⁵By contrast to the equilibrium in the main counterfactual exercise, this equilibrium is pinned down by the net foreign asset distribution of 1986, rather than the one in 1970.

of the roots of the steady increase in trade imbalances, and their potential risks, might lie in the fundamental determinants of bilateral trade costs in goods markets rather than other mechanisms.

Related Literature This paper contributes to several strands of the literature in international economics. First, it contributes to the literature that explores how trade costs affect international macroeconomic variables [*e.g.* Backus, Kehoe and Kydland (1992), Kose and Yi (2006), Fitzgerald (2008), and Barattieri (2014)]. Obstfeld and Rogoff (2000) investigate the potential role of these costs in explaining international macroeconomics puzzles.⁶ However, their framework is not suitable for a quantitative assessment of these effects. Few studies have aimed to address this issue and quantify the effects of trade costs on international macroeconomic puzzles. One notable example is Fitzgerald (2012). By exploiting the gravity structure of an Armington-type model of trade in a dynamic-stochastic environment, Fitzgerald (2012) evaluates how risk-sharing across countries is affected by the degree of incompleteness of financial markets and trade costs in goods markets. Fitzgerald’s results show that trade costs significantly impede risk-sharing, hence, favoring the approach of incorporating these costs when analyzing international macroeconomic variables. In contrast to this paper, her counterfactual exercises do not isolate the effects of the observed decline in trade costs on trade imbalances.⁷ I fill in a gap in this literature by providing a quantitative assessment of the contribution specific to declining trade costs to the evolution of trade imbalances by solving for the counterfactual competitive equilibria that incorporate both the level and tilting effects. Additionally, in contrast to Fitzgerald (2012), I consider multiple sectors in a framework in which intratemporal trade arises due to differences in Ricardian comparative advantage across countries.

This paper is also related to the recent literature on new quantitative general equilibrium models of international trade based on gravity-type equations.⁸ The seminal work of Eaton and Kortum (2002) provided a micro-foundation based on Ricardian forces for gravity models of trade that led to many of the recent contributions in this literature. Dekle *et al.* (2007, 2008) incorporate trade deficits into this model and develop a procedure for quantitative analysis of counterfactual equilibria that is now standard in the literature.⁹ However, their analysis is static, which implies that their framework does not provide an underlying explanation as to why these imbalances arise

⁶The puzzles they consider are: The home-bias-in-trade puzzle, the Feldstein-Horioka puzzle, the home bias in equity holding puzzle, the consumption correlation puzzle, the purchasing-power-parity puzzle, and the exchange rate disconnect puzzle.

⁷Specifically, she solves for the planner’s problem, which implies that in counterfactual exercises she must take a stand on the counterfactual Pareto weights. In her exercises, she focuses on the case in which countries can engage in perfect risk sharing, and does not analyze the counterfactual evolution of trade imbalances.

⁸See Costinot and Rodríguez-Clare (2014) for a recent survey of the literature.

⁹This paper focuses on the effects of rebalancing current accounts by analyzing a counterfactual world in which all imbalances are eliminated.

or might change. Caliendo and Parro (2015) retained the assumption of exogenous trade imbalances and extended the model in Dekle *et al.* (2007, 2008) by incorporating multiple sectors and input-output linkages in a tractable fashion. This type of models provides now the standard framework for quantitative analysis of gross international trade flows driven by multiple disturbances that can be recovered from observed data. Moreover, recent work has exploited this framework to analyze issues that have been traditionally addressed in macroeconomics.¹⁰

Many recent contributions have enriched these models and the way in which they incorporate imbalances in a static setup [*e.g.* Ossa (2014) and Caliendo *et al.* (2014)], however, basically none of them has considered an intertemporal approach to trade imbalances.¹¹ One exception is Eaton *et al.* (2015), which incorporates a structure of international trade, similar to the one in my model, into a dynamic model of business-cycles in order to investigate the forces acting on the global economy during the Great Recession and ensuing recovery.¹² In their model, trade imbalances also arise from optimal intertemporal decisions by economic agents, hence, linking changes in trade costs to trade imbalances. However, there are substantial differences between their work and mine. First, the focus of my paper is on the forces shaping long run changes in trade imbalances, while their paper focuses on forces at the business-cycle frequency. Therefore, their analysis and model shifts attention to investment and capital accumulation rather than changes in trade imbalances. Second, in terms of methodology, in Eaton *et al.* (2015) trade imbalances arise from the solution of a planner’s problem that assigns subjective weights to each country. These weights are held constant across counterfactual exercises. In contrast, I solve for the competitive equilibrium, which implies that weights are mapped to equilibrium outcomes that change across counterfactual equilibria. This difference is key in order to quantify the full effects of trade costs on trade imbalances, like the tilting effect. Third, they incorporate endogenous investment decisions and focus on different sectors for which data on investment is available. Hence, in their counterfactuals, changes in capital stocks over time are driven by endogenous investment decisions which I do not have in my model.¹³

¹⁰For example, Parro (2013) explores the effects of trade and capital-skill complementarity on the skill premium; Caselli *et al.* (2015) analyze how trade affects macroeconomic volatility; and Levchenko and Zhang (2015) exploit the structure of these models to recover the evolution of sectoral productivities and explore changes in comparative advantage over time. Another interesting example is Caliendo *et al.* (2014) which studies the impact of intersectoral and interregional trade linkages in propagating disaggregated productivity changes in particular locations of the U.S. to the rest of the economy.

¹¹As discussed in Obstfeld and Rogoff (1995), this approach views trade imbalances, or more precisely current-account imbalances, as the outcome of forward-looking dynamic saving and investment decisions; currently the standard in international macroeconomic models.

¹²The methodology for counterfactual analysis in my paper was in part motivated by the first version of their paper [Eaton *et al.* (2011)], which did not incorporate endogenous trade imbalances. A subsequent version of their work [Eaton *et al.* (2015)], which came out while I had already started this project, does consider trade deficits derived from optimal saving decisions.

¹³Extending my theoretical framework to incorporate capital accumulation is relatively standard. In an appendix I present a version of my model with endogenous investment decisions. However, solving for counterfactual equilibria numerically is a computationally complex endeavor, and is currently work in progress.

This paper also contributes to the literature in international macroeconomics that studies the causes and consequences of the observed pattern of external imbalances. Gourinchas and Rey (2014) provide an extensive survey of the literature.¹⁴ Most of this literature has focused on financial frictions to explain the fundamental causes of the observed pattern of current account imbalances.¹⁵ For instance, Caballero et al. (2008) and Mendoza et al. (2009) consider the case of differences in the development of financial markets across particular regions or groups of countries. Chang et al. (2013) build on the model with a continuum of countries of Clarida (1990) to quantitatively explore the increase in the dispersion of current account imbalances under uninsurable idiosyncratic risk.¹⁶ Other papers have explored the interaction between trade and capital flows. The work by Antràs and Caballero (2010) and Jin (2012) provide two examples of this work. However, none of these papers explores the effect of declining trade costs on imbalances.

In contrast to this literature, this paper does not take a stand on a particular fundamental cause for observed trade imbalances; I rather attribute them to a set of disturbances that might be generated by multiple underlying frictions. In this sense, this paper relates to Gourinchas and Jeanne (2013) who rely on disturbances or “wedges” to saving and investment decisions to point to where the underlying causes of the “allocation puzzle” might lie. However, one of the set of disturbances in my model maps directly to the trade costs that arise in micro-founded gravity models of trade, thus, providing a sufficient statistic of frictions in bilateral transactions of goods and services across countries, *i.e.* trade costs.¹⁷ By doing so, this paper contributes to the literature in various respects. First, by focusing on frictions in goods rather than financial markets, I show that the effects of the former are quantitatively relevant in the determination of trade imbalances. Second, by considering a multi-country and sector structure and incorporating geography, the model allows me to study the implications for as well as the effects of trade imbalances in particular countries. Third, I contribute by analyzing trade imbalances for a long period of time relative to other studies. As shown in Figure 1 and documented in Faruqee and Lee (2009), the increase in imbalances started well before the late 1990s. Lastly, I focus on explaining the evolution of trade rather than current account imbalances. While this is not the standard in the literature

¹⁴Many studies focus on what they refer to as “global imbalances”, which they define as the steady increase in current account balances since the late 1990s, specifically the increase in capital flows from emerging economies to the U.S.; and the fact that net capital inflows tend to be negatively correlated with productivity growth across developing countries, the “allocation puzzle”.

¹⁵Bernanke (2005) identifies a number of other potential reasons behind what he calls a “saving-glut”, many of which have also been studied in the literature. For example, Aguiar and Amador (2011) study public flows and reserve accumulation and Lane and Milesi-Ferretti (2001) consider demographic factors.

¹⁶Bai and Zhang (2010) use a similar framework to study the Feldstein-Horioka puzzle.

¹⁷Chari et al. (2007) show how models with different types of frictions map to these shocks or “wedges” in a closed economy RBC model. Kehoe, Ruhl and Steinberg (2013) consider a two country world and rely on a similar accounting procedure to evaluate the contribution of global imbalances to structural transformation in the U.S.

on external imbalances, I do so because trade costs primarily affect bilateral trade flows which are directly related to the trade balance rather than the current account. Still, the trade balance accounts for most of the current account in a majority of countries.

Road Map The remainder of this paper is organized as follows. Section 2 describes the model and defines an equilibrium. Additionally, it discusses the main mechanisms through which trade costs affect trade imbalances. Section 3 explains how the model is mapped to aggregate data for a set of 26 countries for the period 1970-2007. This section shows how the structure of the model delivers structural residuals that can be identified using the data previously mentioned. Section 5 conducts the counterfactual exercises that lead to the main results of this paper. Section 6 concludes.

2 The Model

The main goal of this paper is to provide a quantitative assessment of the role of trade costs as determinants of trade imbalances. In order to do so, this section develops the theoretical framework that will be used to study these effects. The framework embeds a quantitative model of international trade into a dynamic environment in which trade imbalances arise endogenously due to consumption-saving decisions. The static structure of the model builds on the quantitative multi-sector extensions of the work by Eaton and Kortum (2002). Specifically, the static part of my model is closest to the framework in Caliendo and Parro (2015).

Consider an infinite horizon in which time is discrete and indexed by $t = 0, 1, \dots$. The world consists of I countries indexed by $i = 1, \dots, I$, each populated by a representative household endowed with $L_{i,t}$ and $K_{i,t}$ units of homogeneous labor and capital in period t . Each economy consists of J sectors that I index by $j = 1, \dots, J$. Hence, in general I will use the letter t to denote time periods, the letter i or h to denote countries, and the letter j to denote sectors. I assume that all economic agents have perfect foresight.

2.1 Nontradable Sectoral Goods

Final output in each sector j is given by an aggregate of a continuum of tradable goods indexed by $\omega^j \in [0, 1]$. I assume that this aggregation takes on a constant elasticity of substitution (CES) functional form with elasticity of substitution $\eta > 0$. Denoting by $Q_{i,t}^j$ sector j 's final output in

country i at time t , we have that

$$Q_{i,t}^j = \left(\int_0^1 d_{i,t}^j(\omega^j)^{\frac{\eta-1}{\eta}} d\omega^j \right)^{\frac{\eta}{\eta-1}}, \quad (1)$$

where $d_{i,t}^j(\omega^j)$ denotes the use in production of intermediate good ω^j .

The demand for each intermediate good is derived from the cost minimization problem of a price-taking representative firm. Moreover, since good ω^j is tradable across countries, the firms producing $Q_{i,t}^j$ search across all countries for the lowest cost supplier of this good.

The final output in each sector j is nontradable and can be used either for final consumption or as an intermediate input into the production of the tradable goods. I will denote by $P_{i,t}^j$ the price of sectoral good j in country i at time t . Note that, since sectoral goods are nontradable, these prices can differ across countries. Let us now focus on the technologies available to produce the tradable goods indexed by ω^j .

2.2 Tradable Goods

Consider a particular good $\omega^j \in [0, 1]$ and let $q_{i,t}^j(\omega^j)$ denote the production of this good in country i at time t . The technology to produce each good ω^j is given by

$$q_{i,t}^j(\omega^j) = x_{i,t}^j(\omega^j) \left[k_{i,t}^j(\omega^j)^{\varphi_i} l_{i,t}^j(\omega^j)^{1-\varphi_i} \right]^{\beta_i^j} \left[M_{i,t}^j(\omega^j) \right]^{1-\beta_i^j}, \quad (2)$$

where $l_{i,t}^j(\omega^j)$ and $k_{i,t}^j(\omega^j)$ are the labor and capital respectively used in the production of good ω^j , and $M_{i,t}^j(\omega^j)$ denotes the amount of intermediates used in production. In particular, I assume that the use of intermediates in production is given by a Cobb-Douglas aggregate of nontradable sectoral goods:

$$M_{i,t}^j(\omega^j) = \prod_{m=1}^J D_{i,t}^{j,m}(\omega^j)^{\nu_i^{j,m}}, \quad (3)$$

where $\sum_{m=1}^J \nu_i^{j,m} = 1$ for all $j = 1, \dots, J$ and $\nu_i^{j,m} \in (0, 1)$ for all $j, m = 1, \dots, J$. Here, $D_{i,t}^{j,m}(\omega^j)$ denotes the intermediate demand by producers of good ω^j for sectoral good m . The efficiency in the production of good ω^j is given by $x_{i,t}^j(\omega^j)$.

Note that the country and sector specific parameter $\beta_i^j \in (0, 1)$ determines the share of value added in gross production, while $\varphi_i \in (0, 1)$ represents the share of capital in value added. Additionally, $\nu_i^{j,m}$ for all $j, m = 1, \dots, J$ determine the input-output structure in each country.

I assume that the efficiency in the production of good ω^j , $x_{i,t}^j(\omega^j)$, is given by the realization of a random variable, $x_{i,t}^j \in (0, \infty)$, distributed conditional on information in period t according to

a Fréchet distribution with shape parameter θ and location parameter $T_{i,t}^j$,

$$F_{i,t}^j(x|t) = \Pr \left[x_{i,t}^j \leq x \right] = e^{-T_{i,t}^j x^{-\theta}}. \quad (4)$$

I assume that, conditional on $T_{i,t}^j$, the random variables $x_{i,t}^j$ are independently distributed across sectors and countries. In this case, the level of $T_{i,t}^j$ represents a measure of absolute advantage in the production of sector j goods, while a lower θ implies more dispersion across the realizations of the random variable and a higher scope for gains from comparative advantage differences through specialization.

I will refer to $T_{i,t}^j$ as the sectoral productivity of country i in sector j at time t , since their values determine the level of the distribution from which producers draw their efficiencies. These productivities change over time and they represent one of the underlying disturbances that drive the dynamics of the world economy.

2.3 Trade Costs and Firms' Optimal Decisions

For each sector $j = 1, \dots, J$, goods $\omega^j \in [0, 1]$ can be traded across countries, but are subject to iceberg type trade costs. Specifically, $\tau_{ih,t}^j \geq 1$ denotes the cost of shipping any good $\omega^j \in [0, 1]$ from country h to country i at time t . This means that, in order for one unit of variety ω^j to be available in country i at time t , country h must ship $\tau_{ih,t}^j$ units of the good. I assume that $\tau_{ii,t}^j = 1$ for all $i = 1, \dots, I$, *i.e.* there are no trade costs associated with trading goods within countries.

Note that these bilateral trade costs are allowed to change over time and that they are sector, but not good specific. Hence, sector specific bilateral trade costs are additional disturbances that drive the dynamics of the model.

Let us now turn to the optimal decisions by firms. In particular, consider first the problem faced by the producer of good $\omega^j \in [0, 1]$. Assuming perfectly competitive markets and given constant returns to scale in the production of good ω^j , the free-on-board price (before trade costs) of one unit of this good, if actually produced in country i at time t , will be equal to its marginal cost, $\frac{c_{i,t}^j}{x_{i,t}^j(\omega^j)}$, where

$$c_{i,t}^j = \varkappa_i^j \left[\left((r_{i,t})^{\varphi_i} (w_{i,t})^{1-\varphi_i} \right)^{\beta_i^j} \left(\prod_{m=1}^J (P_{i,t}^m)^{\nu_i^{j,m}} \right)^{1-\beta_i^j} \right] \quad (5)$$

is the cost of the input-bundle to produce one unit of ω^j , $r_{i,t}$ and $w_{i,t}$ denote the rental rate and the wage in country i respectively, and \varkappa_i^j is a constant that depends on production parameters.¹⁸

¹⁸Specifically, $\varkappa_i^j = (\beta_i^j \varphi_i^{-\varphi_i} (1 - \varphi_i)^{-(1-\varphi_i)})^{-\beta_i^j} ((1 - \beta_i^j) \prod_{m=1}^J (\nu_i^{j,k})^{\nu_i^{j,m}})^{-(1-\beta_i^j)}$.

For a particular sector j , notice that the technologies to produce goods $\omega^j \in [0, 1]$ differ only by their productivity draw, while $c_{i,t}^j$ is constant across tradable goods. Hence, following Caliendo and Parro (2015), we can relabel tradable goods by their efficiencies, $x_{i,t}^j$. Letting $\varrho^j(x^j|t)$ denote the conditional joint density of the sector specific vector of productivity draws for all countries, $x^j = (x_{1,t}^j, \dots, x_{I,t}^j)$, we can define total factor and intermediate input usage from each sector m in sector j as

$$L_{i,t}^j = \int_{\mathbb{R}_+^I} l_{i,t}^j(x^j) \varrho^j(x^j|t) dx^j, \quad (6)$$

$$K_{i,t}^j = \int_{\mathbb{R}_+^I} k_{i,t}^j(x^j) \varrho^j(x^j|t) dx^j, \text{ and} \quad (7)$$

$$D_{i,t}^{j,m} = \int_{\mathbb{R}_+^I} D_{i,t}^{j,m}(x^j) \varrho^j(x^j|t) dx^j. \quad (8)$$

Let us now turn to the problem faced by the nontradable sectoral goods producers. Given the price of each variety $\omega^j \in [0, 1]$ that the representative firm is faced with, $p_{i,t}^j(\omega^j)$, the firm solves a cost minimization problem which delivers demand functions, conditional on $Q_{i,t}^j$, for each tradable good $\omega^j \in [0, 1]$ given by $d_{i,t}^j(\omega^j) = \left(\frac{P_{i,t}^j}{p_{i,t}^j(\omega^j)}\right)^\eta Q_{i,t}^j$, where

$$p_{i,t}^j(\omega^j) = \min_h \left\{ p_{h,t}^j(\omega^j) \right\} = \min_h \left\{ \frac{c_{h,t}^j \tau_{ih,t}^j}{x_{h,t}^j(\omega^j)} \right\} \quad (9)$$

and $P_{i,t}^j$ denotes the price of sectoral good j , which is given by

$$P_{i,t}^j \equiv \left(\int_0^1 p_{i,t}^j(\omega^j)^{1-\eta} d\omega^j \right)^{\frac{1}{1-\eta}}. \quad (10)$$

Note that firms, by minimizing their costs, source tradable good ω^j from the lowest cost supplier after taking into account trade costs, as is implied by (9). This is an important difference of this model relative to Armington-type models in which each good is origin-specific.

2.4 Prices and Trade Shares

Given these distributions of productivities, we can derive an expression for sectoral price indices in equilibrium as functions of all sectoral prices, factor prices, and trade costs around the world. These prices are conditional on the known values of sectoral productivities, $T_{i,t}^j$, and bilateral trade costs, $\tau_{ih,t}^j$, in period t . Using (10) and the properties of the distribution of efficiencies around the world, we can derive the sectoral prices in each country i and every period t . In line with the

derivations of Eaton and Kortum (2002) and Caliendo and Parro (2015), these prices are given by

$$P_{i,t}^j = \Gamma \left[\Phi_{i,t}^j \right]^{-\frac{1}{\theta}}, \quad (11)$$

where Γ is a constant that only depends on η and θ , and

$$\Phi_{i,t}^j = \sum_{h=1}^I T_{h,t}^j \left(c_{h,t}^j \tau_{ih,t}^j \right)^{-\theta} \quad (12)$$

represents a sufficient statistic for sector j in country i of the state of technologies and trade costs around the globe.¹⁹ Note that as long as there is no free trade, *i.e.* $\tau_{ih,t}^j \neq 1$ for some countries i and h , prices will differ across countries. If there is free trade, it will be the case that $P_{i,t}^j = P_{h,t}^j$ for all $i, h = 1, \dots, I$.

The structure of the model not only allows for closed form solutions of sectoral price indices, but we can also recover sectoral trade shares for each country in terms of world prices, technologies and trade costs, *i.e.* we can find expressions for the share of total expenditure on goods produced in sector j that is spent in each country. Let $E_{i,t}^j$ denote total expenditure by country i on sector j goods, and $E_{ih,t}^j$ total expenditure by country i on sector j goods produced in country h , so that $E_{i,t}^j = \sum_{h=1}^I E_{ih,t}^j$. Then, the share of total expenditure in sector j by country i in goods produced by country h , $\pi_{ih,t}^j \equiv \frac{E_{ih,t}^j}{E_{i,t}^j}$, is given by

$$\pi_{ih,t}^j = \frac{T_{h,t}^j \left(c_{h,t}^j \tau_{ih,t}^j \right)^{-\theta}}{\Phi_{i,t}^j}, \quad (13)$$

and are such that $\sum_{h=1}^I \pi_{ih,t}^j = 1$ for all $i = 1, \dots, I$ and $j = 1, \dots, J$. Note that by the expression that we obtained before for equilibrium prices, equation (11), we can rewrite this share in terms of the sectoral price in country i as

$$\pi_{ih,t}^j = \left(\Gamma^{-\theta} \right) T_{h,t}^j \left(\frac{c_{h,t}^j \tau_{ih,t}^j}{P_{i,t}^j} \right)^{-\theta}. \quad (14)$$

These prices and trade shares fully summarize the optimal decisions by the firms given technologies and factor prices, as well as bilateral trade flows given sectoral expenditure levels in all countries. This can be appreciated in (11), which implicitly defines sectoral prices as a function of factor prices, and (14), which defines all bilateral trade shares given these sectoral prices.

¹⁹In particular, $\Gamma = \left(\Gamma \left(1 + \frac{(1-\eta)}{\theta} \right) \right)^{\frac{1}{1-\eta}}$, where $\Gamma(\cdot)$ denotes the Gamma function evaluated for $z > 0$. Notice this implies that parameters have to be such that $\eta - 1 < \theta$.

Up to this point, the structure of the model in a particular period t is very similar to the one in Caliendo and Parro (2015), but adding capital as an additional factor of production. An additional extension relative to their model that is crucial in order to analyze dynamics in the long run is to assume CES preferences rather than Cobb-Douglas. This preference structure will allow us to capture endogenous structural transformation over time due to changes in relative sectoral prices. I now turn to the problem of households in each country and their decisions, which represent the piece of the model that departs from other quantitative general equilibrium models of trade. This will allow us to see how dynamic decisions by the households are affected by trade costs.

2.5 Households

The dynamic dimension of the model comes entirely from the household's decisions. The representative household in country i seeks to maximize its discounted lifetime utility given by

$$U_i = \sum_{t=0}^{\infty} \delta^t \phi_{i,t} u(C_{i,t}), \quad (15)$$

where $\delta \in (0, 1)$ is the subjective discount factor, which is common across all countries; $C_{i,t}$ is an aggregate index of sectoral consumption levels; and $\phi_{i,t}$ is an intertemporal preference disturbance that the household in country i experiences in period t .²⁰ I assume that the household aggregates the amounts of nontradable sectoral goods used for consumption in a CES fashion with an elasticity of substitution given by $\psi > 0$. Hence, aggregate consumption is given by

$$C_{i,t} = \left(\sum_{j=1}^J (\mu_{i,t}^j)^{\frac{1}{\psi}} (C_{i,t}^j)^{\frac{\psi-1}{\psi}} \right)^{\frac{\psi}{\psi-1}}, \quad (16)$$

where $\mu_{i,t}^j > 0$ are sectoral demand disturbance at time t , such that $\sum_{j=1}^J \mu_{i,t}^j = 1$ for all t .²¹

Note that $\mu_{i,t}^j$ for all $j = 1, \dots, J$ and $\phi_{i,t}$ for all $i = 1, \dots, I$ are additional disturbances that are allowed to change over time. These two sets of disturbances to preferences plus those to sectoral productivities and trade costs, aside from changes in the endowment of factors of production, drive the exogenous changes in the world economy over time. I show in the next section how these disturbances imply that the model is exactly identified given data on bilateral trade flows, sectoral price for tradable sectors and GDP, sectoral expenditure levels, and net exports.

²⁰The use of these type of shifters is common in the international macroeconomics literature. See Stockman and Tesar (1995) or Bai and Ríos-Rull (2015). However, as discussed in the introduction, changes in these shifters can also be interpreted as financial frictions that affect households' saving decisions.

²¹This disturbances capture those forces other than changes in relative sectoral prices driving changes in sectoral expenditure shares. For example, if a country's sectoral expenditure shares depend on its level of income, these effects will be captured by these disturbances.

The representative household in a country has access to international financial markets by means of buying and selling one period bonds that are available around the world in zero net supply. International financial markets are assumed to be frictionless. This implies that the return on bonds in terms of the world currency unit is equalized across countries. Moreover, the fact that all economic agents are assumed to have perfect foresight implies that, in the absence of trade frictions, access to these one period bonds is the only savings vehicle needed for resources to be efficiently allocated around the world in every period. As previously mentioned, I treat capital as a fixed endowment in every period and do not consider endogenous capital accumulation decisions. Even though incorporating this dimension to the model is relatively standard, as I show in an appendix, solving for counterfactual equilibria numerically is challenging and is currently work in progress.²² However, given that the focus of this paper is on the long term evolution of trade imbalances rather than changes at the business-cycle frequency, this margin of adjustment might not play such an important role in determining long term changes in imbalances.

Hence, the representative household in country i maximizes (15) by choosing bond holdings at the end of period t , $B_{i,t+1}$, and sectoral consumption levels, $C_{i,t}^j$ for all $j = 1, \dots, I$ subject to the following sequence of budget constraints

$$\sum_{j=1}^J P_{i,t}^j C_{i,t}^j + B_{i,t+1} = w_{i,t} L_{i,t} + r_{i,t} K_{i,t} + R_t B_{i,t}, \quad (17)$$

for all $t = 0, 1, \dots$, and $W_{i,0} \equiv R_0 B_{i,0}$ given for all $i = 1, \dots, I$ such that $\sum_{i=1}^I W_{i,0} = 0$.

Note that the amount of bonds held by country i at the end of period t , $B_{i,t+1}$, is denominated in world currency units (or whatever numeraire we choose) and that these bonds have a nominal gross return of R_t . I choose world GDP as a numeraire, i.e. $\sum_{i=1}^I w_{i,t} L_{i,t} + r_{i,t} K_{i,t} = 1$. This implies that all my result will be in terms of this world GDP, which is in line with other quantitative models of international trade.

2.6 Household's Optimal Decisions

Let us first consider the static problem that the household faces in period t given a choice of $B_{i,t+1}$. In particular, the household optimally chooses sectoral consumption expenditure levels

²²The main challenge comes from the fact that with capital accumulation and trade imbalances, the system of equations that determines the world economy competitive equilibrium's steady state variables is underidentified. This implies that the solution of the transitional dynamics of counterfactual equilibria requires the simultaneous solution of the paths of net foreign asset positions and the net foreign asset position in the counterfactual steady state.

across sectors according to

$$P_{i,t}^j C_{i,t}^j = \mu_{i,t}^j \left(\frac{P_{i,t}^j}{P_{i,t}} \right)^{1-\psi} P_{i,t} C_{i,t}, \quad (18)$$

for all $j = 1, \dots, J$ where $P_{i,t}$ denotes the ideal price index of consumption, which in turn is given by

$$P_{i,t} = \left(\sum_{j=1}^J \mu_{i,t}^j \left(P_{i,t}^j \right)^{1-\psi} \right)^{\frac{1}{1-\psi}}. \quad (19)$$

Therefore, conditional on $P_{i,t} C_{i,t}$, the household choose sectoral consumption expenditures according to (18), and we can rewrite total consumption expenditure in country i simply as $P_{i,t} C_{i,t} = \sum_{j=1}^J P_{i,t}^j C_{i,t}^j$. The dynamic problem of the household in country i then becomes:

$$\begin{aligned} \max_{\{C_{i,t}, B_{i,t+1}\}} \quad & \sum_{t=0}^{\infty} \delta^t \phi_{i,t} u(C_{i,t}) \\ \text{s.t.} \quad & P_{i,t} C_{i,t} + B_{i,t+1} = w_{i,t} L_{i,t} + r_{i,t} K_{i,t} + R_t B_{i,t} \text{ for } t = 0, 1, \dots \end{aligned} \quad (20)$$

and $R_0 B_{i,0}$ given. This is, the household in country i takes prices as given and chooses consumption, $C_{i,t}$, and bond holdings at the end of period t , B_{t+1} , so as to maximize its discounted utility stream, U_i , subject to its sequence of budget constraints.

The optimality condition derived from solving problem (20) is given by the Euler equation that determines the optimal intertemporal consumption choices:

$$u'(C_{i,t}) = \delta \hat{\phi}_{i,t+1} \frac{R_{t+1} P_{i,t}}{P_{i,t+1}} u'(C_{i,t+1}), \quad (21)$$

for all $t = 0, 1, \dots$ where I have defined $\hat{\phi}_{i,t+t} \equiv \frac{\phi_{i,t+1}}{\phi_{i,t}}$. Note that the real interest rate in country i is then given by $r_{i,t} \equiv \frac{R_{t+1} P_{i,t}}{P_{i,t+1}} - 1$.

Nominal interest rate parity holds in the world economy. There are no frictions in the exchange of bonds denominated in a world currency unit across countries. Therefore, the nominal return on bonds is the same for all countries and determined in equilibrium such that assets are in zero net supply. However, real interest rate parity does not hold because of trade costs that lead to differences in price levels across countries. Specifically, the evolution of the price level in each country determines the real return on bonds. Moreover, price levels include information on all shocks and parameters that determine gross trade flows in a particular time period. Hence, changes in trade costs over time have implications for price levels and, therefore, for the real return on bonds. How do changes in trade costs exactly affect the saving decisions by the household? I address this issue in more detail in the last part of this section. First, I close the description of the model by

stating the market clearing conditions.

2.7 Market Clearing Conditions

Let $Y_{i,t}^j$ denote the value of gross production in sector j , and $E_{i,t}^j$ total expenditure by country i on sector j goods. Then, the value of total gross production and total expenditure in country i and sector j define sectoral net exports, $NX_{i,t}^j = Y_{i,t}^j - E_{i,t}^j$, and aggregate net exports are then simply given by $NX_{i,t} = \sum_{j=1}^J NX_{i,t}^j$.

First, the markets for nontradable sectoral goods and factors must clear in every country and period. These conditions are given by

$$C_{i,t}^j + \sum_{k=1}^J D_{i,t}^{k,j} = Q_{i,t}^j \quad (22)$$

for all i and j , and $\sum_{j=1}^J L_{i,t}^j = L_{i,t}$ and $\sum_{j=1}^J K_{i,t}^j = K_{i,t}$ for all i . Condition (22) states that demand for nontradable goods must equal supply in each country i . We can reformulate this condition in terms of expenditures, in which case we can appreciate that total expenditure in goods in sector j in equilibrium must be given by

$$E_{i,t}^j = P_{i,t}^j C_{i,t}^j + \sum_{m=1}^J P_{i,t}^m D_{i,t}^{m,j}. \quad (23)$$

Thus, these equilibrium conditions can be rewritten simply as $E_{i,t}^j = P_{i,t}^j Q_{i,t}^j$.

We now turn to market clearing in tradable goods markets. In terms of expenditure, I refer to these conditions as the flow of goods across countries equilibrium conditions. These conditions are given by

$$Y_{i,t}^j = \sum_{h=1}^I \pi_{hi,t}^j E_{h,t}^j, \quad (24)$$

and must hold for every country i and sector j . This condition states that expenditure by all countries on sector j goods produced in country i must equal the value of total gross production in country i . In particular, country h spends $\pi_{hi,t}^j E_{h,t}^j$ on sector j goods produced in country i .

Lastly, there are country-specific resource constraints. This is one of the main differences between a model with endogenous trade imbalances and static trade models. Net exports in goods and services must be consistent with optimal saving decisions by the representative household in

country i . This equilibrium resource constraint is given by

$$B_{i,t+1} - R_t B_{i,t} = \sum_{j=1}^J \left(Y_{i,t}^j - E_{i,t}^j \right). \quad (25)$$

Another way to interpret this condition is through the balance of payments. This condition is equivalent to the balance of payments identity that is trivially satisfied in most international macroeconomic models and not present in static trade models. This identity can be appreciated by rewriting the previous condition as $NX_{i,t} + (R_t - 1) B_{i,t} + B_{i,t} - B_{i,t+1} = 0$, where $CA_{i,t} \equiv NX_{i,t} + (R_t - 1) B_{i,t}$ denotes the current account in country i , and $KA_{i,t} \equiv B_{i,t} - B_{i,t+1}$ denotes the broadly defined capital account.

2.8 Equilibrium

Given our previous analysis of the problems of the firms, representative household, and market clearing conditions; we can now proceed to define an equilibrium of the world economy. We will do so for particular sequence of disturbances. Thus, let us define the sequence of disturbances by $\{\mathcal{S}_t\}_{t=0}^{\infty}$, where $\mathcal{S}_t \equiv \left\{ \tau_{ih,t}^j, T_{i,t}^j, \mu_{i,t}^j, \phi_{i,t} \right\}_{i,h=1,\dots,I}$.

Definition 1 *Given $R_0 B_{i,0}$, $L_{i,t}$ and $K_{i,t}$ for every $i = 1, \dots, I$ and every $t = 0, 1, \dots$, and $\{\mathcal{S}_t\}_{t=0}^{\infty}$; an equilibrium under disturbances $\{\mathcal{S}_t\}_{t=0}^{\infty}$ is defined by sequences of wages, rates of return on capital, gross interest rates and prices, $\{\{w_{i,t}, r_{i,t}\}_{i=1}^I, R_{t+1}, \{\{P_{i,t}^j\}_{j=1}^J\}_{i=1}^I, \{P_{i,t}\}\}_{t=0}^{\infty}$, and allocations, such that given these prices, the allocations satisfy the optimality conditions for the firms and households in every country, and all markets clear.*

This definition of an equilibrium differs in one particular and relevant respect from equilibria considered in previous work on quantitative general equilibrium models of international trade. This definition includes the gross interest rate as an equilibrium price, which together with changes in country specific prices over time, determines the intertemporal allocation of consumption. Households have an endogenous saving decision, and in equilibrium, they optimally chooses how much to save or consume.

Most previous studies relying on new quantitative models of trade do not consider this margin of households' decisions. Therefore, gains from lower trade costs in my model also include the gains from being able to engage in more intertemporal trade. I now turn to a discussion of how trade costs and the general features of intratemporal trade across countries affect saving decisions by the households in each country.

Effects of Trade Costs on Saving Decisions As pointed out at the beginning of the paper, the effect of declining trade costs on trade imbalances can be analyzed through the lens of two effects: the level and the tilting effect. I now discuss how these effects lead to changes in trade imbalances.

I consider first the level effect. The basic intuition behind this effect is based on the fact that intertemporal trade is realized through the exchange of goods and services in different time periods. Hence, uniformly high bilateral trade costs act as a tax on intertemporal trade just as they do on intratemporal trade.

In terms of the model, note first that using (24) we can rewrite country i 's net exports in sector j in terms of countries' trade shares as $NX_{i,t}^j = Y_{i,t}^j - E_{i,t}^j = \sum_{h=1}^I \left(\pi_{hi,t}^j E_{h,t}^j - \pi_{ih,t}^j E_{i,t}^j \right)$. Therefore, equation (25) becomes

$$B_{i,t+1} - R_t B_{i,t} = \sum_{j=1}^J \left(\sum_{h=1}^I \left(\pi_{hi,t}^j E_{h,t}^j - \pi_{ih,t}^j E_{i,t}^j \right) \right). \quad (26)$$

Equations (26) and (21) incorporate the main information regarding the interaction between trade costs and saving decisions.

Consider equation (21). As previously stated, real interest rate parity does not hold because of trade costs in goods markets that lead to differences in aggregate prices across countries. Hence, countries' saving decisions are based on different real interest rates. Obstfeld and Rogoff (2000) show how these differences in real interest rates due to trade costs in goods markets imply that in equilibrium, trade imbalances are dampened. Their result follows from the following observations. Consider an equilibrium in which country i is running a trade surplus in period t and a deficit in period $t + s$ for $s > 0$. From (21) we see that the real return on a unit of consumption saved at t and consumed at $t + s$ is given by $\frac{(R_{t+1} \times \dots \times R_{t+s}) P_{i,t}}{P_{i,t+s}}$. Consider the extreme case in which trade costs are zero. Then, real interest rate parity holds and the real return from period t to $t + s$ is the same for all countries independently of their trade balance position. Now consider the case with positive trade costs to export from i to h for all h . In order for country i to run a surplus in period t , its equilibrium prices must be low relative to the ones in other countries. This can be inferred from equilibrium condition (26). Given prices, positive trade costs lead to a larger home-bias, *i.e.* greater $\pi_{hh,t}^j$ and smaller $\pi_{hi,t}^j$ for every h and j , which implies that the right hand side of (26) is lower. Therefore, in order for country i to maintain its trade surplus, production costs must decrease in order for country i to export more goods to other countries. Lower production costs lead to low sectoral prices and, therefore, a low aggregate price, $P_{i,t}$. By the exact same logic, country i 's trade deficit in period $t + s$ must be accompanied by high prices relative to those in

other countries. Hence, with positive trade costs, real interest rates are high for borrowers and low for lenders. Thus, differences in country-specific real interest rates imply that consumption smoothing is more costly when trade costs are high, and trade imbalances are dampened.

In a general equilibrium model like the one I propose, there is an additional effect. Note that difference in equilibrium production costs are realized through adjustments in factor prices, wages and rental rates, as implied by (5). These changes affect a country's income. Specifically, aggregate prices depend positively on factor prices. Hence, when a country runs a surplus, it also has a low income relative to when it runs a deficit. This income effect reinforces the effect of real interest rates and dampens trade imbalances further by making consumption smoothing even more costly.

To summarize, there are two basic mechanisms through which the levels of trade costs affect saving decisions. First, the differentials in real interest rates implied by differences in country-specific prices that must be in line with intratemporal trade being consistent with intertemporal trade, including the intertemporal constraint. Second, the income effects generated by adjustments in factor prices in order to be in line with the same country-specific sectoral and aggregate prices. Hence, uniformly higher trade costs imply that trade imbalances are dampened in all time periods.²³

Let us now turn to the titling effect. In the data, trade costs are declining over time. In order to understand the intuition of this effect, consider the thought experiment in which trade costs remain constant instead of following a declining path. In the case of constant trade costs, these are higher in every period, however, the difference between trade costs in the final years is larger than in the initial ones. Therefore, all countries experience negative income effects in future periods from higher trade costs. Consumption-smoothing motives imply that all countries want to transfer resources from the present to the future by increasing their savings. This leads to an excess in world aggregate savings: countries that under declining trade costs borrow in the initial years want to borrow less and countries that lend in initial years want to lend more. In order to restore the world equilibrium, the world real interest rate must fall. However, as the world real interest rate falls, the burden of future payments by countries that were initially borrowing decreases, leading to a positive income effect in the future that reinforces the desire to decrease savings. This effect acts in the exact opposite direction for countries that were initially saving, thus weakening the effect of the decline in the world real interest rate. In the new equilibrium, the world real interest rate is lower and countries borrowing initially and paying later run smaller trade surpluses in the future. Hence, these countries' future incomes relative to the incomes of countries lending are high, as their terms of trade, and therefore factor prices and income, remain relatively high. In other words, the

²³In Section 4.2, I compare counterfactual trade imbalances in the case of trade costs fixed to their levels in 1970 to those fixed to their levels in 2007. This comparison isolates the level effect.

terms of trade of countries running trade surpluses in the future improve as the world real interest rate decreases. This effect implies that trade imbalances tilt, leading to larger trade imbalances in the initial periods.

3 Taking the Model to the Data

We now return to the main question that this paper aims to answer. How much of the increase in trade imbalances in recent decades can be explained by the evolution of bilateral trade costs? To answer this question I proceed in two steps.

First, I will calibrate the model to observed data for the period 1970 to 2007. The calibration requires the identification of the model's time-invariant parameters and time-varying exogenous variables. Time-varying exogenous variables can be divided into those that are directly observed in the data and those that are not. The set of exogenous variables that are not observed are the ones I call disturbances and previously labeled as \mathcal{S}_t . I calibrate these disturbances by relying on endogenous outcomes of the model that are observed in the data, specifically, bilateral trade flows, prices for tradable sectors and GDP, sectoral expenditures and net exports. This implies that these disturbances provide a decomposition of the forces underlying the evolution of this data. In other words, given parameter values and observed exogenous variables of the model, I recover a set of structural residuals that rationalizes the data as an equilibrium of the model.

Second, I use the disturbances obtained from this decomposition to carry out counterfactual exercises to provide an answer to the main question of the paper. In this section I describe the procedure followed to identify the parameters, exogenous variables and disturbances. The counterfactual exercises are left for the following section. Since I consider a perfect foresight economy, it is worth underscoring that it is assumed that at time t , all future exogenous variables, including disturbances, are known by economic agents.²⁴

Let us recall that recall the set of disturbances that decomposes the data: (i) trade costs, $\tau_{ih,t}^j$, (ii) sectoral productivities, $T_{i,t}^j$, (iii) sectoral demand shifters, $\mu_{i,t}^j$, and (iv) intertemporal preference shifters, $\phi_{i,t}$. The trade costs and sectoral productivities affect bilateral trade flows and technologies in each country. The sectoral demand shifters allow us to match the data on sectoral expenditures, which in turn imply that, given trade shares, the model's outcomes match net exports exactly. In general, these disturbances will capture any mechanism other than changes in relative sectoral prices that lead to shifts in economic activity across sectors over time, also known as structural

²⁴Introducing uncertainty and solving for a rational expectations equilibrium becomes untractable in this model because of the high dimensionality of the disturbances. Given that I study a long term phenomenon, the choice of a perfect foresight environment provides a natural baseline framework given the aim of the paper.

transformation. I follow the international macroeconomics literature in naming the intertemporal preference disturbance. Even though it can be interpreted as a shock to intertemporal tastes, it can also be associated with many different channels that affect intertemporal decisions, such as financial frictions. We turn to a more detailed discussion of these disturbances later on in this section.

I carry out the calibration for 26 countries, $I = 26$, and three sectors, $J = 3$. The choice of countries and sectors was dictated mainly by the availability of data. In particular, I consider 25 core countries and one aggregate of all other countries for which there is some data available, I call it Rest of the World (ROW). A full list of the countries considered is provided in the data appendix. I assume that the representative household in each country has logarithmic period utility, $u(C) = \ln(C)$.

I assume that one of the three sectors is nontradable, that is, this sector must source all its goods from home in order to produce the final nontradable sectoral good. In terms of the model, I model the nontradable sector as other sectors, but impose that bilateral trade costs are infinity, *i.e.* $\tau_{ih,t}^S = \infty$ for $i \neq h$ or equivalently, $\pi_{ii,t}^S = 1$.²⁵ This implies that in this sector it is always cheaper to source all tradable goods from domestic suppliers. I consider agriculture and mining (AM) and manufacturing (M) as the two tradable sectors, while all of services (S) are considered nontradable.²⁶ Even though I do not model trade in services, I do take into account trade imbalances in this sector and incorporate them into the model as time-varying exogenous transfers across countries.

There are five sets of time-invariant parameters in the model. Some of these parameters are country and sector specific, others just country-specific or worldwide parameters. I calibrate these parameters either directly from the data or take their values from previous literature. Given these parameters and the exogenous variables of the model that I observe in the data, I can then use the structure of the model to recover the disturbances that drive trade across countries over the period considered.

3.1 Time-invariant Parameters

I focus first on the parameters that I recover directly from the data, which are the value added shares, β_i^j , and the input-output table coefficients, $\nu_i^{j,k}$. These are the two sets of parameters

²⁵The matrix of bilateral trade costs in this sector is such that it has ones along its diagonal and infinity everywhere else.

²⁶Even though many services are nowadays traded across countries, there is no data on bilateral trade flows for most of countries before the mid 1990s. However, the data available shows that international trade in services is still small relative to trade in other sectors.

Table 1: Time-invariant Parameters

Parameter	Value	Variable	Source
β_i^j	-	Value added to gross output ratio	Sectoral Data
$\nu_i^{j,k}$	-	Input-output coefficients	Data, Input-Output Tables
φ_i	-	Capital share in value added	Caselli and Feyrer (2007)
θ	4	Trade elasticity	Range Simonovska and Waugh (2014)
η	2	Elasticity of substitution in tradable goods	Caselli et al. (2014)
ψ	0.4	Elasticity of substitution in consumption	Duarte and Restuccia (2010)
δ	0.95	Discount factor	Standard for annual data

that are country and sector-specific. Using data on gross output and valued added from a combination of data sources that includes EU-KLEMS, UNIDO, GGDC-10 and countries' official statistical agencies, I set β_i^j to the average of value added divided by gross output in each sector $j \in \mathcal{J} \equiv \{AM, MN, S\}$. For the input-output coefficients I use the input-output tables provided by OECD-Stan, World Input-Output Database (WIOD) and countries' statistical agencies. Depending on the availability of the input-output tables, I recover these coefficients mainly from the tables corresponding to the late 1990s.²⁷

I now turn to the parameters that I take from existing literature. For the capital shares in value added, φ_i , I take the values from Caselli and Freyer (2007) who calibrate these parameters for a large set of countries. I calibrate the elasticity of substitution across tradable goods $\eta = 2$, in line with Caselli et al. (2015) and Broda and Weinstein (2006). For the case of the trade elasticity, I consider as a baseline $\theta = 4$, which is consistent with the estimates in Simonovska and Waugh (2011) for the case of international trade models.²⁸

For the case of preference parameters, I consider a value of $\psi = 0.4$ for the elasticity of substitution in consumption. This value is consistent with the literature on structural transformation that calibrates values for this parameter to be less than one. The value I consider is in line with Duarte and Restuccia (2010), and in the midrange of estimates for the U.S. and other less developed economies. For the discount factor I set $\delta = 0.95$ which is considered standard in the literature for the case of annual data. Table 1 summarizes the baseline values of these parameters as well as the data used to obtain them.

²⁷The data appendix provides a detailed and comprehensive list of all data sources.

²⁸Caliendo and Parro (2015) estimate industry-specific trade elasticities and show that these differ across industries. However, there is no clear mapping between their industries and the sectors I consider. Given the broad definition of the two tradable sectors in my model, I choose a uniform trade elasticity as a baseline, as in Costinot et al. (2011). The value I choose for θ is in line with the aggregate elasticity estimated by Caliendo and Parro (2015).

3.2 Time-varying Exogenous Variables

The model's endogenous variables are determined given series of exogenous variables. The time-varying exogenous variables of the model that can be taken directly from the data are the homogeneous labor endowments, $L_{i,t}$, capital stocks, $K_{i,t}$, and net exports in the services sector, $NX_{i,t}^S$.

I construct the series for labor endowments using data on Population, $Pop_{i,t}$, GDP per capita, $rgdpc_{i,t}$, and GDP per worker, $rgdpw_{i,t}$, from the Penn World Tables 7.1. These endowments are then constructed as $L_{i,t} = (rgdpc_{i,t}/rgdpw_{i,t}) \times Pop_{i,t}$. For the capital stock, I use data on capital stocks from the Penn World Tables 7.1 for the year 1970. Then, I use the capital accumulation equation $K_{i,t+1} = (1 - d)K_{i,t} + I_{i,t}$ with $d = 0.5$ and data on investment from the UNStats to construct the stocks from 1971 to 2007.

To construct series for net exports in services, $NX_{i,t}^S$, I consider data on aggregate net export, $NX_{i,t}$, which I obtain from UNStats and bilateral trade flows from country h to country i in tradable sectors, $X_{ih,t}^j$ for $j \in \mathcal{J} \setminus S$, which I obtain from the NBER-UN and CEPII-BACI data sets. Then, country i 's exports and imports in sector j are given by $\sum_{h=1}^I X_{hi,t}^j$ and $\sum_{h=1}^I X_{ih,t}^j$ respectively, and I construct $NX_{i,t}^S = NX_{i,t} - \sum_{j \in \mathcal{J} \setminus S} \left(\sum_{h=1}^I X_{hi,t}^j - \sum_{h=1}^I X_{ih,t}^j \right)$.

3.3 Structural Residuals

The endogenous outcomes of the model that I observe in the data and that I use to recover the disturbances in period t , \mathcal{S}_t , for $t = 1970, \dots, 2007$ are: (i) sectoral bilateral trade flows in tradable sectors, $X_{ih,t}^j$ for $j \in \mathcal{J} \setminus S$; (ii) prices for tradable sectors, $P_{i,t}^j$ for $j \in \mathcal{J} \setminus S$, and GDP, $P_{i,t}$; (iii) sectoral expenditures, $E_{i,t}^j$ for $j \in \mathcal{J}$; and (iv) net exports, $NX_{i,t}$. In order to obtain sectoral expenditures, I rely on data on bilateral trade flows and sectoral gross output, $Y_{i,t}^j$ for $j \in \mathcal{J}$. In addition, I use data on gross domestic product, $GDP_{i,t}$, to recover the factor prices that are consistent with the model instead of relying on data on wages and rental rates of capital that might not be consistent with the labor and capital endowments I recovered in the previous subsection.

Data on bilateral trade flows comes from the same sources that I use to compute net exports for services, and data on sectoral gross output comes from the same sources that I use to calibrate value added to gross output ratios. The data on gross domestic product and net exports comes from UNStats. For aggregate prices I consider gross domestic product prices from the Penn World Tables 7.1. Data on sectoral prices that are comparable across countries for the tradable sectors I consider is not readily available, therefore, I construct these series. In order to do so, first, I fix a base year and estimate relative sectoral prices in that year relying on the static multisector-gravity

structure of the model. Then, using data on sectoral price indexes in tradable sectors that I obtain from EU-KLEMS or construct using data from the GGDC-10 database, I construct the entire time series for prices. In the data appendix I provide the details on how I construct these series.²⁹

Given these data, we can recover the sectoral trade shares, sectoral expenditures and factor prices that map directly to the model's equilibrium conditions laid out in Section 2. These variables provide an explicit mapping between observables and model's outcomes. To compute sectoral expenditures and trade shares, consider the data on sectoral gross output and bilateral trade flows. Then, expenditure on sector j in country i at time t is given by $E_{i,t}^j = Y_{i,t}^j - NX_{i,t}^j$, where $NX_{i,t}^j = \sum_{h=1}^I X_{hi,t}^j - \sum_{h=1}^I X_{ih,t}^j$, and the trade share by importer i from exporter h is computed as $\pi_{ih,t}^j = \frac{X_{ih,t}^j}{E_{i,t}^j}$ for $i \neq h$, and $\pi_{ii,t} = 1 - \sum_{h=1}^I \pi_{ih,t}^j$. For factor prices, note that the equilibrium of the model implies that wages and rental rates must be given by $w_{i,t} = (1 - \varphi_i) GDP_{i,t}/L_{i,t}$ and $r_{i,t} = \varphi_i GDP_{i,t}/K_{i,t}$ respectively, which implies that we can compute factor prices using the data available.

Armed with these variables, we can now proceed to recover the set of disturbances \mathcal{S}_t for all t . First, let us define

$$\mathcal{D}_t \equiv \left\{ \{w_{i,t}, r_{i,t}, L_{i,t}, K_{i,t}, NX_{i,t}, NX_{i,t}^S, P_{i,t}\}, \{E_{i,t}^j, Y_{i,t}^j\}_{j \in \mathcal{J}}, \{P_{i,t}^j\}_{j \in \mathcal{J} \setminus S}, \{\pi_{ih,t}^j\}_{j \in \mathcal{J} \setminus S} \right\}_{i,h=1,\dots,I},$$

the set of data that is observed and used to recover these sets for $t = 1970, \dots, 2007$. For $t = 2008, \dots$, an assumption on the time-varying exogenous variables of the model has to be made in order to conduct counterfactual exercises. I assume that after 2007, the world economy is in a steady state in which all exogenous variables of the model remain at their levels of 2007.

3.3.1 Sectoral Demand Disturbances

First, I recover the sectoral demand disturbances, since knowledge of these is necessary to recover other disturbances, but not the opposite. The key equilibrium conditions that allow us to recover the sectoral demand shocks are the optimal static decisions by the households and the firms, and the market clearing conditions for sectoral goods. The following lemma shows how these disturbances are identified.

Lemma 1 *Given time-invariant parameter values and data \mathcal{D}_t for $t = 1970, \dots, 2007$, there is a one-to-one mapping between observables and sectoral demand shocks, $\{\mu_{i,t}^j\}_{j \in \mathcal{J}}$, given by the*

²⁹Fitzgerald (2012) and Levchenko and Zhang (2015) estimate sectoral prices similarly. However, they do not exploit data on sectoral price indexes.

following equilibrium conditions and model restrictions:

$$\mu_{i,t}^j = \left(\frac{P_{i,t}^j}{P_{i,t}} \right)^{-(1-\psi)} \frac{E_{i,t}^j - \sum_{k=1}^J (1 - \beta_i^k) \nu_i^{k,j} Y_{i,t}^k}{w_{i,t} L_{i,t} + r_{i,t} K_{i,t} - N X_{i,t}} \text{ for } j \in \mathcal{J} \setminus S, \text{ and} \quad (27)$$

$$\mu_{i,t}^S = 1 - \sum_{j \in \mathcal{J} \setminus S} \mu_{i,t}^j. \quad (28)$$

Proof. See Appendix. ■

It is worth mentioning that Lemma 2 does not necessarily imply that $\mu_{i,t}^S > 0$, which is a restriction of the model. However, the data is such that this restriction holds for every country and period in the sample.

The CES structure of preferences allows me to capture the part of the structural transformation in these economies that can be attributed to changes in relative prices over time. Therefore, if a country's evolution of prices in tradable sectors is consistent with long term changes in its expenditure shares according to the CES structure of preferences, the time series that we recover for $\mu_{i,t}^j$ must not show a particular trend over time. This is indeed the case for most developed economies in my core countries. Still, in order for the model to match net exports, these shocks are crucial, since they allow the model to match sectoral expenditures exactly which, together with trade shares, determine net exports.

There are some countries for which sectoral demand shocks show clear trends that are in line with the literature on structural transformation. In particular, less developed countries like China and India show a clear downward trend in $\mu_{i,t}^{AM}$. This implies that the decline in the expenditure share in *AM* in these countries is greater than what can be accounted for solely by changes in prices. The literature on structural transformation has incorporated nonhomotheticities into preferences or technologies in order to explain this kind of trends. These imply that the larger decline in the share could be explained by the fact that expenditure in *AM* rises less than proportionately with income. In any case, for our purpose, these disturbances are enough to capture these effects.

Once we have recovered the static demand shocks, we can proceed to back out trade costs and sectoral productivity shocks.

3.3.2 Trade Costs and Sectoral Productivities

The next lemma shows how, given the data previously described, sectoral bilateral trade costs and sectoral productivities are uniquely identified by the static equilibrium conditions of the model.

Lemma 2 *Given $\{\mu_{i,t}^j\}_{j \in \mathcal{J}}$ for all i , time-invariant parameter values, and data \mathcal{D}_t for $t = 1970, \dots, 2007$; there is a one-to-one mapping between observables and the shocks $\{\tau_{ih,t}^j\}_{j \in \mathcal{J} \setminus S}$*

and $\{T_{i,t}^j\}_{j \in \mathcal{T}}$ in period t given by the following equilibrium conditions:

$$\tau_{ih,t}^j = \frac{P_{i,t}^j}{P_{h,t}^j} \left(\frac{\pi_{hh,t}^j}{\pi_{ih,t}^j} \right)^{\frac{1}{\theta}} \quad \text{for } j \in \mathcal{J} \setminus S, \quad (29)$$

$$\pi_{ii,t}^j = T_{i,t}^j \left(\Gamma^j \frac{C_{i,t}^j}{P_{i,t}^j} \right)^{-\theta} \quad \text{for } j \in \mathcal{J} \setminus S \text{ and } \pi_{ii,t}^j = 1 \text{ for } j = S, \text{ and} \quad (30)$$

$$P_{i,t} = \left(\sum_{j=1}^J \mu_{i,t}^j (P_{i,t}^j)^{1-\psi} \right)^{\frac{1}{1-\psi}} \quad \text{and } \tau_{ih,t}^S = \infty \text{ for all } i \neq h. \quad (31)$$

Proof. See Appendix. ■

It is worth taking some time at this point to discuss in more detail the implications of the previous lemma. Let us start with the case of bilateral trade costs. Note from (29) that trade costs are uniquely determined given our normalization $\tau_{ii,t}^j = 1$ for all i and j . This equation is obtained by taking the ratio of the trade share of importing country i and exporter h to the domestic trade share in country h , $\pi_{ih,t}^j / \pi_{hh,t}^j$. Given the definition of trade shares in (13), this ratio controls for differences in productivity and production costs across countries and implies that data on sectoral trade shares and prices is sufficient to recover the costs.³⁰

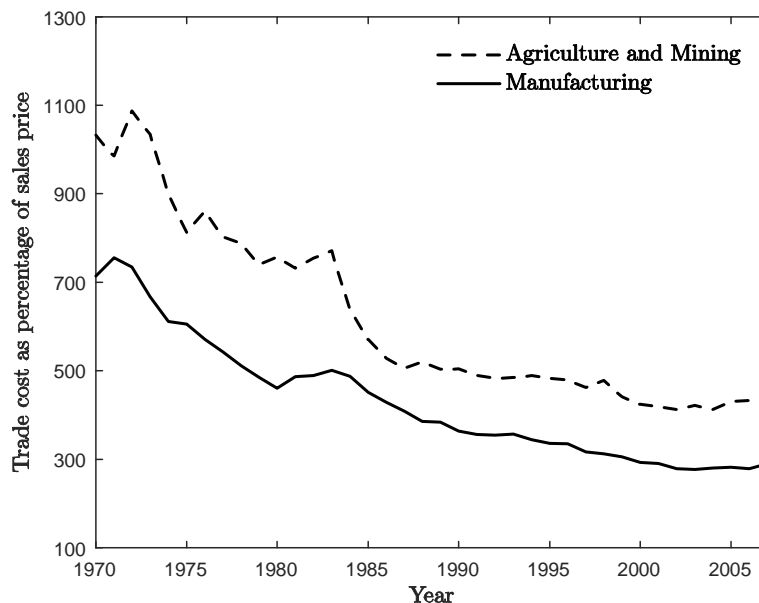
Figure 2 shows the evolution of the average of sectoral bilateral trade costs for all country-pairs trading over time. Note that these trade costs are large, which is in line with the results in the survey by Anderson and van Wincoop (2004). More importantly, note that there is a significant and steady decline in trade costs over the entire period 1970-2007. The evolution of these iceberg-type trade costs is consistent with previous literature, in particular with the aggregate measures of trade costs in Fitzgerald (2012).

One particular feature of the model is that it can only rationalize zero bilateral trade flows for a pair of countries i and h , $\pi_{ih,t}^j = 0$, by means of infinite bilateral trade costs, $\tau_{ih,t}^j = \infty$. This can be appreciated in equation (29) and is a result of the fact that tradable goods' producers draw their efficiencies from a probability distribution with an unbounded support.³¹ The data on bilateral trade flows is such that, even for the broad aggregation of tradable sectors that I consider, there are years, country pairs and sectors for which trade flows are zero. Figure 2 drops all observations for which this is the case. However, I need to assign values to these costs for my numerical exercises. Hence, whenever there is a zero, I assign arbitrarily large values to these bilateral trade costs in

³⁰Similar procedures have become standard in the literature on gravity models of trade. See Head and Mayer (2014).

³¹Another way to put it is that, in every country there is always a "superstar" producer that should be shipping goods to all countries.

Figure 2: Evolution of Average Sectoral Trade Costs



Notes: This figure plots the average over all bilateral trade costs across all country-pairs with nonzero trade flows in each year. These costs are expressed as percentage of sales prices. This means that trade costs equal to 300 are equivalent to an iceberg-type trade cost of 4.

order to generate negligible bilateral trade shares.³²

It is worth mentioning that having data on sectoral prices is crucial for the model to match all trade shares exactly. These prices allow us to recover asymmetric trade costs directly from the data instead of having to rely on estimation procedures as other work has done. Another way in which the literature has dealt with this issue is by imposing a symmetry assumption on trade costs that implies that data on sectoral prices is not needed to recover these. The main drawback of this assumption is that it implies that the model cannot match all bilateral trade flows exactly, *i.e.* the model is overidentified.

Let us now turn to the case of sectoral productivities. First, notice that productivities in the tradable sectors are identified by the equilibrium domestic trade shares. However, these equations do not pin down productivity in the nontradable sector. However, using data on GDP prices, which is equivalent to real exchange rates, I can recover the productivity in this sector. Therefore, sectoral productivities are such that real exchange rates in the data are exactly matched. More importantly, sectoral domestic expenditure shares are also exactly matched.

³²In the simulations of my model I consider the case in which whenever $\pi_{ih,t}^j = 0$, I set $\tau_{ih,t}^j = \max_{ih,t} \{\tau_{ih,t}^j\}$. These trade costs imply that bilateral trade shares are negligible, which is consistent with the data.

Figure 3 summarizes the evolution of sectoral productivities over the entire time period by plotting the means (dashed dark line) and maximum and minimum bands (solid dark lines) of the log of a measure of average sectoral productivity given by $(T_{i,t}^j)^{\frac{1}{\theta}}$. In addition, each plot includes the case of the U.S. (circles) as a reference, as well as the case of particular countries that are either interesting cases on their own, or that follow interesting paths over time (crosses). The figure splits the set of countries into two. The first set of countries includes only developed countries, specifically, it includes all the countries considered in the studies by Bernard and Jones (1996a, 1996b). This set of countries is presented in panel (a). The second set of countries includes all other countries in our sample including ROW. These countries are presented in panel (b) together with the U.S. In line with previous studies, the U.S. represents the technological frontier across developed countries in all sectors except agriculture and mining. My results show that this is also the case for non-developed countries. In addition, as can be appreciated in the figure, for the set of countries in panel (b), the cross section of productivities in each year is more dispersed than for the countries in panel (a). The figure also shows that productivities of countries in panel (b) are lower than those included in panel (a). Moreover, we can appreciate that certain emerging economies experienced significant catch-up growth to the U.S. This is the case of Korea in the Agriculture and Mining sector, or China in the manufacturing sector. In contrast, Portugal has seen a relative decline in its productivity in services that is in line with its real exchange rate appreciation beginning in the 1990s.

3.3.3 Intertemporal Preference Disturbances

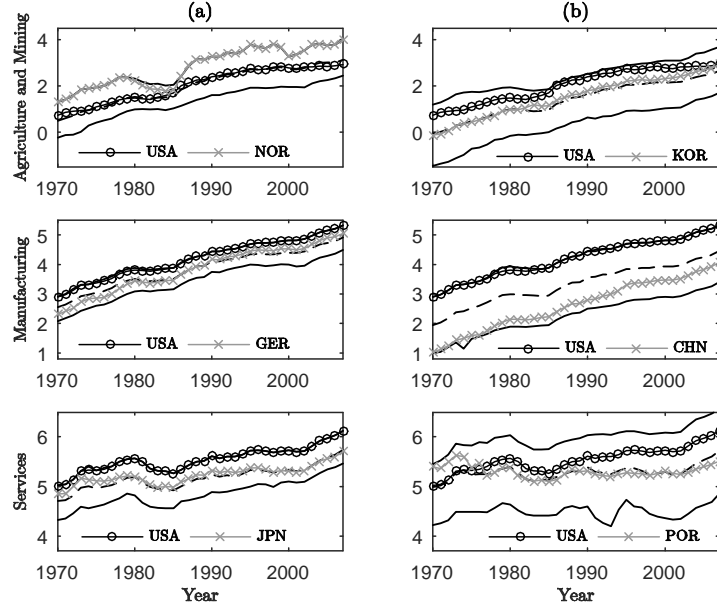
I now proceed to calibrate the disturbances to intertemporal preferences. These disturbances are calibrated in such a way that observed trade imbalances are matched by the model, which implies that dynamic decisions are also optimal. In particular, recall that optimal dynamic decisions are determined by the Euler equation. Assuming that $u(C) = \ln(C)$, we have that the Euler equation is given by

$$\frac{C_{i,t+1}}{C_{i,t}} = \delta \hat{\phi}_{i,t+1} \frac{R_{t+1}}{P_{i,t+1}/P_{i,t}}. \quad (32)$$

Now, notice that the equilibrium nominal interest rate, R_{t+1} , must be such that $\sum_{i=1}^I B_{i,t+1} = 0$ for all t . From the Euler equation we have that

$$\frac{P_{i,t+1}C_{i,t+1}}{P_{i,t}C_{i,t}} = R_{t+1}\delta\hat{\phi}_{i,t+1}, \quad (33)$$

Figure 3: Evolution of Sectoral Productivities: Mean, Max-Min Bounds, U.S. and Selected Countries



Notes: Countries in panel (a): Australia, Belgium, Canada, Denmark, Finland, France, Germany, Italy, Japan, Netherlands, Norway, Sweden, UK and US. Countries in panel (b): Austria, Brazil, China, Greece, India, Korea, Mexico, Portugal, Spain, Switzerland, Venezuela, and ROW. The figure plots the evolution of $\log(T_{i,t}^j)^{\frac{1}{\delta}}$.

which implies that given consumption expenditure levels at $t + 1$, it must be the case that the equilibrium nominal return is

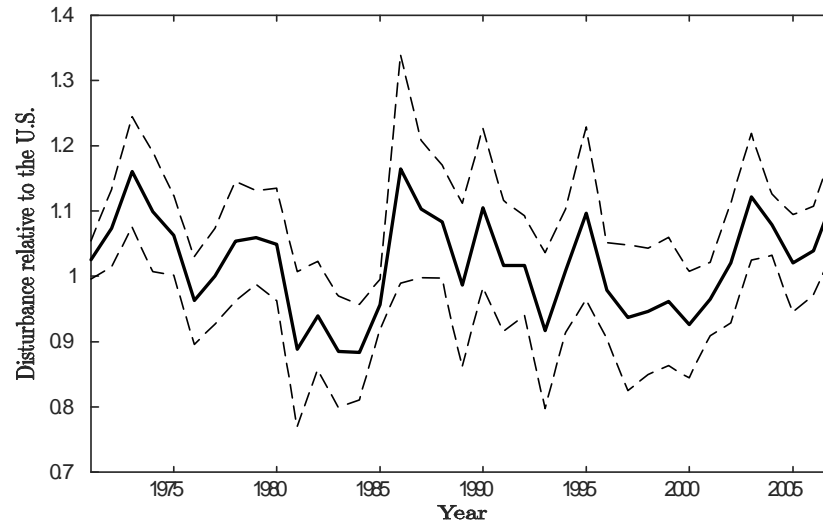
$$R_{t+1} = \frac{1}{\delta} \sum_{i=1}^I \frac{P_{i,t+1} C_{i,t+1}}{\hat{\phi}_{i,t+1}} \left(\sum_{i=1}^I P_{i,t} C_{i,t} \right)^{-1}. \quad (34)$$

Hence, note that equations (33) and (34) define a system of $I + 1$ equation and $I + 1$ unknowns in R_{t+1} and $\hat{\phi}_{i,t+1}$.³³ However, these shocks are only identified up to a normalization, as can be appreciated from (33) and (34). Therefore, I normalize $\hat{\phi}_{US,t+1} = 1$ for all t and recover only the other I shocks. In order to do so, I proceed as follows. Using data on net exports, I simulate the model and recover all prices and expenditure levels that are consistent with an equilibrium of the model. Using these values, I then proceed to recover the dynamic preference disturbances. Hence, the model is block recursive in the sense that we can recover all shocks other than the intertemporal preference shock, without knowing the latter. Similarly, given the data, we could recover the intertemporal preference shock in a first step.

Figure 4 plots the cross sectional mean and a one standard deviation range around it of the

³³I choose world GDP as the numeraire in the model. Note that this implies that world consumption is also equal to one in every period. Therefore, I can recover R_{t+1} having only information consumption expenditure for $t + 1$.

Figure 4: Evolution of Intertemporal Preference Disturbances: Mean and One Standard Deviation Bands



Notes: This figure plots the cross sectional mean of $\hat{\phi}_{i,t}$ (solid line) over time, as well one standard deviation bands around it (dashed lines).

changes in the dynamic preference disturbances over the period 1970-2007. Note that it is not clear from the figure that these shocks or levels are persistently different than one. This provides suggestive evidence that these shocks might not be playing a very relevant role in shaping the long term trend in trade imbalances.

In any case, as long as the sets of disturbances recovered do not systematically correlate with each other, we can isolate the effect of each one of these on equilibrium outcomes of the model by not allowing them to change over time. I turn to this kind of counterfactual exercises in the following section.

4 Counterfactual Exercises

In order to quantify the effects of trade costs on trade imbalances I conduct counterfactual exercises in which trade costs are held fixed at specific levels and all other disturbances change according to their original paths. These exercises isolate the effects of trade costs and allow me to quantify their effects by comparing the equilibrium trade imbalances in the counterfactual to those in the data.

Each counterfactual equilibrium is pinned down by the net foreign asset distribution at the time economic agents realize that the path of trade costs will differ from the one in the data. In my main exercise I assume that economic agents realize the counterfactual evolution of trade costs at the beginning of 1970. Therefore, the counterfactual equilibrium is pinned down by the initial net

foreign asset distribution. I use the equilibrium of the model that matches the data to recover this initial distribution. Specifically, given my assumption that the world economy reaches a steady state after 2007, I use the distribution in the steady state that is consistent with the data. Then, I iterate backwards according to the asset accumulation equation, $B_{i,t+1} = NX_{i,t} + R_t B_{i,t}$, using the equilibrium nominal return on bonds of the model, and recover the distribution $\{R_0 B_{i,0}\}_{i=1}^I$, which will remain unchanged across counterfactual equilibria. I compute these equilibria by iterating on the steady state distribution of net foreign assets until convergence of the initial distribution. Specifically, given a steady state distribution of net foreign assets, I recover the initial one by solving the model backwards.³⁴

I pin down counterfactual sectoral bilateral trade costs using Head-Ries indices. These indices are defined as

$$HR_{ih,t}^j \equiv \left(\frac{\pi_{ih,t}^j \pi_{hi,t}^j}{\pi_{hh,t}^j \pi_{ii,t}^j} \right)^{-\frac{1}{2\theta}}, \quad (35)$$

and provide a measure of country-pair sector-specific bilateral trade frictions that are widely used in the literature on gravity equations.³⁵ Note that these indices are symmetric, $HR_{ih,t} = HR_{hi,t}$, and they are functions of data on bilateral trade shares only. Bilateral trade costs in the model are related to these indices by the fact that, for a particular country pair (i, h) , the arithmetic mean $(\tau_{ih,t}^j \tau_{hi,t}^j)^{\frac{1}{2}}$ is equal to this index, as can be seen from equation (29). I choose this measure to pin down counterfactual levels of trade costs in order to focus on the effects of the decline in the average levels of bilateral trade costs rather than changes in asymmetries in costs. Therefore, my counterfactual results are not generated by specific changes in asymmetries in bilateral trade costs over time, but rather by the pure effects of the fact that trading goods across borders is easier now than in the past for any country-pair.

4.1 Trade Costs Fixed to 1970's Levels

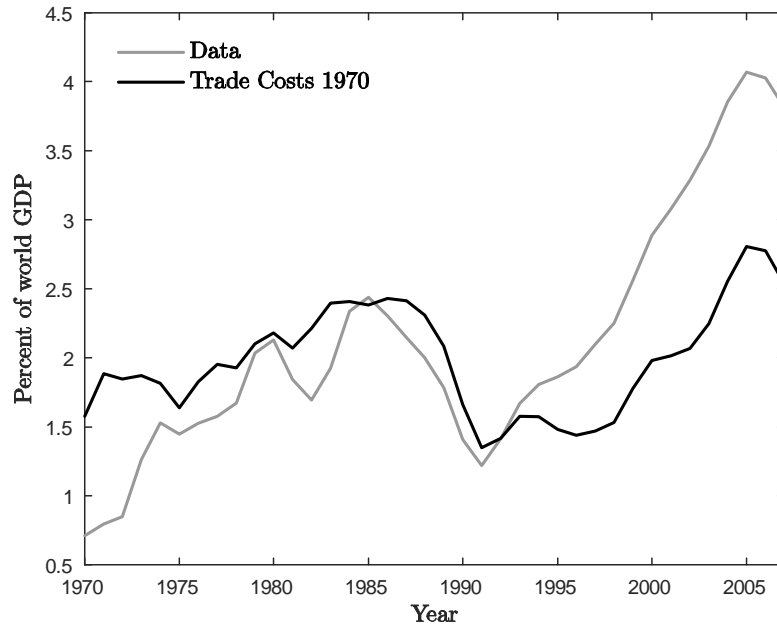
In my first and main counterfactual exercise, I fix trade costs at 1970's Head-Ries index values. That is, in the counterfactual, $HR_{ih,t}^j = HR_{ih,1970}^j$ for all $t = 1970, \dots$ and country pairs. The particular question that I aim to answer by means of this counterfactual exercise is the following: What would trade imbalances have been in the case in which trade costs had remained at their 1970's levels and all economic agents had been aware of it since the beginning of that year, while keeping all other disturbances constant.

Figure 5 plots the evolution of the size of external imbalances, measured as the sum of the

³⁴More details on my computational algorithm are provided in the appendix.

³⁵See Head and Ries (2001) and Head and Mayer (2014).

Figure 5: Trade Imbalances: Sum over Absolute Values of Net Exports



absolute values of the trade imbalances as a share of world GDP. The difference between the data and the counterfactual is evident throughout, but beginning in 1992 these differences become larger. This is in line with the fact that low levels of trade costs are reached around that time according to Figure 2. Moreover, note how with 1970's trade costs, the size of trade imbalances remains at significantly lower levels after this year. Hence, Figure 5 provides evidence of the quantitative relevance of the decrease in trade costs in the increase in trade imbalances.

Table 2 provides some statistics related to Figure 5. In particular, if we consider the change in imbalances between 1970 and 2007, Table 2 implies that the decrease in trade costs accounts for 69% of the increase in these imbalances. An interesting feature of imbalances in the counterfactual scenario is that they are somewhat larger, but still not considerably different, than trade imbalances in the data previous to 1992. The results show that the 69 percent difference in the change in imbalances is the result of a decrease in imbalances in 2007 of 41 percent and an increase in 1970 of 28 percent of the overall change in the data.

The reason that these two series are different in the initial periods is because the difference between the set of bilateral trade flows that is consistent with the data and the one in the counterfactual is not only different in terms of their levels, but also the entire path that they follow over time. As previously discussed, the negative income effect in future periods in the counterfactual relative to the data implies that the world real interest rates in the initial periods is lower in the counterfactual than in the baseline equilibrium. These differences in the world real interest rate

Table 2: Trade Imbalances: Percent of World GDP

Data			Counterfactual			Decomposition		
1970	2007	Diff. ^D	1970	2007	Diff. ^D	1-(Diff. ^{CF} /Diff. ^D)	Diff. ₁₉₇₀ /Diff. ^D	Diff. ₂₀₀₇ /Diff. ^D
0.71%	3.81%	3.1%	1.58%	2.54%	0.96%	0.69%	0.41%	-0.28%

lead to income effects that act in opposite directions depending on a country's trade balance positions in the future. In the new equilibrium, borrowers in initial periods borrow more and lenders also lend more, which implies that trade imbalances increase. Hence, the tilting in the evolution of trade imbalances on top of the downward shift. This emphasizes the relevance of the dynamic mechanism as well as the importance of solving for counterfactual competitive equilibria that are pinned down by the initial net foreign asset position in the world economy. I go back to this issue in the following subsection when I compare trade imbalances across counterfactual equilibria in which only the levels of trade costs change.

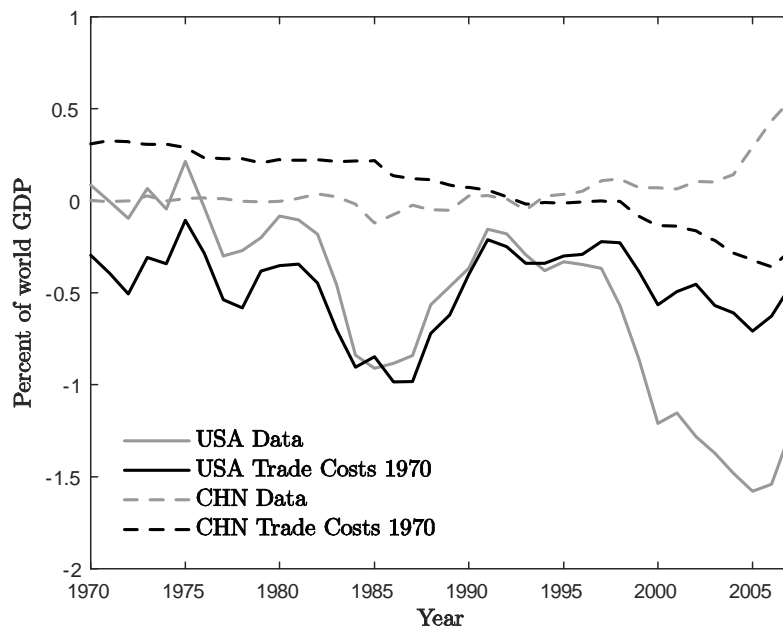
Let us now focus on the case of particular countries. Figure 6 shows the evolution of net exports in the U.S. and China over the time period considered. These two countries provide a clear example of what an important role trade costs can play in shaping imbalances. This figure tells us that if trade costs had not fallen as much as they did, we would have seen a much smaller increase in the trade deficit of the U.S. and actual decrease in the trade surplus of China beginning in the 1990s. According to Table 3, the U.S. trade deficit in 2007 would have been 0.47 percent of world GDP, rather than the three times larger 1.65 percent observed in the data. In the case of China, it would have experienced a trade deficit in 2007 of 0.27 percent of world GDP rather than the surplus of 0.72 percent observed in the data. Moreover, China would have run large trade surpluses from 1970 to the late 1990s, and then would have started to run trade deficits beginning in the 1990s. Table 3 shows that the differences between the data and the counterfactual are quantitatively sizeable. In general, our results point in the direction of the existence of significant effects of the level of trade costs on the magnitude of trade imbalances.

Table 3: Trade Imbalances: U.S. and China (Net Exports, Percent of World GDP)

	Data			Counterfactual		
	1970	2007	Diff.	1970	2007	Diff.
US	-0.16%	-1.65%	-1.49%	-0.30%	-0.47%	-0.17%
CHN	0.00%	0.72%	0.72%	0.31%	-0.27%	-0.58%

Returning to trade imbalances in all countries, Table 4 shows the accumulated trade imbalances for all countries in my sample. I measure accumulated trade imbalances as the sum over the absolute value of net exports as a share of world GDP from 1970 to 2007. Note that accumulated trade imbalances are not greater in the data than in the counterfactual for every country. As previously

Figure 6: Trade Imbalances in U.S. and China: Net Exports



discussed, this is a result of the tilting effect. Breaking the accumulated imbalances into two subperiods, we can see in the table that for the period 1992-2007, the fact that trade imbalances are dampened by high trade costs is more evident. Countries like Japan and Greece experience small changes in accumulated imbalances relative to their levels in the data. Japan experiences a decrease of 7.5 percent of its original accumulated imbalances, while Greece 4.5 percent.

Lastly, I turn to the welfare gains from lower trade costs in this model. Measuring the welfare gains from trade is a fundamental part of most international trade studies. Hence, I also provide a measure of these gains for our counterfactual exercise. Given that we now have a dynamic model, a measure of the welfare gains directly comparable with those in Arkolakis et al. (2012) is not available. Hence, in Table 5, I measure the welfare gains for each country as the time-invariant percentage increase in consumption that a country would need to receive in the counterfactual in order to be indifferent between this scenario and the benchmark case (consumption-equivalent variation). That is, if U_i^D is the lifetime utility of country i in the benchmark scenario, then we compute the welfare gains from trade as the time-invariant consumption transfer, x_i , such that

$$\sum_{t=0}^{\infty} \delta^t \phi_{i,t} \ln \left(C_{i,t}^{CF} \left(\frac{100 + x_i}{100} \right) \right) = U_i^D,$$

where $C_{i,t}^{CF}$ is consumption in the counterfactual in period t and country i . As can be appreciated in the table, most countries gain from the decline in trade costs relative to the counterfactual scenario.

Table 4: Accumulated Trade Imbalances: Percent of World GDP

	Data	$\sum_{t=1970}^{2007} NX_{i,t} $ Counterfactual	Diff.	$\sum_{t=1970}^{1991} NX_{i,t} $ Diff. D-CF	$\sum_{t=1992}^{2007} NX_{i,t} $ Diff. D-CF
AUS	0.92%	1.04%	-0.12%	0.01%	-0.13%
AUT	0.39%	0.21%	0.18%	0.02%	0.16%
BEL	0.88%	1.47%	-0.59%	-0.53%	-0.06%
BRA	1.53%	2.13%	-0.60%	-0.74%	0.14%
CAN	1.99%	1.73%	0.25%	-0.15%	0.40%
CHN	2.77%	6.72%	-3.95%	-4.2%	0.17%
DEN	0.76%	0.60%	0.16%	0.00%	0.16%
FIN	0.58%	0.65%	-0.06%	-0.16%	0.10%
FRA	2.10%	1.46%	0.64%	0.22%	0.42%
GER	5.44%	3.26%	2.18%	1.24%	0.94%
GRC	1.54%	1.47%	0.07%	-0.16%	0.23%
IND	1.08%	1.53%	-0.45%	-0.56%	0.11%
ITA	1.94%	1.94%	0.00%	0.02%	-0.02%
JAP	6.81%	6.30%	0.51%	0.36%	0.15%
KOR	1.29%	2.04%	-0.75%	-0.19%	-0.56%
MEX	2.17%	1.73%	0.45%	0.01%	0.44%
NLD	1.91%	1.85%	0.06%	-0.75%	0.81%
NOR	1.51%	1.40%	0.11%	-0.04%	0.15%
POR	1.05%	1.03%	0.03%	-0.02%	0.05%
SPA	1.64%	1.39%	0.25%	-0.23%	0.48%
SWE	1.21%	1.13%	0.09%	-0.01%	0.10%
SWZ	0.97%	1.02%	-0.04%	-0.32%	0.28%
UK	2.61%	2.26%	0.35%	0.10%	0.25%
US	21.39%	18.12%	3.27%	-4.09%	7.36%
VEN	1.08%	2.05%	-0.97%	-0.88%	-0.09%
ROW	15.37%	11.39%	3.98%	3.06%	0.92%

The cases of Finland and Venezuela are interesting, as according to the model they suffered welfare losses. For the case of Venezuela, it is the case that it was trading more in 1970 than in subsequent years. This fact translates into higher trade costs, mostly driven by policy measures, after 1970. It might also be the case that these countries see a deterioration of their terms of trade in the counterfactual. This seems to be the case for Finland as well.

In line with previous research, small open economies experience significant gains from lower trade costs. Belgium and the Netherlands are two clear examples of this case, with gains of 10.9 and 6.7 percent of additional consumption in every year. However, large emerging economies like China and Korea also experience large gains from lower trade costs. Interestingly, these are two economies that have engaged in export-oriented growth.

4.2 Effects of Changes in Trade Costs' Levels: 1970 versus 2007

In the previous counterfactual exercise, trade costs remain fixed at a constant level over time. This implies that relative to actual bilateral trade costs, not only their levels are different, but also the dynamic path they follow. While in the data trade costs are falling, in the counterfactual they are not. This change in the path of bilateral trade costs affects how agents make consumption-

Table 5: Welfare Gains from Changes in Trade Costs

	$U_i = \sum_{t=0}^{\infty} \delta^t \phi_{i,t} \ln(C_{i,t})$		x_i s.t. $\sum_{t=0}^{\infty} \delta^t \phi_{i,t} \ln(C_{i,t}^{CF} (1 + \frac{x_i}{100})) = U_i^D$
	Data: U_i^D	Counterfactual: U_i^{CF}	Increase in Consumption: $x_i\%$
AUS	191.52	191.29	1.11%
AUT	179.73	178.84	4.26%
BEL	180.58	178.42	10.85%
BRA	216.66	216.58	0.38%
CAN	198.14	197.73	2.02%
CHN	215.35	213.15	10.93%
DEN	166.47	165.90	2.79%
FIN	165.80	166.22	-1.98%
FRA	216.48	216.06	2.03%
GER	222.71	222.19	2.55%
GRC	175.42	175.06	1.75%
IND	205.30	205.05	1.26%
ITA	214.24	213.84	1.94%
JAP	237.14	236.88	1.25%
KOR	203.36	200.94	11.26%
MEX	210.00	209.41	2.80%
NLD	191.14	189.77	6.74%
NOR	167.40	167.05	1.66%
POR	171.51	170.92	2.80%
SPA	211.15	210.72	2.02%
SWE	174.48	174.11	1.80%
SWZ	179.42	178.76	3.18%
UK	213.83	213.43	1.97%
US	244.11	243.90	1.05%
VEN	166.08	166.59	-2.43%
ROW	245.28	244.66	3.15%

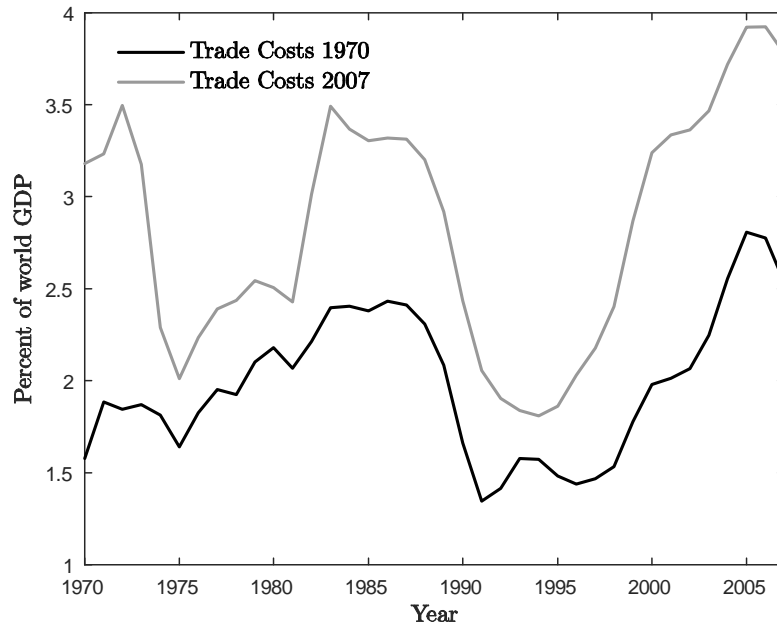
saving decisions independently of the changes in trade costs' levels. In order to understand the implications of changes in the levels of trade costs in isolation, I compare counterfactual equilibria in which bilateral trade costs remain constant over time, but differ in their levels.

Figure 7 shows the evolution of trade imbalances for two counterfactual equilibria in which trade costs are constant over time, but differ in their levels. In particular, I consider the levels of bilateral trade costs in 1970 and 2007 for this comparison. The equilibrium for 1970 trade costs is the same as in our previous exercise. For the case of 2007 trade costs, trade imbalances are obtained by fixing trade at 2007's Head-Ries index values in every year.

As can be appreciated in Figure 7, uniformly lower trade costs across time have significant level effects on trade imbalances. Trade imbalances for low trade costs are higher than for high trade costs across the entire time period. This effect is in line with the level effect explained in Section 2.

In contrast to our first counterfactual, note that uniform differences in the levels of trade costs do not imply a tilting of trade imbalances. Hence, we can attribute this effect in our first counterfactual exercise to the fact that trade costs do not follow a declining path over time. Additionally, this decline seems to be driving part of the increase in observed trade imbalances. We can decompose accumulated trade imbalances from 1970 to 2007 into two effects. The level effect leads to an

Figure 7: Trade Imbalances: Data and Counterfactuals



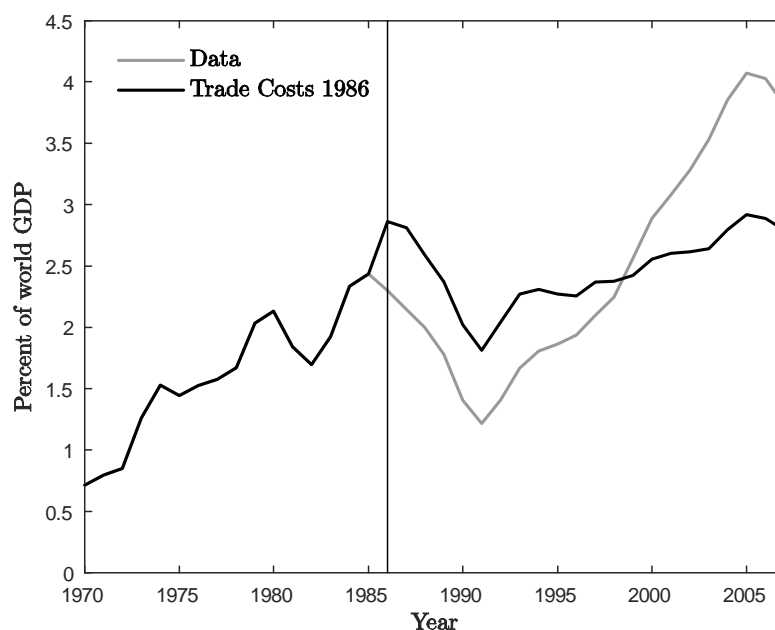
increase in accumulated trade imbalances from 75.56 to 107.97 that is evenly distributed across time periods. Then, the tilting effect, *i.e.* making trade costs in the initial periods higher relative to those in the final ones leads to a decrease in accumulated trade imbalances from 107.97 to 80.76. Thus, the overall change in accumulated trade imbalances is $80.76 - 75.56 = (107.97 - 75.56) - (107.97 - 80.76)$, the increase due to level effects, minus the decrease due to the tilting effect.

4.3 No Trade Liberalizations: Costs of 1986

In the previous exercises I assumed that all agents find out in the year 1970 what the counterfactual path of trade costs will be. Hence, they adjust all their optimal choices thereafter based on perfect knowledge of the future path of changes in disturbances. I also consider a different exercise in which the agents realize in a later period that trade cost will differ from what they initially expected. I conduct such an exercise in this subsection. Specifically, I assume that after 1986 trade costs remain constant. This can be thought of as the case in which many of the trade liberalizations rounds of the late 1980s had not occur.

Consider the counterfactual scenario in which all agents realize at the beginning of the year 1986 that trade costs will no longer follow their original path, *i.e.* a declining path. In contrast, trade costs will remain constant at their 1986 levels thereafter. Figure 8 plots the evolution of trade imbalances for the data and the counterfactual scenario. In line with our initial exercise, trade imbalances increase at the time that the news arrive, and then follow a much flatter path

Figure 8: Trade Imbalances: Data and Counterfactuals



than in the data. Hence, the tilting in trade imbalances because of the constant trade costs is again very apparent. Moreover, the increase in imbalances after 1990 is less pronounced than in the data.

In the case of no trade liberalizations, post 1986 trade imbalances reach a minimum level of 1.81 percent of world GDP in 1991. A minimum level of 1.22 percent of world GDP is achieved in the same year in the data post 1986. In the data, trade imbalances increase from 1.22 percent in 1991 to 3.81 percent of world GDP in 2007. This increase is 0.38 times the increase over the same period in the scenario of no trade liberalizations.

The main difference between this exercise and the previous ones is that now the net foreign asset position that pins down the equilibrium is the one in 1986. Therefore, trade imbalances in the absence of trade liberalizations are determined based on this initial net foreign asset distribution. Suppose we had assigned Pareto weights to countries, solved a social planner's problem rather than the actual competitive equilibrium, and backed out intertemporal preference disturbances. If we consider the same weights in the last exercise, then the planner's allocations do not coincide with the competitive equilibrium allocations. The weights that decentralize the counterfactual equilibrium should be linked to endogenous equilibrium outcomes after 1986, such as the net foreign asset distribution at the beginning of 1986, rather than those including the period 1970-1985. Hence the relevance of solving for the competitive equilibrium.

Table 6: Trade Imbalances: Percent of World GDP

Data			Counterfactual		
1986	2007	Diff.	1986	2007	Diff
2.30%	3.81%	1.51%	2.86%	2.79%	-0.07%

5 Conclusions

This paper provides a quantification of the mechanism through which lower trade costs in goods have helped in shaping the surge in trade imbalances over the last four decades. To my knowledge, this is the first attempt to do so by exploiting the structure of the new quantitative general equilibrium trade models. The results show that 69 percent of the increase in trade imbalances from 1970 to 2007 can be attributed to the fact that trade costs in goods markets declined considerably since 1970. In other words, lower bilateral trade costs across countries have not only allowed for more intratemporal trade, but also for more intertemporal trade around the world. Hence, the key for a better understanding of the roots of the steady increase in trade imbalances might lie in fundamental determinants of bilateral trade costs in goods markets rather than other mechanisms, for example, frictions in international financial markets.

The key mechanism driving these results arises once endogenous trade imbalances driven by consumption-saving decisions are embedded into a framework in which bilateral trade flows are determined by trade costs and comparative advantage across countries. By incorporating these two mechanisms into a unified framework, interesting interactions arise between trade costs and dynamic decisions. These interactions not only show that bilateral trade costs affect trade imbalances, but also that imbalances have implications for bilateral trade flows and the gains from trade. Thus, the paper provides a theoretical framework that incorporates these interactions, but maintains the appealing features of the new quantitative general equilibrium models of trade.

Our results point to the fact that, to the extent that the surge in trade imbalances is a consequence of the process of globalization that has led to lower trade costs, then there is not much room for global welfare improving policies. In other words, the increase in imbalances is simply a result of a more efficient allocation of resources around the world. However, our results also point to the fact that in models in which market imperfections lead to larger imbalances, it is very important to disentangle how much of this increase is simply because of lower trade costs in goods markets. These types of interaction open up the possibility for a more detailed investigation of how trade policy can affect policies targeted to manage capital flows.

References

- Aguiar, Mark and Manuel Amador.** 2011. “Growth in the Shadow of Expropriation.” *Quarterly Journal of Economics* 126 (2): 651–697.
- Anderson, James E., and Eric van Wincoop.** 2004. “Trade Costs.” *Journal of Economic Literature* 42 (3): 691–751.
- Antràs, Pol, and Ricardo J. Caballero.** 2010. “On the Role of Financial Frictions and the Saving Rate during Trade Liberalizations.” *Journal of the European Economic Association* 8 (2-3): 442–455.
- Arkolakis, Costas, Arnaud Costinot, and Andres Rodriguez-Clare.** 2012. “New Trade Models, Same Old Gains?” *American Economic Association* 102 (1): 94–130.
- Backus, David K., Patrick J. Kehoe, and Finn E. Kydland.** 1992. “International Real Business Cycles.” *Journal of Political Economy* 100 (4): 745–75.
- Barattieri, Alessandro.** 2014. “Comparative Advantage, Service Trade, and Global Imbalances.” *Journal of International Economics* 92 (1): 1–13.
- Bernard, Andrew B., and Charles I. Jones.** 1996. “Comparing Apples to Oranges: Productivity Convergence and Measurement across Industries and Countries.” *American Economic Review* 86 (5): 1216–38.
- Bernard, Andrew B., and Charles I. Jones.** 1996. “Technology and Convergence.” *Economic Journal* 106 (437): 1037–44.
- Bai, Yan, and Jing Zhang.** 2010. “Solving the Feldstein-Horioka Puzzle with Financial Frictions.” *Econometrica* 78 (2): 603–632.
- Bai, Yan, and José-Víctor Ríos-Rull.** 2015. “Demand Shocks and Open Economy Puzzles.” *American Economic Review* 105 (5): 644–49.
- Bergin, Paul R. and Reuven Glick.** 2009. “Endogenous Tradability and some Macroeconomic Implications.” *Journal of Monetary Economics* 56 (8): 1086–1095.
- Bernanke, Ben S.** 2005. “The Global Saving Glut and the U.S. Current Account Deficit.” Speech 77, Board of Governors of the Federal Reserve System.
- Blanchard, Olivier, Francesco Giavazzi, and Filipa Sa.** 2005. “The U.S. Current Account and the Dollar,” National Bureau of Economic Research Working Papers 11137.

- Blanchard, Olivier J. and Gian-Maria Milesi-Ferretti.** 2009. "Global Imbalances: In Midstream?" IMF Staff Position Notes 09/29.
- Broda, Christian and David E. Weinstein.** 2006. "Globalization and the Gains from Variety." *Quarterly Journal of Economics* 121 (2): 541-585.
- Caballero, Ricardo J., Emmanuel Farhi, and Pierre-Olivier Gourinchas.** 2008. "An Equilibrium Model of "Global Imbalances" and Low Interest Rates." *American Economic Review* 98 (1): 358-93.
- Caliendo, Lorenzo, and Fernando Parro.** 2015 "Estimates of the Trade and Welfare Effects of NAFTA." *The Review of Economic Studies* 82 (1): 1-44.
- Caliendo, Lorenzo, Fernando Parro, Esteban Rossi-Hansberg, and Pierre-Daniel Sarte.** 2014 "The Impact of Regional and Sectoral Productivity Changes on the U.S. Economy." National Bureau of Economic Research Working Papers 20168.
- Caselli, Francesco and James Feyrer.** 2007. "The Marginal Product of Capital." *The Quarterly Journal of Economics* 122 (2): 535-568.
- Caselli, Francesco, Miklos Koren, Milan Lisicky, and Silvana Tenreyro. "Diversification through trade," London School of Economics, manuscript, July 2015.
- Chang, Yongsung, Sun-Bin Kim, and Jaewoo Lee.** 2013. "Accounting for Global Dispersion of Current Accounts." *Review of Economic Dynamics* 16 (3): 477-496.
- Chari, V. V., Patrick J. Kehoe and Ellen R. McGrattan.** 2007. "Business Cycle Accounting." *Econometrica* 75 (3): 781-836.
- Clarida, Richard H.** 1990. "International Lending and Borrowing in a Stochastic, Stationary Equilibrium." *International Economic Review* 31 (3): 543-558.
- Costinot, Arnaud, Dave Donaldson, and Ivana Komunjer.** 2011. "What Goods Do Countries Trade? A Quantitative Exploration of Ricardo's Ideas." *The Review of Economic Studies* 79 (2): 581-608.
- Costinot, Arnaud and Andrés Rodríguez-Clare.** 2014. "Trade Theory with Numbers: Quantifying the Consequences of Globalization." In Gita Gopinath, Elhanan Helpman and Kenneth Rogoff, eds, *Handbook of International Economics*, Volume 4: 197-261.

Dekle, Robert, Jonathan Eaton, and Samuel Kortum. “Unbalanced Trade,” *American Economic Review*, May 2007, 97 (2), 351–355.

__, __, and __, “Global Rebalancing with Gravity: Measuring the Burden of Adjustment,” *IMF Staff Papers*, July 2008, 55 (3), 511–540.

Dornbusch, Rudiger, Stanley Fischer, and Paul Samuelson. 1977. “Comparative Advantage, Trade, and Payments in a Ricardian Model with a Continuum of Goods.” *American Economic Review* 67 (5): 823–39.

Duarte, Margarida and Diego Restuccia. 2010. “The Role of the Structural Transformation in Aggregate Productivity.” *The Quarterly Journal of Economics* 125 (1): 129–173.

Eaton, Jonathan and Samuel Kortum. 2002. “Technology, Geography, and Trade.” *Econometrica* 70 (5): 1741–1779.

__ and __. 2012. “Putting Ricardo to Work.” *Journal of Economic Perspectives* 26 (2): 65–90.

__, __, **Brent Neiman, and John Romalis.** 2011. “Trade and the Global Recession.” National Bureau of Economic Research Working Papers 16666.

__, __, __ and __. 2015. “Trade and the Global Recession.” Unpublished.

Engel, Charles and John H. Rogers. 2006. “The U.S. Current Account Deficit and the Expected Share of World Output.” *Journal of Monetary Economics* 53 (5): 1063–1093.

Faruqee, Hamid, and Jaewoo Lee. 2009. “Global Dispersion of Current Accounts: Is the Universe Expanding?” *IMF Staff Papers* 56 (3): 574–595.

Fitzgerald, Doireann. 2008. “Can Trade Costs Explain Why Exchange Rate Volatility Doesn’t Feed Into Consumer Prices?” *Journal of Monetary Economics* 55 (3): 606–628.

Fitzgerald, Doireann. 2012. “Trade Costs, Asset Market Frictions, and Risk Sharing.” *American Economic Review* 102 (6): 2700–2733.

Fogli, Alessandra and Fabrizio Perri. 2006. “The “Great Moderation” and the US External Imbalance.” National Bureau of Economic Research Working Papers 12708.

__ and __. 2013. “Macroeconomic Volatility and External Imbalances.” Technical Report, Federal Reserve Bank of Minneapolis.

- Gourinchas, Pierre-Olivier, and Olivier Jeanne.** 2013. "Capital Flows to Developing Countries: The Allocation Puzzle." *The Review of Economic Studies* 80(4): 1484–1515.
- Gourinchas, Pierre-Olivier and H el ene Rey.** 2007. "International Financial Adjustment," *Journal of Political Economy*, 2007, 115 (4), pp. 665–703.
- Gourinchas, Pierre-Olivier and H el ene Rey.** 2014. "External Adjustment, Global Imbalances, Valuation Effects." In Gita Gopinath, Elhanan Helpman and Kenneth Rogoff, eds., *Handbook of International Economics*, Volume 4: 585–645.
- Head, Keith and Thierry Mayer.** 2014. "Gravity Equations: Workhorse, Toolkit, and Cookbook." In Gita Gopinath, Elhanan Helpman and Kenneth Rogoff, eds., *Handbook of International Economics*, Volume 4: 131-195.
- Head, Keith, and John Ries.** 2001. "Increasing Returns versus National Product Differentiation as an Explanation for the Pattern of U.S.-Canada Trade." *American Economic Review* 91(4): 858–876.
- Jin, Keyu.** 2012. "Industrial Structure and Capital Flows." *American Economic Review* 102 (5): 2111–2146.
- Kehoe, Timothy J., Kim J. Ruhl, and Joseph B. Steinberg.** 2013. "Global imbalances and structural change in the United States." National Bureau of Economic Research Working Paper 19339.
- Kose, M. Ayhan, and Kei-Mu Yi.** 2006. "Can the Standard International Business Cycle Model Explain the Relation between Trade and Comovement?" *Journal of International Economics* 68 (2): 267–95.
- Krugman, Paul.** 1993. "What Do We Need to Know About the International Monetary System?" *Princeton Studies in International Economics* 190, International Economics Section, Department of Economics, Princeton University.
- Lane, Philip R. and Gian Maria Milesi-Ferretti.** 2007. "The External Wealth of Nations Mark II: Revised and Extended Estimates of Foreign Assets and Liabilities, 1970-2004." *Journal of International Economics* 73 (2): 223–250.
- Lane, Philip R., and Gian Maria Milesi-Ferretti.** 2001. "The External Wealth of Nations: Measures of Foreign Assets and Liabilities for Industrial and Developing Countries." *Journal of International Economics* 55 (1): 263–294.

- Levchenko, Andrei A., and Jing Zhang.** 2015. “The Evolution of Comparative Advantage: Measurement and Implications” Unpublished.
- Maggiore, Matteo.** 2013. “Financial Intermediation, International Risk Sharing, and Reserve Currencies.” Unpublished.
- Mendoza, Enrique G., Vincenzo Quadrini, and José-Víctor Ríos-Rull.** 2009. “Financial Integration, Financial Development, and Global Imbalances.” *Journal of Political Economy* 117 (3): 371–416.
- Obstfeld, Maurice.** 2012. “Does the Current Account Still Matter?” *American Economic Review* 102 (3): 1–23.
- __ and **Kenneth Rogoff.** 1995. “The Intertemporal Approach to the Current Account.” In G. M. Grossman and K. Rogoff editors, *Handbook of International Economics*, Volume 3, Chapter 34: 1731–1799.
- __ and __. 1996. *Foundations of International Macroeconomics*, Cambridge, MA; MIT Press.
- __ and __. 2000. “The Six Major Puzzles in International Macroeconomics: Is There a Common Cause?” In NBER Macroeconomics Annual 2000, Volume 15, Bernanke and Rogoff.
- __ and __. 2005. “Global Current Account Imbalances and Exchange Rate Adjustments.” *Brookings Papers on Economic Activity* 36 (1), 67–146.
- Ossa, Ralph.** 2014. “Trade Wars and Trade Talks with Data.” *American Economic Review* 104(12): 4104–4146.
- Parro, Fernando.** 2013. “Capital-skill Complementarity and the Skill Premium in a Quantitative Model of Trade.” *American Economic Journal: Macroeconomics*, 5 (2): 72–117.
- Simonovska, Ina and Michael Waugh.** 2014. “The Elasticity of Trade: Estimates and Evidence.” *Journal of International Economics* 92(1): 34–50.
- Stockman, Alan C. and Tesar, Linda L.** 1995. “Tastes and Technology in a Two-Country Model of the Business Cycle: Explaining International Comovements.” *American Economic Review* 85(1): 168–185.

Appendix

A. Proof of Lemma 1

Consider equilibrium condition (23). This condition can be rewritten as

$$P_{i,t}^j C_{i,t}^j = E_{i,t}^j - \sum_{m=1}^J P_{i,t}^j D_{i,t}^{m,j}.$$

Notice that conditional on actually producing, firms producing good ω^j choose intermediate inputs from sector m such that $P_{i,t}^m D_{i,t}^{j,m}(\omega^j) = \nu_i^{j,m}(1 - \beta_i^j) p_{i,t}^j(\omega^j) q_{i,t}^j(\omega^j)$. Now, aggregating over all goods $\omega^j \in [0, 1]$, we have that $P_{i,t}^m D_{i,t}^{j,m} = \nu_i^{j,m}(1 - \beta_i^j) Y_{i,t}^j$ for all $j, m = 1, \dots, J$. These conditions together with (18) imply that

$$\mu_{i,t}^j \left(\frac{P_{i,t}^j}{P_{i,t}} \right)^{(1-\psi)} P_{i,t} C_{i,t} = E_{i,t}^j - \sum_{k=1}^J (1 - \beta_i^k) \nu_i^{k,j} Y_{i,t}^k$$

for all $j = 1, \dots, J$, which together with the budget constraint in period t give us the first set of equations of the lemma. Given the data, notice that the shocks recovered for tradable sectors are uniquely pinned down. The restriction that $\sum_{j=1}^J \mu_{i,t}^j = 1$ pins down the shock for the nontradable sector.

B. Proof of Lemma 2

Consider sectoral trade shares as given by (14). Notice then that

$$\frac{\pi_{ih,t}^j}{\pi_{hh,t}^j} = \left(\frac{P_{h,t}^j}{P_{i,t}^j} \right)^{-\theta} \left(\tau_{ih,t}^j \right)^{-\theta},$$

which immediately delivers (29). Now, consider $\pi_{ii,t}^j$ and notice that rearranging terms we obtain (30). Lastly, data on $P_{i,t}$ and $P_{i,t}^j$ for $j \in \mathcal{J} \setminus S$ imply that $P_{i,t}^S$ is uniquely pinned down by (31). Given $P_{i,t}^S$, we can now recover $T_{i,t}^S$ using (30) as previously.

C. Mapping to Armington Model

Consider a model identical to the one outlined in Section 2 with the exception that trade across countries in each period t is done in an Armington fashion. Formally, this model is almost identical to the one previously outlined except for the fact that there is no longer a unit continuum of goods for each sector j that can potentially be produced in each country. Now, each country produces

one country-specific good, and sectoral goods producers aggregate these goods across countries in a CES fashion with elasticity of substitution $\rho \geq 0$ in order to produce the final nontradable good in sector j :

$$Q_{i,t}^j = \left(\sum_{h=1}^I \left(d_{ih,t}^j \right)^{\frac{\rho-1}{\rho}} \right)^{\frac{\rho}{\rho-1}}.$$

This implies that, for the case of sector j , expenditure by country i on goods produced in country h is given by

$$p_{ih,t}^j d_{ih,t}^j = \left(\frac{p_{ih,t}^j}{P_{i,t}^j} \right)^{1-\rho} P_{i,t}^j Q_{i,t}^j,$$

where $(P_{i,t}^j)^{1-\rho} = \sum_{h=1}^I (p_{ih,t}^j)^{1-\rho}$ and $p_{ih,t}^j = \frac{\tau_{ih,t}^j c_{h,t}^j}{x_{h,t}^j}$. Hence, the share of total expenditure on goods produced in country h is

$$\pi_{ih,t}^j \equiv \frac{p_{ih,t}^j d_{ih,t}^j}{P_{i,t}^j Q_{i,t}^j} = \left(\frac{p_{ih,t}^j}{P_{i,t}^j} \right)^{1-\rho} = \left(x_{h,t}^j \right)^{\rho-1} \left(\frac{\tau_{ih,t}^j c_{h,t}^j}{P_{i,t}^j} \right)^{1-\rho}.$$

Notice then that, given parameters for the model outlined in Section 2, if we let $\rho = \theta + 1$ and $x_{h,t}^j = \Gamma^{-1} \left(T_{h,t}^j \right)^{\frac{1}{\theta}}$, then

$$\pi_{ih,t}^j = \left(\Gamma^{-\theta} \right) T_{h,t}^j \left(\frac{c_{h,t}^j \tau_{ih,t}^j}{P_{i,t}^j} \right)^{-\theta}$$

which is identical to (14). Moreover, sectoral prices are also equivalent, since

$$(P_{i,t}^j)^{1-\rho} = \sum_{h=1}^I (p_{ih,t}^j)^{1-\rho} = \sum_{h=1}^I \left(\frac{\tau_{ih,t}^j c_{h,t}^j}{x_{h,t}^j} \right)^{1-\rho}.$$

D. Model with Capital Accumulation

Consider the same environment as in the main text, but now there are final nontradable goods producers that produce the final good by aggregating the sectoral goods in a CES fashion across sectors with an elasticity of substitution of $\psi > 0$, $X_{i,t} = \left(\sum_{j=1}^J \left(\mu_{i,t}^j \right)^{\frac{1}{\psi}} \left(X_{i,t}^j \right)^{\frac{1-\psi}{\psi}} \right)^{\frac{\psi}{1-\psi}}$, where $X_{i,t}$ denotes production of the final nontradable good, and $X_{i,t}^j$ is the conditional demand for input of sector j . Then, perfect competition and cost minimization by these firms implies that sectoral demand is given by $P_{i,t}^j X_{i,t}^j = \mu_{i,t}^j \left(\frac{P_{i,t}^j}{P_{i,t}} \right)^{1-\psi} P_{i,t} X_{i,t}$. Therefore, the equilibrium conditions in the

nontradable sector are now given by

$$X_{i,t}^j + \sum_{k=1}^J D_{i,t}^{k,j} = Q_{i,t}^j.$$

The representative household in country i now takes $R_0 B_{i,0}$, $K_{i,0}$ and prices as given and solves

$$\max_{\{C_{i,t}, I_{i,t}, K_{i,t+1}, B_{i,t+w}\}_{t=0}^{\infty}} \sum_{t=0}^{\infty} \delta^t \phi_{i,t} \ln(C_{i,t}) \quad (36)$$

subject to

$$P_{i,t} C_{i,t} + P_{i,t} I_{i,t} + B_{i,t+1} = w_{i,t} L_{i,t} + r_{i,t} K_{i,t} + R_t B_{i,t} \quad (37)$$

$$K_{i,t+1} = (1-d) K_{i,t} + \chi_{i,t} I_{i,t}, \quad (38)$$

where $\chi_{i,t}$ is an investment disturbance. Then, the representative household's optimality conditions are given by:

$$u'(C_{i,t}) = \beta \hat{\phi}_{i,t+1} \frac{R_{t+1}}{P_{i,t+1}/P_{i,t}} u'(C_{i,t+1}) \text{ and} \quad (39)$$

$$\frac{R_{t+1}}{P_{i,t+1}/P_{i,t}} = \frac{\chi_{i,t}}{\chi_{i,t+1}} \left(\frac{r_{i,t+1}}{P_{i,t+1}} + (1-d) \right), \quad (40)$$

and changes in investment disturbances would provide an additional structural residual that implies that the model can perfectly match data on capital stocks.

E. Computation Algorithm

Let $\{W_{i,1970}\}_{i=1}^I$ be the net foreign asset distribution in 1970. The following algorithm is used to compute counterfactual equilibria:

1. Guess a steady state net foreign asset distribution, $\{B_{i,SS}\}_{i=1}^I$, such that $\sum_{i=1}^I B_{i,SS} = 0$. Define the vector $\mathbf{B}_{SS} \in \mathbb{R}^I$, and aggregate consumption expenditure in the steady state, $\{P_{i,SS} C_{i,SS}\}_{i=1}^I$.
2. Iterate backwards as follows: In period t ,
 - (a) Compute the vector of aggregate consumption expenditures according to the Euler equations: Given $\{P_{i,t+1} C_{i,t+1}\}_{i=1}^I$, compute the nominal interest rate according to (34). Then, recover $\{P_{i,t} C_{i,t}\}_{i=1}^I$ using countries' Euler equations.

- (b) Given $B_{i,t+1}$, guess (update) a vector of wages, $\mathbf{w}_t \in \mathbb{R}^I$, and compute the vector of returns on capital, $\mathbf{r}_t \in \mathbb{R}^I$, such that $\frac{r_{i,t}}{w_{i,t}} = \frac{\varphi_i}{1-\varphi_i} \frac{L_{i,t}}{K_{i,t}}$. Normalize wages and returns on capital such that world GDP is equal to 1, $\sum_{i=1}^I w_{i,t}L_{i,t} + r_{i,t}K_{i,t} = 1$.
- (c) Compute net exports according to the budget constraint: $NX_{i,t}^D = w_{i,t}L_{i,t} + r_{i,t}K_{i,t} - P_{i,t}C_{i,t}$.
- (d) Given factor prices, solve for sectoral prices according by solving the system of equations defined by (11). Given prices, solve for trade shares according to (#).
- (e) Solve for $I \times J$ sectoral expenditures, $E_{i,t}^j$, by solving the following system of equations:

$$E_{i,t}^j = P_{i,t}^j C_{i,t}^j + \sum_{k=1}^J (1 - \beta_i^k) \nu_i^{k,j} Y_{i,t}^k,$$

$$Y_{i,t}^j = \sum_{h=1}^I \pi_{hi,t}^j E_{h,t}^j.$$

- (f) Compute net exports according to the intratemporal trade condition: $NX_{i,t}^S = \sum_{j=1}^J (Y_{i,t}^j - E_{i,t}^j)$.
- (g) Compute $T_t^S = \max_i |NX_{i,t}^D - NX_{i,t}^S|$.
- (h) Go back to (b) until T_t^S is close to zero.
- (i) If T_t^S is close enough to zero, define $NX_{i,t} = NX_{i,t}^D$, compute R_t according to (34) with $P_{i,t}C_{i,t} = w_{i,t}L_{i,t} + r_{i,t}K_{i,t} - NX_{i,t}$, and recover

$$B_{i,t} = (B_{i,t+1} - NX_{i,t}) / R_t.$$

3. If $t > 0$, set $t = t - 1$ and proceed to 2. Otherwise, go to next step.
4. Obtain $R_0 B_{i,0} = B_{i,1} - NX_{i,0}$ and compute $T^D = \max_i |W_{i,0} - R_0 B_{i,0}|$. If T^D is greater than a target value close to zero, update on the steady state distribution of net foreign assets according to:

$$B_{i,SS} = B_{i,SS} + \nu Z_i,$$

where ν is an adjustment factor, and Z_i a function such that $\sum_{i=1}^I Z_i = 0$. And go back to step 1. using the new \mathbf{B}_{SS} .

The functions Z_i are defined as:

$$Z_i = (W_{i,0} - R_0 B_{i,0}) \left(\prod_{s=1}^T R_s \right).$$

F. Trade Shares

The model's specification allows us to recover the probability that country i imports a particular variety ω^j from country h ,

$$\pi_{ih,t}^j(\omega^j) \equiv \Pr \left[\frac{c_{h,t}^j \tau_{ih,t}^j}{x_{h,t}^j(\omega^j)} \leq \min_{j \neq h} \left\{ \frac{c_{j,t}^j \tau_{ij,t}^j}{x_{j,t}^j(\omega^j)} \right\} \right].$$

Let $E_{i,t}^j$ denote total expenditure by country i on sector j goods, and $E_{ih,t}^j$ total expenditure by country i on sector j goods produced in country h , so that $E_{i,t}^j = \sum_{h=1}^I E_{ih,t}^j$. Then, letting $\mathcal{B}_{ih,t}^j$ denote the subset of \mathbb{R}_+^I over which country i buys goods from country h , we have that

$$E_{ih,t}^j = \int_{\mathcal{B}_{ih,t}^j} p_{i,t}^j(x^j) d_{i,t}^j(x^j) \varrho^j(x^j|t) dx^j.$$

Now note that, since $\omega^j \in [0, 1]$, it must be the case that $\pi_{ih,t}^j(\omega^j)$ for a particular variety is also the share of total expenditure in sector j by country i in goods produced by country h , $\pi_{ih,t}^j \equiv \frac{E_{ih,t}^j}{E_{i,t}^j}$, where $\sum_{h=1}^I \pi_{ih,t}^j = 1$ for all $i = 1, \dots, I$ and $j = 1, \dots, J$.

G. Data

Countries The set of countries that I consider as core countries in the sample are :Australia, Austria, Belgium, Brazil, Canada, China, Denmark, Finland, France, Germany, Greece, India, Italy, Japan, Korea, Mexico, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, UK, US, and Venezuela. In addition, I consider an aggregate of other countries to construct the Rest of the World (ROW).

Aggregate Data Data on GDP, net exports and investment expenditure for all countries comes from the United Nations Statistical Division National Accounts. These data are expressed in current US dollars. For ROW, I compute GDP as the aggregate of all remaining countries that are not part of the core 25 countries.

Gross Output and Value Added I use data on sectoral gross output and value added to compute the average value added shares in gross output from the following sources. For Australia, Austria, Belgium, Denmark, Finland, France, Germany, Greece, Italy, Korea, Netherlands, Portugal, Spain, Sweden and the UK the EU-KLEMS provide data for all year between 1970 and 2007. Data for the following countries also comes from the EU-KLEMS, but some years are missing (years missing in parentheses): Canada (2005-2007), Japan (1970-1972 and 2007) and the US (1970-1976).

For the following countries data on sectoral gross output and value added comes from the United Nations Statistical Division National Accounts (years missing in parentheses): Brazil (1970-1991), India (1970-1998), Mexico (1970-1979) and Venezuela. For the case of China I obtain data on value added from the GGDC-10 database and on gross output directly from its official statistical agency.

The average value added to gross output shares are computed using these data. In order to construct the actual series on gross output, I consider data on sectoral value added in current dollars provided by the United Nations Statistical Division National Accounts that is available for

all countries and years and that is consistent with the source used for aggregate data. Then I use these shares to construct series on gross output. This procedure allows me to recover sectoral value added for ROW using this comprehensive data set, then I consider the average across core countries' value added in gross output shares to construct series on gross output for the rest of the world.

I define the broad sectors considered based on the following ISIC codes: Agriculture and Mining (ISIC A-C), Manufacturing (ISIC D) and Services (ISIC E-P). This definition is in line with the one provided by the United Nations Statistical Division National Accounts.

Input-Output Tables For all core countries except Venezuela I consider data from the OECD Stan Database. The IO table from the mid-1990s were considered for the following 21 countries: Australia, Austria, Belgium, Brazil, Canada, China, Denmark, Finland, France, Germany, Greece, India, Italy, Japan, Netherlands, Norway, Portugal, Spain, Sweden, UK and USA. For the case of Korea, Mexico and Switzerland, the IO tables correspond to the early-2000s. For the case of Venezuela, I use data provided by the Central Bank of Venezuela for the IO table in the year 1997. In order to construct an input-output table for ROW, I consider data from the World Input-Output Database for the year 2000 for the following three countries: Indonesia, Russia and Turkey.

Bilateral Trade Flows In order to construct sectoral bilateral trade flows, I consider data from the NBER-UN for the period 1970-1999 and from CEPII-BACI for the period 1999-2007. These data sets include all core countries and the ROW is constructed by aggregating up all other countries. The data from NBER-UN is only available until the year 2000, while the CEPII-BACI is available from 1999 onwards. The data in these two data sets is not direct comparable in terms of the world sample of countries considered, therefore, I use the growth rates in bilateral trade flows obtained from CEPII-BACI after 1999 to extrapolate the data in the NBER-UN data.

Using this data I also construct net exports in tradable sectors.

Labor and Capital I consider data on GDP per capita, GDP per worker and total population from the Penn World Tables version 7.1. In addition, I consider data on capital stocks in 1970 from the PennWorld Tables version 8.1 to construct capital stocks using data on investment expenditure from the United Nations National Accounts Statistics.

Prices I consider sectoral producer price indexes. The data for gross output prices comes from the EU-KLEMS for the following countries: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Italy, Japan, Korea, Netherlands, Portugal, Spain, Sweden, U.K. and the U.S. Data on value added prices for Brazil, China, India and Mexico comes from the GGDC-10 data set. For Switzerland the data on sectoral producer price indexes comes from its official statistical agency. Sectoral prices for ROW are obtained from the estimation procedure described in Appendix H carried out for every year.

H. Estimation of Sectoral Prices

In order to construct series on sectoral prices, first I estimate sectoral relative prices in a base year and then use information on producer price indexes. Specifically, I consider the year 2000 as the base year and estimate sectoral prices relative to the U.S. by exploiting the multisector gravity structure of the model as follows. Note that from (14) we have that

$$\frac{\pi_{ih,t}^j}{\pi_{ii,t}^j} = \frac{T_{h,t}^j \left(c_{h,t}^j\right)^{-\theta} \left(\tau_{ih,t}^j\right)^{-\theta}}{T_{i,t}^j \left(c_{i,t}^j\right)^{-\theta}}.$$

Taking logs on both sides I obtain that

$$\ln \left(\frac{\pi_{ih,t}^j}{\pi_{ii,t}^j} \right) = \ln \left(T_{h,t}^j (c_{h,t}^j)^{-\theta} \right) - \ln \left(T_{i,t}^j (c_{i,t}^j)^{-\theta} \right) - \theta \ln \left(\tau_{ih,t}^j \right).$$

Given a value of θ , suppose that actual trade costs are given by $\tau_{ih,t}^j = \bar{\tau}_{ih,t}^j \hat{\tau}_{ih,t}^j ex_{h,t}^j$, where $\bar{\tau}_{ih,t}^j = \bar{\tau}_{hi,t}^j$ is a symmetric multiplicative element of bilateral trade costs, and $ex_{h,t}^j$ is an export-specific multiplicative element of bilateral trade costs. I assume that the symmetric element is observable in the data and given by $\bar{\tau}_{ih,t}^j = \left(\frac{\pi_{hh,t}^j \pi_{ii,t}^j}{\pi_{ih,t}^j \pi_{hi,t}^j} \right)^{\frac{1}{2\theta}}$. Note that, actually, according to the model, if trade costs were symmetric, then $\tau_{ih,t}^j = \left(\frac{\pi_{hh,t}^j \pi_{ii,t}^j}{\pi_{ih,t}^j \pi_{hi,t}^j} \right)^{\frac{1}{2\theta}}$ by (29). Then, we have that

$$\ln \left(\frac{\pi_{ih,t}^j \pi_{hh,t}^j}{\pi_{ii,t}^j \pi_{hi,t}^j} \right)^{\frac{1}{2\theta}} = \underbrace{\ln \left(T_{h,t}^j (c_{h,t}^j)^{-\theta} \right)^{\frac{1}{\theta}} - \ln ex_{h,t}^j}_{\text{Exporter Fixed Effect}} - \underbrace{\ln \left(T_{i,t}^j (c_{i,t}^j)^{-\theta} \right)^{\frac{1}{\theta}}}_{\text{Importer Fixed Effect}} - \theta \ln \hat{\tau}_{ih,t}^j.$$

Estimating this equation in $t = 2000$, I can recover $\hat{S}_{i,t}^j \equiv \left(\frac{T_{i,t}^j}{T_{US,t}^j} \right)^{\frac{1}{\theta}} \left(\frac{c_{i,t}^j}{c_{US,t}^j} \right)^{-1}$. Then, I can estimate sectoral prices relative to the U.S. by noticing that $\frac{P_{i,t}^j}{P_{US,t}^j} = \left(\frac{\pi_{ii,t}^j}{\pi_{USUS,t}^j} \frac{1}{S_{i,t}^j} \right)^{\frac{1}{\theta}}$, where $S_{i,t}^j = \left(\hat{S}_{i,t}^j \right)^\theta$.