

Globalization and Structural Change in the United States: A Quantitative Assessment*

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Abstract

We consider a dynamic general equilibrium model of international trade and structural transformation to explore the implications of lower trade costs for structural change in the United States. Changes in trade costs lead to structural change not only through the typical mechanisms present in closed economy models—sectoral-biased technical change and nonhomothetic preferences—but also through two additional channels: the determination of sectoral net exports and the interaction between comparative advantage and aggregate trade imbalances. We map the model to data for the United States and the rest of the world for the period from 1970 to 2007 and show that: (i) the global decline in trade costs can explain 3.2 percent of the decline in manufacturing's share in value added over the entire period, (ii) ignoring the endogenous determination of trade imbalances implies an overestimation of this contribution by a factor of three, and (iii) the decline, in isolation, of trade costs for imported manufacturing goods in the United States can explain up to 32 percent of the decline in this sector's share in value added.

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1 Introduction

The U.S. economy has undergone significant sectoral reallocations of economic activity over the last four decades. For instance, from 1970 to 2007, 13.8% of total value added was relocated from goods-producing sectors—agriculture and manufacturing—, to the services sector. Given that this process of reallocation—commonly known as *structural change*—is one of the main features of economic development and that it is primarily driven by the reallocation of workers and capital across sectors, understanding its causes and consequence has always been at the core of the economic research and policy debates.¹

Over the same time period, the United States has been part of a rapid process of global economic integration—also known as *globalization*—which has significantly impacted the U.S. economy. From 1970 to 2007, expenditure by the United States on agricultural goods produced abroad as a share of total expenditure on agriculture rose from 7.0 percent to 48.9 percent, while this share in the case of manufacturing goods increased from 4.0 percent to 22.1 percent. Furthermore, together with the increase in gross international trade flows, the United States experienced a significant and steady expansion of its trade deficit—or net international trade flows—going from close to balanced trade in 1970 to a trade deficit of 4.9 percent of GDP in 2007.

Even though the correspondence of these two features of the U.S. economy—structural change and globalization, both depicted in Figure 1—has always hinted at globalization as an important driver of structural change in the United States, the consensus has been that the former has only played a minor role and that technological differences across sectors and long-run income effects have been the main drivers of structural change.^{2,3} However, recent research has shown that exposure to exogenous shocks leading to changes in either gross or net trade flows have led to reallocation of economic activity across industries in the United States.⁴ These results have given

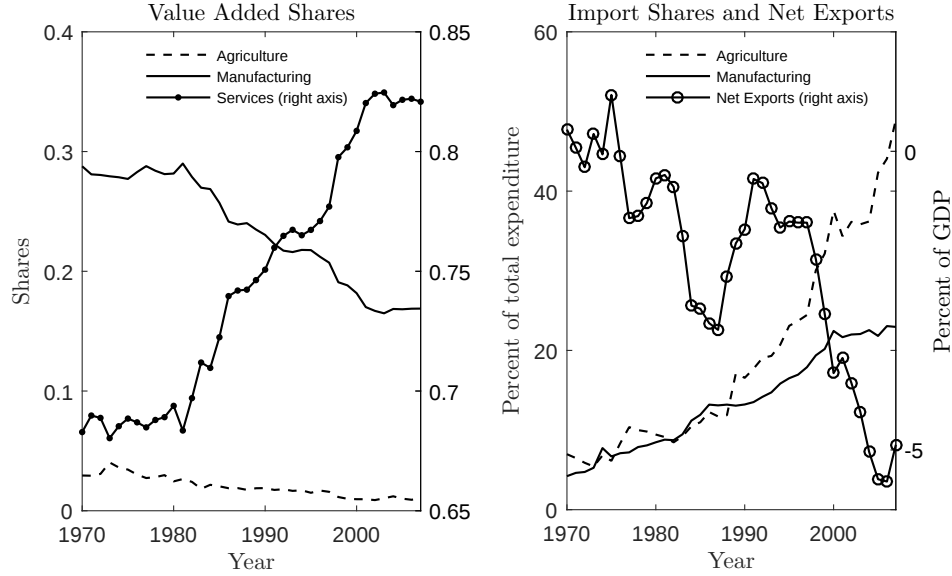
¹This process has not been exclusive to the U.S. economy and, as stated by Herrendorf et al. (2014), it has received much attention in the policy debate of developed countries where it is sometimes claimed that the sectoral reallocation of economic activity is inefficient and that government intervention could reverse it.

²Figure 1 depicts the evolution of sectoral expenditure shares on goods produced abroad and of the U.S. aggregate trade deficit, as well as that of value added shares from 1970 to 2007.

³See Herrendorf et al. (2014) for a survey of the literature on structural change in closed economies focusing on sectoral-biased technical change and non-homothetic preferences as the main drivers of reallocation of economic activity across sectors.

⁴See Autor et al. (2016) for a survey of the empirical literature showing that more exposure to shocks leading to long-run changes in comparative advantage leads to employment reallocation across industries in the United States. Kehoe et al. (2013) show in a dynamic open economy model that

Figure 1: Structural Change and International Trade in the U.S.



rise to a reemergence of the role of globalization in the debate about the sources of structural change. Still, the task of disentangling the importance of the multiple forces that have been identified as drivers of structural change in the United States has not yet been tackled.

This paper proposes a theoretical framework to carry out a structural decomposition of the sources of structural change in a dynamic open economy and applies it to the case of the United States to assess the quantitative importance of changes in trade costs in shaping structural change in the United States from 1970 to 2007. More specifically, we propose a dynamic general equilibrium international trade model of structural transformation to assess the quantitative importance of changes in trade costs for sectoral reallocation of economic activity. The model builds on the static structure of the new quantitative general equilibrium Ricardian models of international trade and incorporates the main mechanisms that drive structural transformation in closed economy models, namely, sectoral-biased technical change and non-homothetic preferences.⁵ This static structure is then embedded into a dynamic framework in which trade imbalances arise endogenously from optimal consumption-saving and investment decisions by economic agents. The dynamics of the model allow us to provide a full account of the effects of globalization on structural transformation, as imbalances change

changes in the U.S. aggregate trade deficit have also led to reallocation of economic activity.

⁵See [Herrendorf et al. \(2014\)](#) and [Comin et al. \(2017\)](#)

endogenously when it becomes easier to trade goods across countries, and such changes can potentially have important effects on structural change.⁶

In order to carry out the decomposition, we calibrate the model to the data for the case of two countries, the United States and the rest of the world (ROW), and recover a set of time series of structural residuals of the model that rationalize observed data on sectoral expenditures and international trade—both bilateral trade shares and trade imbalances—as an equilibrium of the model. This set of residuals, which we will refer to as *disturbances*, include changes in trade costs, changes in sectoral productivities, two types of preferences shifters and investment-specific efficiency shifters.

The specific question that we aim to answer in this paper is: How much did the decline in trade costs from 1970 to 2007 contribute to structural change in the United States? We are particularly interested in how these changes have contributed to the decline of economic activity in the U.S. manufacturing sector. To carry out this quantitative assessment of the importance of globalization for structural change in the United States, we consider counterfactual equilibria in which trade flows across countries differ because of the absence of declines in trade costs. The main results of the paper are as follows:

1. The main result of these counterfactual exercises is that globalization has not had sizable effects on structural transformation in the United States. Changes in global trade costs account for 3.2% of the decline in manufacturing’s VA share relative to baseline calibration.
 - In the counterfactual there is marginal reallocation from services to agriculture relative to the baseline.
2. Changes in trade costs for U.S. imports of manufacturing goods account for 32% of decline in manufacturing’s VA share relative to baseline calibration.
 - Over 40% of increase in services accounted for by this decline.
3. Not allowing for endogenous changes in net trade flows implies that the effects of globalization are underestimated.

⁶Kehoe et al. (2013) consider a dynamic open-economy model of structural change with unbalanced trade and quantify how changes in aggregate savings decisions affect structural change in the United States. However, this paper does not consider changes in trade costs nor any other forces that could be driving changes in gross trade flows as shown in the right panel of 1.

These results support the quantitative relevance that changes in trade flows, both gross and net, have had in shaping structural change in the United States.

This paper contributes to multiple literatures. First, it contributes to the extensive traditional literature on structural change in closed economies. Recent work focuses on the interaction between economic growth and structural transformation. The literature has posited two main mechanisms as the drivers of structural transformation. The first mechanism relies on differences in income elasticities of demand across sectors, mainly driven by non-homothetic preferences. The work by [Caselli and Coleman \(2001\)](#), [Kongsamut et al. \(2001\)](#), [Buera and Kaboski \(2011\)](#) and [Buera and Kaboski \(2012\)](#) are only a few of the most recent contributions emphasizing this mechanism. The second mechanism is a supply-side mechanism that relies on sectoral biased productivity growth. [Baumol \(1967\)](#) was the first one to point out how this mechanism could generate structural change, while [Ngai and Pissarides \(2007\)](#) recently formalized Baumol’s idea. The current benchmark framework to study structural change in closed economies relies on both mechanism to try to understand their quantitative relevance. [Buera and Kaboski \(2009\)](#), [Duarte and Restuccia \(2010\)](#), [Herrendorf et al. \(2013\)](#) and [Comin et al. \(2017\)](#) are some of the most recent contributions. [Herrendorf et al. \(2014\)](#) provide an extensive survey of the literature. Our contribution to this literature is twofold. First, we provide a general equilibrium framework that incorporates the forces driving both gross and net trade flows into the benchmark structural change closed economy model as proposed by [Comin et al. \(2017\)](#). Second, our methodology for open economies also contributes to the recent work that aims to decompose the forces driving structural change by recovering model’s wedges ([Cheremukhin et al., 2017](#)).

This paper also contributes to the recent literature on the effects of international trade on structural change. One relevant issue with studies in a closed economy framework is that they cannot account for large changes in trade flows observed in the data. Hence, recent work has started to emphasize the role that an open economy can play in shaping structural transformation. Early studies include the work by [Matsuyama \(1992\)](#), [Matsuyama \(2009\)](#) and [Echevarria \(1995\)](#). Recent work has started to exploit the structure of the new quantitative general equilibrium models of international trade ([Eaton and Kortum, 2002](#); [Caliendo and Parro, 2015](#); [Levchenko and Zhang, 2016](#)) to study structural transformation in open economies. Some of these papers consider the two drivers of structural change aforementioned ([Sposi, 2012, 2016](#); [Uy et al., 2013](#); [Świecki, 2017](#)) while others have focused only on sectoral price effects generated by

changes in trade costs (Cravino and Sotelo, 2017).^{7,8} These studies have shown that for particular countries more access to trade allows the model to generate features of the data that closed economy models cannot, or that for the case of multiple countries changes in trade shares have led to structural change through changes in gross trade flows. We contribute to this literature by adding the features of these static open economy models to study structural change in the United States. Hence, our framework takes into account how these mechanisms are influenced by the forces underlying the large increase in trade flows shown in 1. In addition, this paper contributes to this literature by extending these models to a dynamic setup in which net trade flows, that is trade imbalances, are determined endogenously because of optimal consumption-saving decisions. This paper provides the first quantification of the effects of globalization—seen through the lens of declines in broadly defined trade barriers—on structural transformation in the United States when globalization affects both gross and net trade flows across countries.⁹

We also contribute to the growing literature on dynamic general equilibrium quantitative models of international trade. (Eaton et al., 2016, 2015; Reyes-Heroles, 2016; Ravikumar et al., 2017; Caliendo et al., 2017) As previously mentioned, in order to provide a correct quantification of the effects of a more integrated world economy, that is, lower trade costs, on structural change we need a dynamic framework in which trade deficits are determined endogenously. This issue becomes even more relevant for the case of the United States which has run sizeable trade deficits since the late 1980s. One of the novel results of this paper is that changes in trade costs lead to changes in trade imbalances that can have sizable effects on sectoral reallocation of economic activity. This is an important result that the literature has not yet studied formally and from a quantitative perspective, even though it has been mentioned that not accounting for the increasing trade deficit can lead to over or underestimating the effects of globalization.

⁷The theoretical framework considered in this paper is very related to the one proposed by Uy et al. (2013). However, one very important difference is that this paper takes into account the fact that net trade flows, that is, trade imbalances change endogenously given changes in trade costs, which Uy et al. (2013) cannot do in their framework. Sposi (2012) considers endogenous changes in trade imbalances for the particular case of South Korea.

⁸While these studies focus on the effect of trade flows on structural change, novel work explores the opposite direction, that is, how structural change affects trade flows. (Lewis et al., 2017)

⁹I am only aware of two other papers that consider dynamic open-economy model of structural change with unbalanced trade, Sposi (2012) and Kehoe et al. (2013). Sposi (2012) studies how well such a model can replicate the experience of South Korea, while Kehoe et al. (2013) quantify how changes in aggregate savings decisions affect structural change in the United States. However, the latter study does not consider changes in trade costs nor any other forces that could be driving changes in gross trade flows as shown in the right panel of Figure 1.

Exploring this novel channel is an additional contribution of this paper and contributes to the frontier in the literature that focuses on analyzing quantitative trade models in a fully dynamic setting and its relevance for structural change. A recent paper studying the effects of the increase in the U.S. trade deficit on structural transformation is [Kehoe et al. \(2013\)](#). However, our paper differs significantly from [Kehoe et al. \(2013\)](#) in the question that aims to answer and the methodology used to do so. While [Kehoe et al. \(2013\)](#) are interested in how an exogenous change in the desire to borrow internationally by the United States leading to an increase in its trade deficits has affected structural transformation in the United States, this paper is mainly concerned with the effects of globalization summarized by declines in trade cost in goods markets.

To summarize the three contribution previously mentioned, recent quantitative open economy models of structural change do not provide a full account of how globalization, that is lower trade barriers, affect structural change. Static models cannot account for changes in net trade flows while dynamic models have focused only on forces shaping net trade flows rather than gross trade flows. This paper provides a model that bridge this gap in the literature.

Lastly, this paper contributes to the growing recent literature on the effects of globalization shocks on labor market outcomes ([Autor et al., 2013](#); [Pierce and Schott, 2016](#)).¹⁰ This empirical literature has provided clear evidence that globalization greater exposure to globalization shocks leads to more reallocation of labor across industries among many other interesting effects on outcomes related to labor markets. However, some important shortcomings of the empirical methodology used in these studies have been pointed out include: (i) the fact that it is insufficient to think about the aggregate impact of trade, (ii) the limited structural interpretation of the results as no counterfactuals that take into account general equilibrium can be carried out, and (iii) the fact that it ignores key aspect of the macroeconomic context in the United States, mainly, its growing trade imbalances.¹¹ While recent work has made progress in addressing the first two shortcomings ([Caliendo et al., 2017](#); [Adao et al., 2017](#)), the third one has received less attention in the international trade field. We address this third shortcoming by adding dynamics, including endogenous trade imbalances, to the static structural approaches used in the quantitative international trade literature. We also see as surprising that the literature on the effects of globalization shocks on labor market outcomes has not directly related the forces that the literature commonly

¹⁰See [Autor et al. \(2016\)](#) for a survey

¹¹[Adao et al. \(2017\)](#) clearly point the first two shortcoming, while has been emphasized more in the literature in international macroeconomics.

identifies as driving the globalization process, that is, falling trade costs, with those commonly assumed to drive structural transformation, namely sectoral-biased technical change and non-homothetic preference. We believe this paper bridges part of this gap in the literature.

The remainder of the paper is organized as follows. Section 2 describes the full open economy model of structural change that we propose. Section 3 considers a simplified version of his model to describe how changes in trade costs in the model lead to structural change. Section 4 describes the data and shows how the model can be mapped to observables in the general case, and applies this mapping to the case of the United States and the rest of the world for the year 1970 until 2007. The main results of the paper are derived in Section 5 where we conduct the counterfactual exercises that deliver the quantitative assessment of declines in trade costs for structural change in the United States.

2 An Open Economy Model of Structural Change

We consider an infinite horizon economy where time is discrete and indexed by $t = 0, 1, \dots$. The world consists of two countries, the United States (US) and the rest of the world (ROW), indexed by $i \in \mathcal{I} \equiv \{US, ROW\}$. Each country is populated by a representative household endowed with $L_{i,t}$ units of homogeneous labor in every period t , and $K_{i,0}$ units of homogeneous physical capital in period $t = 0$. Both factors of production are nontradeable across countries.

Households in both countries have access to international financial markets by means of buying and selling one-period bonds denominated in terms of world currency units and available in zero-net supply around the world. The representative household at time $t = 0$ is born with a stock of these net foreign assets, $W_{i,0}$, such that $\sum_{i \in \mathcal{I}} W_{i,0} = 0$. We will assume that all economic agents have perfect foresight.

Each economy consists of three sectors indexed by $j \in \mathcal{J} \equiv \{a, m, s\}$, referring to agriculture, manufacturing and services respectively. Sectoral goods are nontradeable across countries, however, they are produced by aggregating a continuum of sector-specific varieties that are tradeable and that add value when produced. Nontradeable sectoral goods can be used for consumption, investment or as intermediate inputs in the production of sector-specific varieties.

2.1 Households and Dynamic Decisions

The dynamic dimension of the model comes entirely from the household's saving and investment decisions. We consider the benchmark case in which financial markets are frictionless, which implies that the return on these bonds denominated in a single currency is the same for both countries.

The problem of the representative household in country i is as follows. Household in country i must choose for every $t = 0, 1, \dots$ consumption and investment levels in each sector, as well as next period's aggregate capital stock and bond holdings, $\{\{C_{i,t}^j\}_{j \in \mathcal{J}}, \{X_{i,t}^j\}_{j \in \mathcal{J}}, K_{i,t+1}, B_{i,t+1}\}_{t=0}^\infty$, in order to maximize lifetime utility

$$U_i = \sum_{t=0}^{\infty} \delta^t \phi_{i,t} u(C_{i,t}/L_{i,t}) \quad (1)$$

subject to the sequence of budget constraints

$$\sum_{j \in \mathcal{J}} P_{i,t}^j C_{i,t}^j + \sum_{j \in \mathcal{J}} P_{i,t}^j X_{i,t}^j + B_{i,t+1} = w_{i,t} L_{i,t} + r_{i,t} K_{i,t} + R_t B_{i,t}, \quad (2)$$

and the law of motion for capital

$$K_{i,t+1} = (1 - d) K_{i,t} + \chi_{i,t} (X_{i,t})^\sigma (K_{i,t})^{1-\sigma}, \quad \sigma \in (0, 1), \quad (3)$$

for all t , where aggregate consumption, $C_{i,t}$, is implicitly defined as

$$\sum_{j \in \mathcal{J}} (\mu_{i,t}^j)^{\frac{1}{\psi}} \left(\frac{C_{i,t}^j}{L_{i,t}} \right)^{\frac{\psi-1}{\psi}} = 1, \quad (4)$$

with $\psi \geq 0$, $\mu_{i,t}^j > 0$, $\sum_{j \in \mathcal{J}} \mu_{i,t}^j = 1$ and $\sum_{j \in \mathcal{J}} \mu_{i,t}^j = \kappa_i$ for all $t = 0, 1, \dots$; and aggregate investment combines sectoral investment levels in a constant-elasticity-of-substitution fashion with an elasticity of substitution given by $\zeta \geq 0$,

$$X_{i,t} = \left(\sum_{j \in \mathcal{J}} (v_i^j)^{\frac{1}{\zeta}} (X_{i,t}^j)^{\frac{\zeta-1}{\zeta}} \right)^{\frac{\zeta}{\zeta-1}} \quad (5)$$

with $v_i^j > 0$ and $\sum_{j \in \mathcal{J}} v_i^j = 1$.

The multiple elements of this problem deserve further explanation and clarification. First, notice that household's preferences are subject to two types of shifters

that vary over time, an *intertemporal preference shifter*, $\phi_{i,t}$, that is akin to variations in household's discounting over time, and a set of *sectoral demand shifters*, $\{\mu_{i,t}^j\}_{j \in \mathcal{J}}$, that lead to changes in relative tastes for sectoral goods. These two sets of shifters are part of the set of exogenous structural disturbances of the model leading to changes in the model's endogenous outcomes over time. Second, notice that capital accumulation is subject to adjustment costs parameterized by $\sigma \in (0, 1)$ and that the efficiency of investment for capital accumulation, $\chi_{i,t}$, varies over time. These investment-specific technology shifters are an additional set of disturbances that lead to changes in the world economy's endogenous outcomes over time.

Let us now turn to the details of the consumption and investment aggregators. While the investment aggregator is relatively standard, the definition of aggregate consumption deserves a more detailed explanation. The study of this type of preferences in static, partial-equilibrium models goes back to [Gorman \(1965\)](#) and [Hanoch \(1975\)](#). More recently, [Comin et al. \(2017\)](#) have exploited the fact that this preference specification, which they refer to as *nonhomothetic CES*, incorporates both the relative price and long-run income effects that the literature on structural change in closed economies has emphasized as drivers of structural change in a way that fits the data relatively well.¹² The appealing features of these preferences will become clearer when we solve the households problem in the remainder of the section. This type of utility function will allow the model to incorporate the two main mechanisms that the literature has suggested as driving structural change independently from each other: relative prices effects leading to substitution of expenditure across sectors and long-run income effects driven by nonhomotheticities leading to differences in income elasticities across sectors.¹³

Turning to international borrowing and lending, and capital accumulation, notice that the dynamics in households problems arise entirely through these two decisions. Here, $B_{i,t}$ is the stock of one period bonds in terms of world currency units owned by country i at the beginning of period t . As previously mentioned, in period $t = 0$, these bonds exist in zero-net supply, that is, $\{R_0 B_{i,0}\}_{i=1}^I$ are given and such that $\sum_i R_0 B_{i,0} = 0$. Capital is nontradeable, so households rent it to domestic firms and must use domestic resources to invest and accumulate capital over time. The entire endogenous dynamics of the model will arise through these two channels. In other words, decisions by firms in the model, as we will show in the following subsection, are

¹²[Comin et al. \(2017\)](#) show that this type of preferences can match the data better than other preference specification previously used, like Stone-Geary preferences.

¹³Existing literature has focused on the case of Stone-Geary preferences ([Herrendorf et al., 2014](#)). However, as pointed out by [Comin et al. \(2017\)](#), this type of preferences do not allow the separation of income and price effects.

static.

Solving the problem for the household can be simplified by dividing it into two subproblems, a static subproblem and a dynamic one. Let us first consider the static subproblem that the household faces in period t given choices for $B_{i,t+1}$ and $K_{i,t+1}$. Then, conditional on $C_{i,t}$ which implied by the choices of $B_{i,t+1}$ and $K_{i,t+1}$, the household optimally chooses sectoral consumption expenditure shares across sectors according to

$$s_{i,t}^j \equiv \frac{P_{i,t}^j C_{i,t}^j}{P_{i,t}^C C_{i,t}} = \mu_{i,t}^j \left(\frac{P_{i,t}^j}{P_{i,t}^C} \right)^{1-\psi} \left(\frac{C_{i,t}}{L_{i,t}} \right)^{\epsilon^j - 1}, \quad (6)$$

where $P_{i,t}^C$ denotes the ideal consumption price index given by

$$P_{i,t}^C = \left(\sum_{j \in \mathcal{J}} \mu_{i,t}^j \left(\frac{C_{i,t}}{L_{i,t}} \right)^{\epsilon^j - 1} (P_{i,t}^j)^{1-\psi} \right)^{\frac{1}{1-\psi}} \quad (7)$$

such that total consumption expenditure is given by $E_{i,t}^C \equiv \sum_{j \in \mathcal{J}} P_{i,t}^j C_{i,t}^j = P_{i,t}^C C_{i,t}$ and

$$C_{i,t} = \frac{1}{P_{i,t}^C} (w_{i,t} L_{i,t} + r_{i,t} K_{i,t} - P_{i,t}^X X_{i,t} - N X_{i,t}). \quad (8)$$

From equation (6) we can immediately see how depending on the value of the elasticity of substitution across sectoral consumption, $\psi > 0$, changes in sectoral relative prices can lead to reallocation of consumption expenditure across sectors. This is the sense in which *price effects* can lead to structural change. All else constant, changes in relative prices lead to structural change as long as $\sigma \neq 1$. To the extent that sectoral-biased technical change leads to changes in relative prices, we should see economies going through structural change over time. What the literature has found using data on sectoral prices is that $\sigma < 1$, implying that broadly defined sectoral goods are gross complements (Herrendorf et al., 2013). The second common driver of structural change, long-run income effects, and also be appreciated in equation (6). To isolate this mechanism, suppose for a moment that $\sigma = 1$. Then, (6) and (8) imply that long-run change in income leading to changes in $C_{i,t}$ will lead to nonlinear Engel curves that differ across sectors as long as $\epsilon^j \neq \epsilon^{j'}$ for $j \neq j'$.¹⁴ For instance, long-run economic growth will cause reallocation out of sector j and into j' whenever $\epsilon^j < \epsilon^{j'}$.¹⁵ This preference specification will lead to structural transformation through

¹⁴See Comin et al. (2017) for details on additional features of this preferences.

¹⁵We have chosen to normalize ϵ^j 's such that $\sum_{j \in \mathcal{J}} \epsilon^j = 1$ because this implies that the definition

the aforementioned mechanisms and their implications for sectoral reallocation of final consumption. In addition, as we will see in the Section 3, trade across countries and comparative advantage consideration can also lead to structural change in this model.

Turning now to investment, conditional on the choice of $X_{i,t}$ which is also pinned down by the choices of $B_{i,t+1}$ and $K_{i,t+1}$, the household optimally chooses sectoral investment levels across sectors according to

$$x_{i,t}^j \equiv \frac{P_{i,t}^j X_{i,t}^j}{P_{i,t}^X X_{i,t}} = v_i^j \left(\frac{P_{i,t}^j}{P_{i,t}^X} \right)^{1-\zeta} \quad (9)$$

where $P_{i,t}^X = \left(\sum_{j \in \mathcal{J}} v_i^j (P_{i,t}^j)^{1-\zeta} \right)^{\frac{1}{1-\zeta}}$ and $E_{i,t}^X \equiv \sum_{j \in \mathcal{J}} P_{i,t}^j X_{i,t}^j = P_{i,t}^X X_{i,t}$. Equation (9) implies that price affects will also potentially lead to structural change by reallocating investment expenditures across sectors.¹⁶

Notice that given prices, the ideal price index of aggregate investment, $P_{i,t}^X$, is independent of any choice by the household. However, the consumption ideal price index does depend on the household's optimal choice of aggregate consumption. This point will become relevant when we consider the dynamic problem that the household solves.

Let us now turn to the dynamic subproblem, that is, the optimal determination of $C_{i,t}$ and $X_{i,t}$ implied by the optimal choices of $B_{i,t+1}$ and $K_{i,t+1}$ by the household in country i . Let us rewrite this dynamic problem. Let $\bar{C}_{i,t} \equiv C_{i,t}/L_{i,t}$. Then, the household in country i takes its wealth at $t = 0$ as given, composed of $W_{i,0} \equiv R_0 B_{i,0}$ and $K_{i,0}$, and chooses $\{\bar{C}_{i,t}, X_{i,t}, K_{i,t+1}, B_{i,t+1}\}_{t=0}^{\infty}$ to maximize

$$U_i = \sum_{t=0}^{\infty} \delta^t \phi_{i,t} \ln(\bar{C}_{i,t}) \quad (10)$$

subject to the sequence of budget constraints and the law of motion for capital given by

$$E_{i,t}^C(\bar{C}_{i,t}, \{P_{i,t}^j\}_{j \in \mathcal{J}}) + P_{i,t}^X X_{i,t} + B_{i,t+1} = w_{i,t} L_{i,t} + r_{i,t} K_{i,t} + R_t B_{i,t}, \quad (11)$$

and

$$K_{i,t+1} = (1-d) K_{i,t} + \chi_{i,t} (X_{i,t})^{\sigma} (K_{i,t})^{1-\sigma}, \quad (12)$$

of preferences (4) is consistent with consumption per capita, $C_{i,t}/L_{i,t}$, being an argument without imposing further restriction on other parameters. See Matsuyama (2017).

¹⁶In our baseline calibration of the model this channel of structural transformation will not be present because we set $\zeta = 1$.

respectively for every $t = 0, \dots$, where we have used the fact that total consumption expenditure is a function of aggregate consumption per capita, $\bar{C}_{i,t}$, and sectoral prices, $\{P_{i,t}^j\}_{j \in \mathcal{J}}$, which can be seen directly from the expression of $P_{i,t}^C$ in (7).

The solution to the household's dynamic problem is characterized by a pair of Euler equations. First, the Euler equation corresponding to the optimal choice of bonds,

$$\frac{P_{i,t+1}^C C_{i,t+1}}{P_{i,t}^C C_{i,t}} = \frac{\tilde{\phi}_{i,t+1}}{\tilde{\phi}_{i,t}} \delta R_{t+1}, \quad (13)$$

where $\tilde{\phi}_{i,t} \equiv \phi_{i,t} (1 - \psi) \left(\sum_{j \in \mathcal{J}} \varepsilon^j \varpi_{i,t}^j - \psi \right)^{-1}$ and $\varpi_{i,t}^j \equiv P_{i,t}^j C_{i,t}^j / E_{i,t}^C$. Notice that the change in $\tilde{\phi}_{i,t}$ leads to an Euler equation wedge driven by two forces, exogenous changes in the intertemporal preference shifters and endogenous changes in the sectoral composition of the economy. What these wedges tell us is that, assuming that $\epsilon^s > \epsilon^j$ for $j \in a, m$, as economies develop and $\varpi_{i,t}^s$ increases, the rate at which aggregate consumption is discounted increases. This occurs because tilting consumption expenditure upwards is accompanied by an increase in the price index leading to a decline in the effective return on savings, and that is internalized by the household. Hence, notice that in this model, structural change also has direct implications for optimal dynamic decisions by the household.

The second Euler equation corresponds to optimal capital accumulation decisions and is given by

$$R_{t+1} \frac{P_{i,t}^X}{\chi_{i,t}} \left(\frac{X_{i,t}}{K_{i,t}} \right)^{1-\sigma} = \sigma \left(r_{i,t+1} + (1 - \sigma) \frac{P_{i,t+1}^X X_{i,t+1}}{\sigma K_{i,t+1}} + (1 - d) \frac{P_{i,t+1}^X}{\sigma \chi_{i,t+1}} \left(\frac{X_{i,t+1}}{K_{i,t+1}} \right)^{1-\sigma} \right). \quad (14)$$

In addition, the budget constraint and the law of motion for capital complete the set of equations that characterize the household's problem.

Notice that in this model, as in [Reyes-Heroles \(2016\)](#), changes in trade costs have implications for differences in effective interest rates across countries that have dynamic implications. For instance, in [Reyes-Heroles \(2016\)](#), the decline in trade costs lead to the equalization of effective interest rates across countries over time and an increase in trade imbalances. We will show in [Section 3](#) that these imbalances have implications for structural change. It is in that sense that we need a dynamic model to fully understand the effect of globalization on structural change. In addition, change in trade costs also

affect the evolution of the price of investment, $P_{i,t}^X$. As can be appreciated from (14), this will also affect capital accumulation decisions leading to long-run income effects that affect structural change.¹⁷ That is, in this model declines in trade costs affect structural change thorough multiple channels. The aim of Section 4 and Section ?? is to disentangle the effects of trade costs and how they affect these multiple channels. But first we turn to the specifications of technologies in the model.

2.2 Technologies: Nontradable Sectoral Goods

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

$$Q_{i,t}^j = \left(\int_0^1 d_{i,t}^j(\omega^j)^{\frac{\eta-1}{\eta}} d\omega^j \right)^{\frac{\eta}{\eta-1}}, \quad (15)$$

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

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

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

2.3 Technologies: Tradable Goods

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

$$q_{i,t}^j(\omega^j) = x_{i,t}^j(\omega^j) \left[k_{i,t}^j(\omega^j)^{\varphi_i} l_{i,t}^j(\omega^j)^{1-\varphi_i} \right]^{\beta_i^j} [M_{i,t}^j(\omega^j)]^{1-\beta_i^j}, \quad (16)$$

¹⁷See Ravikumar et al. (2017) for the effects of lower trade costs on capital accumulation

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

$$M_{i,t}^j(\omega^j) = \prod_{m=1}^J D_{i,t}^{j,m}(\omega^j)^{\nu_i^{j,m}}, \quad (17)$$

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

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

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

$$F_{i,t}^j(x|t) = \Pr[x_{i,t}^j \leq x] = e^{-T_{i,t}^j x^{-\theta}}. \quad (18)$$

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

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

2.4 Technologies: Trade Costs and Firms' Optimal Decisions

For each sector $j = 1, \dots, J$, goods $\omega^j \in [0, 1]$ can be traded across countries, but are subject to iceberg type trade costs. Specifically, $\tau_{ih,t}^j \geq 1$ denotes the cost of shipping any good $\omega^j \in [0, 1]$ from country h to country i at time t . This means that, in order for one unit of variety ω^j to be available in country i at time t , country h must ship

$\tau_{ih,t}^j$ units of the good. I assume that $\tau_{ii,t}^j = 1$ for all $i = 1, \dots, I$, *i.e.* there are no trade costs associated with trading goods within countries.

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

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

$$c_{i,t}^j = \varkappa_i^j \left[\left((r_{i,t})^{\varphi_i} (w_{i,t})^{1-\varphi_i} \right)^{\beta_i^j} \left(\prod_{m=1}^J (P_{i,t}^m)^{\nu_i^{j,m}} \right)^{1-\beta_i^j} \right] \quad (19)$$

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

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

$$L_{i,t}^j = \int_{\mathbb{R}_+^I} l_{i,t}^j(x^j) \varrho^j(x^j|t) dx^j, \quad (20)$$

$$K_{i,t}^j = \int_{\mathbb{R}_+^I} k_{i,t}^j(x^j) \varrho^j(x^j|t) dx^j, \text{ and} \quad (21)$$

$$D_{i,t}^{j,m} = \int_{\mathbb{R}_+^I} D_{i,t}^{j,m}(x^j) \varrho^j(x^j|t) dx^j. \quad (22)$$

Let us now turn to the problem faced by the nontradable sectoral goods producers. Given the price of each variety $\omega^j \in [0, 1]$ that the representative firm is faced with, $p_{i,t}^j(\omega^j)$, the firm solves a cost minimization problem which delivers demand functions,

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

conditional on $Q_{i,t}^j$, for each tradable good $\omega^j \in [0, 1]$ given by $d_{i,t}^j(\omega^j) = \left(\frac{P_{i,t}^j}{p_{i,t}^j(\omega^j)} \right)^\eta Q_{i,t}^j$, where

$$p_{i,t}^j(\omega^j) = \min_h \{p_{h,t}^j(\omega^j)\} = \min_h \left\{ \frac{c_{h,t}^j \tau_{ih,t}^j}{x_{h,t}^j(\omega^j)} \right\} \quad (23)$$

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

$$P_{i,t}^j \equiv \left(\int_0^1 p_{i,t}^j(\omega^j)^{1-\eta} d\omega^j \right)^{\frac{1}{1-\eta}}. \quad (24)$$

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 (23). This is an important difference of this model relative to Armington-type models in which each good is origin-specific.

2.5 Technologies: Prices and Trade Shares

Given these distributions of productivities, we can derive an expression for sectoral price indices in equilibrium as functions of all sectoral prices, factor prices, and trade costs around the world. These prices are conditional on the known values of sectoral productivities, $T_{i,t}^j$, and bilateral trade costs, $\tau_{ih,t}^j$, in period t . Using (24) 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 . These prices are given by

$$P_{i,t}^j = \Gamma [\Phi_{i,t}^j]^{-\frac{1}{\theta}}, \quad (25)$$

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

$$\Phi_{i,t}^j = \sum_{h=1}^I T_{h,t}^j (c_{h,t}^j \tau_{ih,t}^j)^{-\theta} \quad (26)$$

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

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

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

$$\pi_{ih,t}^j = \frac{T_{h,t}^j (c_{h,t}^j \tau_{ih,t}^j)^{-\theta}}{\Phi_{i,t}^j}, \quad (27)$$

and are such that $\sum_{h=1}^I \pi_{ih,t}^j = 1$ for all $i = 1, \dots, I$ and $j = 1, \dots, J$. Note that by the expression that we obtained before for equilibrium prices, equation (25), we can rewrite this share in terms of the sectoral price in country i as

$$\pi_{ih,t}^j = (\Gamma^{-\theta}) T_{h,t}^j \left(\frac{c_{h,t}^j \tau_{ih,t}^j}{P_{i,t}^j} \right)^{-\theta}. \quad (28)$$

These prices and trade shares fully summarize the optimal decisions by the firms given technologies and factor prices, as well as bilateral trade flows given sectoral expenditure levels in all countries. This can be appreciated in (25), which implicitly defines sectoral prices as a function of factor prices, and (28), which defines all bilateral trade shares given these sectoral prices.

2.6 Market Clearing Conditions

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

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

$$C_{i,t}^j + X_{i,t}^j + \sum_{k=1}^J D_{i,t}^{k,j} = Q_{i,t}^j \quad (29)$$

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 (29)

states that demand for nontradable goods must equal supply in each country i . We can reformulate this condition in terms of expenditures, in which case we can appreciate that total expenditure in goods in sector j in equilibrium must be given by

$$E_{i,t}^j = P_{i,t}^j C_{i,t}^j + P_{i,t}^j X_{i,t}^j + \sum_{m=1}^J P_{i,t}^j D_{i,t}^{m,j}. \quad (30)$$

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

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

$$Y_{i,t}^j = \sum_{h=1}^I \pi_{hi,t}^j E_{h,t}^j, \quad (31)$$

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

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

$$B_{i,t+1} - R_t B_{i,t} = \sum_{j=1}^J (Y_{i,t}^j - E_{i,t}^j). \quad (32)$$

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.

3 Globalization and Structural Change

We now turn to investigate in more detail how changes in trade costs affect the process of structural transformation in a particular country. In order to do so, we will focus on the value added share of one particular sector and country, namely the United States. Furthermore, we will simplify things by considering the case in which there is no investment nor intermediate inputs, that is, $\beta_i^j = 1$ for all $j \in \mathcal{J}$. These simplifications will help us understand the main mechanisms through which changes in trade costs lead to structural change. Since we are considering the case without investment, there is no longer an aggregate price for investment and we will use $P_{i,t}$ to refer to the ideal price index for consumption in Section 2, $P_{i,t}^C$.

We will proceed in steps. Let us first consider the case of autarky, this is, $\tau_{USROW,t}^m = \infty$ and trade is balanced in every period, $NX_{US,t} = 0$ for all t . In this case we have that, for the United States, the value added share in sector j is given by

$$\begin{aligned} va_{US,t}^j &= s_{US,t}^j = \mu_{US,t}^j \left(\frac{P_{US,t}^j}{P_{US,t}} \right)^{1-\psi} \left(\frac{C_{US,t}}{L_{US,t}} \right)^{\epsilon^j-1} \\ &= \mu_{US,t}^j \left(\frac{P_{US,t}^j}{P_{US,t}} \right)^{1-\psi} \left(\frac{w_{US,t}}{P_{US,t}} + \frac{r_{US,t}}{P_{US,t}} \frac{K_{US,t}}{L_{US,t}} \right)^{\epsilon^j-1} \end{aligned} \quad (33)$$

where $P_{US,t}^j = (T_{US,t}^j)^{-\frac{1}{\theta}} c_{US,t}^j$ which implies that

$$\begin{aligned} \frac{va_{US,t}^j}{va_{US,t}^{j'}} &= \frac{\mu_{US,t}^j}{\mu_{US,t}^{j'}} \left(\frac{P_{US,t}^j}{P_{US,t}^{j'}} \right)^{1-\psi} \left(\frac{w_{US,t}}{P_{US,t}} + \frac{r_{US,t}}{P_{US,t}} \frac{K_{US,t}}{L_{US,t}} \right)^{\epsilon^j-\epsilon^{j'}} \\ &= \frac{\mu_{US,t}^j}{\mu_{US,t}^{j'}} \left(\frac{T_{US,t}^j}{T_{US,t}^{j'}} \right)^{-\frac{1-\psi}{\theta}} \left(\frac{w_{US,t}}{P_{US,t}} + \frac{r_{US,t}}{P_{US,t}} \frac{K_{US,t}}{L_{US,t}} \right)^{\epsilon^j-\epsilon^{j'}} \end{aligned} \quad (34)$$

for two sectors $j \neq j'$, where the second equality follows from the fact that in the absence of intermediates, $c_{US,t}^j = c_{US,t}^{j'}$.²⁰

Equation (34) reflects the two mechanisms driving structural change in closed economy models. To isolate each of these mechanisms, consider first the extreme case in which preferences are homothetic, this is, $\epsilon^j = 1$ for all $j \in \mathcal{J}$. I will refer to this case as *homothetic*. Then, notice that all changes in value added shares are driven by sectoral biased technical change as long as $\psi \neq 1$. That is, absent changes in relative

²⁰We are also assuming equal factor intensities in production across countries.

sectoral productivities over time, sectoral value added shares would remain constant over time. Now consider the case in which technical change is neutral, that is, sectoral productivities grow at exactly the same rate and preferences are non-homothetic. Then, income growth will generate changes in value added shares over time depending on the values of $\epsilon^j \neq 1$ for each $j \in \mathcal{J}$.

Let us now consider a second case in which countries trade with each other, but trade is balanced in every period, that is, countries are in financial autarky, implying that $NX_{US,t} = 0$ for all t . In this case we have that

$$va_{US,t}^j = s_{US,t}^j + \left(\pi_{ROWUS,t}^j s_{ROW,t}^j \frac{GDP_{ROW,t}}{GDP_{US,t}} - \pi_{USROW,t}^j s_{US,t}^j \right) \quad (35)$$

where $GDP_{i,t} = w_{i,t}L_{i,t} + r_{i,t}K_{i,t}$,

$$s_{i,t}^j = \mu_{i,t}^j \left(\frac{P_{i,t}^j}{P_{i,t}} \right)^{1-\psi} \left(\frac{w_{US,t}}{P_{US,t}} + \frac{r_{US,t}}{P_{US,t}} \frac{K_{US,t}}{L_{US,t}} \right)^{\epsilon^j - 1} \quad (36)$$

$$P_{i,t}^j = \left(\frac{T_{i,t}^j}{\pi_{ii,t}^j} \right)^{-\frac{1}{\theta}} c_{i,t}^j, \quad (37)$$

for $i \in \mathcal{I}$, and trade shares, $\pi_{ih,t}^j$, are defined as in (27). Define the first term in equation (35) as the *expenditure effect*, which determines value added shares independently of the economy being open or closed, and the second term as the *sectoral net exports effect*, which arises only when we consider an open economy. Notice that in this case the value added shares also depend on how much a country net exports in a particular sector. Sectoral net exports are in turn determined by sectoral trade shares, final expenditure shares given by (36), and a country's size relative to the other. Hence, a decline in a country's net exports of a particular sectoral good would lead to a decline in its sectoral value added share, assuming that the *expenditure effect* remains constant. It is in this sense that an open economy framework changes a country's process of structural transformation by delinking production from expenditure in the country.

It is important to mention that independently of the *sectoral net exports effect*, changes in trade costs affect structural change. Suppose that countries are symmetric and consider two cases, when trade costs are constant and when trade costs decline over time. Notice that in both cases the *sectoral net exports effect* vanishes, but declining trade costs accelerate any existing process of structural transformation by affecting both the *SBTC* and the *NH* mechanisms. Declining trade costs lead to decreasing domestic

trade shares, $\pi_{ii,t}^j$, which imply faster declines in sectoral prices as can be appreciated in (37), reinforcing the *SBTC* mechanism. Declines in trade costs also reinforce the *NH* mechanism by making countries richer over time.

Lastly, consider the *homothetic* case. Notice that even though it seems as if value added shares now depend on a country's income, this cannot be true. This fact can be checked by means of contradiction. Suppose there is a change, say positive, in $GDP_{US,t}$ such that value added shares are affected while everything else stays constant. Then, since these shares must decrease on all sectors, this would imply that the share would no longer add up to 1, which is contradicts the definition of shares. Therefore, in the *homothetic* case for an open economy under balanced trade, value added shares do not depend on a country's income.

We now turn to the most general case in which balanced trade is not imposed period by period. In this case we have that

$$va_{US,t}^j = s_{US,t}^j(1 - nx_{US,t}) + \left(\pi_{ROWUS,t}^j s_{ROW,t}^j (1 + nx_{US,t}) \frac{GDP_{ROW,t}}{GDP_{US,t}} - \pi_{USROW,t}^j s_{US,t}^j (1 - nx_{US,t}) \right) \quad (38)$$

where $s_{i,t}^j$ and $P_{i,t}^j$ are given by (36) and (37) respectively, and $nx_{US,t}$ denotes U.S. net exports as a share of its GDP. We can clearly see in (38) how changes in net exports work similarly to simple transfers across countries. A trade deficit in the United States is like a transfer from the rest of the world. This transfer increases expenditure in the United States leading to a potential increase in the value added share of any sector through the *expenditure effect*, however, the *sectoral net exports effect* must respond in order to level out such increase in all shares. In a sector in which *ROW* has comparative advantage, say $j = m$, we would have that for tradeable sectors q and m ,

$$\frac{\pi_{USROW,t}^m}{\pi_{ROWUS,t}^m} > \frac{\pi_{USROW,t}^a}{\pi_{ROWUS,t}^a}. \quad (39)$$

This condition would imply that the increase in the aggregate trade deficit in the United States, assuming that expenditure shares are not too different across countries, would lead to a decline in the manufacturing value added share.

4 Taking the Model to the Data

In this section of the paper we calibrate a particular version of the model which we will then use to conduct counterfactual exercises in Section 5. The particular version that we consider is when capital adjustment costs are infinite, that is, when $\sigma = 0$. In this particular case, equation (14) does not longer hold, the evolution of investment expenditure is no longer pinned down by the equilibrium conditions of the model and additional data is needed to recover investment-specific-efficiency shifters. In the remainder of this section we will show the general procedure to recover all structural disturbances of the model when $\sigma \in (0, 1)$, and will leave the details regarding additional data and assumptions needed to take the model to the data when $\sigma = 0$ for the end of the section.

We now proceed to calibrate the model to observed data for the period 1970 to 2007. The calibration requires the identification of the model's time-invariant parameters and time-varying exogenous variables. Time-varying exogenous variables can be divided into those that are directly observed in the data and those that are not. The set of exogenous variables that are not observed are the ones we call disturbances and are given by $\{\mathcal{S}_t\}_{t=0}^\infty$, where

$$\mathcal{S}_t \equiv \{\tau_{ih,t}^j, T_{i,t}^j, \mu_{i,t}^j, \phi_{i,t}, \chi_{i,t}\}_{i,h=1,\dots,I} \quad (40)$$

for all t . We 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, aggregate investment expenditure and net exports. This implies that these disturbances provide a decomposition of the forces underlying the evolution of this data. In other words, given parameter values and observed exogenous variables of the model, we recover a set of structural residuals that rationalizes the data as an equilibrium of the model.

We consider the case of two countries, the United States and the rest of the world.²¹ We will also consider the case in which the services sector, $j = m$, is non-tradeable. However, we will take into account trade imbalances in this sector, $NX_{i,t}^s$, as one of the disturbances that can be directly observed in the data. Lastly, I assume that households value consumption in every period according to $u(\cdot) = \ln(\cdot)$.

²¹The ROW was constructed using a set of 24 countries and an aggregate of the rest of the world. The 24 countries considered are Australia, Austria, Belgium, Brazil, Canada, China, Denmark, Finland, France, Germany, Greece, India, Italy, Japan, Korea, Mexico, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, UK and Venezuela.

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)
ζ	1	Elasticity of substitution in investment	Atalay (2015)
σ	0	Investment adjustment costs	No capital accumulation
v_i^j	-	Aggregate investment expenditure shares	Sectoral Data)
ψ	0.57	Elasticity of substitution in consumption	Comin et al. (2015)
ϵ^j	-	Preference parameters	Comin et al. (2015)
δ	0.95	Discount factor	In line with annual data
d	0.05	Depreciation rate	In line with annual data

The procedure to take the model to the data can be summarized as follows. Given values for time-invariant parameters β_i^j , $\nu_i^{j,k}$, φ_i , θ , η , v_i^j , ζ , ϵ^j , ψ , δ , d and σ for all i and j, k and series for exogenous variables observed in the data (endowments), we calibrate disturbances given by (1) trade costs, $\tau_{ih,t}^j$; (2) sectoral productivities, $T_{i,t}^j$; (3) sectoral demand shifters, $\mu_{i,t}^j$; (4) intertemporal preference shifters, $\phi_{i,t}$; and (5) investment-specific efficiency shifters, $\chi_{i,t}$, so that the model's equilibrium outcomes match data on (1) bilateral trade shares, $\pi_{ih,t}^j$, in tradable sectors $j = a, m$; (2) sectoral prices in tradeable sectors, $P_{i,t}^j$ for $j = a, m$, and GDP prices, $P_{i,t}$; (3) sectoral expenditure levels, $E_{i,t}^j$; (4) aggregate net exports, $NX_{i,t}$; and (5) investment expenditures, $E_{i,t}^X$.

Let us define the following set of observables for any $t = 1970, \dots, 2007$ and $i, h = 1, \dots, I$,

$$\mathcal{D}_t = \{L_{i,t}, K_{i,t}, NX_{i,t}, GDP_{i,t}, P_{i,t}, \{Y_{i,t}^j\}_{j \in \mathcal{J} \setminus s}, E_{i,t}^X, \{P_{i,t}^j\}_{j \in \mathcal{J} \setminus s}, \{X_{ih,t}^j\}_{j \in \mathcal{J} \setminus s}\}_{\forall i,h}. \quad (41)$$

Table 1 provides the parameter values considered along with the sources used to choose these values. Hence, given values for time-invariant parameters and the set of observables, we present a set of lemmas that go over the procedure to identify all disturbances in the model using the available data step by step.

First we proceed to recover sectoral demand shifters, $\{\mu_{i,t}^j\}_{j \in \mathcal{J}}$. Lemma 4.1 shows how we can use the demand systems for sectoral consumption and investment together with market clearing conditions and a normalization for each country to recover this set of disturbances.²²

²²The choice of normalization is innocuous for the dynamics of the model. It can be shown, however, that the relative normalization, κ_{US}/κ_{ROW} , is equivalent to choosing relative prices across countries in the nontradeable sector. If these data was readily available at a particular point in time we could

Lemma 4.1 (Sectoral Demand Shifters) *Given time-invariant parameter values and data $\mathcal{D}_t$ for $t = 1970, \dots, 2007$; there is a one-to-one mapping between observables and sectoral demand shifters $\{\mu_{i,t}^j\}_{j \in \mathcal{J}}$ given by the following set of equations consisting of equilibrium conditions and model restrictions:*

$$\mu_{i,t}^j = \frac{Y_{i,t}^j - NX_{i,t}^j - \sum_{m \in \mathcal{J}} P_{i,t}^j D_{i,t}^{m,j} - \mu_i^{Xj} \left(\frac{P_{i,t}^j}{P_{i,t}^X} \right)^{1-\psi^X} P_{i,t}^X X_{i,t}}{L_{i,t} (P_{i,t}^j)^{1-\psi} \left(\frac{E_{i,t}^C}{L_{i,t}} \right)^\psi \left(\frac{C_{i,t}}{L_{i,t}} \right)^{\varepsilon^j - \psi}} \text{ for } j \in \mathcal{J} \setminus s,$$

$$\mu_{i,t}^s = \frac{1 - \sum_{j \in \mathcal{J} \setminus s} \mu_{i,t}^j \left(\frac{P_{i,t}^j}{P_{i,t}^C} \right)^{1-\psi} \left(\frac{C_{i,t}}{L_{i,t}} \right)^{\varepsilon^j - 1}}{\left(\frac{P_{i,t}^s}{P_{i,t}^C} \right)^{1-\psi} \left(\frac{C_{i,t}}{L_{i,t}} \right)^{\varepsilon^s - 1}}, \text{ and } \kappa_i = \sum_{j \in \mathcal{J}} \mu_{i,t}^j.$$

Proof See Appendix.

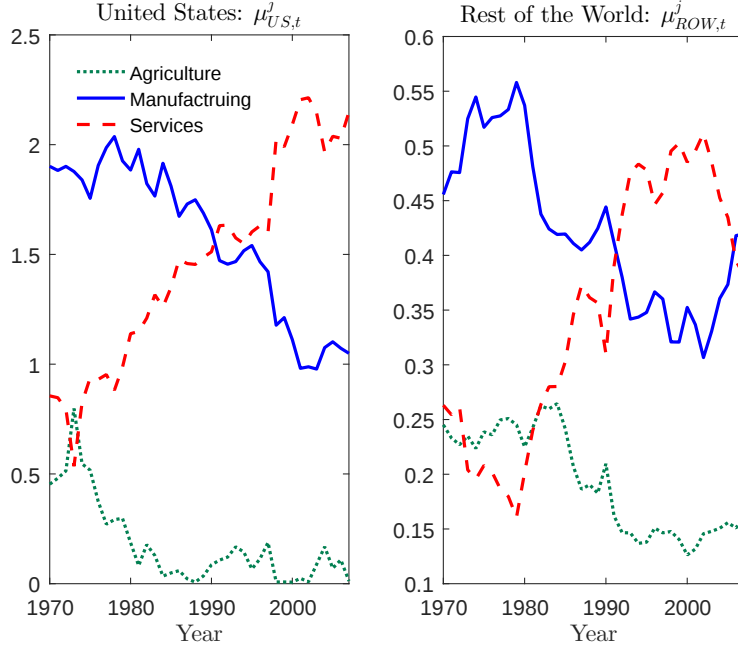
The evolution of the sectoral demand shifters for the US and ROW is depicted in Figure 2. The figure shows that there is still a sizeable amount of structural change that cannot be explained by the endogenous structural change generated by the model's current parametrization. This exogenous structural change is being picked by the sectoral demand shifters. This is a common issue in the literature, in particular for the case of the United States, as is pointed out by Comin et al. (2017).

Lemma 4.2 shows how the static structure of the model, the multisector-gravity equations, can be inverted to recover separately sectoral productivities and trade costs exploiting data on relative prices and bilateral trade shares. The fact that that we can separately identify these disturbances from aggregate disturbance—sectoral demand and investment-specific-efficiency shifter—comes from the separation between the static-trade structure of the model and the dynamic decisions by the household. This appealing feature will become apparent in the lemmas to follow after Lemma 4.2.

Lemma 4.2 (Productivities and Trade Costs) *Given time-invariant parameter values and data $\mathcal{D}_t$; there is a one-to-one mapping between observables and the disturbances $\{\tau_{ih,t}^j\}_{j \in \mathcal{J} \setminus S}$ and $\{T_{i,t}^j\}_{j \in \mathcal{T}}$ in period t given by the following set of equations*

discipline this relative normalization.

Figure 2: Evolution of Sectoral Demand Shifters



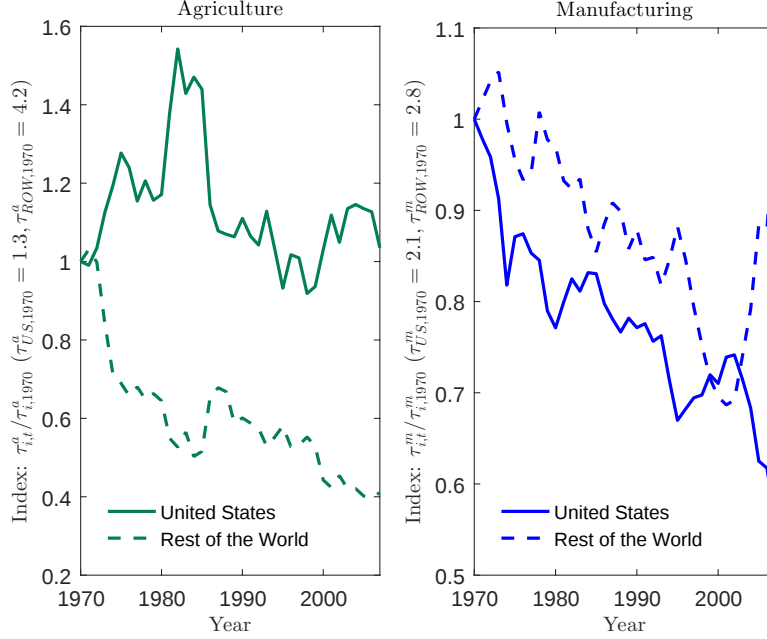
consisting of equilibrium conditions and model restrictions:

$$\begin{aligned} \tau_{ih,t}^j &= \frac{P_{i,t}^j}{P_{h,t}^j} \left(\frac{\pi_{hh,t}^j}{\pi_{ih,t}^j} \right)^{\frac{1}{\theta}} \quad \text{for } j \in \mathcal{J} \setminus S, \\ \pi_{ii,t}^j &= T_{i,t}^j \left(\Gamma^j \frac{c_{i,t}^j}{P_{i,t}^j} \right)^{-\theta} \quad \text{for } j \in \mathcal{J} \setminus S \text{ and } \pi_{ii,t}^j = 1 \text{ for } j = S, \text{ and} \\ \tau_{ih,t}^S &= \infty \text{ for all } i \neq h. \end{aligned}$$

Proof See Appendix.

Figure 3 plots the evolution of the sectoral trade costs in each country, $\tau_{ih,t}^j$. The trade costs that *ROW* needs to pay in order to import goods from *US* follow a clear long-run downward trend at least until the early 2000s. However, the evolution of these costs for *US* differs across sectors. There is a clear decline in trade costs in the manufacturing sector throughout the entire period, but this is not the case in the agricultural sector. For this sector in the *US* there is a clear long-run decline in trade costs beginning in the early 1980s, but the high variability in these costs is clear from

Figure 3: Evolution of Sectoral Trade Costs

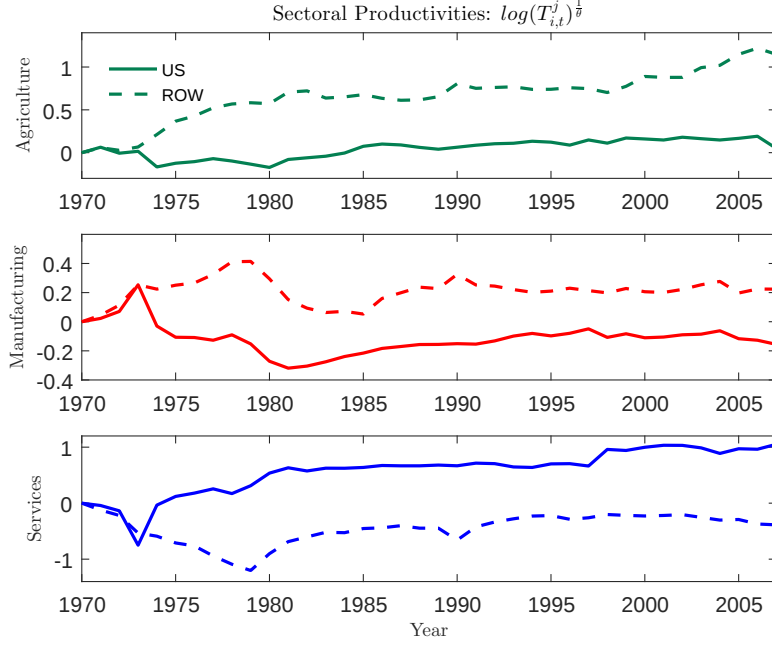


the figure and deserves further investigation. Interestingly, there is a very large spike in the manufacturing trade costs for the rest of the world, $\tau_{ROWUS,t}^m$, in the early 2000s. This feature deserves further investigation as it happens precisely at the point in time when the United States started running very large trade deficits and this increase in costs might be picking up other factors that happened abroad that disappear because when we aggregate countries into the ROW and forget about heterogeneity across all other countries.

Let us now turn to the evolution of sectoral productivities. Figure 4 plots the evolution of these productivities, more specifically, of $\log(T_{i,t}^j)^{\frac{1}{\theta}}$ for $i \in \mathcal{I}$. The evolution of these productivities is in line with what the structural transformation literature has documented when considering closed economy frameworks after the early 1980s. Notice that there are some significant swings in the 1970s, however, beginning in the 1980s it is clear the productivity in the agriculture sector grows at the fastest rate, followed by that of manufacturing and last that of services. Notice that Figure 4 plots fundamental sectoral productivities, while measured productivities, those we would obtain by simply computing $\frac{P_{i,t}^j}{c_{i,t}^j} = \left(\frac{T_{i,t}^j}{\pi_{ii,t}^j}\right)^{-\frac{1}{\theta}}$ would also reflect the fact that trade improves efficiency in production in the tradeable sectors.

We now turn to recover the third set of disturbances of the model, the intertemporal

Figure 4: Evolution of Sectoral Productivities



preference shifters. To do so, we proceed as follows. Given aggregate investment expenditures, $P_{i,t}^X X_{i,t}$, and net exports, $NX_{i,t}$, we solve the model period by period and recover the equilibrium prices and quantities such that the model matches the data. Next, we rely on the Euler equations for bonds in each country $i \in \mathcal{I}$, to solve for the equilibrium world interest rate, that is, the interest rate that clears international financial markets. This procedure is done as follows. Notice that market clearing in bonds market, $\sum_{i \in \mathcal{I}} B_{i,t+1} = 0$, implies that in every t ,

$$\sum_{i \in \mathcal{I}} (w_{i,t} L_{i,t} + r_{i,t} K_{i,t} - E_{i,t}^X) = \sum_{i \in \mathcal{I}} E_{i,t}^C. \quad (42)$$

In addition, from (13) we have that

$$\frac{E_{i,t+1}^C}{E_{i,t}^C} = \hat{\phi}_{i,t+1} \delta R_{t+1}, \quad (43)$$

where $\hat{\phi}_{i,t+1} \equiv \tilde{\phi}_{i,t+1} / \tilde{\phi}_{i,t}$, $\tilde{\phi}_{i,t} = \phi_{i,t} (1 - \psi) \left(\sum_{j \in \mathcal{J}} \varepsilon^j \varpi_{i,t}^j - \psi \right)^{-1}$ and $\varpi_{i,t}^j \equiv P_{i,t}^j C_{i,t}^j / E_{i,t}^C$.

Hence, from (42) and (43), we obtain that the equilibrium interest rate is given by

$$R_{t+1} = \frac{1}{\delta} \left(\sum_{i \in \mathcal{I}} \frac{E_{i,t+1}^C}{\hat{\phi}_{i,t+1}} \right) \left(\sum_{i \in \mathcal{I}} E_{i,t}^C \right)^{-1}. \quad (44)$$

Substituting the equilibrium interest rate into the two Euler equation delivers a system of equations that identifies the Euler equation wedges, $\hat{\phi}_i, t$, up to a normalization. We will normalize the Euler equation wedge in the ROW to unity. Notice that the change in the fundamental intertemporal trade shifters, $\frac{\phi_{i,t+1}}{\phi_{i,t}}$, can then be simply recovered using the fact that

$$\hat{\phi}_{i,t+1} = \frac{\phi_{i,t+1}}{\phi_{i,t}} \frac{\left(\sum_{j \in \mathcal{J}} \varepsilon^j \varpi_{i,t+1}^j - \psi \right)}{\left(\sum_{j \in \mathcal{J}} \varepsilon^j \varpi_{i,t}^j - \psi \right)}. \quad (45)$$

Hence, we obtain the following lemma.

Lemma 4.3 (Intertemporal Preference Shifters) *Given time-invariant parameter values and data $\mathcal{D}_t$; there is a one-to-one mapping up to a normalization between observables and the change in disturbances, $\frac{\phi_{i,t+1}}{\phi_{i,t}}$, given by the following set of equations consisting of equilibrium conditions and model restrictions:*

$$\sum_{i \in \mathcal{I}} B_{i,t+1} = 0, \quad \frac{P_{i,t+1}^C C_{i,t+1}}{P_{i,t}^C C_{i,t}} = \hat{\phi}_{i,t+1} \delta R_{t+1}, \text{ and}$$

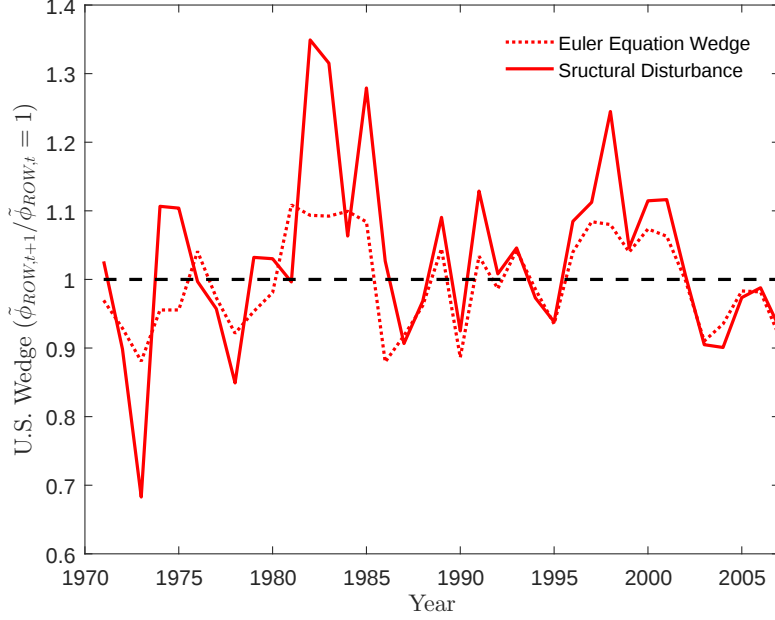
$$\hat{\phi}_{i,t+1} = \frac{\phi_{i,t+1}}{\phi_{i,t}} \frac{\left(\sum_{j \in \mathcal{J}} \varepsilon^j \varpi_{i,t+1}^j - \psi \right)}{\left(\sum_{j \in \mathcal{J}} \varepsilon^j \varpi_{i,t}^j - \psi \right)}.$$

Proof See the text above.

Figure 5 shows the evolution of the US Euler equation wedges, $\hat{\phi}_U S, t$, as well as that of the changes in the actual structural disturbances—the intertemporal preference shifters—. Two important features of the evolution of these wedges is that they show no clear trend in their level nor their volatility. Interestingly, the changes in actual structural residuals show more volatility than the Euler equation wedges.

We now proceed to recover the last set of disturbances of the model, the investment-specific-efficiency shifters. Notice that according to the model, equilibrium investment

Figure 5: Evolution of Intertemporal Preference Shifters in the U.S.



decisions are such that for any given t the following two equations must hold:

$$R_{t+1} \frac{P_{i,t}^X}{\chi_{i,t}} \left(\frac{X_{i,t}}{K_{i,t}} \right)^{1-\sigma} = \sigma \left(r_{i,t+1} + (1-\sigma) \frac{P_{i,t+1}^X X_{i,t+1}}{\sigma K_{i,t+1}} + (1-d) \frac{P_{i,t+1}^X}{\sigma \chi_{i,t+1}} \left(\frac{X_{i,t+1}}{K_{i,t+1}} \right)^{1-\sigma} \right) \text{ and}$$

$$K_{i,t+1} = (1-d) K_{i,t} + \chi_{i,t} (X_{i,t})^\sigma (K_{i,t})^{1-\sigma}.$$

We proceed in two steps. First, we use data on investment expenditure to recover the capital stock that is consistent with the equilibrium of the model that is arbitrarily close to its steady state after T periods for T large. Then we use these capital stocks to recover the investment-specific-efficiency shifters.

To carry out the first step, suppose that at any period t , we know the values of all variables at $t+1$.²³ Then, notice that the two previous equations define a system of two

²³To carry out this procedure and recover capital stocks in a reverse fashion we use the fact that the model reaches a steady state that is uniquely pinned down by initial conditions. See [Eaton et al. \(2015\)](#) and [Reyes-Heroles \(2016\)](#) for more details on how to carry out this procedure and how to use additional data to pin down initial conditions of the model for the net foreign asset distribution across countries.

nonlinear equations and two unknowns, namely, $\frac{(P_{i,t}^X)^\sigma}{\chi_{i,t}}$ and $K_{i,t}$. This system is given by

$$\begin{aligned}\kappa_{i,t+1}^1 &= \frac{(P_{i,t}^X)^\sigma}{\chi_{i,t}} \left(\frac{P_{i,t}^X X_{i,t}}{K_{i,t}} \right)^{1-\sigma}, \\ \kappa_{i,t+1}^2 &= (1-d) K_{i,t} + \chi_{i,t} (P_{i,t}^X)^{-\sigma} (P_{i,t}^X X_{i,t})^\sigma (K_{i,t})^{1-\sigma},\end{aligned}$$

where

$$\begin{aligned}\kappa_{i,t+1}^1 &\equiv \frac{\sigma}{R_{t+1}} \left(r_{i,t+1} + (1-\sigma) \frac{P_{i,t+1}^X X_{i,t+1}}{\sigma K_{i,t+1}} + (1-d) \frac{P_{i,t+1}^X}{\sigma \chi_{i,t+1}} \left(\frac{X_{i,t+1}}{K_{i,t+1}} \right)^{1-\sigma} \right) \text{ and} \\ \kappa_{i,t+1}^2 &\equiv K_{i,t+1}\end{aligned}$$

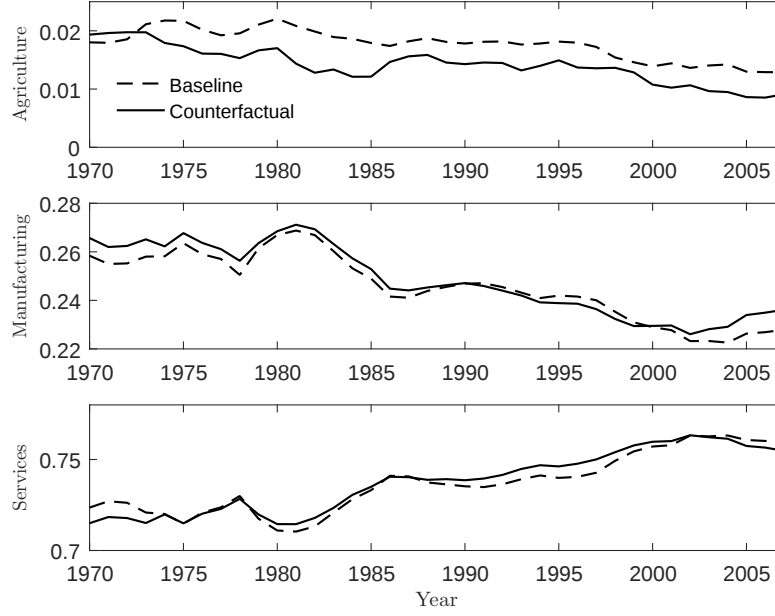
are known in period t . Notice then that, given $\kappa_{i,t+1}^1$, $\kappa_{i,t+1}^2$ and data on $P_{i,t}^X X_{i,t}$, we can recover capital stocks by iterating backwards starting from the steady state of the model and then use the law of motion for capital, (12), to recover the investment-specific shifters in every period.

The previous procedure describes how to recover the investment-specific-efficiency shifters when $\sigma \in (0, 1)$. However, notice that this procedure cannot be carried out in the case in which $\sigma = 0$. In this case, additional data for capital stocks could be used to recover this shifters using only the law of motion for capital (12). However, these disturbances are no longer informative to carry out counterfactual exercises and investment expenditure is no longer pinned down by equilibrium conditions. Our strategy in this case is to assume that the investment rates observed in the data, $E_{i,t}^X/GDP_{i,t}$, do not change in the counterfactual equilibria that we consider. We follow this strategy in the following section when we conduct our counterfactual experiments.

5 Counterfactuals

In this section we derive our main results by conducting counterfactual exercises in which we compute the competitive equilibria of the model under counterfactual configurations in the evolution of trade costs. We conduct two counterfactual exercises. The first exercise, conducted in Section 5.1, considers the case in which trade costs around the globe, that is, in all countries and sectors, remain constant at their levels in the year 1970 throughout the time period considered. The second exercise is conducted in Section ?? and considers the case in which only trade costs in the United States remain

Figure 6: Evolution of Value Added Shares in the U.S.



constant at their levels of 1970, while trade costs paid by the *ROW* decline over time.

5.1 Counterfactual: Trade Costs Fixed to 1970

See Figure 6.

5.2 Counterfactual: $\tau_{USROW,t}^m$ Fixed to 1970

See Figure 7.

5.3 Summary of Results

Table 2 provides a summary of the results of the previous exercises. In addition, Figure 8 shows the evolution of the share of the U.S. in world GDP as well as the evolution of trade imbalances across for the counterfactuals.

6 Conclusions

TBD

Figure 7: Evolution of Value Added Shares in the U.S.

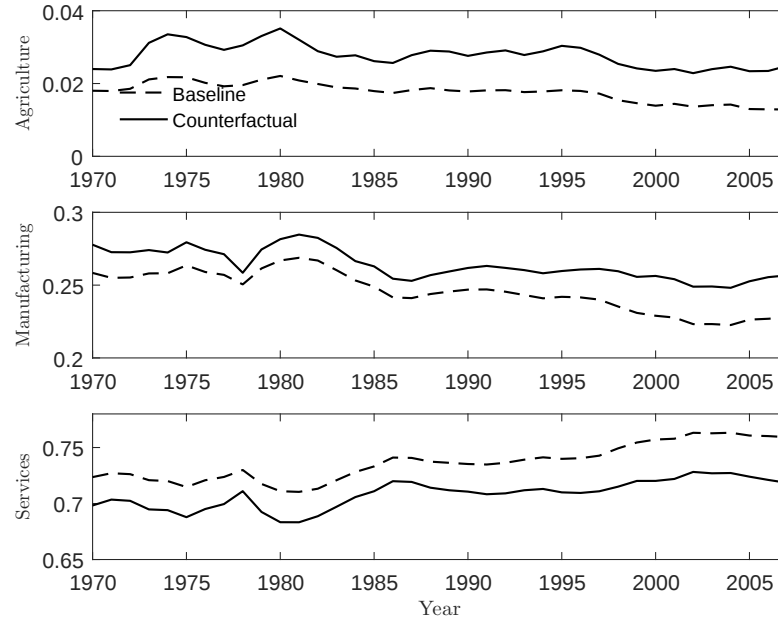


Figure 8: Evolution of Trade Imbalances and U.S. GDP

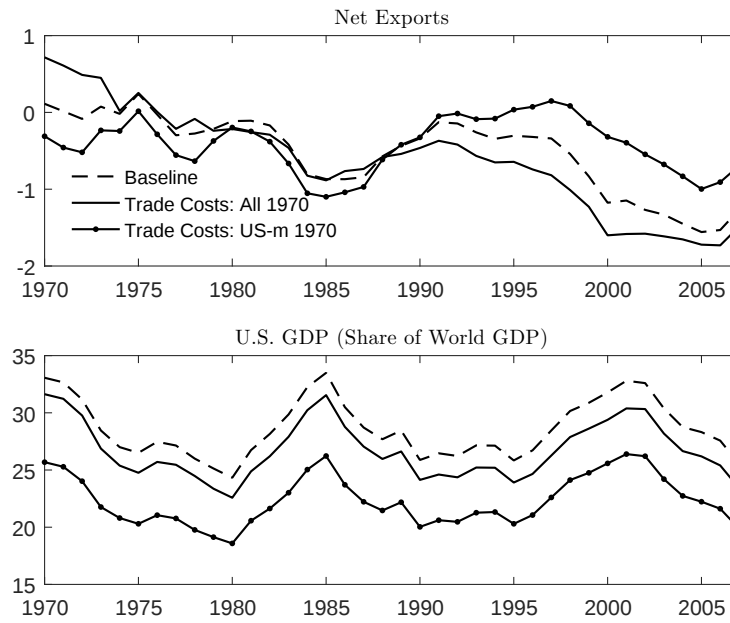


Table 2: Value Added Shares

Agriculture						
	Data	Baseline	Trade Costs 1970	$\tau_{USROW,t}^m$ fixed to 1970	+ Fix	Trade Deficit
va_{1970}^a	0.029	0.018	0.019	0.024		0.025
va_{2007}^a	0.018	0.013	0.009	0.025		0.023
$\text{diff.}_{1970-2007}^a$	-0.010	-0.005	-0.010	0.001		-0.002
Manufacturing						
	Data	Baseline	Trade Costs 1970	$\tau_{USROW,t}^m$ fixed to 1970	+ Fix	Trade Deficit
va_{1970}^m	0.256	0.258	0.266	0.278		0.284
va_{2007}^m	0.171	0.228	0.236	0.257		0.247
$\text{diff.}_{1970-2007}^m$	-0.084	-0.031	-0.030	-0.021		-0.037
Services						
	Data	Baseline	Trade Costs 1970	$\tau_{USROW,t}^m$ fixed to 1970	+ Fix	Trade Deficit
va_{1970}^s	0.715	0.724	0.715	0.698		0.691
va_{2007}^s	0.809	0.759	0.755	0.718		0.731
$\text{diff.}_{1970-2007}^s$	0.094	0.035	0.040	0.020		0.040

- Declines in trade costs have contributed to the decline of manufacturing share in value added.
 - Importance of considering open economy framework when studying SC
- Limitations of static framework calls for further development of a dynamic quantitative model of international trade and SC .
 - Challenges in solving such a model: isolate mechanism.
 - Endogenous investment $\implies$ capital deepening channel [Acemoglu and Guerrieri (2009)]
- Future work: improve fit of the model and analyze other measures of economic activity.

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