

# Structural Change and Global Trade

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## Abstract

Since 1970, services has risen from 50 percent of the world's final consumption expenditures to close to 80 percent. Services are also far less traded between countries compared to goods. Thus, as consumers become more service-oriented, the world will become "less open", affecting international trade volumes. Using a general equilibrium trade model with non-homothetic preferences and endogenous shifts in consumption behavior, we quantify the impact of such structural change on global trade across 27 countries. We find that world trade as a fraction of GDP would have been about 23 percentage points higher by 2015 if country-level expenditure patterns were unchanged from 1970 onwards. Income effects explain about one-quarter of this difference. Input-output linkages in production amplify the degree in which structural change restricts trade.

*JEL classifications:* F41, L16, O41

*Keywords:* Globalization, Structural Change, International Trade

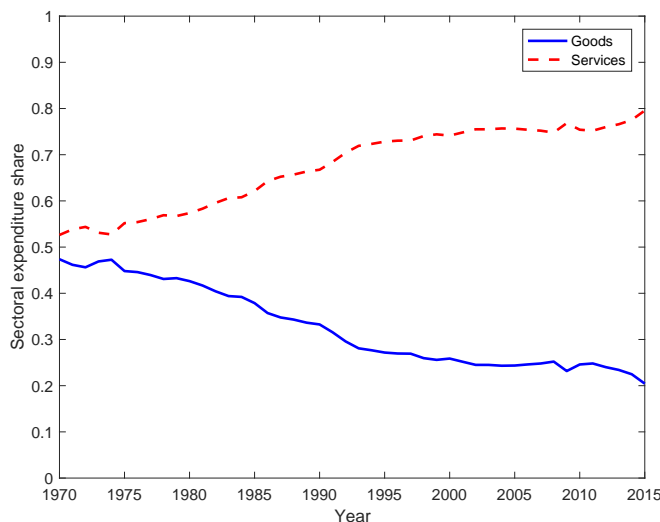
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# 1 Introduction

Long-run economic growth is accompanied by seismic shifts in the types of products consumers buy—countries move away from the consumption of goods towards services. Such structural change is thoroughly studied and is well-known to be a foundational component of economic growth. Indeed, as shown in Figure 1 from the period 1970 to 2015, the share of goods in total world expenditure dropped from 47 percent to 20 percent.<sup>1</sup> It is also the case, however, that a much smaller share of services are traded internationally than goods. As a greater share of the world economy is devoted to services, the share of spending on less-tradable consumption categories will increase relative to more-tradable goods. Thus structural change could have profound implications on global trade.

Figure 1: Share of World Expenditure on Goods and Services



There is a robust literature that has focused on the impact of global trade on structural change. The impact of structural change on global trade, by contrast, remains largely unexplored. The goal of this paper is to quantify the effect of structural change on international trade flows. We start with a straightforward but naïve computation of counterfactual global trade that had no structural change; in other words, assuming that sectoral expenditure shares are fixed at the initial year of data, while the sectoral trade over expenditure ratios rise as in the data. We find that the global trade to expenditure ratio in 2015 would have been 91 percent or 43 percentage points higher than the

<sup>1</sup>Throughout this paper, we will refer to trade as a fraction of expenditure. Global expenditure of goods and services is equal to global GDP of goods and services because global trade is balanced and all sectoral linkages are included. On a country level or by sector, however, final expenditure need not equal value-added.

48 percent in the data. Indeed, structural change may be more consequential for international trade than international trade is for explaining the pattern of structural change in many countries.

This simple calculation suggests that the world movement towards the consumption of less-tradables suppressed the growth of trade in the last five decades. At the same time, the exercise leaves something to be desired. Not only is the endogenously changing pattern of consumption in these countries potentially an important factor in driving what countries trade through its impact on factor prices and output prices, but there are many other factors, such as sectoral input-output linkages, productivity growth, and changes in trade costs that could simultaneously affect both sectoral expenditure and trade. In other words, how “open” sectors are is likely to have been simultaneously affected by these forces alongside the expenditure shares. The interactions between these factors imply that a true quantification of the effects of structural change on trade patterns needs a more fully fleshed out system.

For this reason, we build a tractable general equilibrium model that allows for endogenous structural change and trade patterns, similar to Uy, Yi and Zhang (2013) and Sposi (2016). We set up the exercise as a multi-country Eaton-Kortum model. On the production side, trade flows are governed by Ricardian forces as in Eaton and Kortum (2002), and it features intermediate input linkages as in Levchenko and Zhang (2016). Sectoral productivities and bilateral trade costs at the sector level vary over time and influence the patterns of production and trade. We calibrate the underlying deep parameters and time-varying processes of the model similar to Sposi (2016) and Świącki (2016). Changes in these exogenous forces over time influence structural change primarily through endogenous changes in consumer expenditures. The set of non-homothetic preferences we use derive from Comin, Lashkari and Mestieri (2015) and feature non-unitary income and substitution elasticities to allow dynamics of income and relative prices to shape sectoral expenditure shares.

The model is calibrated and solved for 26 countries and a rest of world aggregate from 1970-2015. Using data on sectoral expenditure shares, sector prices, and employment levels, we estimate the key parameters for our preference structure, namely the elasticity of substitution between goods and services, the income elasticity of demand for goods and services, as well as sector-specific demand shifters. Coupling these with input-output coefficients from the World Input-Output Database and bilateral trade data enables us to back out estimates of productivity and trade costs from the structural equations of the model. This allows exact computation of the model as in Alvarez and Lucas (2007).

After solving the model, we conduct a similar counterfactual as the one specified in the empirical section. By restricting the preferences to be Cobb Douglas over goods and services, we deliver constant expenditure shares for all sectors in each country across time, effectively shutting down structural change. What is different from the simpler empirical calculation is that the model allows for counterfactual structural change to flow through an input-output structure and also affect endogenous factor prices. We show that the model-based counterfactual still implies a substantial increase

in the global trade-to-expenditure ratio, but that it is somewhat less than the simple empirical counterfactual. The primary reason for this result is that the openness of goods in the counterfactual is substantially lower: goods expenditure rises relative to the baseline, but through the input-output structure of the model, goods trade does not rise by the same degree.

Besides the original counterfactual, we are able to perform additional exercises using the flexibility of the model. For example, by setting the income elasticity in preferences to be 1, so that expenditure shares do not respond to changes in income levels, we find that income effects explain about one-quarter of the effects of structural change on international trade. We also find that the magnitude of the effects structural change has had on holding back trade flows is similar to the effects declining trade costs had on increasing trade over the same time period. Projecting our model results out into the future indicates that the trade-to-GDP ratio has likely peaked, and will decline to around 40 percent by 2030. That said, there is little evidence that the slowdown in international trade which started in 2011 is a result of structural change.

A well-established literature documents how international trade and openness affects structural change. Matsuyama (2009) emphasized that trade can alter patterns of structural change and that using closed-economy models may be insufficient. Uy et al. (2013) find that non-homothetic preferences in an open economy can explain South Korea's hump-shaped manufacturing employment share over time. Betts, Giri and Verma (2016) explore the effects of South Korea's trade policies on structural change, finding that these policies raised the industrial employment share and hastened industrialization in general. Teignier (2016) finds that international trade in agricultural goods affected structural change in the United Kingdom even more than South Korea. Sposi (2016) documents how the input-output structure of advanced economies is systematically different from those of developing economies, and that this contributes to industry's hump-shaped response of the industry employment share over time. McMillan and Rodrik (2011) find that the effect of structural change on growth depends on a country's export pattern, specifically the degree to which a country exports natural resources. Cravino and Sotelo (2017) show that structural change originating from increase manufacturing trade increases the skill premium, particularly in developing countries.

Some analysis suggests that international trade plays only a small role in explaining the pattern of structural change on average. Kehoe, Ruhl and Steinberg (2016) find that for the United States, relatively faster manufacturing productivity growth primarily caused the reduction in goods employment, with a smaller role for trade deficits. Świącki (2016) also finds differential productivity growth is more important on average for explaining structural change than other mechanisms, including international trade. Nonetheless, even if international trade only contributes a small portion to structural change, we show that structural change plays a large role in the growth of world trade.

Non-homothetic preferences are important in understanding other aspects of international trade as well. Fieler (2011) finds that non-homothetic preferences can explain why trade grows with income per capita but not population. Simonovska (2015) shows that non-homothetic preferences

can replicate the pattern that higher income countries have higher prices of tradable goods.

Finally, this paper also contributes to an earlier literature on how global trade grows relative to GDP. In an early theoretical contribution, Markusen (1986) includes non-homothetic preferences in a trade model to be consistent with empirical evidence of a relationship between income and trade volumes. Rose (1991) shows that increases in income and international reserves along with declines in tariff rates help explain the differences in trade growth across countries over three decades. Baier and Bergstrand (2001) find that income growth explains nearly two-thirds of the increase in global trade, with tariffs explaining an additional one-quarter. Imbs and Wacziarg (2003) document a U-shaped pattern of specialization as countries become richer, that they first diversify across industries and only later specialize as they grow. Yi (2003) shows how vertical specialization, the splitting of production stages across borders, can amplify gross trade relative to value-added trade and help explain the large increases in trade-to-GDP ratios.

The remainder of the paper is set up as follows. Section 2 describes the empirical counterfactual, while Section 3 sets up the general equilibrium model with endogenous trade and consumption shares. Section 4 describes the calibration and solution of the model, while Section 5 presents the quantitative results. Section 6 concludes.

## 2 Empirical Counterfactual

The ratio of global trade to GDP rose from about 20 percent to 50 percent between 1970 and 2010, before flattening out through 2015. How would this trend have been different without the significant changes in the share of total expenditure spent on goods and services over that time (i.e. structural change)? This section presents a direct and simplified answer to the question by holding the share of goods and services expenditure fixed at their 1970 level, and tracing out a counterfactual path for the trade-to-GDP ratio. This will provide a rough idea of how important structural change, as defined by changes in expenditure shares, was in affecting global trade growth.

We begin with a few broad concepts, then discuss how we get at each concept using data for a large set of countries. First, structural change refers to changes in the relative expenditure of goods and services as a share of total expenditure. Second, sectoral openness (or tradability) is defined as imports plus exports of a sector as a share of expenditure in that sector. For every country and for the world as a whole, we can decompose the trade over expenditure ratio of period  $t$  as

$$\frac{Trade_t}{Exp_t} = \frac{Trade_{gt}}{Exp_{gt}} \frac{Exp_{gt}}{Exp_t} + \frac{Trade_{st}}{Exp_{st}} \frac{Exp_{st}}{Exp_t}, \quad (1)$$

where  $g$  and  $s$  denote goods and services. Clearly, both the evolution of sectoral openness measures and sectoral structural change (expenditure shares) over time shape the aggregate openness measure.

To gauge the contribution of structural change to the trade-to-expenditure ratio, we freeze the

expenditure shares at the first period of data and compute a counterfactual trade over expenditure ratio as:

$$\widetilde{\frac{Trade_t}{Exp_t}} = \frac{Trade_{gt} Exp_{g0}}{Exp_{gt} Exp_0} + \frac{Trade_{st} Exp_{s0}}{Exp_{st} Exp_0}, \quad (2)$$

By holding the expenditure shares of sector  $k$  fixed at the start of the period, we shut down the process of structural change that happened in the data. The new counterfactual trade to expenditure ratio is free of structural change, but it is consistent with the observed sectoral openness measures. If the counterfactual trade-expenditure ratios are significantly different from the observed ratios, it suggests that structural change has an important impact on global trade.

For the exercise below, we calculate equation (2) country by country. In other words, holding goods and expenditure shares fixed for each country, we compute country-specific trade to expenditure ratios. Summing the numerator and denominator of these ratios across countries gives the world ratio.

## 2.1 Data

We gather data needed to compute the baseline and counterfactual ratios in equations (1) and (2) for 26 country groupings and a “rest of world” aggregate over the period 1970-2015.<sup>2</sup> This includes imports and exports by each broad sectoral category, as well as expenditure on goods and services. In UN nomenclature, we take the goods sector to consist of “agriculture, hunting, forestry, fishing” and “mining, manufacturing, utilities”, while services include “construction”, “wholesale, retail trade, restaurants, and hotels” “transport, storage, and communication”, and “other activities”.

Although sector-level value added production data is easily available, data on sectoral demand is not. Conceptually, we need to split final expenditure (consumption, investment, and government spending) for each country into goods and services, accounting for the fact that some of that expenditure is made up of the usage of intermediate inputs. To do this, we rely on input-output coefficients from the World Input-Output Database (WIOD) from 1995 to 2011, and transform value added data into gross expenditure.<sup>3</sup>

The important pieces are thus comparable value-added production data for goods and services across countries, as well as imports and exports by sector. We take value added by sector from the UN Main Aggregates Database (UN (2017)) and trade data from the IMF DOTS database and the WIOD. The exact compilation procedure is detailed in Appendix A.

<sup>2</sup>The full list of countries is listed in Appendix A.

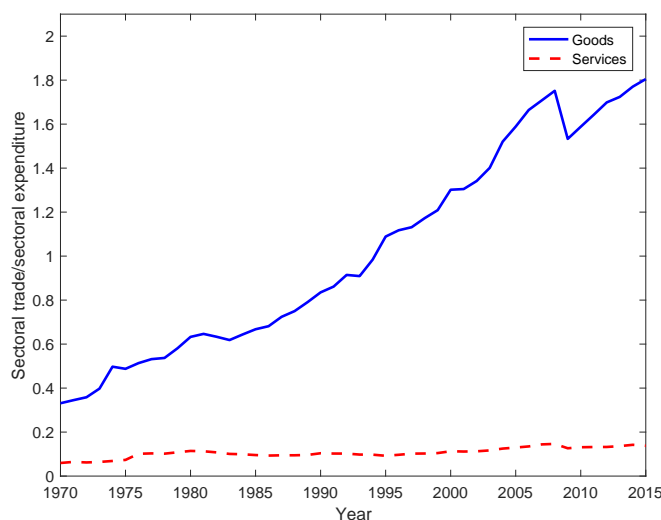
<sup>3</sup>We go into greater detail of how we turn value added data into expenditure in the model section.

## 2.2 Results

We start by presenting the patterns of structural change in the world economy. Returning to Figure 1, there was a steady decline in the goods share until the early 2000s and a commensurate increase in the share of services. The share of the service sector rises by 27 percentage points from 53 percent in 1970 to 80 percent in 2015. Thus, there is substantial reallocation across sectors in the past four decades.

If sectoral openness is similar across sectors, regardless of how large structural change is across sectors, the impact of structural change on aggregate openness will be small. In the data, however, trade openness differs substantially across sectors. Figure 2 plots the sectoral trade over sectoral expenditure ratio over 1970-2015. Clearly goods are much more open than services; the trade-expenditure ratio is about 6 percent for services but 33 percent for goods in 1970. Over time, trade openness rises for both sectors, but it is much more pronounced for goods. By the end of the period, the trade-expenditure ratio is about 14 percent for services and 180 percent for goods.<sup>4</sup>

Figure 2: World Trade to Expenditure Ratios, by Sector

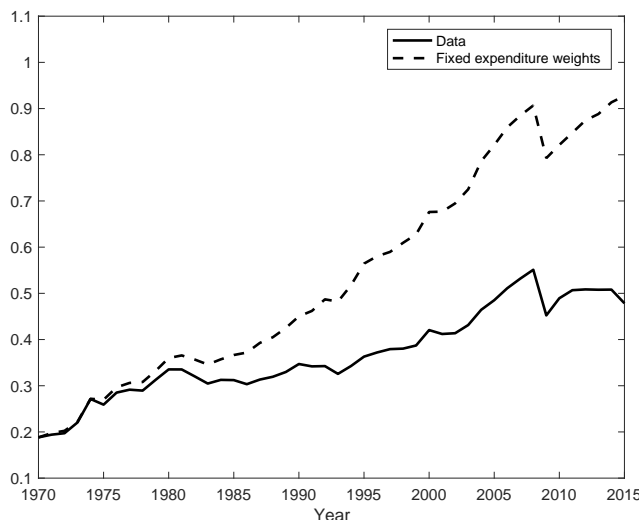


Now we look at the counterfactual trade openness as constructed in equation (2). For ease of comparison, Figure 3 contrasts the aggregate trade openness measure in the data with the one in the counterfactual, where sectoral expenditure shares are fixed at 1970 levels. As can be seen, the gap between the counterfactual openness measure and the actual data widens substantially over the 1990s and early 2000s, indicating that without underlying movements towards less-tradable

<sup>4</sup>The ratio of trade to expenditure can be over 100%, since trade is a gross measure (as a result of trade in inputs) and expenditure is a final consumption measure.

services, global trade growth would have been far higher. According to this exercise, structural change has lopped about 45 percentage points off the trade to expenditure ratio since 1970.

Figure 3: Aggregate Trade to Expenditure Ratio



Note: The data line is the aggregate trade to expenditure ratio for 26 countries and ROW listed in the data appendix. The counterfactual line holds the expenditure shares constant at the start of the sample.

Of course, this counterfactual has a major deficiency: trade openness is also very likely to have been simultaneously affected by structural change. For example, the evolution of consumption patterns over this time period is also driving what countries trade, through its effect on factor prices and sectoral prices. Additionally, input-output linkages also affect what countries produce and what they trade. Declining trade costs can affect structural change and openness, too. Specifically, the degree to which goods and services have become more open over time is endogenous, and this exercise assumes that openness in the counterfactual would have occurred identically to the data. Thus, a more comprehensive exercise is needed to quantify the impact of structural change on international trade more completely.

### 3 Model

We consider a multi-country model of the global economy in a two-sector Eaton Kortum trade model. There are  $I$  countries, indexed by  $i$  and  $j$ . There are two sectors: goods ( $g$ ) and services ( $s$ ), indexed by  $k$  and  $n$ . Household preferences have non-unitary income and substitution elasticities of demand. In each sector, there is a continuum of goods, and production uses both labor and intermediate inputs. All goods are tradable, but trade costs vary across sectors, country-pairs, and over



time, to capture different trade intensities. Productivities also differ in initial levels and subsequent growth rates across sectors and countries. These time-varying forces drive structural change. We omit the time subscript unless needed.

### 3.1 Endowments and Preferences

Labor is perfectly mobile across sectors within a country, but immobile across countries. Let  $L_i$  denote total labor endowment in country  $i$  and  $L_{ik}$  denote labor employed in sector  $k$ . The factor market clearing conditions is given by

$$L_i = L_{ig} + L_{is}. \quad (3)$$

The household in country  $i$  has a standard period utility function  $U(C_i)$  over the aggregate composite good  $C_i$ . The aggregate composite consumption combines sectoral composite goods according to the implicitly defined function

$$\sum_{k=g,s} \omega_k \left( \frac{C_i}{L_i} \right)^{\frac{\varepsilon_k - \sigma}{\sigma}} \left( \frac{C_{ik}}{L_i} \right)^{\frac{\sigma-1}{\sigma}} = 1, \quad (4)$$

where for each sector  $k \in \{g, s\}$ ,  $C_{ik}$  is consumption of sector- $k$  composite goods, and the preference share parameters  $\omega_k$ 's are positive and sum to one across sectors. The elasticity of substitution across sectoral composite goods is  $\sigma > 0$ . If  $\sigma > 1$ , the sectoral composite goods are substitutes, and if  $\sigma \leq 1$ , the sectoral composite goods are complements.  $\varepsilon_k$  denotes the income elasticity of demand for sector  $k$ .

These preferences are proposed by Comin et al. (2015). They show that this specification of nonhomothetic preferences has two attractive properties. First, the elasticity of the relative demand for the two sectoral composites is constant over aggregate consumption or income. In contrast to Stone-Geary nonhomothetic preferences, the elasticity of relative demand vanishes to zero as income or aggregate consumption rises, which is at odds with the empirical data both at the macro and micro levels. Second, the elasticity of substitution between sectoral composites is constant, given by  $\sigma$ , over income. They demonstrate that this specification has the potential to be flexible enough to capture the structural change patterns in the data.

The representative household maximizes his/her utility (4) subject to the following budget constraint in each period:

$$\underbrace{P_{ig}C_{ig} + P_{is}C_{is}}_{P_i C_i} + \rho_i w_i L_i = w_i L_i + R L_i, \quad (5)$$

where  $w_i$  and  $P_{ik}$  denote the wage rate and the price of the sector- $k$  composite good, respectively,

and  $P_i$  denotes the aggregate consumption price. The household supplies its labor endowment inelastically and spends its labor income on consumption. A fraction  $\rho_i$  of income is sent into a global portfolio, and the portfolio disperses, in lump sum,  $R$  equally across countries on a per-worker basis. Therefore, each country lends, on net,  $\rho_i w_i L_i - R L_i$  to the rest of the world. This aspect enables the model to match trade imbalances in the data, as in Caliendo, Parro, Rossi-Hansberg and Sarte (2016).

The first-order conditions imply that the consumption demand of sectoral goods satisfies, for any  $k \in \{g, s\}$ ,

$$C_{ik} = L_i \omega_k^\sigma \left( \frac{P_{ik}}{P_i} \right)^{-\sigma} \left( \frac{C_i}{L_i} \right)^{\varepsilon_k}, \quad (6)$$

where the aggregate price is given by

$$P_i = \frac{L_i}{C_i} \left[ \sum_{k=g,s} \omega_k^\sigma \left( \frac{C_i}{L_i} \right)^{\varepsilon_k - \sigma} P_{ik}^{1-\sigma} \right]^{\frac{1}{1-\sigma}}. \quad (7)$$

The sectoral expenditure shares are given by

$$e_{ik} = \frac{P_{ik} C_{ik}}{P_i C_i} = \omega_k^\sigma \left( \frac{P_{ik}}{P_i} \right)^{1-\sigma} \left( \frac{C_i}{L_i} \right)^{\varepsilon_k - 1}. \quad (8)$$

Thus, how relative price and real income per capita shape the sectoral expenditure shares are governed by the elasticity of substitution between sectors  $\sigma$  and the sectoral elasticity of income  $\varepsilon_k$ . Specifically, when  $\sigma < 1$ , rising sectoral relative prices pushes up sectoral expenditure shares, and vice versa. When the sectoral income elasticity is larger than one, i.e.,  $\varepsilon_k > 1$ , sectoral expenditure shares also rise with the income per capita.

### 3.2 Technology and Market Structure

There is a continuum of varieties,  $z \in [0, 1]$ , in the goods ( $g$ ) and services ( $s$ ) sectors. The composite sectoral good  $Q_{ik}$  is an aggregate of the individual goods  $Q_{ik}(z)$ :

$$Q_{ik} = \left( \int_0^1 Q_{ik}(z)^{\frac{\eta-1}{\eta}} dz \right)^{\frac{\eta}{\eta-1}},$$

where the elasticity of substitution across varieties within a sector is  $\eta > 0$ . Each good  $z$  is either produced locally or imported from abroad. The composite sectoral goods are used in domestic final consumption and domestic production as intermediate inputs:

$$Q_{ik} = C_{ik} + \sum_{n=g,s} M_{ink},$$

, where  $M_{ink}$  is the intermediate input usage of sector  $k$  in the production of sector  $n$ .

Each country possesses technologies for producing all the varieties in all sectors. The production function for variety  $z \in [0, 1]$  in sector  $k \in \{g, s\}$  of country  $i$  is

$$Y_{ik}(z) = A_{ik}(z) (T_{ik} L_{ik}(z))^{\lambda_{ik}} [\Pi_{n=g,s} M_{ikn}^{\gamma_{ikn}}(z)]^{1-\lambda_{ik}} \quad (9)$$

where  $A_{ik}$  denotes exogenous productivity,  $\lambda_{ik}$  denotes the country-specific value-added share in production, and  $\gamma_{ikn}$  denotes the country-specific share of intermediate inputs sourced from sector  $n$ .  $Y_{ik}(z)$  denotes output,  $L_{ik}(z)$  denotes labor, and  $M_{ikn}(z)$  denotes sector- $n$  composite goods used as intermediates in the production of the sector  $k$  variety  $z$ .  $T_{ik}$  is the fundamental productivity of varieties in sector  $k$  and scales value added, as opposed to  $A_{ik}$ , which scales gross output.  $A_{ik}(z)$  is the realization of a random variable drawn from the cumulative distribution function  $F(A) = \Pr[Z \leq A]$ . Following Eaton and Kortum (2002), we assume that  $F(A)$  is a Fréchet distribution:  $F(A) = e^{-A^{-\theta_k}}$ , where  $\theta_k > 1$ . The larger is  $\theta_k$ , the lower the heterogeneity or variance of  $A_{ik}(z)$ .<sup>5</sup> The parameters governing the distribution of idiosyncratic productivity draws are invariant across countries but different across sectors. We assume that the productivity is drawn each period.<sup>6</sup>

Total sectoral labor, input usage, and production in sector  $k$  in country  $i$  are the aggregates of the variety-level components taken over the set of varieties produced in country  $i$ ,  $V_{ik}$ :

$$L_{ik} = \int_{V_{ik}} L_{ik}(z) dz; \quad M_{ikn} = \int_{V_{ik}} M_{ikn}(z) dz; \quad Y_{ik} = \int_{V_{ik}} Y_{ik}(z) dz.$$

Goods markets are perfectly competitive; goods prices are determined by marginal costs of production. The cost of an input bundle in sector  $k$  is

$$v_{ik} = B_{ik} w_i^{\lambda_{ik}} (\Pi_{n=g,s} (P_{in})^{\gamma_{ikn}})^{1-\lambda_{ik}},$$

where  $B_{ik} = \lambda_{ik}^{-\lambda_{ik}} ((1 - \lambda_{ik}) \Pi_{n=g,s} \gamma_{ikn}^{-\gamma_{ikn}})^{\lambda_{ik}-1}$ . The cost of an input bundle is the same within a sector, but varies across sectors given different input shares across sectors.

### 3.3 Trade

When varieties are shipped abroad, they incur trade costs, which include tariffs, transportation costs, and other barriers to trade. We model these costs as iceberg costs. Specifically, if one unit of variety  $z$  is shipped from country  $j$ , then  $\frac{1}{\tau_{jm}}$  units arrive in country  $i$ . We assume that trade costs within a country are zero, i.e.,  $\tau_{ia} = \tau_{im} = 1$ . This means that the price at which country  $j$  can supply variety  $z$  in sector  $k$  to country  $i$  equals  $p_{ijk}(z) = \frac{\tau_{ijk} v_{jk}}{T_{ik}^{\lambda_k}}$ . Since buyers will select to purchase from

<sup>5</sup>  $A_k(z)$  has geometric mean  $e^{\frac{\gamma}{\theta_k}}$  and its log has a standard deviation  $\frac{\pi}{\theta_k \sqrt{6}}$ , where  $\gamma$  is Euler's constant.

<sup>6</sup> Alternatively, we could assume that the productivity is drawn once in the initial period, and as the  $T$ 's change over time, the productivity relative to  $T$  remains constant.

the cheapest source, the actual price for this good in country  $i$  is  $p_{ik}(z) = \min \{p_{ijk}(z)\}_{j=1}^I$ .

Under the Fréchet distribution of productivities, Eaton and Kortum (2002) show that the price of composite good  $k \in \{g, s\}$  in country  $i$  is

$$P_{ik} = \Gamma_k \left[ \sum_{j=1}^I \left( T_{jk}^{-\lambda_{jk}} v_{jk} \tau_{ijk} \right)^{-\theta_j} \right]^{-\frac{1}{\theta_k}}, \quad (10)$$

where the constant  $\Gamma_k = \Gamma(1 - \frac{\eta-1}{\theta_k})^{\frac{1}{1-\eta}}$  denotes the Gamma function, and the summation term on the right-hand side summarizes country  $i$ 's access to global production technologies in sector  $k$  scaled by the relevant unit costs of inputs and trade costs.<sup>7</sup>

The share of country  $i$ 's expenditure on sector- $k$  goods from country  $j$ ,  $\pi_{ijk}$ , equals the probability of country  $i$  importing sector- $k$  goods from country  $j$ , and is given by

$$\pi_{ijk} = \frac{\left( T_{jk}^{-\lambda_{jk}} v_{jk} \tau_{ijk} \right)^{-\theta}}{\sum_{s=1}^I \left( T_{sk}^{-\lambda_{sk}} v_{sk} \tau_{isk} \right)^{-\theta}}. \quad (11)$$

Equation (11) shows how a higher average productivity, a lower unit cost of input bundles, and a lower trade cost in country  $j$  translates into a greater import share by country  $i$ .

### 3.4 Equilibrium

Combining the goods and factor market clearing conditions and demand equations with the equations for the consumption of the composite good, trade shares, prices, and the global portfolio balance yields a set of conditions that fully characterize the equilibrium of the model. Table 1 collects all these conditions. Equations (D1)-(D4) are from the household demand side. (D1) and (D2) are the optimal conditions for sectoral consumption and sectoral expenditure shares. (D3) specifies the aggregate price index given the preferences. (D4) is the budget constraint.

Equations (S1)-(S7) are from the supply side. (S1) gives bilateral import shares in total absorption at the sectoral level. (S2) specifies the cost of an unit of the input bundle. (S3) gives sectoral prices. (S4) and (S5) state the optimal value added and intermediate input usages implied by the Cobb-Douglas production function. (S6) link sectoral aggregate absorption with final demand and intermediate input demand. (S7) links a country's total output in a sector with the sum of all demand from all countries.

Equations (G1)-(G2) are from the global market clearing. Equation (G1) specifies net transfers across countries are zero globally. Equation (G2) is the resource constraint at the country level.

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<sup>7</sup>We need to assume  $\eta - 1 < \theta$  to have a well-defined price index. Under this assumption, the parameter  $\eta$ , which governs the elasticity of substitution across goods within a sector, can be ignored because it appears only in the constant term  $\Gamma$ .

Table 1: Equilibrium conditions

D1	$C_{ik} = L_i \omega_k^\sigma \left(\frac{P_{ik}}{P_i}\right)^{-\sigma} \left(\frac{C_i}{L_i}\right)^{\varepsilon_k}$	$\forall i, k$
D2	$e_{ik} = \omega_k^\sigma \left(\frac{P_{ik}}{P_i}\right)^{1-\sigma} \left(\frac{C_i}{L_i}\right)^{\varepsilon_k - 1}$	$\forall i, k$
D3	$P_i = \left(\frac{L_i}{C_i}\right) \left(\sum_{k \in \{g, s\}} \omega_k^\sigma \left(\frac{C_i}{L_i}\right)^{\varepsilon_k - \sigma} P_{ik}^{1-\sigma}\right)^{\frac{1}{1-\sigma}}$	$\forall i$
D4	$P_i C_i + \rho_i w_i L_i = w_i L_i + R L_i$	$\forall i$
S1	$\pi_{ijk} = \frac{\left(T_{jk}^{-\lambda_{jk}} v_{jk} \tau_{ijk}\right)^{-\theta}}{\sum_{s=1}^I \left(T_{sk}^{-\lambda_{sk}} v_{sk} \tau_{isk}\right)^{-\theta}}$	$\forall i, j, k$
S2	$v_{ik} = B_{ik} w_i^{\lambda_{ik}} \prod_{n \in \{g, s\}} P_{in}^{(1-\lambda_{ik}) \gamma_{ikn}}$	$\forall i, k$
S3	$P_{ik} = \Gamma_k \left(\sum_{j=1}^I \left(T_{jk}^{-\lambda_{jk}} v_{jk} \tau_{ijk}\right)^{-\theta}\right)^{\frac{1}{\theta}}$	$\forall i, k$
S4	$w_i L_{ik} = \lambda_{ik} P_{ik} Y_{ik}$	$\forall i, k$
S5	$P_{in} M_{ikn} = (1 - \lambda_{ik}) \gamma_{ikn} P_{ik} Y_{ik}$	$\forall i, k, n$
S6	$C_{ik} + \sum_{n \in \{g, s\}} M_{ink} = Q_{ik}$	$\forall i, k$
S7	$\sum_{j=1}^I P_{jk} Q_{jk} \pi_{jik} = P_{ik} Y_{ik}$	$\forall i, k$
G1	$\sum_{i=1}^I \rho_i w_i L_i = R \sum_{i=1}^I L_i$	
G2	$\sum_{k \in \{g, s\}} P_{ik} Y_{ik} - \sum_{k \in \{g, s\}} P_{ik} Q_{ik} = \rho_i L_i - R L_i$	$\forall i$

These two conditions together imply that the good market clears.

We define a competitive equilibrium of our model economy with the exogenous time-varying processes for every country  $i, j$ : labor endowment  $\{L_i\}$ , trade cost  $\{\tau_{ijg}, \tau_{ijs}\}$ , productivity  $\{T_{ig}, T_{is}\}$ , and contribution shares to the global portfolio  $\{\rho_i\}$ ; time-varying structural parameters for every country  $\{\lambda_{ik}, \gamma_{ikn}\}$ ; and time-invariant structural parameters  $\{\sigma, \varepsilon_k, \omega_k, \theta_k\}_{k=g, s}$  as follows.

**Definition 1.** A *competitive equilibrium* is a sequence of output and factor prices  $\{w_i, P_{ig}, P_{is}, P_i\}_{i=1}^I$ , allocations  $\{L_{ig}, L_{is}, M_{igg}, M_{igs}, M_{isg}, M_{iss}, Q_{ig}, Q_{is}, Y_{ig}, Y_{is}, e_{ig}, e_{is}, C_{ig}, C_{is}, C_i\}_{i=1}^I$ , transfers from the global portfolio,  $R$ , and trade shares  $\{\pi_{ijg}, \pi_{ijs}\}_{i, j=1, \dots, I}$ , such that each condition in Table 1 holds.

## 4 Calibration and Solution

To quantify the role of structural change in global trade flows, we calibrate the exogenous processes and parameters in the model to the data. Given the data availability, we include 26 countries plus one rest-of-the-world aggregate over period 1970-2015 in our analysis. Preference parameters,  $(\sigma, \varepsilon_g, \varepsilon_s, \omega_g, \omega_s)$ , are estimated using data on sectoral prices and expenditures. Processes for sectoral trade costs,  $\tau_{ijkt}$ , productivity,  $T_{ikt}$ , and trade imbalances,  $\rho_{it}$ , are constructed to match data on

sectoral value added and bilateral trade flows. The production coefficients are constructed using the input-output data, and the trade elasticity,  $\theta_k$ , is taken from the literature.

We will discuss the calibration procedures in detail in the next three subsections. With these in hand, we can solve the baseline model completely in levels for each year  $t = 1970, \dots, 2015$ .

#### 4.1 Common parameters

The upper panel of Table 2 provides the values for common parameters. Beginning with technology parameters, we set  $\theta_g = 4$  following Simonovska and Waugh (2014). There is no reliable estimate of the trade elasticity for services so we set  $\theta_s = 4$  as well. The elasticity of substitution between varieties in the composite good,  $\eta$ , plays no quantitative role in the model other than satisfying  $1 + (1 - \eta)/\theta > 0$ ; we set this value at 2.

Table 2: Parameter values

<b>Common parameters</b>		
$\theta_g$	Trade elasticity in goods sector	4
$\theta_s$	Trade elasticity in service sector	4
$\eta$	Elasticity of substitution b/w varieties in composite good	2
$\sigma$	Elasticity of substitution b/w sectors	0.4
$\varepsilon_g$	Elasticity of income in goods	1
$\varepsilon_s$	Elasticity of income in services	1.59
$\omega_g$	Preferences share of goods	0.49
<b>Cross-country, cross-time averages</b>		
$\lambda_g$	Ratio of value added to gross output in goods	0.39
$\lambda_s$	Ratio of value added to gross output in goods	0.61
$\gamma_{gg}$	Good's share in intermediates used by goods sector	0.68
$\gamma_{sg}$	Good's share in intermediates used by service sector	0.34

**Preference parameters** Our estimation of preference parameters utilizes data on sectoral prices, sectoral expenditure shares, and employment levels. Taking ratio of equation (8) as it applies to each sector we can see

$$\left(\frac{e_{ig}}{e_{is}}\right) = \left(\frac{\omega_g}{\omega_s}\right)^\sigma \left(\frac{P_{ig}}{P_{is}}\right)^{1-\sigma} \left(\frac{C_i}{L_i}\right)^{\varepsilon_g - \varepsilon_s},$$

which illustrates the intuition. Holding fixed variation in total consumption (income effects), the extent that expenditure shares move with relative prices helps us identify the elasticity of substitution,  $\sigma$ . Holding fixed relative prices, the extent that expenditures shares move with the aggregate level of consumption helps us identify income elasticities,  $\varepsilon_k$ . By setting the sector weights,  $\omega_k$ , to be

constant across countries and over time allows us to exploit both the cross-sectional and time-series variation to identify the price and income elasticities.

We estimate the preference parameters  $(\omega_g, \omega_s, \sigma, \varepsilon_g, \varepsilon_s)$  to minimize the sum of the squared deviation of relative sectoral expenditure shares between the model and the data. Specifically, we solve the constrained minimization problem:

$$\min_{(\omega_g, \omega_s, \sigma, \varepsilon_g, \varepsilon_s)} \sum_{t=1970}^{2015} \sum_{i=1}^I \sum_{k \in \{g,s\}} \left[ \left( \frac{\omega_g}{\omega_s} \right)^\sigma \left( \frac{\widehat{P}_{igt}}{\widehat{P}_{ist}} \right)^{1-\sigma} \left( \frac{C_{it}}{\widehat{L}_{it}} \right)^{\varepsilon_g - \varepsilon_s} - \left( \frac{\widehat{e}_{igt}}{\widehat{e}_{ist}} \right) \right]^2 \quad (12)$$

$$\text{s.t. } \frac{\widehat{P}_{it} \widehat{C}_{it}}{\widehat{L}_{it}} = \left( \sum_{k \in \{g,s\}} \omega_k^\sigma \left( \frac{C_{it}}{\widehat{L}_{it}} \right)^{\varepsilon_k - \sigma} \widehat{P}_{ikt}^{1-\sigma} \right)^{\frac{1}{1-\sigma}}, \forall (i,t) \quad (13)$$

$$\sum_{k \in \{g,s\}} \omega_k = 1, \quad (14)$$

where hats on variables indicate that the objects come from data. That is, we use data on sectoral prices,  $\widehat{P}_{ik}$ , sectoral expenditure shares,  $\widehat{e}_{ik}$ , aggregate expenditures,  $\widehat{P}_i \widehat{C}_i$ , and employment levels,  $\widehat{L}_i$ . We have no direct empirical counterpart to the aggregate consumption index,  $C_i$ , as it is defined in the model, so the constraint in the optimization problem allows us to pin this object down in a model-consistent way by internally deflating the aggregate expenditures by an appropriate price deflator.

Our procedure to solve the minimization problem is as follows. First, following Comin et al. (2015), we normalize the income elasticity for goods  $\varepsilon_g \equiv 1$ . Then we make a guess for the remaining preference parameters:  $(\omega_g, \omega_s, \sigma, \varepsilon_s)$ . Given these parameters we exploit aggregate expenditure data to impute the aggregate consumption index,  $C_{it}$ , for each country in every year using constraint (13), which is a simple nonlinear equation with one unknown. Given the imputed consumption indexes we exploit data on sectoral prices and expenditures and use nonlinear least squares on the objective function (12) to obtain updated estimates of  $(\omega_g, \omega_s, \sigma, \varepsilon_s)$ . With the updated estimates of the preference parameters we impute updated consumption indexes and, in turn, new estimates of the preference parameters. We continue the procedure until converging to a fixed point in the preference parameters.

The result of the estimation delivers  $\sigma = 0.4$  and  $\varepsilon_s = 1.59$ . Implicitly we also obtain estimates of the aggregate consumption index,  $C_{it}$ , which has no direct empirical counterpart. This object will be used later on in order to calibrate productivity levels in an internally consistent manner.

## 4.2 Country-specific parameters

A subset of country-specific parameters are directly observable. Others are calibrated to match specific targets in the data.

**Labor endowment** The country-specific time-varying labor endowment,  $L_{it}$ , comes from version 9.0 of the Penn World Table and the World Banks' World Development Indicator Database. These data correspond to the number of workers engaged in market activity.

**Production shares** The country-specific time-varying production parameters  $\gamma_{iknt}$  and  $\lambda_{ikt}$  are constructed using the World Input-Output Database (WIOD), condensed down to a two-sector input-output database for each country from 1995-2011. Specifically,  $\lambda_{ikt}$  is the ratio of value added to total production in sector  $k$ , while the  $\gamma_{iknt}$  terms are the share of sector  $k$  inputs that are sourced from sector  $n$ . We apply the 1995 values to all years prior to 1995, similarly, we apply the 2011 values to all years after 2011.

While these production shares vary quite a bit across countries, there are notable patterns that hold across countries. First, production of services is more value-added intensive than production of goods. Table 2 indicates that, on average, 61 percent of total service production compensate value added factors, compared to 39 percent in goods. Second, inputs from goods sectors account for 68 of intermediate expenditures by the goods sector. That is, goods production is goods-intensive. Similarly, services production is service intensive: inputs from the service sector account for 66 percent of intermediate expenditures by the service sector. Even still, cross-sector linkages are relatively strong: roughly one-third of intermediate inputs in each sector is sourced from the other sector.

**Trade imbalances** The parameters,  $\rho_{it}$ , are calibrated to match each countries ratio of net exports to GDP. In the model, the ratio of net exports to GDP in country  $i$  at time  $t$  is  $\frac{R_t L_{it} - \rho_{it} w_{it} L_{it}}{w_{it} L_{it}}$ . In the calibration we can imagine  $R_t = 0$  and simply set  $\rho_{it} = \frac{\widehat{NX}_{it}}{GDP_{it}}$ . So long as net exports sum to zero across countries (which it does in our data) then the global portfolio is balanced. In counterfactual analysis, the endogenous term  $R_t$  will adjust to ensure that the global portfolio balances period-by-period:  $R_t \sum_{i=1}^I L_{it} = \sum_{i=1}^I \rho_{it} w_{it} L_{it}$ .

### 4.3 Technology and trade costs

We recover the productivity terms,  $T_{ik}$ , and trade costs,  $\tau_{ijk}$ , by exploiting structural relationships from our model in order to match data on sectoral final expenditures and bilateral trade flows in each country and every year. Our procedure is similar to that of Świącki (2016), but incorporates input-output linkages as in Sposi (2016). By explicitly making use of the observed input-output linkages our procedure also implies that we simultaneously match sectoral value added.



Two key structural relationships provide identification for productivity and trade costs:

$$T_{ik}^{\lambda_{ik}} = \frac{B_{ikt} V_{ikt}}{\Gamma_k^{-1} P_{ik} (\pi_{iik})^{-\frac{1}{\theta_k}}}, \quad (15)$$

$$\tau_{ijk} = \left( \frac{\pi_{ijk}}{\pi_{jjk}} \right)^{-\frac{1}{\theta_k}} \left( \frac{P_{ik}}{P_{jk}} \right). \quad (16)$$

Both structural relationships are derived by manipulating equations (10) and (11). Measurement of sectoral productivity takes into account differences between input costs and output prices. Holding fixed the unit costs of inputs, the model assigns a country with a low price a high productivity, meaning that inputs are converted to output at an efficient rate. It also takes into account the home trade share, which reflects the selection effect common to Ricardian trade models.

Measurement of the trade costs takes into account relative price differences and the bilateral trade shares. Holding fixed the price difference between countries  $i$  and  $j$ , if country  $i$  imports a large share from country  $j$  relative to what  $j$  sources from itself, the inferred trade barrier is low. In this sense, the trade costs are treated as wedges that reconcile the observed pattern of bilateral trade.

**Inferring internally consistent sector expenditures and prices** Equations (15) and (16) require data on unit costs, sector prices, and trade shares; unit costs themselves require wages and sector prices. While we do have data on prices, we do not use them for this part of the calibration. Instead, we impute sector prices through the lens of the model so that they are internally consistent with sector expenditures. Our model does not have enough degrees of freedom to match both sector prices and sector expenditures, simultaneously, so we choose to match expenditures since they are of first order interest to our question.

The procedure to recover internally consistent prices can be broken down into two steps. 1) Using data on sector value added, sector net exports, and input-output linkages we recover sector expenditures. 2) Given the sector expenditures and data on consumption levels, we recover the sector prices that support the expenditures using the representative household's first-order conditions.

First, in order to recover sector expenditures, some manipulation of the equilibrium conditions S5-S7 yields the following expression:

$$P_{ik} C_{ik} = P_{ik} Q_{ik} - \sum_{n=\{g,s\}} (1 - \lambda_{in}) \gamma_{ikn} (P_{in} Q_{in} + NX_{in}), \quad (17)$$

where  $NX_{ik}$  is net exports in country  $i$  sector  $k$ , and  $P_{ik} Q_{ik}$  is total absorption. From equilibrium condition S4, we also know total absorption of the composite good can be written as:

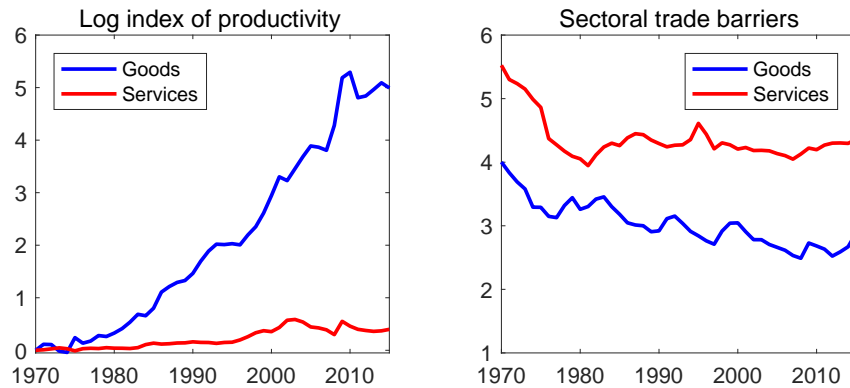
$$P_{ik} Q_{ik} + NX_{ik} = \frac{w_i L_{ik}}{\lambda_{ik}}. \quad (18)$$

Using data on sector value added  $w_i L_{ik}$  along with sector net exports  $NX_{ik}$  and the production share  $\lambda_{ik}$ , we can calculate total expenditure  $P_{ik} C_{ik}$  via Equation (17) and (18). From 1995-2011 we directly observed the sectoral final expenditures in the input-output tables so this procedure simply returns the observations. For all of the other years in which these data are unavailable, however, this procedure allows us to construct the sectoral expenditures in a reliable way.

Second, given preference parameters,  $(\omega_g, \omega_s, \sigma, \varepsilon_g, \varepsilon_s)$ , imputed data on sector expenditures,  $P_{ik} C_{ik}$ , labor endowment,  $L_i$ , and the estimated levels of aggregate consumption,  $C_i$  (obtained from estimating preference parameters), we invert the household's first-order condition (8) and use the definition of aggregate expenditures (7) to recover model-implied price levels that support the expenditures.

With these constructed sector prices in hand, we compute the sector productivity and trade costs in equations (15) and (16). Figure 4 illustrates the calibrated processes at the world level. The left panel plots the global sector productivity growth index. The global sector productivity is computed as the average across countries weighted by each country's share in sector value added. The index is taken relative to 1970 and is reported in logs. As shown in the figure, the global sectoral productivity grows faster in goods than in services.

Figure 4: Calibrated global productivity and trade costs



The right panel of Figure 4 plots the global trade costs for goods and services. The global trade cost is computed as an average of all bilateral trade costs weighted by the bilateral trade flows. As illustrated in the figure, trade costs for both goods and services decline over time, and trade costs in services are higher than in goods in general.

#### 4.4 Model fit

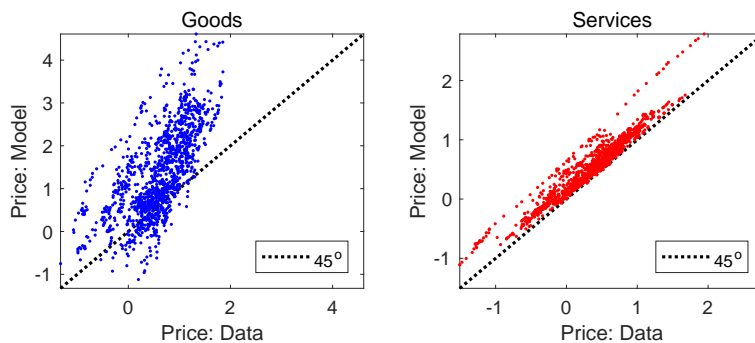
With all of the exogenous parameters in hand we can compute the equilibrium of the model. Our solution procedure is based on Alvarez and Lucas (2007). Start with an initial guess for the vector

of wages. Given the wages, recover all remaining prices and quantities across countries using optimality conditions and market clearing conditions, excluding the trade balance condition. Then use departures from the trade balance condition to update the wages. Iterate on wages until the trade balance condition holds. The exact details are available in Appendix B.

Our calibration procedure ensures that the model fits data on sectoral value added, sectoral gross output, sectoral absorption, sectoral bilateral trade flows, and sectoral expenditures. In order to rationalize the sectoral expenditures under our preference specification, the set of equilibrium prices differ from those in the data. Alternatively, one could force the model to match the observed price data, but then the model would not match the sectoral expenditures due to the limited degrees of freedom in the preference specification. We opt to match expenditures since the sectoral trade-to-expenditure ratios are of first-order interest in our counterfactuals.

Nonetheless, we can compare the prices generated by the model to those the data as a test of fit. This is illustrated in Figure 5; all prices are taken relative to the U.S. in 2015. Each point corresponds to the price in one country in one year. The prices of services fit the data very well; the correlation between model and data is 0.96. The price variation for goods in the model is overstated relative to that in the data, but the correlation seems quite reasonable: 0.69. The correlation for bilateral trade shares is 1, while that for sector expenditures shares is also 1.

Figure 5: Sector prices: model versus data



## 5 Model-based Counterfactual

### 5.1 Setup

To examine the implications on global trade flows from structural change, we construct a counterfactual model in which structural change is absent. To do so, we assume that the preferences in the

counterfactual are given by

$$C_i = \sum_{k \in \{g,s\}} \omega'_{ik} \log C_{ik}. \quad (19)$$

With the log specification, the income elasticities are one for both sectors and the substitution elasticity is also one across the two sectors. Consequently, the expenditure shares across sectors are constant over time. That is,

$$e_{ikt} = e_{ik0} = \omega'_{ik}. \quad (20)$$

All underlying processes in the counterfactual are identical to those in the baseline. To be more specific, in the counterfactual we assume all other parameters and time varying processes for  $T$ ,  $\tau$ , and  $L$  are unchanged from the baseline, except that the preference parameters  $\{\sigma, \varepsilon_k, \omega_k\}$  in the baseline are set to  $\{1, 1, \omega'_{ik}\}$  in the counterfactual experiment. We choose values for  $\omega'_{ik} = e_{ik0}$  so that in 1970 the sectoral expenditure shares are identical to those in the baseline model. We compute the equilibrium for the counterfactual experiment and analyze the implications of structural change.

Figure 6: Share of Goods Expenditure, baseline and counterfactual

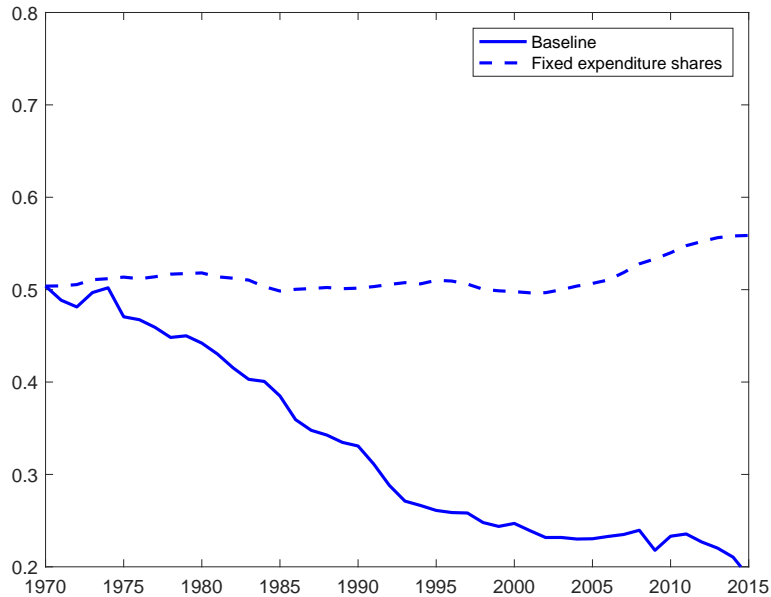
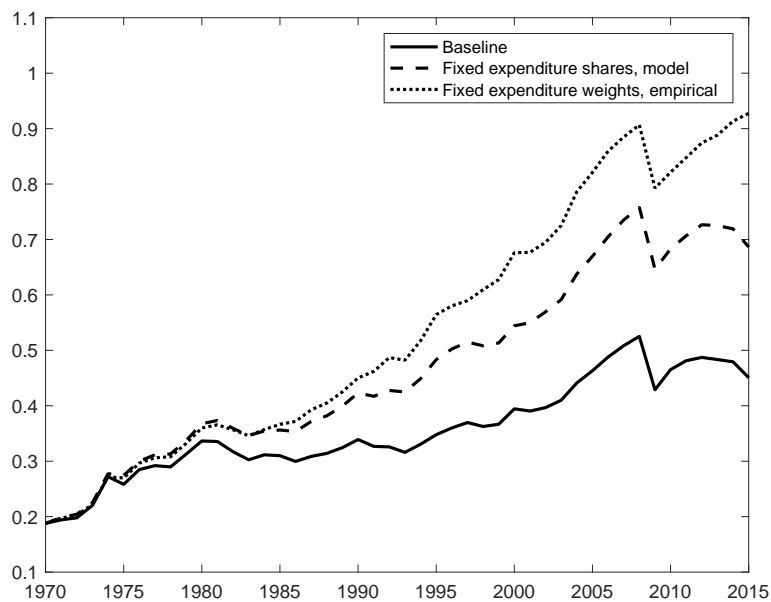


Figure 6 shows the driving force of the counterfactual: in the data and baseline model, the goods share of total expenditure falls from about 50 percent to 20 percent. In the counterfactual, goods

expenditure is held fixed country-by-country. When aggregated to a global expenditure share, it remains close to 50 percent, increasing somewhat near the end of the sample. The slight rise since 2002 is driven by the increasing weight of China and India in the world economy, and they have larger expenditure shares in goods, compared to the developed countries.

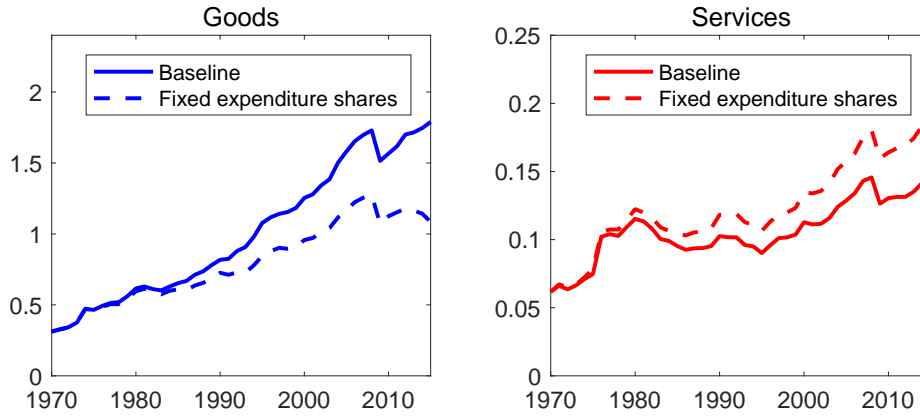
In Figure 7, we compare the global trade to expenditure ratio between the model baseline, model-based counterfactual, and empirical (reduced form) counterfactual. In both counterfactuals, global trade would have been much higher had structural change not occurred. By 2015, the reduced-form counterfactual puts the trade-GDP ratio at about 91 percent while the model-based counterfactual is about 68 percent, compared to 45 percent in the data. The difference between the two counterfactuals peaks in 2015 and is driven by the endogenous changes to sectoral openness generated by the model.

Figure 7: World trade over expenditure, baseline and counterfactual



The key difference between the reduced-form counterfactual and the model-based one is that in the reduced-form counterfactual, sectoral openness follows the same path as the data. Figure 8 shows how sectoral openness in the model-based counterfactual deviates from baseline sectoral openness. The left panel shows that goods openness (goods trade as a share of goods expenditure) is about 70 percentage points lower relative to the baseline in 2015, while services openness is about 5 percentage points higher.

Figure 8: World sector trade over expenditure

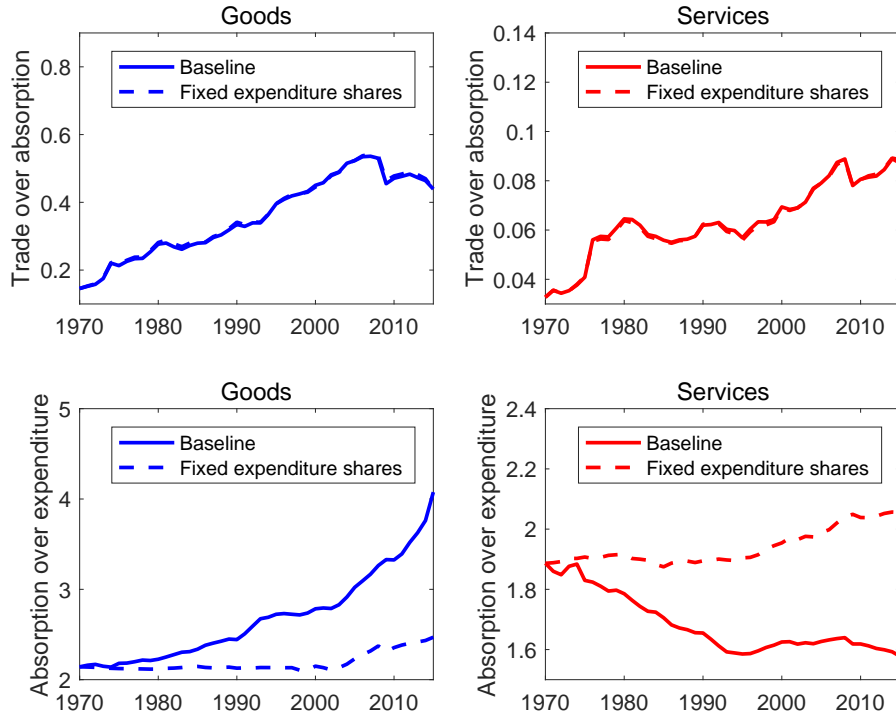


To understand the endogenous responses of sectoral trade in the model, it is helpful to decompose sectoral trade openness into two terms: one of trade as a share of absorption and a second of absorption as a share of expenditure:

$$\frac{Trade_{kt}}{Exp_{kt}} = \frac{Trade_{kt}}{Abs_{kt}} \frac{Abs_{kt}}{Exp_{kt}}. \quad (21)$$

Figure 9 shows that the primary reason why the counterfactual sectoral trade openness differs from the baseline is differences in the absorption-to-expenditure ratio. As shown in the upper panel, the trade-absorption ratios are almost identical in the baseline and the counterfactual. Alternatively, how much each country sources its intermediate inputs abroad ( $1 - \pi_{iik}$ ) in each sector is driven mainly by the supply fundamentals. In the lower panel of the figure, total absorption of goods rose much less than expenditure in the counterfactual than in the data. This points to the presence of input-output linkages as a key explanation for why sectoral openness changed over time. That is, total sectoral absorption, equal to final plus intermediate demand for the sector composite good, changes at a different rate than final sectoral demand. Sectoral absorption shares change less than one-for-one with changes in final expenditure shares because inputs from other sectors are used in production. For instance, consider counterfactually increasing goods share in final demand. In order to do deliver more final goods intermediates must be sourced from the service sector, implying that the intermediate demand for goods relative to services increases at a slower rate than does the increase in the final demand for goods. Since the intermediate demand is incorporated in the absorption, goods absorption increases by a smaller proportion than goods expenditure.

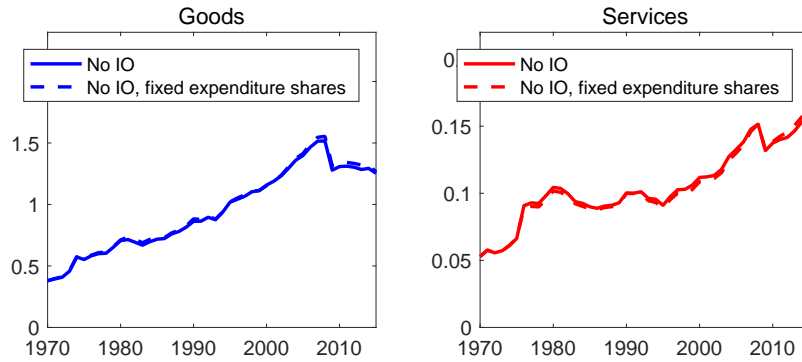
Figure 9: Sector trade over absorption and absorption over expenditure



Put differently, we hypothesize that much of the driver for those changes in openness seen in the data was increasing trade via input-output linkages. To check this, we recalculate the baseline and counterfactual in a world with no input-output linkages between sectors ( $\gamma_{gg} = \gamma_{ss} = 1$ ), and recalibrating the other pieces of the model to match the same targets as in the baseline model. This requires a manipulation of sectoral expenditures using equations (17) and (18). This manipulation ensures that the model matches the sectoral value added and sectoral net exports as in the data and the national accounting identity holds.

As can be seen in Figure 10, in a world without input-output linkages, there is little deviation in trade openness between the baseline and fixed-expenditure share counterfactuals. Thus the presence of input-output linkages lead to a somewhat smaller increase in the global trade-to-expenditure ratio than seen in the counterfactual.

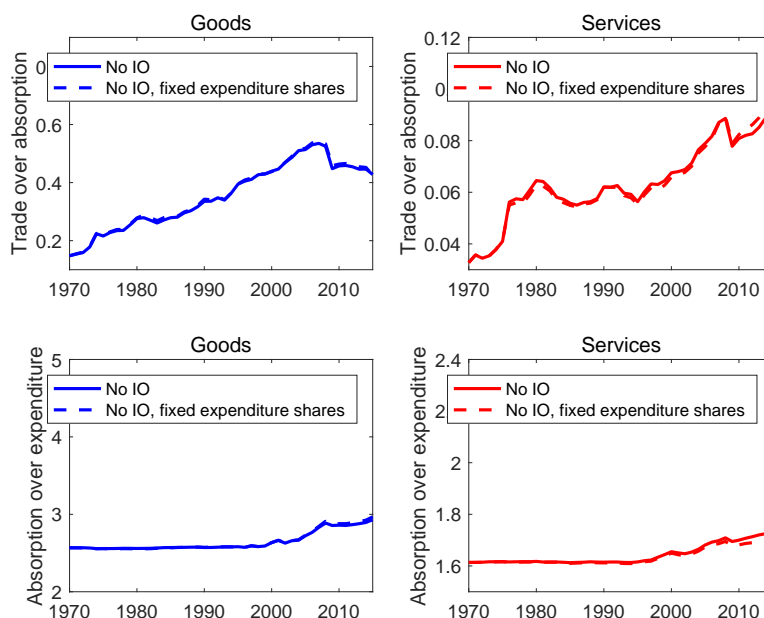
Figure 10: World sector trade over expenditure, no input-output linkages



In Figure 11, we see that goods trade increases similarly to goods absorption. In other words, goods trade as a share of goods expenditure falls in the model-based counterfactual primarily because the input-output linkages imply that increasing goods expenditure requires some services; this means that goods trade will not increase one-for-one with goods expenditure. While Figure 8 shows that services openness does rise because of this intermediate input requirement, it is insufficient to offset the fall in goods openness. So relative to the reduced-form counterfactual in which sectoral openness is taken from the data, the model-based counterfactual implies a somewhat smaller increase in the global trade-to-expenditure ratio.



Figure 11: Sector trade over absorption and absorption over expenditure, no input-output linkages



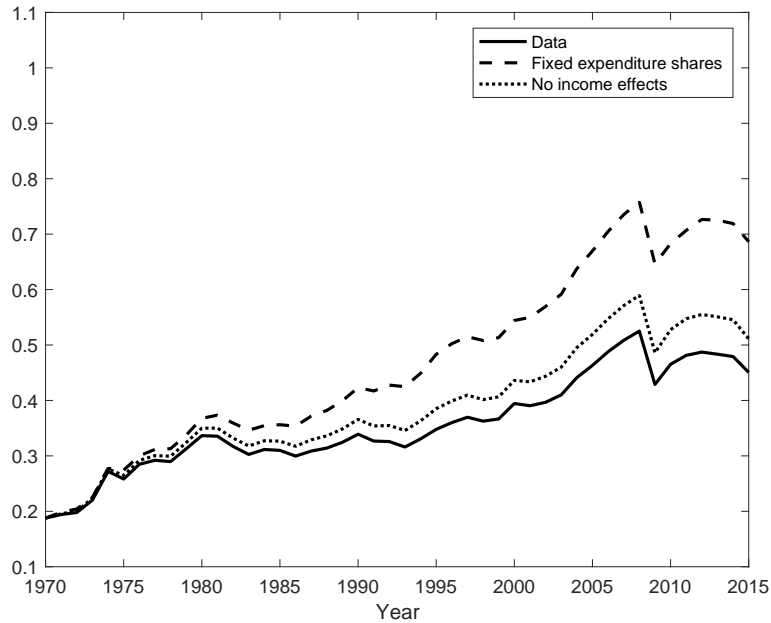
## 5.2 Removing income effects

An additional experiment we can perform is to determine how important non-homothetic preferences are to understanding our result. As income changes over time, demand is changing differently based on the respective income elasticities for goods and services. If we eliminate this channel, we can see to what extent our results are driven by income effects.

To carry out this counterfactual we set  $\varepsilon_y = 1$  so that preferences are homothetic, i.e., income elasticity of demand in each sector equals 1. We adjust the preferences weights,  $\omega_{ik}$ , so that in 1970 the sectoral expenditures are identical to those in the baseline model.

As can be seen in Figure 12, a model that shuts down the role of changing income over time for relative expenditure on goods and services leads to a trade-expenditure ratio about 10 percentage points higher than the data, or about one-fourth of the difference between the data and the fixed expenditure shares counterfactual. Thus income effects do play some part in the way structural change affected international trade over this time period.

Figure 12: World trade over expenditure, baseline and counterfactual



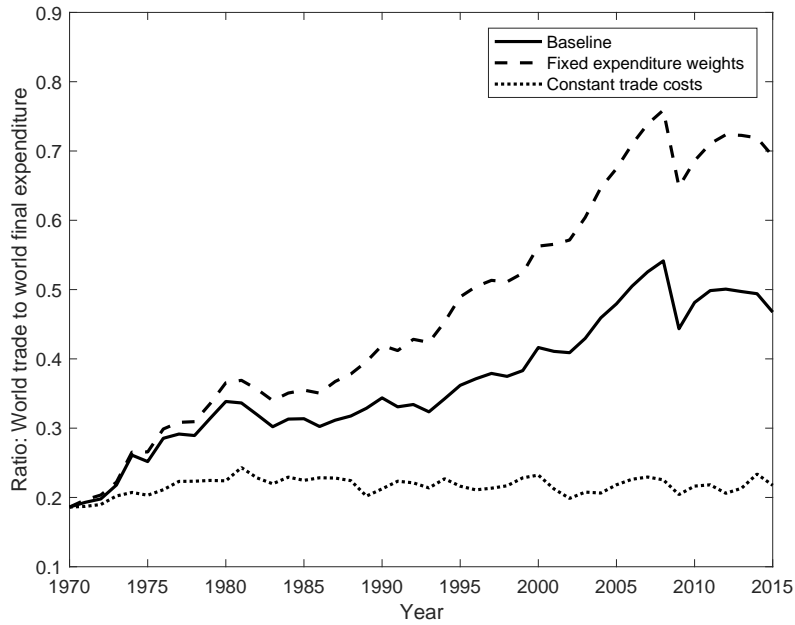
### 5.3 The growth of world trade

In the model, global trade-to-expenditure can grow from several sources: trade costs, differential productivity changes, and changing input-output linkages (vertical specialization). In Figure 13, we show that the growth in world trade is largely driven by a reduction in trade costs. The dotted line shows a counterfactual in which trade costs are held at their 1970 level, and in this world, the global trade-to-expenditure ratio grows only modestly.

Of course, trade costs in the baseline model are calculated as the residuals required to account for changes in trade not driven by technology or demand. As such, they incorporate a wide variety of economic forces, including tariff reductions, improvements in shipping technology, or even compositional changes in demand at a finer level of disaggregation than our goods and services distinction.

That said, the constant trade cost counterfactual also demonstrates the quantitative significance of structural change: structural change has held back trade by roughly the same magnitude as reductions in trade costs have boosted trade as a share of expenditure over these four decades.

Figure 13: World Trade to Expenditure Ratio



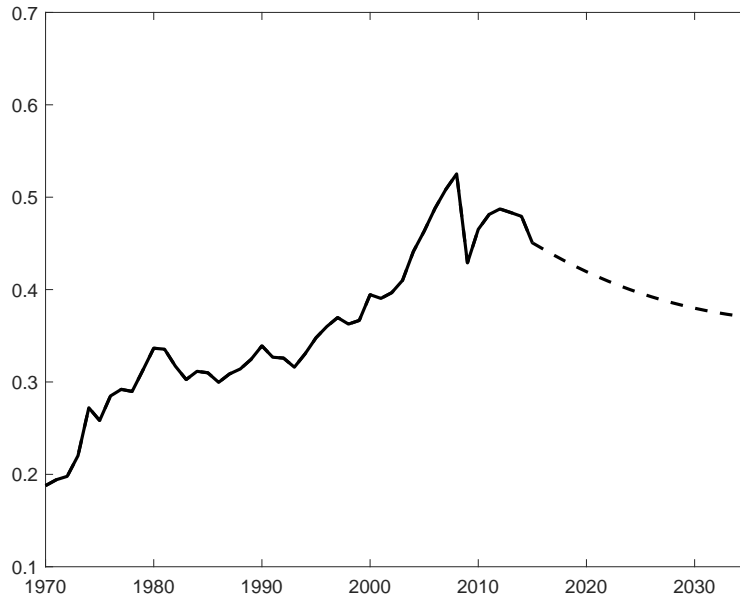
#### 5.4 Projecting the future impact of structural change on trade

The recent slowdown in the growth of international trade has prompted careful consideration of the forces that might be holding back trade or no longer boosting it (IMF 2016b). While structural change has not been a stronger drag on trade growth recently than it was in preceding decades, without additional reductions in trade costs, world trade as a share of total expenditure is likely to fall in the future.

We show this quantitatively through the lens of our model in Figure 14, where we extrapolate our sample of countries holding trade costs fixed at their 2015 value and letting goods and services productivity grow at the world average rate observed between 1970-2015.<sup>8</sup> Without additional factors boosting trade, our model implies that the trade to expenditure ratio would fall from 45 percent in 2015 to 37 percent in 2035.

<sup>8</sup>Goods productivity grows 14.1 percent and services grows 1.1 percent annually.

Figure 14: World Trade to Expenditure Ratio, Projection



## 6 Conclusion

We show that structural change, whereby the world is consuming a great share of total income on services compared to goods, has been a significant drag on global trade growth over the last four decades. In the absence of structural change, defined as a fixing expenditure share in goods and services at their 1970 level, the global trade-to-GDP ratio would be 23 percentage points higher than the data (or about 71 percent). We estimate this counterfactual with a structural model incorporating comparative advantage, non-homothetic preferences, and an input-output structure.

There are a number of channels through which structural change has been a drag on trade flows. First, structural change has led to greater openness in the goods sector, mainly because of the presence of input-output linkages. This means that relative to a simple empirical counterfactual holding expenditure shares fixed but letting sectoral openness change as in the data overstates the importance of structural change on trade. Second, consumption patterns have adjusted as a result of income effects, accounting for about one-quarter of the effect structural change has had on international trade.

Though structural change has been a significant drag on global trade growth over recent decades, it has not been a particularly strong drag since the global financial crisis. Instead, the recent slow-down in trade can be attributed to a lack of factors that have historically caused trade to rise as a share of expenditure. Indeed, our paper demonstrates how unusual the 1990s and 2000s were: even

as the share of services in total expenditure rose, international trade flows expanded, as input-output linkages proliferated across country borders. For the same reasons, however, our results indicate that world trade as a fraction of GDP has likely peaked, and similar patterns of structural change projected out to the near future predict declines in the ratio.

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## A Data appendix

In this section, we describe the data sources we use to construct both the empirical counterfactual in Section 2 and to estimate the model in Section 4. The empirical counterfactual requires 1) total exports and imports of goods and services for every country and 2) value added in goods and services for every country. The model estimation requires these things plus 3) bilateral goods and services trade data; 4) input-output coefficients; 5) value added to gross output ratios; 6) sectoral price indices; and 7) the real wage for every country. The date range is 1970-2015. The list of countries/regions is Australia, Austria, Belgium-Luxembourg, Brazil, Canada, China, Cyprus, Denmark, Finland, France, Germany, Greece, India, Indonesia, Ireland, Italy, Japan, Korea, Mexico, Netherlands, Portugal, Spain, Sweden, Turkey, United Kingdom, and United States, plus a “Rest of World”.

Our strategy is to work with the World Input-Output Database (WIOD) from 1995-2011, as described in (Timmer, Dietzenbacher, Los, Stehrer and de Vries 2015), and then build out from those numbers using splicing techniques with other longer-running datasets. We splice in this way so that the input-output coefficients generate sensible expenditure shares during WIOD years- otherwise, the input-output coefficients would be applied to trade data that does not add up to the source of the coefficients.

**Total Exports and Imports by Country** For each of the 27 groupings above, we take total goods and services exports and imports from the WIOD from 1995-2011. Then, for all other years (i.e. 1970-1994 and 2012-2015), we splice with other data. The splicing procedure is to divide the average of three years of the WIOD data by the average of three years of a longer dataset to generate a splicing factor, then applying that splicing factor to the longer dataset in non-WIOD years. The averages are calculated from 1995-1997 for all years before 1995, and from 2009-2011 for all years after 2011. For goods trade, we splice the WIOD trade data with world trade from the IMF Direction of Trade Statistics (IMF 2016a) database. For services, we use aggregate services trade data from the World Development Indicators (WDI) as the comparison. If WDI data on services is not available, we supplement in growth rates where necessary with OECD services data.

**Value Added** For value added data, we rely on the UN Main Aggregates Database (UN (2017)). We take nominal goods value added in a country to be the combination of expenditure in “Agriculture, hunting, forestry, fishing” and “Mining, Manufacturing, Utilities”, while services value added is expenditure in “Construction”, “Wholesale, retail trade, restaurants and hotels”, “Transport, storage, and communication”, and “Other Activities”.<sup>9</sup>

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<sup>9</sup>Results are qualitatively similar defining construction as a goods category, but given the lack of direct trade in construction, categorizing it as a service will make goods sectoral openness lower and services sectoral openness higher. Both the model-based counterfactual and especially the empirical counterfactual would be smaller in magnitude relative



**Bilateral goods and services trade** As with total goods trade, when not taken directly from the WIOD, goods trade between two different regions in our sample is generated by splicing importer-reported bilateral goods trade data in the IMF DOTS database with WIOD data, using the same three-year combinations as above. Bilateral services data is extremely patchy, so instead of splicing, we simply apply average bilateral shares over three year periods to the total services trade data calculated as above. Again, for all years prior to 1995, we use average bilateral shares from 1995-1997, and for all years after 2011, we use average bilateral shares from 2009-2011.

**Input-Output coefficients and Value Added to Gross Output ratios** To construct  $\gamma_{kn}$ , the country-specific share of intermediate inputs sourced from sector  $n$ , we use the numbers directly from WIOD. The value added to gross output ratio in sector  $k$ ,  $\lambda_{ik}$  is also a straightforward manipulation of data in the WIOD. In both cases, we use 1995 coefficients for years prior to 1995, and 2011 coefficients for years after 2011.

**Sectoral Prices** In order to estimate the preference parameters  $\varepsilon, \omega_i$  and  $\sigma$ , we need gross-output sectoral prices. First, we take nominal and real value added (indexed to 2005) data in goods and services from the UN Main Aggregates Database. We generate sectoral prices for each sector as the ratio of nominal to real value added. We then multiply the sectoral value added indices in PPP terms from the GGDC Productivity Level Database “2005 Benchmark” (Inklaar and Timmer 2014) by our value added price terms to make the country-level price indices comparable to each other in each year. Finally, we “gross up” the value added prices using the equation for the value added deflator in Appendix C4 of Sposi (2016).

Note that these prices are only used in our estimating equation for the preference parameters; the price indices in the calibration of the model are separate model-specific objects. The iterative procedure for deriving elements of the model, including prices, relies on our estimates of the preference parameters. Other objects, such as the expenditure shares and consumption, are also pure model objects and not generated from data.

**Labor** We take total employment data in the Penn World Tables as our measure of  $L_i$  that goes into the model. Since this data only goes through 2014, we create a splicing factor with WDI total employment data in 2015 in order to estimate the model through 2015.

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to the data.

## B Solution algorithm

Here we present the detailed version of our solution algorithm.

- Guess the vector of wages,  $w_i$ , across countries.
- Compute sectoral unit costs  $v_{ik}$  using condition S2 and prices,  $P_{ik}$ , using condition S3. The prices in every sector and every country must be determined as a simultaneous system of equations.
- Compute the sectoral bilateral trade shares  $\pi_{ijk}$  using condition S1.
- Compute the per-capita transfers from the global portfolio,  $R$ , using condition G1.
- Compute the aggregate price levels,  $P_i$ , and aggregate consumption indexes,  $C_i$ , using conditions D3 and D4, simultaneously.
- Compute the sectoral consumption levels,  $C_{ik}$  using condition D1.
- Compute sectoral demand for labor,  $L_{ik}$ , using condition S4.
- Compute sectoral demand for intermediate inputs,  $M_{ikn}$ , using condition S5.
- Compute quantity of gross absorption in each sector,  $Q_{ik}$ , using condition S6.
- Compute quantity of gross production in each country,  $Y_{ik}$ , using condition S7.
- Define an excess demand equation as the net exports minus net contributions to the global portfolio:

$$Z_{it}^w(\vec{w}) = \frac{P_{it}Y_{it} - P_{it}Q_{it} - (\rho_i w_i L_i - RL_i)}{w_{it}}.$$

Condition 11 requires that  $Z_i^w(\vec{w}) = 0$ , for all  $i$ , in equilibrium. If this is different from zero in at least some country, update the wages as follows.

$$\Lambda_i^w(\vec{w}) = w_i \left( 1 + \kappa \frac{Z_i^w(\vec{w})}{L_i} \right)$$

is the updated guess of wages and  $\kappa$  is chosen to be sufficiently small so that  $\Lambda^w > 0$ . Use the updated wage vector and repeat every step to get a new value for excess demand. Continue this procedure until the excess demand is sufficiently close to zero in every country. Note that Walras' Law ensures that the labor market clears in each country.

## C Country results

Figure 15: Trade to Expenditure Ratio by Country

