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 global bilateral gross trade flows has notably contributed to the surge in the size of 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. I identify and describe two mechanisms through which declines in trade costs lead to larger imbalances in the model. 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 the size of world trade imbalances can be explained by the decline in trade costs across countries.

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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, as well as any risks that they might entail, hinges on identifying how changes in trade costs affect these imbalances.[1] Even though this fact is self-evident, previous work has overlooked the effects of these costs and focused on those of asset market frictions on trade imbalances, or what might be called intertemporal trade.[2]

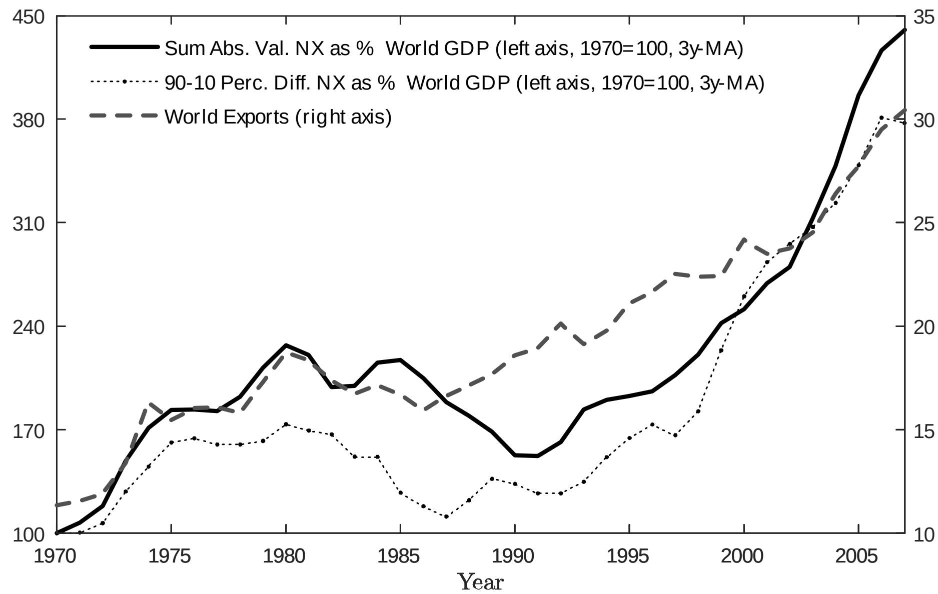
In this paper I develop a framework that exploits data on bilateral gross trade flows to provide a quantitative assessment of the contribution of declining trade costs to the increase in the size of trade imbalances in recent decades. As can be observed in Figure 1, there was a steady and sizable increase 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 show in this paper that the decline in trade costs that underlies the increase in observed bilateral trade flows notably contributed to the steady long-term increase in the size of 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. Hence, the majority of the increase in the size of trade imbalances, sometimes referred to as global imbalances, can be explained solely by the fact that it is less costly to ship goods across countries today than four decades ago.

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, and that is suitable for quantitative analysis. 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 multi-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-

[1] For 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).

[2] One contribution that stands out in exploring the role of trade costs in goods markets is Obstfeld and Rogoff (2000). Caballero et al. (2008) and Mendoza et al. (2009) are examples of work focusing on asset market frictions. See Gourinchas and Rey (2014) for a recent survey of the literature.

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



Notes: The figure plots the evolution of bilateral trade flows aggregated 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.

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. The second component of the model introduces dynamics that give 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 buying and selling one-period bonds in international financial markets. In an equilibrium of the model, perfectly foreseen changes in trade costs, productivities, and preferences over time lead to changes in trade imbalances arising from optimal intertemporal decisions. These imbalances, in turn, have to be consistent with those arising from optimal intratemporal trade across countries.

In the model, bilateral trade costs affect equilibrium trade imbalances through two effects. The first 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 because 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 link between real interest rates and trade costs arises from the differences in prices due to these costs, together with the fact that these prices determine the real or effective interest rate in each country.

The second effect is associated with the fact that trade costs have been declining over time, which I refer to as the "tilting effect". This general equilibrium effect arises from the fact that lower trade costs in the future imply that the world economy is becoming richer. This future increase in wealth implies that, compared with 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 because of high real interest rates, while countries that lend in initial periods lend less as a result of the positive income effect from higher interest rates. To the best of my knowledge, this is the first paper pointing out this novel mechanism through which differences across present and future trade costs in goods markets affect the evolution of trade imbalances.

In order to quantify the effects of trade costs on trade imbalances, I map the model to the observed data for the 1970–2007 period 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 the 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 consists 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 and that have been emphasized in previous literature. For instance, frictions in international financial markets directly affecting aggregate saving decisions are captured by the shifters in intertemporal preferences, *i.e.*, wedges in countries' Euler equations.[3]

Relying on this decomposition, I conduct counterfactual exercises to quantify the conse-

[3] As it will become clear when I describe the model, the framework 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 wedge. For example, in Mendoza *et. al* (2009) frictions show up as wedges in Euler equations.

quences of changes in trade costs. My focus is on the contribution of declining trade costs to the surge in trade imbalances. In the main counterfactual exercise, I assume that bilateral trade costs are held fixed at their 1970 levels, and I re-solve for the competitive equilibrium of the world economy. Solving for counterfactual competitive equilibria is key to providing a quantification that isolates the role of trade costs, thus leading to both the level and tilting effects.[4]

The results of the main counterfactual exercise show that, if trade costs had remained at their 1970 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 imbalances that are 41 percent smaller in 2007 and 28 percent larger in 1970 than of the actual change found 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 and 2007 levels. These results highlight the importance of solving for counterfactual competitive equilibria that incorporate income effects because of changes in trade costs.

In an additional exercise I consider the counterfactual scenario in which agents arrive at the year 1986 and suddenly realize that trade costs will remain constant in all subsequent periods. This exercise is aimed at quantifying the effects of the trade liberalizations that came after 1986. In this counterfactual, there is basically no increase in trade imbalances between 1986 and 2007. This result highlights the relevance of declines in trade costs for the more recent evolution of imbalances.

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 United States and China have been substantially shaped by the fact that trade costs have declined. For example, if trade costs had not decreased, the United States would not have experienced the observed increase in its trade deficit from 1970 to 2007. China would have

[4] An alternative would be to solve a planner's problem. In this case, we could either assign Pareto weights to countries and recover all wedges based on the planner's optimality conditions [Eaton et al. (2016b)] or abstract from wedges to intertemporal preferences in a stochastic environment and recover time-varying weights using the data [Fitzgerald (2012)]. However, when conducting counterfactual exercises, the counterfactual weights that decentralize the equilibrium are unknown and it is necessary to take a particular stance regarding these weights. This issue implies that counterfactual exercises might miss differential income effects across countries and not consider the effects of trade costs in isolation. I consider counterfactual competitive equilibria that are pinned down by the initial net foreign asset distribution of the world economy, thus allowing for endogenous changes in implied Pareto weights.

experienced trade surpluses from 1970 until the early 1990s and deficits thereafter. This result is actually exactly the opposite of 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, for example, in Japan and Greece.

Reductions in trade costs not only have implications for trade imbalances, but also important consequences for welfare. I compute the welfare gains from lower trade costs in terms of the consumption-equivalent variation in each country. Hence, these measures include not only 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 at lower cost. I then show how to decompose these gains into two components: one that reflects the welfare gains that would be obtained in a variant of the model abstracting from optimal interetemporal decisions, which I call the static gains, and the rest. The results show that the total gains are substantial and that they can vary significantly across countries. For example, the median gain is 2 percent of additional consumption per year, but countries like Venezuela and Finland suffer welfare losses of the order of 2 percent, and Belgium, China, and Korea gain additional consumption on the order of 10 percent per year. Most strikingly, the decomposition shows that the static gains from lower trade costs can differ substantially from the total gains. While 25 of the 26 countries experience static gains from lower trade costs, 11 countries experience non-static welfare losses. These findings show that not incorporating endogenous trade imbalances into static trade models can substantially bias results on the welfare gains from lower trade costs.

The findings in this paper provide proof of the quantitative relevance of the level and evolution of trade costs in goods markets for countries' intertemporal trade decisions. Hence, a better understanding of the secular increase in the size of trade imbalances over the past decades requires a careful consideration and dissemination of these costs. These findings open up a number of avenues for future research, as they indicate that the key for a better understanding of the roots of global imbalances might lie in the fundamental determinants of bilateral trade costs in goods markets rather than other frictions. Moreover, these findings critically highlight that new quantitative accounts of global imbalances should incorporate the fact that gross trade flows have also increased significantly.[5]

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

[5] Alessandria and Choi (2016) and Alessandria et al. (2016) are examples of work that has also recently exploited the information in gross trade flows.

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.

A limited amount of research has aimed to quantify the effects of trade costs on international macroeconomic puzzles. For example, Fitzgerald (2012) exploits the gravity structure of an Armington-type model of trade in a dynamic-stochastic environment to evaluate 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 a gap in this literature by providing a quantitative assessment of the contribution specifically of 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. In recent complementary work, Eaton *et al.* (2016a) use a theoretical framework related to the one I propose in this paper to quantitatively study the effects of eliminating trade costs on a number of the puzzles studied by Obstfeld and Rogoff. Their results provide further support to the approach taken in this paper to explore the counterfactual trend in the size of world trade imbalances absent observed declines in trade costs.

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 or might change. Caliendo and Parro (2015) retained the assumption of exogenous trade imbalances and extended the model in Dekle *et*

[6] The 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.

[7] Specifically, 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 analyzes the case in which countries can engage in perfect risk-sharing and does not focus the counterfactual evolution of trade imbalances.

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

[9] These papers focus on the effects of rebalancing current accounts by analyzing a counterfactual world in which all imbalances are eliminated.

al. (2007, 2008) by incorporating multiple sectors and input–output linkages in a tractable fashion. This type of model now provides 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, almost none have considered an intertemporal approach to trade imbalances.[11] One exception is Eaton *et al.* (2016b), which incorporates a structure of international trade, similar to the one in my model, into a dynamic model of business-cycles 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 the size of trade imbalances, while their paper focuses on forces affecting gross trade flows 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.* (2016b) 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 are available. Hence, in their counterfactuals, changes over time in capital stocks are driven by endogenous investment decisions that I do not have in my model.[13]

[10] For 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 effect of intersectoral and interregional trade linkages in propagating disaggregated productivity changes in particular locations of the United States to the rest of the economy.

[11] As 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.

[12] The methodology for counterfactual analysis I consider 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. (2016b)] that considers endogenous trade deficits was developed in parallel to this paper.

[13] The existing literature has shown that (1) empirically, investment decisions do not seem to have first-order effects on the determination of long-run trends in imbalances (the focus of this paper) and (2) existing models lead to counterfactual implications for such trends when investment decisions are incorporated.

This paper also contributes to the literature on 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 from 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, such as Antràs and Caballero (2009) and Jin (2012). However, none of these papers explore the effect of declining trade costs on imbalances, and to the best of my knowledge, this is the first paper to do so.[17]

In contrast to the literature, this paper does not take a stand on a particular fundamental cause for observed trade imbalances; I rather attribute imbalances to a set of structural residuals that might be generated by multiple underlying frictions. In this sense, this paper relates to Gourinchas and Jeanne (2013), who rely on "wedges" in saving and investment decisions to point to the underlying causes of the "allocation puzzle". However, one of the sets of residuals 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.[18] 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 multi-sector structure and

Appendix I provides further details on these issues. These are reasons why I abstract from investment decisions here. In addition, even though incorporating such investment decisions in my model is relatively standard (see Appendix D), this task bears substantial technical difficulties when trying to solve numerically for counterfactual competitive equilibria of the model. Appendix K provides more details on why solving for competitive equilibria is needed in order to answer the main question of this paper.

[14] Many studies focus on "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 United States– and the fact that net capital inflows tend to be negatively correlated with productivity growth across developing countries; the "allocation puzzle".

[15] Bernanke (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.

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

[17] Recent work by Alessandria and Choi (2016) and Alessandria et al. (2016) also explores the implications of rising gross trade flows for net trade in the United States and China, respectively. Their results also point to the drivers of gross trade flows as relevant determinants of the size of net trade flows.

[18] Chari 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 United States.

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 focus is not the standard in the literature 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 1970-2007 period. This section shows how the structure of the model delivers residuals that can be identified using the data previously mentioned. Section 4 conducts the counterfactual exercises that lead to the main results of this paper. Section 5 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. 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 as a result of 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 $t = 0, 1, \ldots$. The world consists of I countries indexed by $i = 1, \ldots, I$, each populated by a representative household endowed with $L_{i,t}$ and $K_{i,t}$ units of homogeneous labor and capital in period t.[19] Each economy consists of J sectors that I index by $j = 1, \ldots, J$. 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.

[19] I consider capital as exogenously given in each period. See footnote 13 for more details on this assumption.

2.1 Nontradable Sectoral Goods

The 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

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

where $d_{i,t}^j \left(\omega^j \right)$ 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, because 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 $q_{i,t}^j \left(\omega^j \right)$ denote the production of this good in country i at time t. The technology to produce each good ω^j is given by

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

where $l_{i,t}^j \left(\omega^j \right)$ and $k_{i,t}^j \left(\omega^j \right)$ are the labor and capital, respectively, used in the production of good ω^j, and $M_{i,t}^j \left(\omega^j \right)$ denotes the quantity 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:

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

where $\sum_{m=1}^J \nu_i^{j,m} = 1$ for all $j = 1, \ldots, J$ and $\nu_i^{j,m} \in (0,1)$ for all $j, m = 1, \ldots, J$. Here, $D_{i,t}^{j,m} \left(\omega^j \right)$ 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 $x_{i,t}^j \left(\omega^j \right)$.

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 $j, m = 1, \ldots, J$ 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 $T_{i,t}^j$,

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

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, because 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 $j = 1, \ldots, J$, 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 assumption implies 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 $i = 1, \ldots, I$, *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, $\frac{c^j_{i,t}}{x^j_{i,t}(\omega^j)}$, where

$$c^j_{i,t} = \varkappa^j_i \left[\left((r_{i,t})^{\varphi_i} (w_{i,t})^{1-\varphi_i} \right)^{\beta^j_i} \left(\prod_{m=1}^{J} \left(P^m_{i,t} \right)^{\nu^{j,m}_i} \right)^{1-\beta^j_i} \right] \tag{5}$$

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 $\varkappa^j_i$ is a constant that depends on production parameters.[20]

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

$$L^j_{i,t} = \int_{\mathbb{R}^I_+} l^j_{i,t} \left(x^j \right) \varrho^j \left(x^j | t \right) dx^j, \tag{6}$$

$$K^j_{i,t} = \int_{\mathbb{R}^I_+} k^j_{i,t} \left(x^j \right) \varrho^j \left(x^j | t \right) dx^j, \text{ and} \tag{7}$$

$$D^{j,m}_{i,t} = \int_{\mathbb{R}^I_+} D^{j,m}_{i,t} \left(x^j \right) \varrho^j \left(x^j | t \right) dx^j. \tag{8}$$

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, $p^j_{i,t}\left(\omega^j\right)$, the firm solves a cost minimization problem that delivers demand functions, conditional on $Q^j_{i,t}$, for each tradable good $\omega^j \in [0,1]$, given by $d^j_{i,t}\left(\omega^j\right) = \left(\frac{P^j_{i,t}}{p^j_{i,t}(\omega^j)} \right)^{\eta} Q^j_{i,t}$, where

$$p^j_{i,t}\left(\omega^j\right) = \min_h \left\{ p^j_{h,t}\left(\omega^j\right) \right\} = \min_h \left\{ \frac{c^j_{h,t} \tau^j_{ih,t}}{x^j_{h,t}\left(\omega^j\right)} \right\} \tag{9}$$

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

$$P^j_{i,t} \equiv \left(\int_0^1 p^j_{i,t}\left(\omega^j\right)^{1-\eta} d\omega^j \right)^{\frac{1}{1-\eta}}. \tag{10}$$

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 feature of the

[20] Specifically, $\varkappa^j_i = (\beta^j_i \varphi_i^{-\varphi_i} (1-\varphi_i)^{-(1-\varphi_i)})^{-\beta^j_i} ((1-\beta^j_i) \prod_{m=1}^{J} (\nu^{j,k}_i)^{\nu^{j,m}_i})^{-(1-\beta^j_i)}$.

model is an important difference 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 indexes 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, $T^j_{i,t}$, and bilateral trade costs, $\tau^j_{ih,t}$, 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

$$P^j_{i,t} = \Gamma \left[\Phi^j_{i,t}\right]^{-\frac{1}{\theta}}, \tag{11}$$

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

$$\Phi^j_{i,t} = \sum_{h=1}^{I} T^j_{h,t} \left(c^j_{h,t}\tau^j_{ih,t}\right)^{-\theta} \tag{12}$$

represents a sufficient statistic for sector j in country i of the state of technologies and trade costs around the globe.[21] Note that as long as there is no free trade, *i.e.*, $\tau^j_{ih,t} \neq 1$ for some countries i and h, prices will differ across countries. If there is free trade, it will be the case that $P^j_{i,t} = P^j_{h,t}$ for all $i, h = 1, \ldots, I$.

The structure of the model not only allows for closed-form solutions of sectoral price indexes, 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 $E^j_{i,t}$ denote total expenditure by country i on sector j goods and $E^j_{ih,t}$ total expenditure by country i on sector j goods produced in country h, so that $E^j_{i,t} = \sum_{h=1}^{I} E^j_{ih,t}$. Then, the share of total expenditure in sector j by country i in goods produced by country h, $\pi^j_{ih,t} \equiv \frac{E^j_{ih,t}}{E^j_{i,t}}$, is given by

$$\pi^j_{ih,t} = \frac{T^j_{h,t}\left(c^j_{h,t}\tau^j_{ih,t}\right)^{-\theta}}{\Phi^j_{i,t}} \tag{13}$$

and these shares are such that $\sum_{h=1}^{I} \pi^j_{ih,t} = 1$ for all $i = 1, \ldots, I$ and $j = 1, \ldots, J$. Note that using the expression we obtained before for equilibrium prices, equation (11), we can

[21] In particular, $\Gamma \equiv (\Gamma(1 + \frac{(1-\eta)}{\theta}))^{\frac{1}{1-\eta}}$, where $\Gamma(z)$ denotes the Gamma function evaluated at $z > 0$. Notice this result implies that parameters have to be such that $\eta - 1 < \theta$.

rewrite this share in terms of the sectoral price in country i as

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

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 fact 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.

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 adds 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 an elasticity of substitution in consumption of final goods different than unity. 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 component of the model will allow us to see how dynamic decisions by 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

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

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 shifter that the household in country i experiences in period t.[22] I assume that the household aggregates the amounts of nontradable sectoral goods used for consumption in a CES fashion

[22] The use of these types 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, the fact that these shifters lead to wedges in Euler equations implies that they can also be viewed as generated by frictions underlying asset markets that directly affect households' aggregate saving decisions.

with an elasticity of substitution given by $\psi > 0$. Hence, aggregate consumption is given by

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

where $\mu_{i,t}^{j} > 0$ are sectoral demand shifters at time t, such that $\sum_{j=1}^{J} \mu_{i,t}^{j} = 1$ for all t.[23]

Note that $\mu_{i,t}^{j}$ for all $j = 1, \ldots, J$ and $\phi_{i,t}$ for all $i = 1, \ldots, I$ are additional disturbances that are allowed to change over time. These two sets of shifters in preferences plus 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 structural residuals imply that the model is exactly identified given data on bilateral trade flows, sectoral prices for tradable sectors and GDP, sectoral expenditure levels, and net exports.

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 assumption 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 into the model is relatively standard, as I show in Appendix D, solving numerically for counterfactual competitive equilibria is challenging given the large number of countries considered.[24] However, given that the focus of this paper is on the long term evolution of the size of trade imbalances rather than changes at the business-cycle frequency, this assumption should not have first-order effects on my results.[25]

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

[23] These 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.

[24] The 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 feature implies that the solution to the transitional dynamics of counterfactual equilibria requires the simultaneous solution of both the paths of net foreign asset positions, and the net foreign asset position in the counterfactual steady state.

[25] See footnote 13 and Appendix I.

the following sequence of budget constraints:

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

for all $t = 0, 1, \ldots$, and $W_{i,0} \equiv R_0 B_{i,0}$ given for all $i = 1, \ldots, I$ 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 normlization implies that all results will be in terms of 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 across sectors according to

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

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

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

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

$$\begin{array}{cl} \max\limits_{\{C_i, B_{i,t+1}\}} & \sum_{t=0}^{\infty} \delta^t \phi_{i,t} u\left(C_{i,t}\right) \\ \text{s.t.} & P_{i,t} C_{i,t} + B_{i,t+1} = w_{i,t} L_{i,t} + r_{i,t} K_{i,t} + R_t B_{i,t} \text{ for } t = 0, 1, \ldots \end{array} \tag{20}$$

and $R_0 B_{i,0}$ given. That 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:

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

for all $t=0,1,\ldots$, 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 $r_{i,t}\equiv\frac{R_{t+1}P_{i,t}}{P_{i,t+1}}-1$. Also, notice how changes in intertemporal preference shifters translate into wedges in countries' Euler equations.

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 is 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, more precisely, do changes in trade costs 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 $E_{i,t}^{j}$ the 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

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

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 the total expenditure in goods in sector j in equilibrium must be given by

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

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

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

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 set of conditions 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

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

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 a particular sequence of disturbances. Thus, let us define the sequence of disturbances by $\{\mathcal{S}_t\}_{t=0}^{\infty}$, where $\mathcal{S}_t \equiv \left\{\tau_{ih,t}^{j}, T_{i,t}^{j}, \mu_{i,t}^{j}, \phi_{i,t}\right\}_{i,h=1,\ldots,I}$.

Definition 1 *Given $R_0 B_{i,0}$, $L_{i,t}$ and $K_{i,t}$ for every $i = 1, \ldots, I$ and $t = 0, 1, \ldots$, 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 choose 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 effect 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

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

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 $\frac{(R_{t+1}\times\cdots\times R_{t+s})P_{i,t}}{P_{i,t+s}}$. 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 independent 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 those prevailing in other countries. This fact can be inferred from equilibrium condition (26). Given prices, positive trade costs lead to a larger home-bias, *i.e.*, greater $\pi^j_{hh,t}$ and smaller $\pi^j_{hi,t}$ for every h and j, which implies that the right-hand side of (26) is lower. Therefore, 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 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 differences 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, and, 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.[26]

Let us now turn to the tilting effect. In the data, trade costs are declining over time. To understand the intuition of this effect, consider the thought experiment in which trade costs

[26]In Section 4.2, I compare counterfactual trade imbalances in the case of trade costs fixed to their levels in 1970 (high uniform trade costs) and 2007 (low uniform trade costs). This comparison isolates the level effect.

remain constant and equal to their intial levels instead of following a declining path. In this experiment, trade costs 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 desire for smoothing 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 lending countries are high, as their terms of trade, and therefore factor prices and income, remain relatively high. In other words, the 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 of this paper. 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, calibrate the model to the observed data for the period from 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 procedure implies that these disturbances provide a decomposition of the forces underlying the evolution of these 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. Because 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.[27]

Let us recall that the set of disturbances that decomposes the data: (1) trade costs, $\tau^j_{ih,t}$; (2) sectoral productivities, $T^j_{i,t}$; (3) sectoral demand shifters, $\mu^j_{i,t}$; and (4) 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 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, which I call the 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, *i.e.*, this sector must source all its goods from home in order to produce the final nontradable sectoral good. I model the nontradable sector as any other sector, but impose bilateral trade costs to be infinite, *i.e.* $\tau^S_{ih,t} = \infty$ for $i \neq h$ or equivalently, $\pi^S_{ii,t} = 1$.[28] This assumption 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 services (S) are considered nontradable.[29] Even though I do not model trade in services, I do take into

[27] Introducing uncertainty and solving for a rational expectations equilibrium becomes intractable in this model because of the high dimensionality of the disturbances. Given that the aim of the paper is to understand a long term phenomenon, the choice of a perfect foresight enviroment provides a natual baseline framework.

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

[29] Even though many services are now traded across countries, there are no data on bilateral trade flows for most countries before the mid-1990s. However, the data available show that international trade in services

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, while others are 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 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 that are country and sector-specific. Using data on gross output and valued added from a combination of sources that include 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, the 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.[30]

I now turn to the parameters that I take from the 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 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.[31]

For the 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, which 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 United States and other less-developed economies. For the discount factor I set $\delta = 0.95$ which is considered standard in the literature for annual data. Table 1 summarizes the baseline values of these

is still small relative to trade in other sectors.

[30] The data appendix provides a detailed and comprehensive list of all data sources.

[31] Caliendo and Parro (2015) estimate industry-specific trade elasticities and show that they 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).

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

parameters as well as the data used to obtain them.

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 $d = 0.05$ and the 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 $j \in \mathcal{J}\backslash S$, 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 $NX_{i,t}^S = NX_{i,t} - \sum_{j\in\mathcal{J}\backslash S}\left(\sum_{h=1}^{I} X_{hi,t}^j - \sum_{h=1}^{I} X_{ih,t}^j\right)$.

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 $t = 1970, \ldots, 2007$ are: (1) sectoral bilateral trade flows in tradable sectors, $X_{ih,t}^j$ for $j \in \mathcal{J}\backslash S$; (2) prices for tradable sectors, $P_{i,t}^j$ for $j \in \mathcal{J}\backslash S$, and GDP, $P_{i,t}$; (3) sectoral expenditures, $E_{i,t}^j$ for $j \in \mathcal{J}$; and (4) 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 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 come from the same sources I use to compute net exports for services, and data on sectoral gross output come from the same sources I use to calibrate value-added-to-gross-output ratios. The data on gross domestic product and net exports come 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 are not readily available; therefore, I construct these series. 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.[32]

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 the model's outcomes. To compute sectoral expenditures and trade shares, consider the data on sectoral gross output and bilateral trade flows. Then, the expenditure on sector j in country i at time t is given by $E^j_{i,t} = Y^j_{i,t} - NX^j_{i,t}$, where $NX^j_{i,t} = \sum_{h=1}^{I} X^j_{hi,t} - \sum_{h=1}^{I} X^j_{ih,t}$, and the trade share by importer i from exporter h is computed as $\pi^j_{ih,t} = \frac{X^j_{ih,t}}{E^j_{i,t}}$ for $i \neq h$, and $\pi_{ii,t} = 1 - \sum_{h=1}^{I} \pi^j_{ih,t}$. 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

$$\mathcal{D}_t \equiv \left\{ \left\{ w_{i,t}, r_{i,t}, L_{i,t}, K_{i,t}, NX_{i,t}, NX^S_{i,t}, P_{i,t} \right\}, \{E^j_{i,t}, Y^j_{i,t}\}_{j\in\mathcal{J}}, \{P^j_{i,t}\}_{j\in\mathcal{J}\setminus S}, \{\pi^j_{ih,t}\}_{j\in\mathcal{J}\setminus S} \right\}_{i,h=1,\ldots,I},$$

the set of data that is observed and used to recover these sets for $t = 1970, \ldots, 2007$. For $t = 2008, \ldots$, 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 2007 levels.

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

3.3.1 Sectoral Demand Shifters

First, I recover the sectoral demand disturbances because knowledge of them is necessary to recover other disturbances, but not the reverse. The key equilibrium conditions that allow us to recover the sectoral demand shocks are the optimal static decisions by the households and 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 $t = 1970, \ldots, 2007$, there is a one-to-one mapping between observables and sectoral demand shocks, $\{\mu_{i,t}^j\}_{j\in\mathcal{J}}$, given by the following equilibrium conditions and model restrictions:*

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

$$\mu_{i,t}^S = 1 - \sum_{j\in\mathcal{J}\backslash S} \mu_{i,t}^j. \tag{28}$$

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 are 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 case is indeed true for most developed economies in my core countries. Still, for the model to match net exports, these shocks are crucial, as they allow the model to exactly match sectoral expenditures, which, together with trade shares, determine net exports.

Some countries for which sectoral demand shocks show clear trends 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 finding 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 trend. These forces 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 $\{\mu^j_{i,t}\}_{j\in\mathcal{J}}$ for all i, time-invariant parameter values, and data $\mathcal{D}_t$ for $t = 1970, \ldots, 2007$; there is a one-to-one mapping between observables and the shocks $\{\tau^j_{ih,t}\}_{j\in\mathcal{J}\backslash S}$ and $\{T^j_{i,t}\}_{j\in\mathcal{T}}$ in period t given by the following equilibrium conditions:*

$$\tau^j_{ih,t} = \frac{P^j_{i,t}}{P^j_{h,t}} \left(\frac{\pi^j_{hh,t}}{\pi^j_{ih,t}} \right)^{\frac{1}{\theta}} \quad \textit{for } j \in \mathcal{J}\backslash S, \tag{29}$$

$$\pi^j_{ii,t} = T^j_{i,t} \left(\Gamma^j \frac{c^j_{i,t}}{P^j_{i,t}} \right)^{-\theta} \quad \textit{for } j \in \mathcal{J}\backslash S \textit{ and } \pi^j_{ii,t} = 1 \textit{ for } j = S, \textit{ and} \tag{30}$$

$$P_{i,t} = \left(\sum_{j=1}^{J} \mu^j_{i,t} \left(P^j_{i,t}\right)^{1-\psi} \right)^{\frac{1}{1-\psi}} \quad \textit{and } \tau^S_{ih,t} = \infty \textit{ for all } i \neq h. \tag{31}$$

Proof. See Appendix. ■

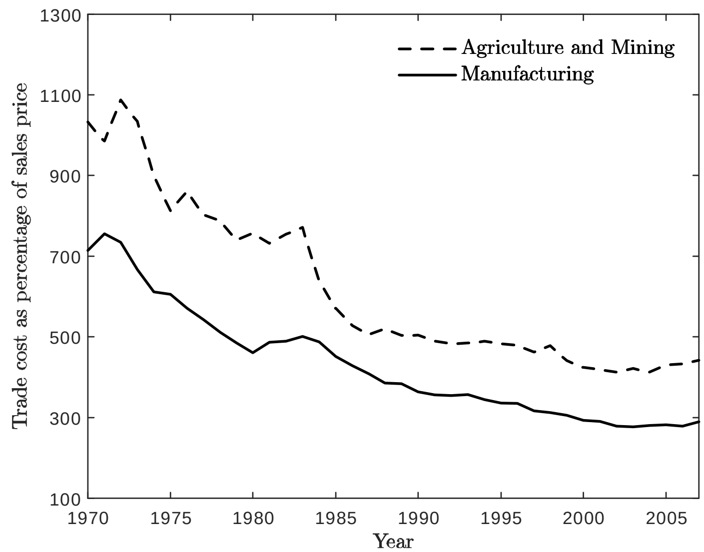
It is worth taking some time now to discuss in more detail the implications of the previous lemma. Let us start with the case of bilateral trade costs. Note from (29) that trade costs are uniquely determined given our normalization $\tau^j_{ii,t} = 1$ for all i and j. This equation is obtained by taking the ratio of the trade share of importing country i and exporter h to the domestic trade share in country h, $\pi^j_{ih,t}/\pi^j_{hh,t}$. 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 are sufficient to recover the costs.[33]

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 1970–2000 period. 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, $\pi^j_{ih,t} = 0$, by means of infinite bilateral trade costs, $\tau^j_{ih,t} = \infty$.

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

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, which means that trade costs equal to 300 are equivalent to an iceberg-type trade cost of 4.

This feature can be seen in equation (29) and is a result of the fact that tradable goods producers draw their efficiencies from a probability distribution with unbounded support.[34] The data on bilateral trade flows are 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 order to generate negligible bilateral trade shares.[35]

It is worth emphasizing 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 in other work. Another way the literature has dealt with this issue is by imposing a symmetry assumption on trade costs that implies that data on sectoral prices are not needed to recover these frictions. 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.

[34] In other words, in every country there is always a "superstar" producer that should be shipping goods to all countries.

[35] In the simulations of my model, whenever $\pi^j_{ih,t} = 0$ in the data, I set $\tau^j_{ih,t} = \max_{ih,t} \left\{ \tau^j_{ih,t} \right\}$. These trade costs imply that bilateral trade shares are negligible, which is consistent with the data.

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. Using data on GDP prices, which are 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.

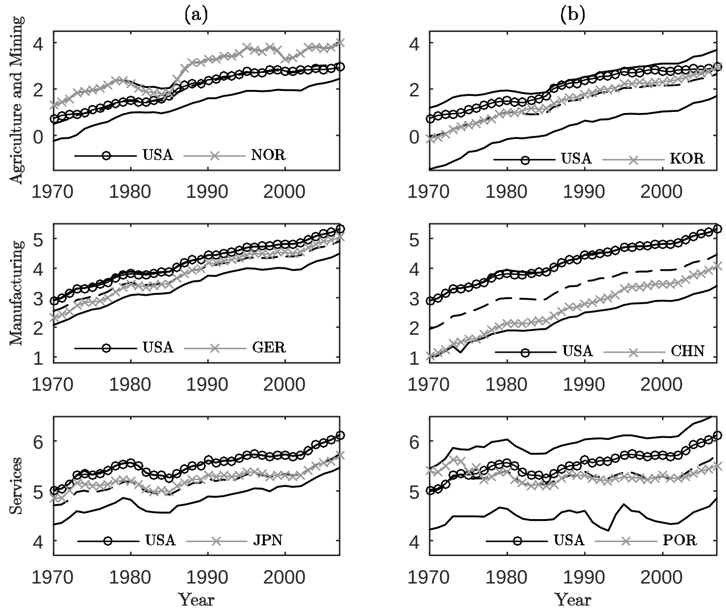
Figure 3 summarizes the evolution of sectoral productivities over the entire time period by plotting the means (dashed dark line) and maximum and minimum bands (solid dark lines) of the log of a measure of average sectoral productivity given by $(T_{i,t}^{j})^{\frac{1}{\theta}}$. In addition, each plot includes the United States (circles) as a reference, as well as 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 includes only developed countries; specifically, it includes the countries considered in Bernard and Jones (1996a, 1996b). This set of countries is presented in panel (a). The second set includes all other countries in our sample, including ROW. These countries are presented in panel (b) together with the United States. In line with previous studies, the United States 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 the productivities of countries in panel (b) are lower than those in panel (a). Moreover, we can see that certain emerging economies experienced significant catch-up growth to the United States. Korea is an example for the Agriculture and Mining sector and China for the manufacturing sector. In contrast, Portugal has seen a relative decline in its productivity in services, which is in line with its real exchange rate appreciation beginning in the 1990s.

3.3.3 Intertemporal Preference Shifters

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

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

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, U.K., and U.S. Countries in panel (b): Austria, Brazil, China, Greece, India, Korea, Mexico, Portugal, Spain, Switzerland, Venezuela, and ROW. The figure plots the evolution of $\log(T^j_{i,t})^{\frac{1}{\theta}}$.

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

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

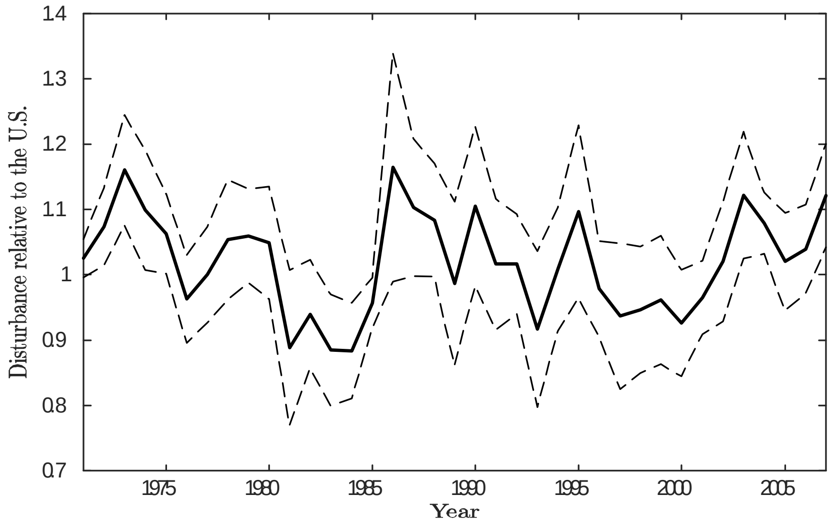
which implies that, given consumption expenditure levels at $t+1$, the equilibrium nominal return must be

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

Hence, note that equations (33) and (34) define a system of $I+1$ equations and $I+1$ unknowns in R_{t+1} and $\hat{\phi}_{i,t+1}$.[36] 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. 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 recover the Euler equation wedges, $\hat{\phi}_{i,t+1}$. Hence,

[36] I choose world GDP as the numeraire in the model. Note that this choice implies that world consumption is also equal to one in every period. Therefore, I can recover R_{t+1} having only the information on 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).

the model is block recursive in the sense that we can recover all residuals other than the changes in intertemporal preference shifters without knowing the latter. Similarly, given the data, we could recover the Euler equations' wedges in a first step.

Figure 4 plots the cross-sectional mean and a one standard deviation range around it of the changes in the intertemporal preference shifters over the 1970–2000 period. Note that it is not clear from the figure that these shocks or levels are persistently different than one, nor that their dispersion has followed a particular trend. These facts provide 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 residuals recovered do not systematically correlate with each other, we can isolate the effect of each 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.[37]

[37] The set of structural residuals recovered are such that a subset of equilibrium outcomes of the model exactly matches the data selected. However, real interest rates in each country i, $\{R_{i,t+1}/(P_{i,t+1}/P_{i,t})\}_{t=0}^{\infty}$, are equilibrium outcomes that are not targeted by the set of strutural residuals recovered in this section. Therefore, comparing these outcomes with the data can provide further information on the fit of the model. This comparison is carried out in Appendix K.

4 Counterfactual Exercises

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 with 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.[38] 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. In order to recover this initial distribution, I use the equilibrium of the model that matches the data. Specifically, given my assumption that the world economy reaches a steady state after 2007, I compute the net foreign asset positions in the steady state, $\{B_{i,SS}\}_{i=1}^{I}$, that are consistent with data on net exports. Then, I iterate backward 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 (*i.e.*, final) 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 backward.[39]

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

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

and provide a measure of country-pair sector-specific bilateral trade frictions that are widely used in the literature on gravity equations.[40] Note that these indexes are symmetric, $HR_{ih,t} = HR_{hi,t}$, and that they are functions of data on bilateral trade shares only. Bilateral trade costs in the model are related to these indexes 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

[38] Suppose that economic agents realize at time t' that the path of trade costs will differ from the one in the data. The only underlying assumption pinning down counterfactual competitive equilibria is that the distribution $\{R_{t'} B_{i,t'}\}_{i=0}^{I}$ is fixed. Economic agents then re-optimize in t' and the future given this distribution. The main difference between solving for competitive equilibria and a planner's problem is the treatment of households' intertemporal budget constraints which must not be satisfied in the planner's problem for given Pareto weights.

[39] More details on my computational algorithm are provided in Appendix E. I have also considered the case in which the net foreign asset positions in the steady state, $\{B_{i,SS}\}_{i=1}^{I}$, are consistent with the data on countries' net investment incomes in 2007. The results are robust to this choice.

[40] See Head and Ries (2001) and Head and Mayer (2014).

seen from equation (29). For more specifics about how I pin down counterfactual costs, consider the case in which I refer to a counterfactual scenario where trade costs are held constant and equal to their 1970 levels. Then, I define counterfactual trade costs in sector j and period t, $\bar{\tau}^{j}_{ih,t}$, as $\bar{\tau}^{j}_{ih,t} \equiv \tau^{j}_{ih,t} \times (HR_{ih,1970}/HR_{ih,t})$. Notice then that counterfactual trade costs in every t are such that their Head-Ries indexes are equal to $HR_{ih,1970}$, $\overline{HR}_{ih,1970} \equiv (\bar{\tau}^{j}_{ih,t}\bar{\tau}^{j}_{hi,t})^{\frac{1}{2}} = HR_{ih,1970}$, but that symmetry across country pairs is not imposed. 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 that are being ignored, 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 Levels

In my first and main counterfactual exercise, I fix trade costs at 1970 Head-Ries index values. That is, in the counterfactual, $HR^{j}_{ih,t} = HR^{j}_{ih,1970}$ for all $t = 1970, \ldots$ and country pairs. The particular question I aim to answer by means of this counterfactual exercise is the following: What would trade imbalances have been if trade costs had remained at their 1970 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 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 change is in line with the fact that low levels of trade costs were reached around that time according to Figure 2. Moreover, note how with 1970 trade costs, the size of trade imbalances remains at significantly lower levels after 1992. 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.

These two series are different in the initial periods because the difference between the

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

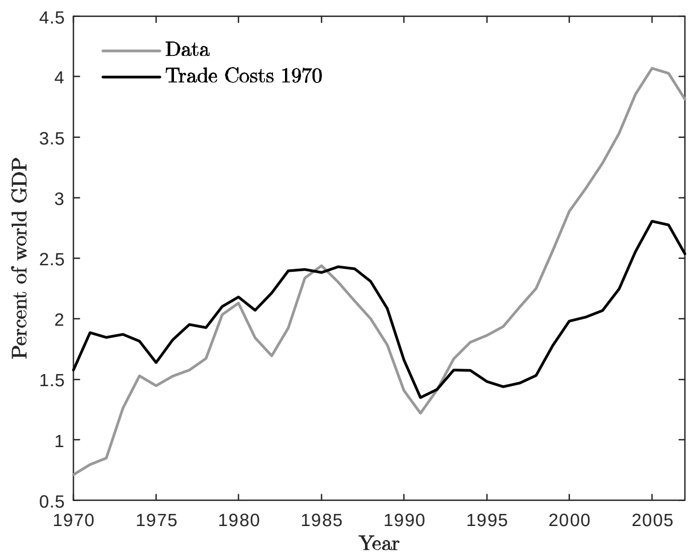


Table 2: Trade Imbalances: Percent of World GDP

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%

set of bilateral trade flows that is consistent with the data and the one in the counterfactual is not uniform for all periods, but the entire path that they follow over time is different. As previously discussed, the negative income effect in future periods in the counterfactual relative to the data implies that the world real interest rate in the initial periods is lower in the counterfactual than in the baseline equilibrium. These differences in the world real interest rate 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 result 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.[41] I come 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.

[41] Appendix K provides further details on the relevance of solving for competitive equilibria in order to incorporate endogenous changes in Pareto weights across counterfactuals. In the appendix I compute the actual change in relative Pareto weights across counterfactuals and show how these affect the welfare gains from lower trade costs that are obtained.

Let us now focus on particular countries. Figure 6 shows the evolution of net exports in the United States 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 United States 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. China 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 trade deficits in the late 1990s and 2000s. Table 3 shows that the differences between the data and the counterfactual are quantitatively sizable. In general, our results point to the level of trade costs having a significant effect on the magnitude of trade imbalances.

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

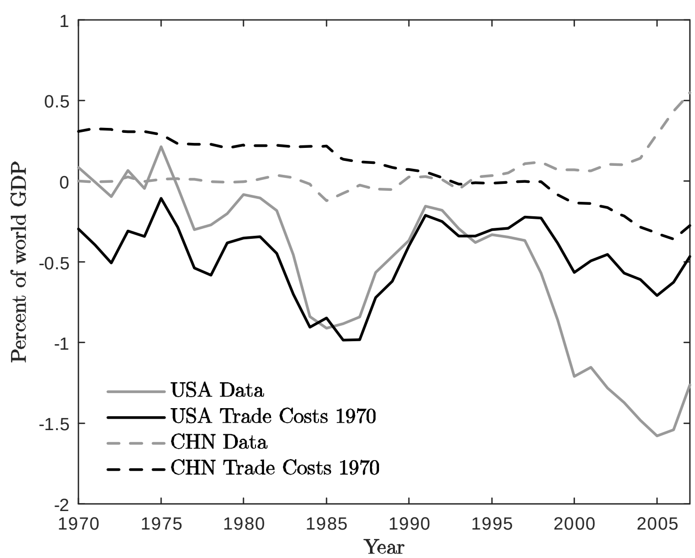


Table 3: Trade Imbalances: U.S. and China (Net Exports, Percent of World GDP)

	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%

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

Table 4: Accumulated Trade Imbalances: Percent of World GDP (percent)

	$\sum_{t=1970}^{2007} \lvert NX_{i,t} \rvert$			$\sum_{t=1970}^{1991} \lvert NX_{i,t} \rvert$	$\sum_{t=1992}^{2007} \lvert NX_{i,t} \rvert$
	Data	Counterfactual	Diff.	Diff. D-CF	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

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 discussed, this result is due to the tilting effect. Breaking the accumulated imbalances into two subperiods, we can see in the table that for the 1992–2007 period, 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's original accumulated imbalances decrease 7.5 percent, while Greece's 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 this counterfactual exercise. Given that we now have a dynamic model and multiple factors of production, a measure of the welfare gains directly comparable with those in Arkolakis et al. (2012) is not available. Hence, 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, *i.e.*, $U_i^D = \sum_{t=0}^{\infty} \delta^t \phi_{i,t} \ln(C_{i,t}^D)$, where $C_{i,t}^{D}$ is consumption in the data in period t and country i, then we compute the welfare gains from trade as the time-invariant consumption transfer, x_i, such that

$$\sum_{t=0}^{\infty} \delta^t \phi_{i,t} \ln \left(C_{i,t}^{CF} \left(1 + x_i\right) \right) = U_i^D, \tag{36}$$

where $C_{i,t}^{CF}$ is consumption in the counterfactual in period t and country i. This measure of welfare gains from lower trade costs is presented in column (1) of Table 5. As can be seen in the table, most countries gain from the decline in trade costs relative to the counterfactual scenario, and these gains are substantial. The decline in trade costs from 1970 to 2007 implies gains of 2.02 percent of consumption per annum for the median country. However, these gains vary considerably across countries. Countries like Belgium, China, Korea, and the Netherlands experience gains from lower trade costs that are between three and six times larger than the median country. On the other side of the spectrum, countries like Finland and Venezuela actually suffer losses from lower trade costs. Venezuela 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 of Finland. However, one alternative driver of such losses could be the deterioration in what can be called intertemporal terms of trade. In other words, intricate general equilibrium changes in effective interest rates might be leading to lifetime welfare losses.

To better understand the results in column (1) of Table 5, we can decompose these total gains into two components: one that is comparable with results in the existing literature computing welfare gains from lower trade costs in static general equilibrium models of trade, and a second that encompasses the gains from the remainder forces that arise in a model that allows for optimal consumption-saving decisions.[42] To do this decomposition, we first compute the equilibrium of the model in which for each country we (1) impose that consumption equals production in every period (zero trade imbalances) and (2) ignore the Euler equation and the intertemporal budget constraint, in the case of both low (recovered from observed data) and high (those in the counterfactual) trade costs.[43] Let $\{\bar{C}_{i,t}^{D}\}_{t=0}^{\infty}$ and $\{\bar{C}_{i,t}^{CF}\}_{t=0}^{\infty}$ de-

[42] The literature has considered static variations of this model to compute what could be called the "static" welfare gains from lower trade costs. By considering repeated static economies in which trade imbalances ($NX_{i,t}$) are exogenously given, the literature has computed these gains as follows: (1) First, compute counterfactual static economies in which trade imbalances are set equal to zero ($NX_{i,t} = 0$ for all t), and then (2) compare across different levels of trade costs, keeping zero imbalances. Ossa (2014) explains why conducting counterfactual exercises using different levels of trade costs while keeping trade imbalances constant and different than zero is troublesome. Caliendo and Parro (2015) follow Ossa's methodology.

[43] Notice that this procedure is not equivalent to solving the model under financial autarky. Two key differences are the treatments of the initial distribution of net foreign assets across countries as well as the intertemporal budget constraints.

Table 5: Welfare Gains from Changes in Trade Costs

	Total (x_i%)	Static (μ_i%)	Non-Static (ν_i%)
	(1)	(2)	(3)
AUS	1.11	-1.88	3.04
AUT	4.26	3.66	0.58
BEL	10.85	8.84	1.85
BRA	0.38	1.29	-0.90
CAN	2.02	2.16	-0.14
CHN	10.93	1.82	8.95
DEN	2.79	0.98	1.79
FIN	-1.98	2.27	-4.16
FRA	2.03	2.14	-0.11
GER	2.55	2.45	0.10
GRC	1.75	1.44	0.31
IND	1.26	1.75	-0.48
ITA	1.94	1.87	0.07
JAP	1.25	2.63	-1.35
KOR	11.26	4.71	6.25
MEX	2.80	2.30	0.49
NLD	6.74	5.85	0.85
NOR	1.66	2.39	-0.71
POR	2.80	4.45	-1.58
SPA	2.02	1.37	0.64
SWE	1.80	2.39	-0.57
SWZ	3.18	2.50	0.67
UK	1.97	0.82	1.14
US	1.05	1.20	-0.15
VEN	-2.43	0.76	-3.17
ROW	3.15	3.03	0.12

Notes: The welfare gains from lower trade costs in this table are computed by means of consumption equivalent variations. This is, the percent increase in consumption per annum in order to be indifferent between alternative consumption streams.

note the equilibrium consumption streams of country i that are obtained by imposing the conditions previously specified in the case of low and high trade costs, respectively. Then, notice that from the definition of U_i^D and equation (36) we obtain that

$$\ln(1+x_i) = \ln(1+\mu_i) + \ln(1+\nu_i)\,, \tag{37}$$

where μ_i is such that $\sum_{t=0}^{\infty} \delta^t \phi_{i,t} \ln(\bar{C}_{i,t}^{CF}(1+\mu_i)) = \sum_{t=0}^{\infty} \delta^t \phi_{i,t} \ln(\bar{C}_{i,t}^{D})$, and $\ln(1+\nu_i)$ is the remainder.[44] The term μ_i is the time-invariant consumption increase associated with the decline in trade costs absent any trade imbalances. This term captures the welfare gains from lower trade costs that are associated exclusively with changes in countries' real incomes, that

[44]Specifically, $\sum_{t=0}^{\infty} \delta^t \phi_{i,t} \ln(1+\nu_i) = \sum_{t=0}^{\infty} \delta^t \phi_{i,t} \ln\left(\frac{C_{i,t}^{D}}{\bar{C}_{i,t}^{D}} \frac{\bar{C}_{i,t}^{CF}}{C_{i,t}^{CF}}\right)$. Actually, it can be shown that, for the particular counterfactual exercise in which trade costs coincide in the first period, this second component is the result of the difference in welfare gains from not imposing financial autarky under observed and counterfactual trade costs.

is, absent any transfers across countries. These gains are shown in column (2) of Table 5, and I call them the "static" gains from lower trade costs. Because these gains are computed following the same methodology used in previous research, they are comparable with those in the existing literature.

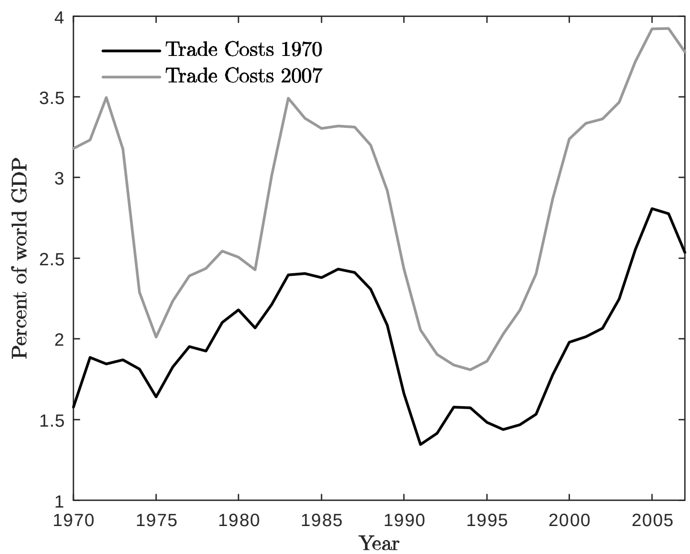
Several interesting and novel conclusions can be derived from this decomposition. First, notice that computing welfare gains in a static rather than a dynamic framework can lead to substantial differences across results depending on each country. While some small open economies like Belgium and the Netherlands experience large total gains mostly due to static gains (8.84% of 10.85% and 5.85% of 6.74%, respectively), other large winners like China and Korea derive most of their gains from the non-static component (8.95% of 10.83% and 6.25% of 11.26%). This decomposition also sheds light on the cases of Finland and Venezuela. These two economies experience static gains form lower trade costs; however, these gains are more than offset by non-static losses. The exact opposite is the case of Australia, which experiences static losses that are more than offset by non-static gains.

A second novel insight derived from the results in Table 5 is that while all countries except Australia experience static welfare gains from lower trade costs, this result is not the case for non-static gains. Out of the sample of 26 countries, 11 actually experience non-static losses. Even though a substantial number of countries suffer non-static losses, only two, Finland and Venezuela, suffer losses large enough to counteract static gains. Although the understanding of the particular mechanism through which lower trade costs lead to static welfare gains or losses is relatively straight-forward, a thorough understanding of the mechanisms driving the non-static welfare gains or losses is more complicated. If we interpret effective interest rates as terms of trade across time periods, then changes in these interest rates generate intricate substitution and income effects that are not easy to disentangle. A better understanding of the main determinants of non-static welfare gains from lower trade costs is beyond the scope of this project and left for future research.

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

In the previous counterfactual exercise, trade costs remain fixed at a constant level over time. This fact implies that, relative to actual bilateral trade costs, not only are their levels different, but the dynamic paths they follow also differ. Although 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-saving decisions independently of the changes in trade costs' levels. To understand the implications of uniform changes in trade costs in isolation, I compare counterfactual equilibria in which bilateral trade costs remain constant over time,

Figure 7: Trade Imbalances: Data and Counterfactuals



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. The equilibrium for 1970 trade costs is the same as in our previous exercise. For the 2007 trade costs, trade imbalances are obtained by fixing trade costs at 2007 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 average trade imbalances from 1970 to 2007 into two effects. Observed average imbalances over the period 1970-2007 were 2.13 percent of world GDP. The level effect leads to an increase in average trade imbalances from 1.99 to 2.84 percent of world GDP 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 2.84 to 2.13 percent of world GDP. Thus, the overall change in average trade imbalances is equal to

$$0.14 = 2.13 - 1.99 = \underbrace{(2.84 - 1.99)}_{\text{Level effect}} + \underbrace{(2.13 - 2.84)}_{\text{Tilting effect}}$$

percent of world GDP, the increase due to level effects plus 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 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 costs 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 case can be thought of as the one in which many of the trade liberalization rounds of the late 1980s did 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. Instead, 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 when the news arrives and then follow a much flatter path 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. In the data, post-1986 trade imbalances reach a minimum of 1.22 percent of world GDP also in 1991, and then increase to 3.81 percent of world GDP in 2007. This increase is 0.38 times the increase over the same period in the scenario with 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 realized 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 shifters. If we consider the same weights in the previous 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

Figure 8: Trade Imbalances: Data and Counterfactuals

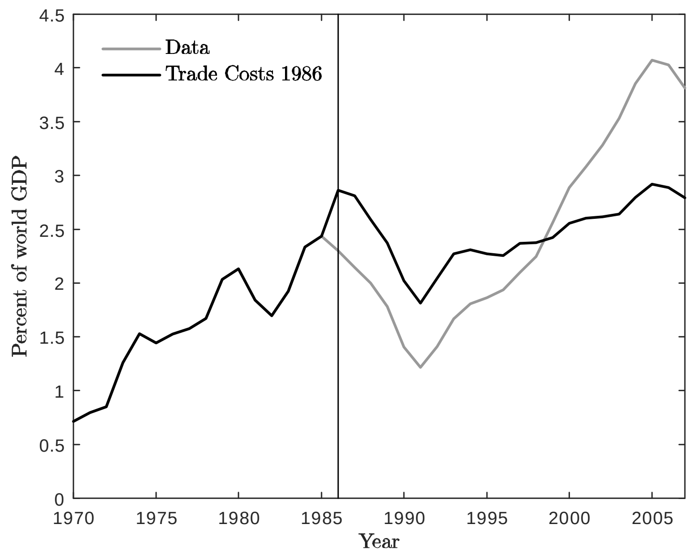


Table 6: Trade Imbalances: Percent of World GDP

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

equilibrium outcomes after 1986, such as the net foreign asset distribution at the beginning of 1986, rather than those including the 1970–1985 period. Hence, solving for the competitive equilibrium is relevant to carry out this analysis.

5 Conclusions

Why have trade imbalances across countries become so much larger in recent years? Answering this question is fundamental to understand the roots of global imbalances and their potential implications. The previous literature has stressed frictions in asset markets as the main source of large imbalances and has ignored the potential role of trade costs in goods markets. This paper takes the role of these costs seriously and shows that most of the long-term increase in the size of net trade imbalances is due to the decline in trade costs, leading to larger gross trade flows across countries. Specifically, the paper provides a quantification of the mechanisms through which lower trade costs in goods have helped in shaping the surge in trade imbalances over the last four decades. I develop a natural framework to carry out this quantification by extending the new multi-country quantitative general equilibrium models of international trade to a dynamic setup. By doing so, this paper also proposes a new mechanism through which future trade costs affect imbalances, the tilting effect, and contributes to the longstanding literature trying to incorporate dynamics into international trade models. To the best of my knowledge, this paper represents the first attempt to seriously consider trade imbalances arising from dynamic decisions within the structure of the new quantitative general equilibrium trade models.

The main results show that the majority, 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 after 1970. In other words, lower bilateral trade costs across countries have not only allowed for more intratemporal trade, but also for more intertemporal trade. In addition, the results show that the effects of changes in trade costs have been heterogeneous across countries, affecting imbalances in the United States and China more substantially than in other countries. The paper also provides measures of welfare gains from the observed decline in trade costs and shows that, for particular countries, these gains can differ significantly from those that would be obtained in static models of trade. Hence, in line with the scant literature that has quantified the effects of trade costs on macroeconomic variables, this paper shows that these costs also have important implications for trade imbalances and welfare.

The results in this paper suggest that 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 in other types of frictions. Hence, additional progress in the literature investigating the drivers of these costs could be made by considering the insights in this paper, *e.g.*, that these costs have implications for financial flows. The results also show that not only do 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 useful theoretical framework to further investigate these interactions while still maintaining the appealing features of the new quantitative general equilibrium models of trade.

Lastly, this paper also indicates 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 the result of a more efficient allocation of resources around the world. However, 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. These types of interactions open up the possibility for a more detailed investigation of how trade policy can interact with policies targeted to manage capital flows.

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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 $j, m = 1, \ldots, J$. These conditions together with (18) imply that

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

for all $j = 1, \ldots, J$, 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 $j \in \mathcal{J} \backslash S$ 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 the 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 assumption 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 $(P^j_{i,t})^{1-\rho} = \sum_{h=1}^I (p^j_{ih,t})^{1-\rho}$ and $p^j_{ih,t} = \frac{\tau^j_{ih,t} c^j_{h,t}}{x^j_{h,t}}$. Hence, the share of total expenditure on goods produced in country h is

$$\pi^j_{ih,t} \equiv \frac{p^j_{ih,t} d^j_{ih,t}}{P^j_{i,t} Q^j_{i,t}} = \left(\frac{p^j_{ih,t}}{P^j_{i,t}} \right)^{1-\rho} = \left(x^j_{h,t} \right)^{\rho-1} \left(\frac{\tau^j_{ih,t} c^j_{h,t}}{P^j_{i,t}} \right)^{1-\rho}.$$

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

$$\pi^j_{ih,t} = \left(\Gamma^{-\theta} \right) T^j_{h,t} \left(\frac{c^j_{h,t} \tau^j_{ih,t}}{P^j_{i,t}} \right)^{-\theta},$$

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

$$(P^j_{i,t})^{1-\rho} = \sum_{h=1}^I (p^j_{ih,t})^{1-\rho} = \sum_{h=1}^I \left(\frac{\tau^j_{ih,t} c^j_{h,t}}{x^j_{h,t}} \right)^{1-\rho}.$$

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 $\psi > 0$, $X_{i,t} = \left(\sum_{j=1}^J \left(\mu^j_{i,t} \right)^{\frac{1}{\psi}} \left(X^j_{i,t} \right)^{\frac{1-\psi}{\psi}} \right)^{\frac{\psi}{1-\psi}}$, where $X_{i,t}$ denotes production of the final nontradable good and $X^j_{i,t}$ 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 $P^j_{i,t} X^j_{i,t} = \mu^j_{i,t} \left(\frac{P^j_{i,t}}{P_{i,t}} \right)^{1-\psi} P_{i,t} X_{i,t}$. Therefore, the equilibrium conditions in the nontradable sector are now given by

$$X^j_{i,t} + \sum_{k=1}^J D^{k,j}_{i,t} = Q^j_{i,t}.$$

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

$$\max_{\{C_{i,t}, I_{i,t}, K_{i,t+1}, B_{i,t+w}\}_{t=0}^\infty} \sum_{t=0}^\infty \delta^t \phi_{i,t} \ln \left(C_{i,t} \right) \tag{38}$$

subject to

$$P_{i,t} C_{i,t} + P_{i,t} I_{i,t} + B_{i,t+1} = w_{i,t} L_{i,t} + r_{i,t} K_{i,t} + R_t B_{i,t}, \tag{39}$$

$$K_{i,t+1} = \left(1 - d \right) K_{i,t} + \chi_{i,t} I_{i,t}, \tag{40}$$

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

$$u'\left(C_{i,t}\right) = \beta\hat{\phi}_{i,t+1}\frac{R_{t+1}}{P_{i,t+1}/P_{i,t}}u'\left(C_{i,t+1}\right) \text{ and} \tag{41}$$

$$\frac{R_{t+1}}{P_{i,t+1}/P_{i,t}} = \frac{\chi_{i,t}}{\chi_{i,t+1}}\left(\frac{r_{i,t+1}}{P_{i,t+1}}\chi_{i,t+1} + (1-d)\right), \tag{42}$$

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 backward 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 by solving the system of equations defined by (11). Given prices, solve for trade shares according to (13).

    (e) Solve for $I \times J$ sectoral expenditures, $E_{i,t}^{j}$, by solving the following system of equations:

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

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

(f) Compute net exports according to the intratemporal trade condition: $NX_{i,t}^S = \sum_{j=1}^J \left(Y_{i,t}^j - E_{i,t}^j\right)$.

(g) Compute $T_t^S = \max_i \left|NX_{i,t}^D - NX_{i,t}^S\right|$.

(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

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

3. If $t > 0$, set $t = t - 1$ and proceed to 2. Otherwise, go to the 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 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 $\sum_{i=1}^I Z_i = 0$. Then go back to step 1 using the new $\mathbf{B}_{SS}$.

The functions Z_i are defined as

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

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,

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

Let $E_{i,t}^j$ denote the 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

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

Now note that, because $\omega^j \in [0,1]$, it must be the case that $\pi_{ih,t}^j\left(\omega^j\right)$ for a particular variety is also the share of total expenditure in sector j by country i in goods produced by country

h, $\pi^j_{ih,t} \equiv \frac{E^j_{ih,t}}{E^j_{i,t}}$, where $\sum_{h=1}^{I} \pi^j_{ih,t} = 1$ for all $i = 1, \ldots, I$ and $j = 1, \ldots, J$.

G. Data

Countries The set of countries that I consider as core countries in the sammple are Australia, Austria, Belgium, Brazil, Canada, China, Denmark, Finland, France, Germany, Greece, India, Italy, Japan, Korea, Mexico, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, U.K., U.S., 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 come from the United Nations Statistical Division National Accounts. These data are expressed in current U.S. dollars. For ROW, I compute GDP as the aggregate of all remaining countries that are not part of the 25 core 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 U.K. the EU-KLEMS provide data for all years between 1970 and 2007. Data for the following countries also come 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 come from the United Nations Statistical Division National Accounts (years missing in parentheses): Brazil (1970-1991), India (1970-1998), Mexico (1970-1979), and Venezuela. For China I obtain data on value added from the GGDC-10 database and on gross output directly from its official statitical 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 are available for all countries and years and that are 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, and then I consider the average across core countries' value added in gross output shares to construct series on gross output for the ROW.

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 tables 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, U.K. and U.S.A. For Korea, Mexico, and Switzerland, the IO tables correspond to the early 2000s. For 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 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 all other countries. The data from NBER-UN are only available until the year 2000, while the CEPII-BACI are available from 1999 onward. The data in these two data sets are not directly 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 NBER-UN data.

Using these 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 Penn World 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 come 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 come from the GGDC-10 data set. For Switzerland, the data on sectoral producer price indexes come 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

To construct series on sectoral prices, I first 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 United States by exploiting the multisector gravity structure of the model as follows. Note that from (14) we have that

$$\frac{\pi^j_{ih,t}}{\pi^j_{ii,t}} = \frac{T^j_{h,t}\left(c^j_{h,t}\right)^{-\theta}\left(\tau^j_{ih,t}\right)^{-\theta}}{T^j_{i,t}\left(c^j_{i,t}\right)^{-\theta}}.$$

Taking logs on both sides, I obtain that

$$\ln\left(\frac{\pi^j_{ih,t}}{\pi^j_{ii,t}}\right) = \ln\left(T^j_{h,t}\left(c^j_{h,t}\right)^{-\theta}\right) - \ln\left(T^j_{i,t}\left(c^j_{i,t}\right)^{-\theta}\right) - \theta\ln\left(\tau^j_{ih,t}\right).$$

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

$$\ln\left(\frac{\pi^j_{ih,t}}{\pi^j_{ii,t}}\frac{\pi^j_{hh,t}}{\pi^j_{hi,t}}\right)^{\frac{1}{2\theta}} = \underbrace{\ln\left(T^j_{h,t}\left(c^j_{h,t}\right)^{-\theta}\right)^{\frac{1}{\theta}} - \ln ex^j_{h,t}}_{\text{Exporter Fixed Effect}} \underbrace{- \ln\left(T^j_{i,t}\left(c^j_{h,t}\right)^{-\theta}\right)^{\frac{1}{\theta}}}_{\text{Importer Fixed Effect}} - \theta\ln\hat{\tau}^j_{ih,t}.$$

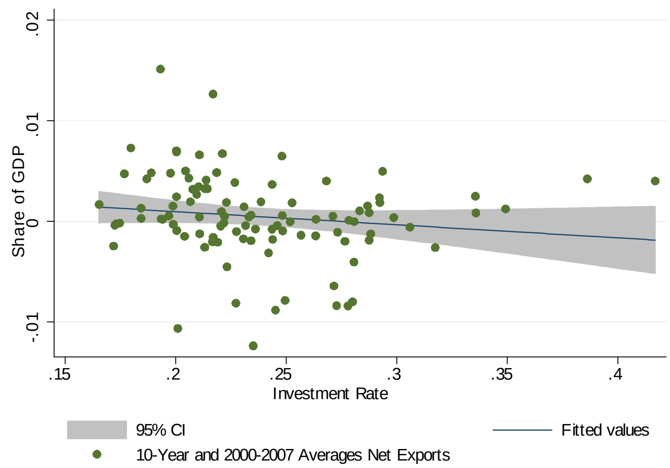
Estimating this equation in $t = 2000$, I can recover $\hat{S}^j_{i,t} \equiv \left(\frac{T^j_{i,t}}{T^j_{US,t}}\right)^{\frac{1}{\theta}}\left(\frac{c^j_{i,t}}{c^j_{US,t}}\right)^{-1}$. Then, I can estimate sectoral prices relative to the United States by noticing that $\frac{P^j_{i,t}}{P^j_{US,t}} = \left(\frac{\pi^j_{ii,t}}{\pi^j_{USUS,t}}\frac{1}{S^j_{i,t}}\right)^{\frac{1}{\theta}}$, where $S^j_{i,t} = \left(\hat{S}^j_{i,t}\right)^{\theta}$.

I. Net Exports and Investment

This appendix discusses existing empirical evidence, and provides additional evidence for the sample of countries and time period considered in this paper, that there exists no systematic long-run relationship between investment rates and net exports. Because the focus of the paper is on the long-run change in the size of net trade imbalances, this discussion and evidence support the view that investment decisions do not have first-order effects on the determination of net exports in the long run. This view is in line with the strategy in this paper to treat capital stocks as exogenously given.

The literature has documented a discrepancy between the long- and short-run relationship between current accounts and investment rates. For instance, in the short run this relationship is consistently negative [Glick and Rogoff (1995), Kraay and Ventura (2003)], and studies on international business cycles have emphasized the role of investment as a driver of the dynamics of net exports [Backus et al. (1992, 1994)], which closely commove with current accounts. The latter emphasis has prevailed despite the fact that this mechanism actually leads to a number of counterfactual theoretical implications [Raffo (2008)]. However, in the long run this relationship is weak and in most cases statistically insignificant

Figure F1: Investment Rates and Net Exports (10-year Averages)

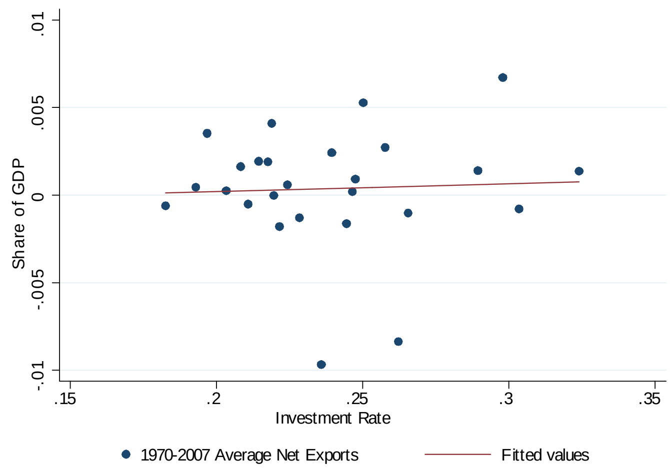


[Tesar (1991), Kraay and Ventura (2003)]. This evidence is in part driven by the fact that over long periods of time, investment rates are relatively stable and do not vary considerably across a number of country pairs (see Figure F3).[45]

Figures F1 and F2 provide evidence that there is no long-run systematic relationship between investment rates and net exports for the sample of countries considered in this paper. Specifically, Figure F1 plots country-specific 10-year-average investment rates against country-specific 10-year-average net exports as a share of GDP. The figure shows that the coefficient obtained from regressing net exports as a share of GDP on investment rates is not statistically significantly different from zero at a 5 percent significance level (95% CI). Figure F2 considers the case of averages over the entire 1970–2007 period. The figure shows that the regression coefficient is positive. Put differently, in the long run countries with higher average investment rates have experienced larger average trade surpluses. However, as in the previous case, this coefficient is not statistically significantly different from zero, but in this case at a 15 percent significance level.

[45] Actually, standard open economy models used to study capital flows across counries, and therefore also current accounts, in the long run lead to counterfactual predictions when investment decisions are endogenized. These models cannot account for the empirical facts known as the "Lucas" and "Allocation" puzzles [Prasad et al. (2007), Gourinchas and Jeanne (2013), Gourinchas and Rey (2014), Heathcoate and Perri (2014)].

Figure F2: Investment Rates and Net Exports (1970-2007 Average)



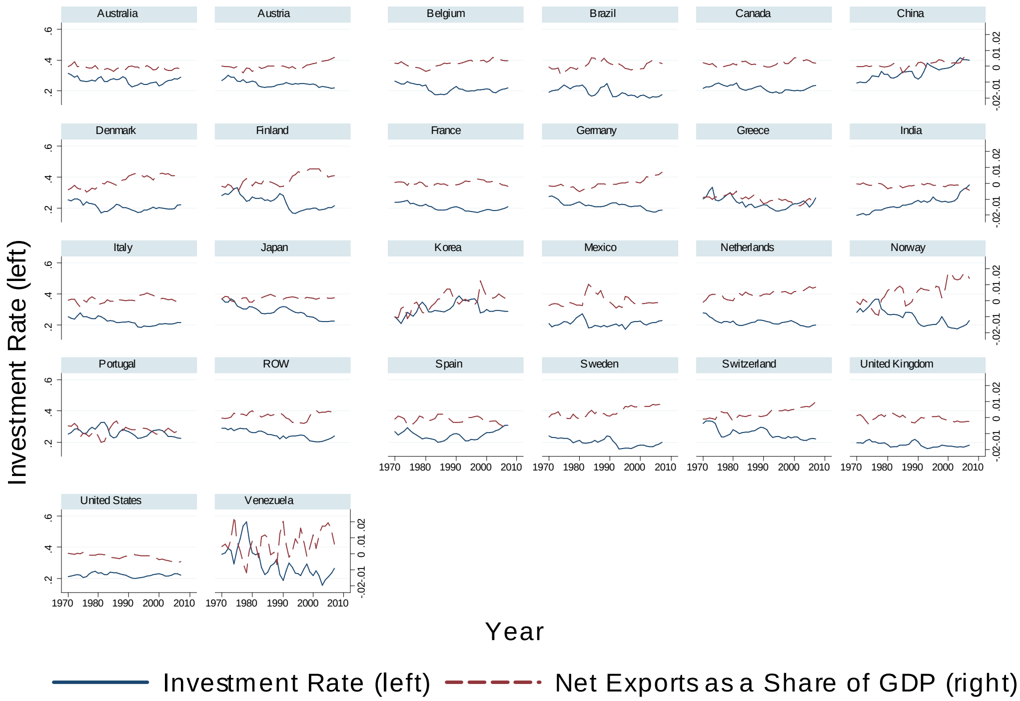
J. Real Interest Rates: Data and Model

The structural residuals recovered in Section 3 are such that a subset of equilibrium outcomes of the model exactly matches the time series selected. An additional set of equilibrium outcomes of the model consists of the real interest rates in each country i, $\{R_{i,t+1}/(P_{i,t+1}/P_{i,t})\}_{t=0}^{\infty}$. Three facts on the evolution of real interest rates in the medium to long run in the United States and around the world have been established.[46] *Fact 1*: The real interest rate in the United States increased in the 1970s and early 1980s, peaking around the mid-1980s. This interest rate has since then steadily declined, with the exception of the late 1990s when it increased temporarily, peaking around 1998. *Fact 2*: The median real interest rate across countries steadily increased from the early 1970s until 1990. This rate has declined since then with a minor increase around 1998. *Fact 3*: Real interest rate dispersion across countries increased in the early 1970s, remained relatively stable until the late 1980s, and has steadily declined since then.

These facts are shown in Figure G1 for the sample of countries and time period considered in this paper. Facts 1 and 2 are shown in panel (a) and fact 3 in panel (b). Figure G1 also plots the corresponding equilibrium real interest rates predicted by model. Starting with fact 1, notice that the equilibrium interest rate in the model does a decent job in following the medium- to long-run trends in the data. However, a clear difference arises from the fact that the initial increase in the interest rate (1971–1984) is muted in the model compared

[46] See Yi and Zhang (2016) and IMF (2014).

Figure F3: Evolution of Investment Rates and Net Exports

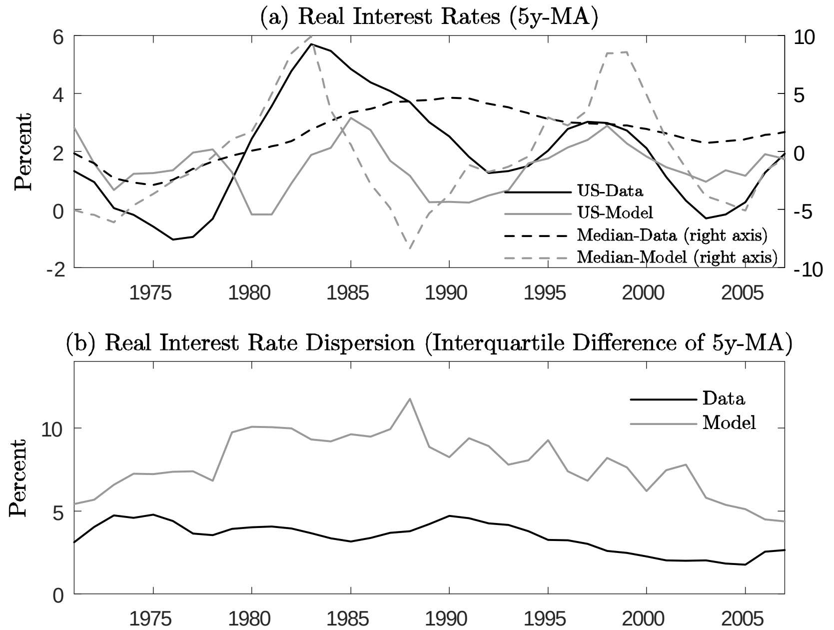


with the data, while the second increase in the interest rate (1990s) is amplified. Regarding fact 2, the difference is more pronounced. Specifically, the model predicts a large dip and recovery of the median interest rate between the early 1980s and the late 1990s that does not happen in the data. Hence, the model cannot match the fact that the median real interest rate remained relatively constant over this time period. Even though the structure of international financial markets in the model is remarkably stylized, the model seems to do a decent job in tracking the medium- to long-run evolution of real interest rates. It is worth pointing out that the evolution of real interest rates in the model could be disciplined further by relying on more data to choose the normalization of intertemporal preference shifters in every period.[47]

Let us now turn to fact 3. Panel (b) in Figure G1 plots the evolution of the interquartile difference across countries in each year in the data and in the model. Even though the model predicts approximately twice as much dispersion across real interest rates than the one implied by the data, the model does a remarkably good job in following the inverted U-shape observed in the data. It is worth emphasizing this point, as one of the mechanisms

[47] This interesting point is left for further research on the evolution of global real interest rates.

Figure G1: Interest Rates: Data and Model



Notes: This figure plots 5-year moving averages for each of the time series considered. Real interest rates were constructed following the methodology in Yi and Zhang (2016). The data sources are the International Financial Statistics published by the International Monetary Fund and Haver Analytics. Data for all periods for the majority of countries are available. Exceptions are Brazil (available for 1980-2007), China (available for 1987-2007), and Mexico (available for 1978-2007).

through which lower trade costs lead to larger trade imbalances –namely, the level effect explained in Section – operates by means of such a prediction: Lower trade costs should lead to convergence in equilibrium real interest rates, which in turn allow for larger imbalances. This convergence is very clear in the data beginning in 1990. We conclude that the model is consistent with the observed evolution in the dispersion of real interest rates, which in turn play a crucial role in the determination of trade imbalances.

K. Changes in Welfare and Pareto Weights

In Section 4.1 we provided a decomposition of the welfare gains from lower trade costs into static and non-static gains. Alternatively, total welfare gains can be decomposed in a way that delivers one component that reflects the changes in the Pareto weights that would decentralize each competitive equilibrium considered if we were to solve the problem of a planner subject to trade costs. It could be the case that these Pareto weights do not vary considerably across equilibria, in which case solving counterfactual optimal allocations relying on a planner's problem given fixed Pareto weights would be close to those obtained from solving the counterfactual competitive equilibrium. However, changes in these weights could be substantial, and this case would underscore the relevance of computing counterfactual competitive equilibria instead of taking a stance on Pareto weights in order to isolate the effects of changes in trade costs on equilibrium outcomes.

To shed some light on how relevant changes in Pareto weights are when computing welfare gains (as well as other equilibrium outcomes like trade imbalances), consider the following alternative decomposition of these gains. Let TWG_i denote the total welfare gains from lower trade costs for country i (column (1) in Table H1). Then:

Lemma H1 *The total welfare gains from lower trade costs in country i, TWG_i (more specifically $\ln(1+x_i)$), can be decomposed into three components,*

$$\ln(1+x_i) = \ln(1+x_i^{Initial}) + \ln(1+x_i^{PW}) + \ln(1+x_i^{Int}),$$

where $\ln(1+x_i^{Initial})$ reflects the gains derived from the change at time $t=0$ in consumption prices in country i relative to the U.S., as well as a common factor for all countries; $\ln(1+x_i^{PW})$ measures the gains derived from the change in the Pareto weight for country i, relative to the U.S., that decentralizes the competitive equilibrium under low trade costs relative to the analog relative Pareto weight that decentralizes the competitive equilibrium under high trade costs; and $\ln(1+x_i^{Int})$ measures the gains derived from changes in real or effective interest rates.

Proof. Let $l \in \{D, CF\}$. Then, notice that from the Euler equation for country i we have that for each l, $C_{i,t+1}^l / C_{i,t}^l = \delta \phi_{i,t+1} R_{t+1}^l / \left(P_{i,t+1}^l / P_{i,t}^l\right)$. Hence, $C_{i,t+1}^l$ for $t \geq 0$ can be written in terms of $C_{i,0}^l$ as follows:

$$C_{i,t+1}^l = C_{i,0}^l \left(\delta^t \frac{\phi_{i,t+1}}{\phi_{i,0}}\right) \prod_{s=0}^{t} \left(1+\rho_{i,s+1}^l\right),$$

where $1+\rho_{i,s+1}^l \equiv R_{t+1}^l / \left(P_{i,t+1}^l / P_{i,t}^l\right)$. Substituting this equality into lifetime utility, we obtain

$$\sum_{t=0}^{\infty}\delta^t\phi_{i,t}\ln\left(\frac{C_{i,t}^D}{C_{i,t}^{CF}}\right) = \sum_{t=0}^{\infty}\delta^t\phi_{i,t}\ln\left(C_{i,0}^D\prod_{s=0}^{t}\left(1+\rho_{i,s+1}^D\right)\right)-\sum_{t=0}^{\infty}\delta^t\phi_{i,t}\ln\left(C_{i,0}^{CF}\prod_{s=0}^{t}\left(1+\rho_{i,s+1}^{CF}\right)\right)$$
$$= \sum_{t=0}^{\infty}\delta^t\phi_{i,t}\ln\left(\frac{C_{i,0}^D}{C_{i,0}^{CF}}\right)$$
$$+\sum_{t=0}^{\infty}\delta^t\phi_{i,t}\ln\left(\prod_{s=0}^{t}\left(1+\rho_{i,s+1}^D\right)\right)-\sum_{t=0}^{\infty}\delta^t\phi_{i,t}\ln\left(\prod_{s=0}^{t}\left(1+\rho_{i,s+1}^{CF}\right)\right).$$

Notice then that we can rewrite these gains as

$$\sum_{t=0}^{\infty}\delta^t\phi_{i,t}\ln\left(\frac{C_{i,t}^D}{C_{i,t}^{CF}}\right) = \sum_{t=0}^{\infty}\delta^t\phi_{i,t}\underbrace{\ln\left(\frac{P_{i,0}^{CF}/P_{US,0}^{CF}}{P_{i,0}^{D}/P_{US,0}^{D}}\frac{C_{US,0}^D}{C_{US,0}^{CF}}\right)}_{\ln(1+\mu_i^{Initial})}+\sum_{t=0}^{\infty}\delta^t\phi_{i,t}\underbrace{\ln\left(\frac{P_{i,0}^{D}C_{i,0}^{D}/P_{US,0}^{D}C_{US,0}^{D}}{P_{i,0}^{CF}C_{i,0}^{CF}/P_{US,0}^{CF}C_{US,0}^{CF}}\right)}_{\ln(1+\mu_i^{PW})}$$
$$+\sum_{t=0}^{\infty}\delta^t\phi_{i,t}\ln\left(\prod_{s=0}^{t}\left(1+\rho_{i,s+1}^D\right)\right)-\sum_{t=0}^{\infty}\delta^t\phi_{i,t}\ln\left(\prod_{s=0}^{t}\left(1+\rho_{i,s+1}^{CF}\right)\right)$$

and

$$\ln(1+\mu_i^{Int})\equiv\frac{\sum_{t=0}^{\infty}\delta^t\phi_{i,t}\ln\left(\prod_{s=0}^{t}\left(1+\rho_{i,s+1}^D\right)\right)-\sum_{t=0}^{\infty}\delta^t\phi_{i,t}\ln\left(\prod_{s=0}^{t}\left(1+\rho_{i,s+1}^{CF}\right)\right)}{\sum_{t=0}^{\infty}\delta^t\phi_{i,t}}.$$

Let $\left\{\omega_i^D\right\}_{i=1}^{I}$ and $\left\{\omega_i^{CF}\right\}_{i=1}^{I}$ be the sets of Pareto weights that decentralize the equilibria with low and high trade costs, respectively. Then, it is straightforward to show that for every $t=0,1,\ldots$

$$\frac{P_{i,t}^D C_{i,t}^D}{P_{US,t}^D C_{US,t}^D}=\frac{\phi_{i,t}\omega_i^D}{\phi_{US,t}\omega_{US}^D}.$$

This condition implies that

$$\frac{P_{i,0}^{D}C_{i,0}^{D}/P_{US,0}^{D}C_{US,0}^{D}}{P_{i,0}^{CF}C_{i,0}^{CF}/P_{US,0}^{CF}C_{US,0}^{CF}}=\frac{\omega_i^D/\omega_{US}^D}{\omega_i^{CF}/\omega_{US}^{CF}},$$

hence the interpretation of changes in Pareto weights across equilibria. ■

Columns (2), (3), and (4) in Table H1 report each part of this decomposition. The results in column (2) show that changes in relative Pareto weights across competitive equilibria are heterogeneous and large. These changes are not captured in counterfactual allocations that solve a planner's problem, given exogenous Pareto weights. Taking these changes into account is essential to provide a correct measure of welfare gains from lower trade costs, and therefore also to correctly quantify the effect of the decline in trade costs on the size of trade imbalances.

Table H1: Welfare Gains from Changes in Trade Costs

	Total (x_i%)	Initial ($x_i^{Initial}$%)	Pareto Weights (x_i^{PW}%)	Interest Rates (x_i^{Int}%)
	(1)	(2)	(3)	(4)
AUS	1.11	-5.60	6.35	0.36
AUT	4.26	-6.73	9.50	1.41
BEL	10.85	-7.46	17.59	0.17
BRA	0.38	-0.40	-3.08	3.86
CAN	2.02	-3.05	3.70	1.35
CHN	10.93	-30.94	55.30	-13.98
DEN	2.79	-5.73	6.97	1.52
FIN	-1.98	-4.83	3.49	-0.66
FRA	2.03	-5.84	5.95	1.90
GER	2.55	-6.43	8.05	0.91
GRC	1.75	-3.35	1.01	4.07
IND	1.26	2.35	-4.94	3.83
ITA	1.94	-5.32	5.14	2.10
JAP	1.25	-6.23	6.97	0.50
KOR	11.26	-11.66	24.83	-2.51
MEX	2.80	0.47	-2.12	4.41
NLD	6.74	-7.89	15.86	-1.44
NOR	1.66	-5.57	6.52	0.71
POR	2.80	-3.89	1.91	4.75
SPA	2.02	-2.24	-0.27	4.50
SWE	1.80	-5.55	6.11	1.23
SWZ	3.18	-6.04	10.18	-1.01
UK	1.97	-4.68	4.42	2.21
US	1.05	-1.38	0.00	2.42
VEN	-2.43	-2.74	1.52	-1.25
ROW	3.15	-4.82	4.21	3.71