Federal Reserve Bank of Dallas
Globalization and Monetary Policy Institute
Working Paper No. 333
https://doi.org/10.24149/gwp333

Structural Change and Global Trade*

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January 2018

Abstract

Since 1970, services has risen from 50 percent of the world's final consumption expenditures to nearly 80 percent. Services are also far less traded between countries than 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 or 70 percent higher by 2015 if country-level expenditure patterns were unchanged from 1970 onwards. Income effects explain about one-quarter of this counterfactual. Without input-output linkages in production, the counterfactual increase in world trade with no structural change would be even greater. Finally, the process of structural transformation toward services systematically impedes the gains from trade.

JEL codes: F41, L16, O41

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1 Introduction

The ratio of world trade to world GDP more than doubled between 1970 to 2015. This remarkable growth in “trade openness" occurred over the same period that the world (and individual countries) experienced a seismic shift in the composition of total spending; global expenditure on services rose from about half of the world’s expenditures in 1970 to 80 percent in 2015. This phenomenon of “structural change" is thoroughly studied and is well-known to be a foundational component of economic growth and development. Less appreciated in the literature, however, is the combination of such structural change with the fact that services are much less traded internationally than goods. Indeed, years when the world featured faster growth in services tended to be those years in which openness grew more slowly. Since an ever-greater share of the world economy was devoted to services—less-tradable consumption categories—it must be that structural change held back trade flows during this time, and could potentially lead to declines going forward.

Table 1: Trade Openness and Structural Change

	1970	2015
Trade, % of World Expenditure	18.8	47.9
Services Expenditure, % of World Expenditure	52.6	80.0
Correlation of annual growth rates	-0.72	

Source: IMF Direction of Trade Statistics, World Input-Output Database, UN Main Aggregates Database, authors’ calculations.

While there is a robust literature that has focused on the impact of trade on structural change, the goal of this paper is to quantify the effect of structural change on trade flows, and demonstrate how gains from trade are mismeasured when ignoring these trends.

We start with a straightforward but naïve computation of counterfactual global trade with no structural change; in other words, we assume that sectoral expenditure shares are fixed at the initial year of data, while the sectoral trade-to-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 in the data.

This simple calculation suggests that 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 expenditures and trade. The literature has established that differential productivity growth across sectors, combined with a non-unit elasticity of substitution, leads to structural change. In addition, higher income due to higher productivity growth also results in structural change. These same forces can affect the volume of trade. In other words, sectoral "openness" is likely to have been simultaneously affected by these forces alongside the expenditure shares. The interactions between these factors imply that a more accurate 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 Święcki (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, sectoral 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. We deliver constant expenditure shares for all sectors in each country across time by restricting the preferences to be Cobb-Douglas over goods and services, effectively shutting down structural change. What is different from the simpler empirical calculation is that the model allows for the counterfactual expenditure shares 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.

Our model-based counterfactual permits us to better understand the mechanisms underlying structural change and consequences of omitting structural change. 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. To put the quantitative findings in perspective, we consider a counterfactual in which trade barriers are held constant over time. We find that the magnitude that structural change has held back trade flows is about the same as the magnitude that declining trade costs boosted trade.

The ongoing process of structural change has important implications for inferring trade costs, and therefore, measuring the gains from trade. As in much of the trade literature, our model admits a gravity equation, allowing us to exploit the observed bilateral trade flows to infer the trade costs. Our inferred trade costs for both goods and services decline over time, while the services trade costs are higher than those in goods. Inferring trade costs in a one-sector model using aggregate bilateral trade flows implies smaller declines in trade costs over time, particularly during periods when structural change was more prominent.

The biased estimates of trade costs in the one-sector model imply that the measured gains from trade are overstated relative to our two-sector model with structural change; The extent that the gains are overstated becomes larger as service's share increases. In 1970, the one-sector gains are 1.3 times larger that those in the two-sector model; in 2015, the gains are 1.5 times larger. An immediate corollary is that a country's gains from trade depends not only on its home trade share, as in typical sufficient-statistics calculations, but also on its expenditure shares and hence on its level of development. Less-developed countries that have lower service expenditure shares have higher gains from trade than developed countries, even with the same home trade shares.

Projecting our model results out into the future indicates that the trade-to-GDP ratio has perhaps peaked, and will decline to around 40 percent by 2030. Importantly, this occurs without any changes in trade costs, meaning that the downward trend in trade relative to GDP is driven by the effects of increased services consumption. At the same time, there is little evidence that the slowdown in international trade growth which started in 2011 is a result of structural change; that is, structural change has been a drag on trade growth for decades, and this drag has not been stronger in recent years.

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 rapid productivity growth in South Korea's manufacturing sector contributed to the rise in its manufacturing employment share due to improved comparative advantage. In a closed economy, the same productivity growth would have produced a decline in the manufacturing share. 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. We find in this paper that structural change may in fact be more consequential for international trade than international trade is for explaining the pattern of structural change in many countries.

More broadly, our findings point to structural change as being an important link between international trade and economic development. 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. Sposi (2016) documents how the input-output structures of advanced economies is systematically different from those of developing economies, and that this contributes to systematic differences in resource allocations between rich and poor countries.

Some analysis suggests that international trade plays only a small role in explaining the pattern of structural change. 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. Święcki (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 proceeds 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 Empirics and a simple 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 shift in expenditures from goods to services over that time (i.e. structural change)? This section presents a direct and simplified answer to the question by holding each country's expenditure share on goods and services fixed at its 1970 level and tracing out a counterfactual path for the global 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.

2.1 Data

This subsection defines our concepts of structural change and trade openness, then discusses 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. Expenditure refers to final demand: consumption, investment and government spending. For every country and for the world as a whole, we can decompose the ratio of trade to expenditure in period t as

$$\frac{Trade_t}{Exp_t} = \frac{Trade_{gt}}{Exp_{gt}}\frac{Exp_{gt}}{Exp_t} + \frac{Trade_{st}}{Exp_{st}}\frac{Exp_{st}}{Exp_t}, \tag{1}$$

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

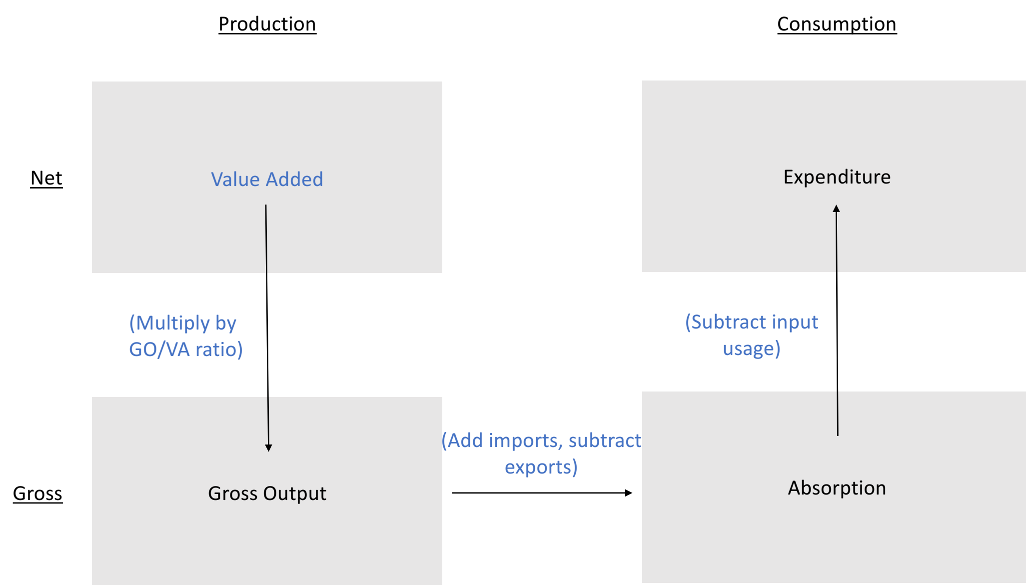
We gather data needed to compute equation (1) for 26 country groupings and a "rest of world" aggregate over the period 1970-2015.[1] This includes imports and exports by each broad sector, as well as expenditures on goods and services. In UN nomenclature, we take the goods sector to consist of "agriculture, 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 GDP data is easily available, data on sectoral expenditure is not. Conceptually, we need to split *expenditure*, the sum of consumption, investment, and government spending, into goods and services. In order to achieve this split we exploit data on sectoral value added, sectoral net exports, and input-output linkages. We begin with sectoral value added and gross it up using the share of value added in gross output for each sector; these ratios are available in the World Input-Output Database (WIOD). We subtract out sectoral net exports from sectoral gross output to arrive at *sectoral absorption*—a gross concept—which is equal to final expenditures plus interme-

[1] The full list of countries is listed in Appendix A.

diate expenditures on that sector. In other words, the value of that sector that is absorbed by the economy either by final consumers or by firms. Using data from input-output tables we can measure what fraction of the final absorption went to intermediate usage. The remaining absorption, by definition, corresponds to final expenditures. A stylized depiction of this calculation is in Figure 1

Figure 1: Deriving Sectoral Expenditures from Sectoral Value Added



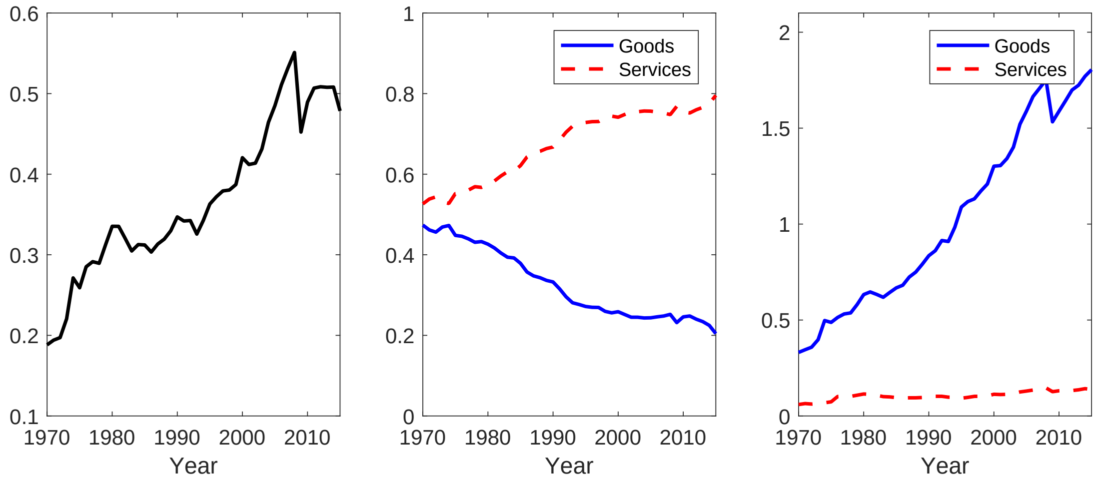
Note: Categories in blue represent publicly available data, while categories in black represent imputed moments.

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

2.2 Trade openness and structural change

This section presents the patterns of openness and structural change in the world economy. Figure 2 Panel (a) shows the pattern for the ratio of world trade (imports plus exports) to world GDP. A major increase in the growth rate of the ratio of trade to expenditure occurred over this time period, accelerating through the late 1990s and 2000s. Since 2011, the ratio has been nearly flat.

Figure 2: Global Trade Openness and Structural Change



(a) Trade to GDP (b) Sectoral Expenditure Shares (c) Sectoral Trade Openness

Even while this trend has been going on, world consumption has been shifting to services. Figure 2 Panel (b) demonstrates the substantial shift in expenditures from goods to services from 1970-2015. Service's share rises steadily over the period by a total of 27 percentage points, from 53 percent in 1970 to 80 percent in 2015.

If these two sectors were both traded internationally with similar intensities, the impact of structural change on aggregate openness would be small. In the data, however, trade openness significantly differs across sectors. Figure 2 Panel (c) plots the ratio of sectoral trade to sectoral expenditure over 1970-2015. Clearly, goods are much more open than services; the ratio of trade to expenditure is about 6 percent for services but is 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.[2]

Considering these three figures together presents a puzzle of sorts: how could trade grow so quickly at the same time that a relatively less-traded sector gains expenditure share? The answer is that trade growth was so spectacular *despite* the ongoing transition to services in the world economy, a trend which held back further growth in trade. This becomes apparent when calculating the correlation of growth rates between openness and the services expenditure share. For the world, the overall correlation is -0.72, meaning that periods when the ratio of trade to GDP is growing faster indeed feature a slower-growing service share. The same result holds when calculating 10-year rolling correlations between the growth rates of the two series, as shown in Figure 3. It is also a consistent pattern across countries: Table 2 shows the results of regressing the country-level growth rate of

[2]The ratio of trade to expenditure can be over 100% for two reasons. First, trade here refers to the sum of import and exports. Second, trade is a gross measure (as a result of trade in inputs) and expenditure is a final consumption measure.

trade openness on the country-level growth rate of the service share for the 27 country groupings (including "Rest of World") in our sample. Again, we find strong evidence of negative correlations; when a country featured higher growth in its service consumption, it had lower growth in openness, even accounting for the level of wealth. In the next subsection, we present a simplified view of how much structural change held back global trade growth.

Figure 3: 10 Year Rolling Correlations, Growth Rate of Openness and Service Share

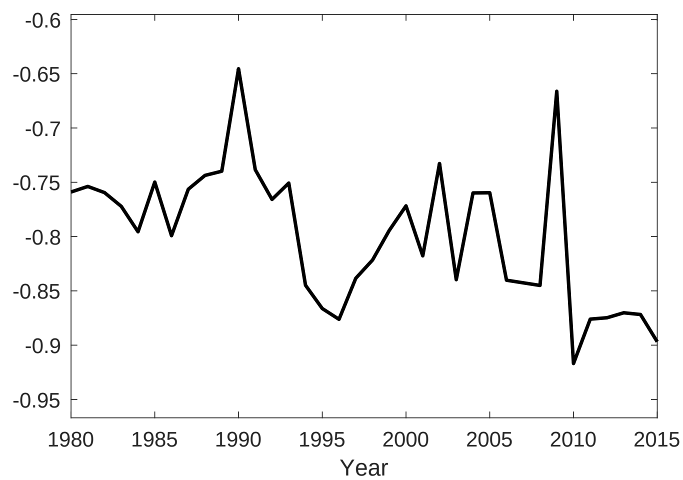


Table 2: Country-Level Openness and Service Share

Dependent Variable: Openness Growth				
Services Share Growth	-0.464***	-0.459***	-0.220***	-0.226***
	(0.157)	(0.157)	(0.062)	(0.062)
Per Capita GDP		-15.323*		-45.508***
		(9.048)		(9.110)
Year FE	NO	NO	YES	YES
Country FE	YES	YES	YES	YES
N	1215	1215	1215	1215
R^2	0.07	0.07	0.33	0.35

2.3 A simple counterfactual

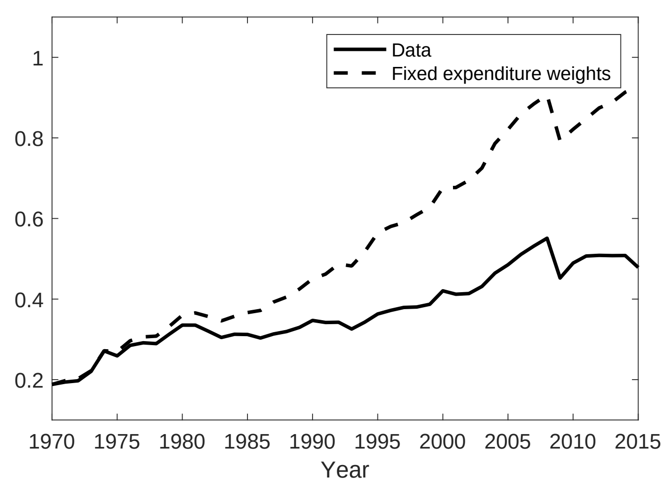
To gauge the contribution of structural change to the ratio of trade to expenditure, we return to equation (1), but freeze the expenditure shares at the first period of data and compute a counterfactual ratio of trade to expenditure as:

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

By holding the expenditure shares of sector k fixed at the first period, we shut down the process of structural change that happened in the data. The counterfactual ratio of trade to expenditure is free of structural change, but it is consistent with the observed sectoral openness measures. If the counterfactual ratios of trade to expenditure are significantly different from the observed ratios, it suggests that structural change has an important impact on global openness. We calculate equation (2) country-by-country. In other words, holding sectoral expenditure shares fixed for each country, we compute country-specific ratios of trade to expenditure. Summing the numerator and denominator of these ratios across countries gives the world ratio.

Figure 4 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 services, global trade growth would have been far greater. According to this exercise, persistent structural change since 1970 has lopped about 45 percentage points off the ratio of trade to expenditure as of 2015.

Figure 4: 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: sectoral trade openness is also very likely to have been simultaneously affected by the same forces that instigated structural change. For example, differential productivity growth, which shifted relative prices and income levels, likely altered comparative advantage and trade flows. Furthermore, 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 accurately.

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

$$L_i = L_{ig} + L_{is}. \tag{3}$$

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

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

where for each sector $k \in \{g,s\}$, C_{ik} is consumption of the sector-k composite good, and the preference share parameters ω_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. ε_k denotes the income elasticity of demand for sector k.

This set of preferences (known as "normalized Constant Elasticity of Substitution") were first studied by Gorman (1965) and Hanoch (1975), and were found to be especially apt for studying long-run structural change by Comin et al. (2015). Comin et al. (2015) show that this specification of nonhomothetic preferences has two attractive properties. First, the elasticity of the relative demand for the two sectoral composites with respect to consumption is constant. This contrasts with Stone-Geary preferences, where the elasticity of relative demand vanishes to zero as income or aggregate consumption rises—a prediction at odds with the data both at the macro and micro levels. Second, the elasticity of substitution between sectoral composites, given by σ, is constant over income, meaning that there is no functional relationship between income and substitution elasticities.[3] 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 its utility from aggregate consumption, C_i, subject to the following budget constraint in each period:

$$\underbrace{P_{ig}C_{ig} + P_{is}C_{is}}_{P_iC_i} + \rho_i w_i L_i = w_i L_i + RL_i, \tag{5}$$

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 ρ_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, $\rho_i w_i L_i - RL_i$ 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 $k \in \{g, s\}$,

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

where the aggregate price is given by

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

[3] This is a key difference from the preferences used in Fajgelbaum and Khandelwal (2016), whose framework could be used to ask a similar question to ours.

The sectoral expenditure shares are given by

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

Thus, how relative price and real income per capita shape the sectoral expenditure shares are governed by the elasticity of substitution between sectors σ and the sectoral elasticity of income ε_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 sectoral composite good, Q_{ik}, is an aggregate of the individual varieties $Q_{ik}(z)$:

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

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 compsite good 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

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

where λ_{ik} denotes the country-specific value-added share in production, and γ_{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 equally across all varieties. $A_{ik}(z)$is a variety-specific productivity level that scales gross output, which 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 θ_k, the lower the heterogeneity or variance of

$A_{ik}(z)$.[4] 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.[5]

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

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

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 $\frac{1}{\tau_{ijm}}$ units arrive in country i. We assume that trade costs within a country are zero, i.e., $\tau_{iig} = \tau_{iis} = 1$. 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 the cheapest source, the actual price for this good in country i is $p_{ik}(z) = \min\left\{p_{ijk}(z)\right\}_{j=1}^{I}$.

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

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

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.[6]

The share of country i's expenditure on sector-k goods from country j, π_{ijk}, equals the proba-

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[4] $A_k(z)$ has geometric mean $e^{\frac{\gamma}{\theta_k}}$ and its log has a standard deviation $\frac{\pi}{\theta_k\sqrt{6}}$, where γ is Euler's constant.

[5] 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.

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

bility of country i importing sector-k goods from country j, and is given by

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

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 3 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.

Table 3: 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	$\pi_{ijk} = \frac{\left(T_{jk}^{-\lambda_{jk}} \nu_{jk} \tau_{ijk}\right)^{-\theta}}{\sum_{s=1}^{I} \left(T_{sk}^{-\lambda_{sk}} \nu_{sk} \tau_{isk}\right)^{-\theta}}$	$\forall i,j,k$
S2	$\nu_{ik} = B_{ik} w_i^{\lambda_{ik}} \prod_{n\in\{g,s\}} P_{in}^{(1-\lambda_{ik})\gamma_{ikn}}$	$\forall i,k$
S3	$P_{ik} = \Gamma_k \left(\sum_{j=1}^{I} \left(T_{jk}^{-\lambda_{jk}} \nu_{jk} \tau_{ijk}\right)^{-\theta}\right)^{\frac{1}{\theta}}$	$\forall i,k$
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	$\sum_{k\in\{g,s\}} P_{ik} Y_{ik} - \sum_{k\in\{g,s\}} P_{ik} Q_{ik} = \rho_i L_i - R L_i$	$\forall i$

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. 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 $\{\pi_{ijg}, \pi_{ijs}\}_{i,j=1,..I}$, such that each condition in Table 3 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, τ_{ijkt}, productivity, T_{ikt}, and trade imbalances, ρ_{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, θ_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 $t = 1970, \ldots, 2015$.

4.1 Common parameters

The upper panel of Table 4 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, η, plays no quantitative role in the model other than satisfying $1 + (1 - \eta)/\theta > 0$; we set this value at 2.

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

Table 4: Parameter values

Common parameters		
θ_g	Trade elasticity in goods sector	4
θ_s	Trade elasticity in service sector	4
η	Elasticity of substitution b/w varieties in composite good	2
σ	Elasticity of substitution b/w sectors	0.4
ε_g	Elasticity of income in goods	1
ε_s	Elasticity of income in services	1.59
ω_g	Preferences share of goods	0.49
Cross-country, cross-time averages		
λ_g	Ratio of value added to gross output in goods	0.39
λ_s	Ratio of value added to gross output in goods	0.61
γ_{gg}	Good's share in intermediates used by goods sector	0.68
γ_{sg}	Good's share in intermediates used by service sector	0.34

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, σ. Holding fixed relative prices, the extent that expenditures shares move with the aggregate level of consumption helps us identify income elasticities, ε_k. By setting the sector weights, ω_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:

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

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

$$\sum_{k\in\{g,s\}} \omega_k = 1, \tag{14}$$

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, $\widehat{P_iC_i}$, 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 deflater.

Our procedure to solve the minimization problem is as follows. First we normalize the income elasticity for goods $\varepsilon_g \equiv 1$ (as in Comin et al. (2015)). Second, we make a guess for the remaining preference parameters: $(\omega_g, \omega_s, \sigma, \varepsilon_s)$. Third, given these parameter guesses 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. Fourth, 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 γ_{iknt} and λ_{ikt} are constructed using the World Input-Output Database (WIOD), condensed down to a two-sector input-output construct for each country from 1995-2011. Specifically, λ_{ikt} is the ratio of value added to total production in sector k, while the γ_{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, they are fairly stable over time. Moreover, there are notable patterns that hold across countries. First, production of services is more value-added intensive than production of goods. Table 4 indicates that, on average, 61 percent of total service production compensates 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, ρ_{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 $\rho_{it} = \frac{\widehat{NX_{it}}}{\widehat{GDP_{it}}}$. 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, τ_{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 Święcki (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:

$$T_{ik}^{\lambda_{ik}} = \frac{B_{ikt} \nu_{ikt}}{\Gamma_k^{-1} P_{ik} \left(\pi_{iik}\right)^{-\frac{1}{\theta_k}}}, \tag{15}$$

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

Both structural relationship 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 sectoral expenditures and prices Equations (15) and (16) require data on units costs, sectoral prices, and trade shares; unit costs themselves require wages and sectoral prices. While we do have data on prices, we do not use them for this part of the calibration. Instead, we impute sectoral 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 sectoral prices and sectoral 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 sectoral value added, sectoral net exports, and input-output linkages we recover sectoral expenditures. 2) Given the sectoral expenditures and data on consumption levels, we recover the sectoral prices that support the expenditures using the representative household's first-order conditions.

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

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

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:

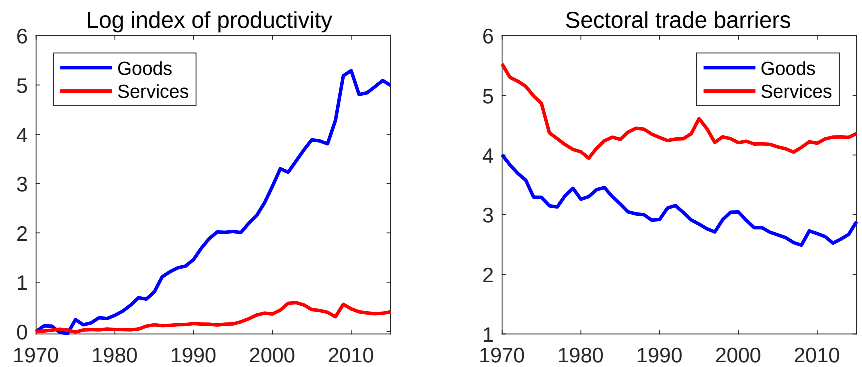
$$P_{ik}Q_{ik} + NX_{ik} = \frac{w_i L_{ik}}{\lambda_{ik}}. \tag{18}$$

Using data on sectoral value added, $w_i L_{ik}$, along with sectoral net exports, NX_{ik}, and the production share, λ_{ik}, we can calculate total expenditure, $P_{ik}C_{ik}$, via equations (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 these data are unavailable, however, this procedure allows us to construct the sectoral expenditures in a reliable way.

Second, given preference parameters, $(\omega_g, \omega_s, \sigma, \varepsilon_g, \varepsilon_g)$, imputed data on sectoral 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 sectoral prices in hand, we compute the sectoral productivity and trade costs in equations (15) and (16). Figure **??** illustrates the calibrated processes at the world level. The left panel plots the global sectoral productivity growth index. The global sectoral productivity is computed as the average across countries weighted by each country's share in sectoral 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 5: Calibrated global productivity and trade costs



The right panel of Figure 5 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.

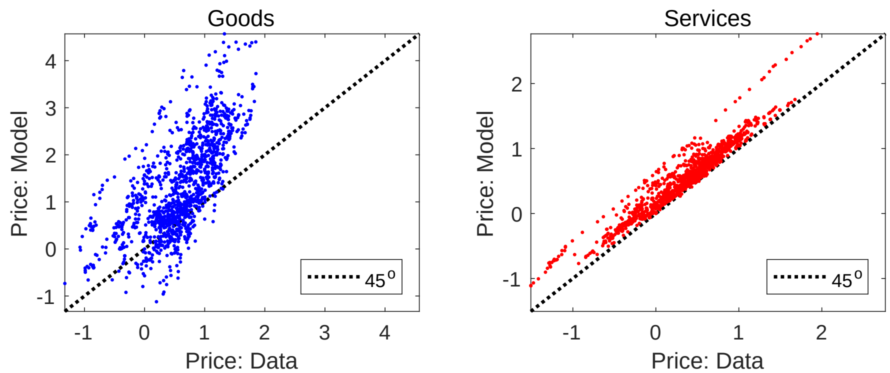
4.4 Model fit

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 ratios of trade to expenditure 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 6; 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 sectoral expenditures shares is also 1.

Figure 6: Sectoral prices: model versus data, in logs, relative to the U.S. in 2015



5 Model-based counterfactuals

This section quantitatively assesses the role of structural transformation on global trade volumes by conducting counterfactuals using the calibrated model. We also highlight the importance of structural change on model-based measures of trade costs and welfare gains from trade.

5.1 Global trade in the absence of structural change

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

$$C_i = \prod_{k \in \{g,s\}} C_{ik}^{\omega'_{ik}}. \tag{19}$$

With the Cobb-Douglas 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,

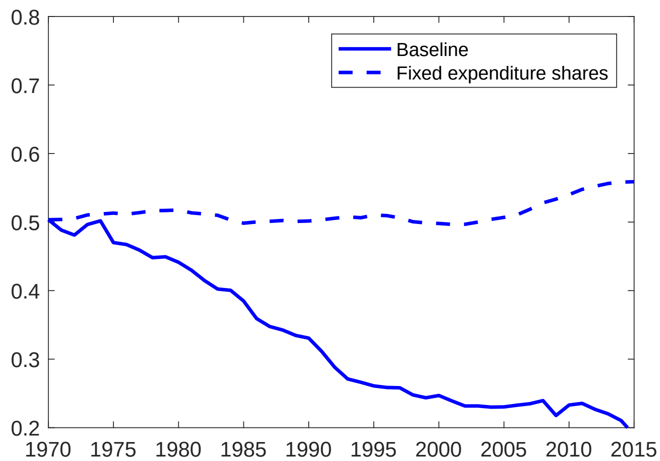
$$e_{ikt} = e_{ik0} = \omega'_{ik}. \tag{20}$$

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, τ, 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 how the absence of structural change impacts global trade flows.

5.1.1 Model counterfactual results

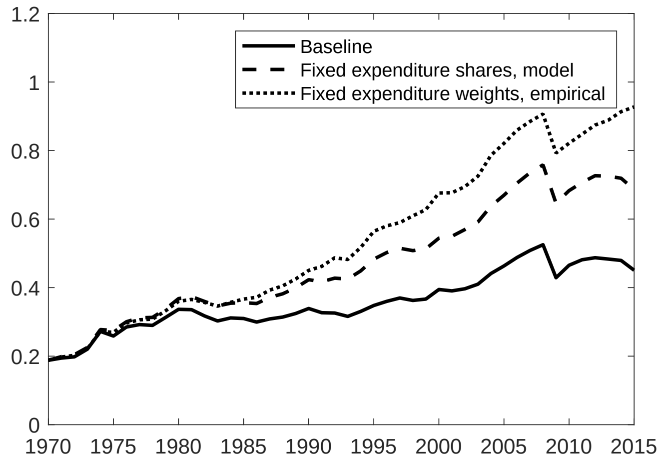
We start by highlighting the driving force of the counterfactual in Figure 7. In the data and baseline model, the goods share of total expenditure falls from about 50 in 1970 percent to 20 percent in 2015, as illustrated by the solid line. In the counterfactual, goods expenditure is held fixed over time at 50 percent country-by-country. When aggregated to a global expenditure share, it remains close to 50 percent over time, increasing somewhat near the end of the sample, as shown by the dotted line. The slight rise since 2002 is driven by the increasing weight of China and India in the world economy, both of which have larger expenditure shares in goods compared to the developed countries.

Figure 7: Goods expenditure shares, baseline and counterfactual



We next present the model-counterfactual implications for global trade flows. Figure 8 compares the global ratio of trade to expenditure between the model baseline (solid line), model counterfactual (dashed line), and empirical counterfactual (dotted line). In both counterfactuals, global trade would have been much higher had structural change not occurred. By 2015, the empirical counterfactual puts the trade-GDP ratio at 91 percent while the model counterfactual puts it at 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.

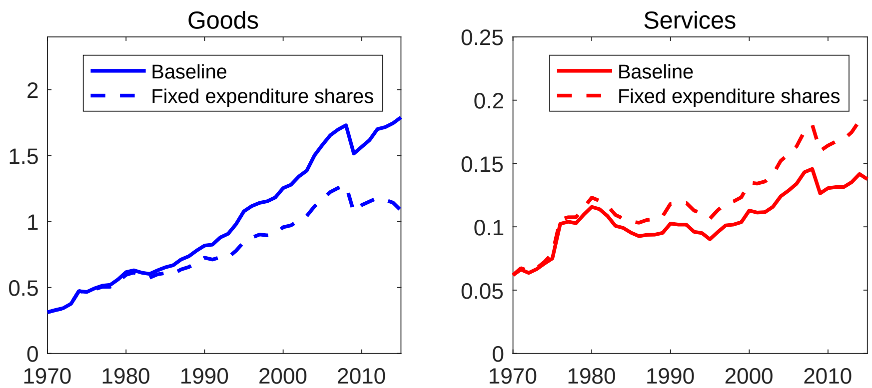
Figure 8: World trade over expenditure, baseline and counterfactuals



5.1.2 Quantitative mechanisms

The key difference between the empirical counterfactual and the model one is the path of sectoral openness, given that the sectoral expenditure share is set constant at the initial year for each country in both experiments. Figure 9 shows sectoral openness in the model counterfactual compared with observed sectoral openness, which is the same as in the model baseline and the empirical counterfactual. The left panel shows that goods openness (ratio of goods trade to goods expenditure) is about 70 percentage points lower relative to the baseline in 2015, while services openness is about 5 percentage points higher.

Figure 9: World sectoral trade over expenditure



To understand how sectoral openness endogenously responds to changes in expenditure shares in the model, we decompose sectoral trade openness into two terms: (i) the ratio of trade to absorption and (ii) the ratio of absorption to expenditure:

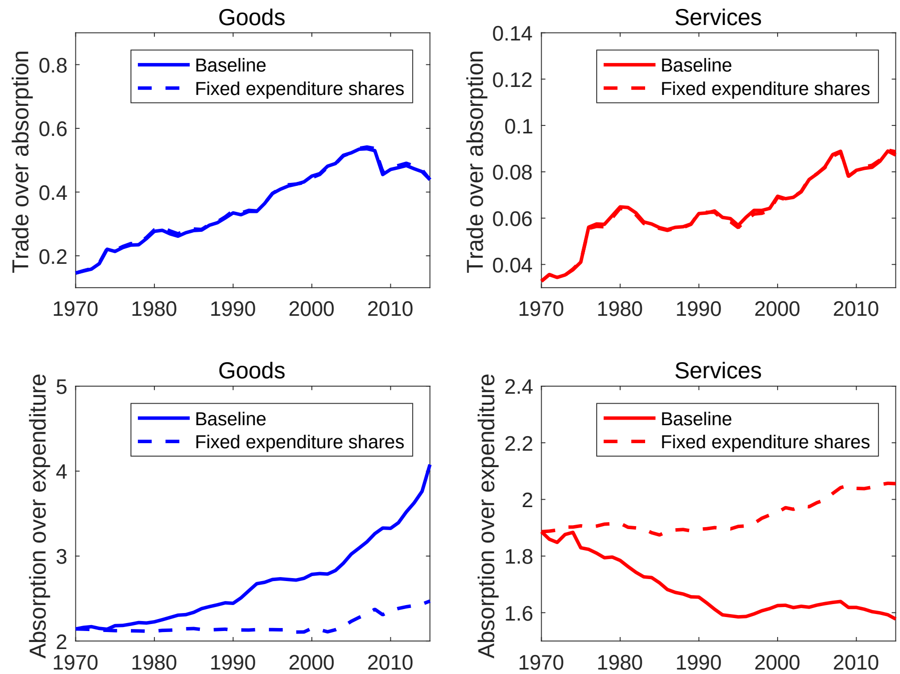
$$\frac{Trade_{kt}}{Exp_{kt}} = \left(\frac{Trade_{kt}}{Abs_{kt}}\right) \times \left(\frac{Abs_{kt}}{Exp_{kt}}\right). \tag{21}$$

These two terms correspond to two potential channels of bias produced by the empirical counterfactual. Through endogenous general equilibrium effects, changing sectoral demand might change the relative wages across countries and thus the ratio of trade to absorption, which is captured by the first term. In the model, at the country level the first term is similar to $1-\pi_{iik}$ for each country i and sector k.[7] Also, changing the sectoral demand shares might affect the ratio of absorption to expenditure through input-output linkages, captured by the second term.

We now quantify the bias of each channel. The ratios of trade to absorption in each sector are almost identical in the baseline and in the counterfactual, as shown in the upper panel of Figure 10. Recall the expression of π_{iik} in equation (S1) in Table 3. Since the productivity and the trade cost processes are unchanged, the only way that changing expenditure patterns affect the trade-over-absorption ratios is through its impact on relative wages across countries. It turns out that the general equilibrium effect on relative wages is quantitatively small in the model counterfactual. Thus, the share of each country's absorption that is sourced from abroad in each sector barely changes from the baseline to the counterfactual.

[7] Sectoral imports over expenditure is exactly equal to $1-\pi_{iik}$. Sectoral exports differs, but quantitatively is highly correlated with sectoral imports across countries.

Figure 10: Sectoral trade over absorption and absorption over expenditure



The primary reason why sectoral trade openness in the model counterfactual differs from the baseline is due to differences in the ratio of absorption to expenditure, as shown in the lower panel of Figure 10. The ratios of absorption to expenditure in the counterfactual rise by less over time for the goods sector, but rise by more over time for the services sector, compared to the baseline. Using the expression of sectoral absorption in equation (S6) of Table 3, we can write the sectoral ratio of absorption to expenditure as

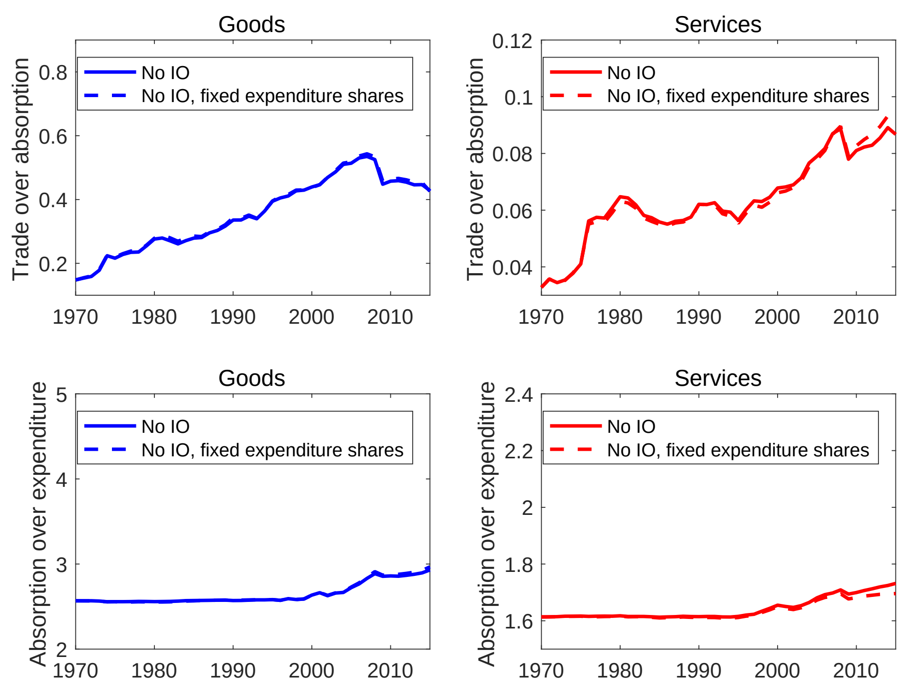
$$\frac{Q_{ig}}{C_{ig}} = \frac{C_{ig} + M_{igg} + M_{isg}}{C_{ig}}, \qquad \frac{Q_{is}}{C_{is}} = \frac{C_{is} + M_{iss} + M_{igs}}{C_{is}},$$

where sectoral absorption equals to final plus intermediate demand for the sectoral composite good. In order counterfactually increase consumption of goods, C_{ig}, intermediates must be sourced from both sectors implying that M_{igg} and M_{igs} rise. At the same time, M_{iss} and M_{isg} decline in response to a decline in C_{is}. Consequently, absorption rises by less than expenditure in the goods sector, while absorption declines by less than expenditure in the services sector, implying lower $\frac{Q_{ig}}{C_{ig}}$ and higher $\frac{Q_{is}}{C_{is}}$ in the model counterfactual compared to the baseline.

Going back to Figure 9, we conclude that although services trade openness goes up, goods openness decreases sufficiently enough to imply a lower overall trade openness in the model counterfactual than in the empirical counterfactual. This major bias of the empirical counterfactual in predicting global trade openness in the absence of structural change comes from ignoring input-output linkages across sectors.

To confirm the importance of input-output linkages across sectors, we recalibrate the baseline model and the corresponding counterfactual in a world with no intersectoral linkages across sectors ($\gamma_{gg} = \gamma_{ss} = 1$).[8] In this world, the absence of structural change in the model counterfactual implies little deviation in sectoral trade openness from the baseline/data. As can be seen in Figure 11, the sectoral ratios of trade to expenditure barely change from the baseline to the counterfactual. Also, the sectoral ratios of expenditure to absorption ratios barely change either. In other words, in the model with no intersectoral linkages, the empirical counterfactual yields the same prediction as the model counterfactual.

Figure 11: No input-output linkages across sectors



5.1.3 Decomposing income versus substitution effects

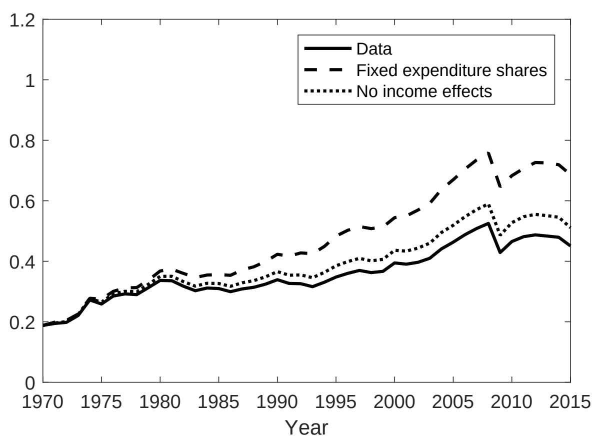
The literature on structural change has established two key mechanisms: income effects and substitution effects. Boppart (2014) provides the first model that incorporates both income and substitution effects to generate structural transformation along a balanced growth path. Herrendorf, Rogerson and Valentinyi (2013) demonstrate that when structural change is defined over final expenditures instead of value added, as it is in our paper, then income effects play a nontrivial role relative to substitution effects.

[8]This recalibration requires a manipulation of sectoral expenditures using equations (17) and (18) to ensure that the model matches the sectoral value added and sectoral net exports as in the data and the national accounting identity holds.

We use our model to evaluate the relative importance of each effect in shaping global trade flows. In our model counterfactual, we set $\varepsilon_s = 1$ so that preferences are homothetic, i.e., income elasticity of demand in each sector equals 1.[9] By comparing global trade openness implied by this experiment with that by the counterfactual with both effects shut off, we can see to what extent our results are driven by the income effect. Alternatively, the comparison will illustrate the power of the substitution effect alone.

Figure 12 plots the world ratio of trade to expenditure implied by our model counterfactual without the income effect with the dotted line. For easy comparison, we also plot trade openness in the data with the solid line and the one implied by our model counterfactual without the income and substitution effect with the dashed line. As can be seen in the figure, the model that shuts down the income effect leads to a ratio of trade to expenditure 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, the income effect's contribution to structural change affects international trade over this time period, but the substitution effect's contribution is greater.

Figure 12: World trade over expenditure, Income Effect



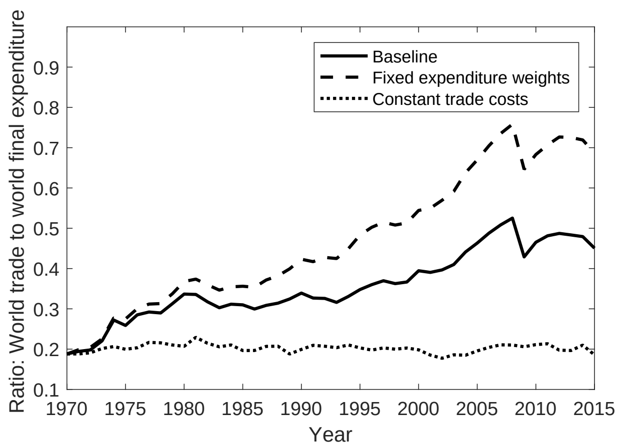
5.2 Global trade in the absence of declining trade costs

Arguably, declining trade costs over time is the most common factor attributed to the rise in global openness. Indeed, the past few decades have witnessed drastic reductions in shipping costs and in tariffs. In the model, consider a counterfactual where trade barriers are held at their 1970 levels to examine the role of declining trade barriers. The resulting trade openness is illustrated by the dotted line in Figure 13. In this world, the global ratio of trade to expenditure barely grows at all. 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

[9] We adjust the preferences weights, ω_{ik}, so that in 1970 the sectoral expenditures are identical to those in the baseline model.

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.

Figure 13: World Trade to Expenditure Ratio



That said, the constant-trade-cost counterfactual also demonstrates the quantitative significance of structural change on global trade openness. As shown in Figure 13, structural change has held back trade by roughly the same magnitude that reductions in trade costs have boosted trade over the past four decades.

5.3 Importance of structural change in trade models

So far we have emphasized how the process of structural change restricts the progress in trade openness over time, as measured by the ratio of trade to expenditure (or trade to GDP). A prominent force is that as countries consume relatively more services, which are traded less intensively than goods, then global trade volumes are restricted. The trade literature relies heavily on interpreting observed trade volumes through the lens of a model to estimate trade costs and welfare gains from trade. An immediate corollary of our findings is that incorporating structural change in the model is important for these estimates. The goal of this subsection is to elaborate on this point.

5.3.1 Structural change and trade costs

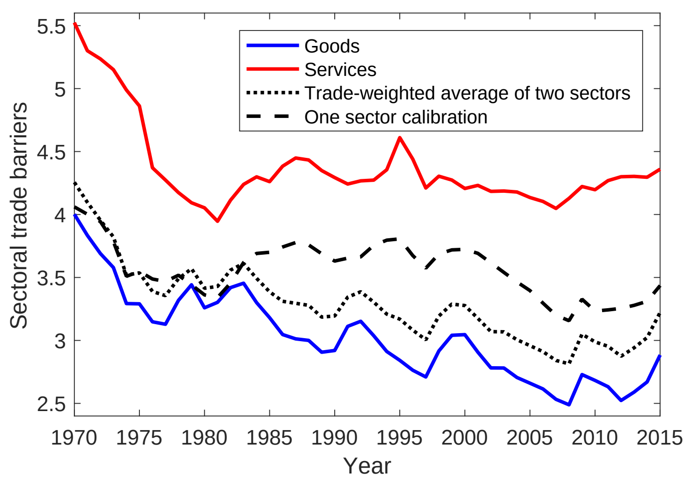
Consider a standard one-sector model that is analogous to our baseline two-sector model. There is one composite good, constructed from a continuum of tradable varieties, and used as an intermediate input by firms or as a final consumption by the household. The household's preferences are defined only over consumption of the one composite good. Structural change is absent by construction in this one-sector model.

We calibrate trade costs using a structural equation similar to equation (16) in the two-sector model, but use aggregate price levels and aggregate trade shares:

$$\tau_{ij} = \left(\frac{\pi_{ij}}{\pi_{jj}}\right)^{-\frac{1}{\theta}} \left(\frac{P_i}{P_j}\right). \tag{22}$$

We contrast the estimates of trade costs in a one-sector model with those in the two-sector model in Figure 14. The aggregate trade barrier in the one-sector model is plotted as a dashed line, while the trade-weighted aggregate from the sectoral barriers in the two-sector model are plotted in a dotted line.[10] The estimated trade barrier declines by less in one-sector model than the trade-weighted aggregate from the two-sector model, although both estimates target the same observed trade flows. The key reason is that in the absence of structural change, which dampens openness, the estimated trade barrier does not need to decline by much to rationalize the observed trade flows in the one-sector model.

Figure 14: Model based estimates of trade barriers



The period 1980-2000 particularly highlights the bias in trade cost estimates when ignoring structural change. Figure 14 shows that the trade cost rises since 1980 and stays high until 2000 in the one-sector model, while it declines by about 5% in the two-sector model. The behavior of trade costs is even qualitatively different across these two models. The one-sector model estimates are at odds with the degree of trade integration occurring across the globe during this period. The reason behind this difference is that in this period the speed of structural change is fast, while the growth of trade openness is slow. The one-sector model requires a slightly rising trade barrier to capture the muted growth in trade openness because it ignores the dampening effect of structural change on trade openness that occurred during those two decades (recall Figure 2).

[10] Recall that the world-level barrier is the average of all country-level bilateral trade barriers weighted by the bilateral trade flows.

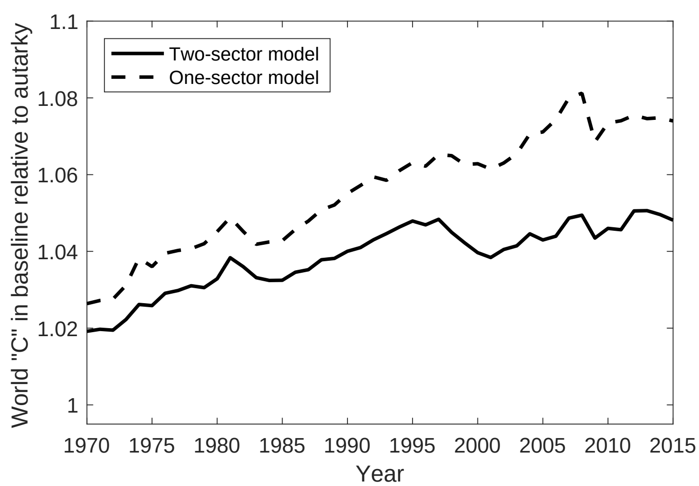
5.3.2 Structural change and the gains from trade

In a one-sector model, welfare gains from trade would be computed as the ratio of consumption in a world with trade relative to consumption in a world without trade. In a multi-sector model, a country's gain from trade depends on not only the percent change in consumption of each good, but also on the composition of its consumption basket. Since expenditure shares endogenously evolve with structural change, the gains from trade also depend on structural change.

We compute the global welfare gains as world consumption (the sum of consumption levels across countries) in the baseline relative to that under autarky in every year. Recall that in the two-sector model, aggregate consumption in each country is given implicitly by equation (4). We also compute the global gains from trade in the one-sector version of our model.

The gains in the one-sector model are illustrated by the dashed line, and those in the two-sector model are illustrated by the solid line in Figure 15. The gains from trade are estimated to increase by far more in the one-sector model than in the two-sector model over time. The gains rise from 2.6% in 1970 to 7.5% in 2015 in the one-sector model, by about 5 percentage points. In contrast, the welfare gains rise only from 2% to 5%, by 3 percentage points. Note that both models exactly match the ratio of trade to expenditures in every country and every year. Thus, in addition to trade openness, structural change matters for the dynamics of the gains from trade.

Figure 15: Global gains from trade



To see transparently how structural change affects the gains from trade, it is useful to look at a simplified economy where aggregate consumption is given by a Cobb-Douglas aggregate over goods and services, and the expenditure shares exogenously vary over time governed by ω's:

$$C_{it} = C_{igt}^{\omega_{igt}} C_{ist}^{\omega_{ist}}.$$

Imposing aggregate balanced trade in each country, real consumption is equal to the real wage:

$$\frac{w_{it}}{P_{ict}} = \left(\frac{w_{it}}{P_{igt}}\right)^{\omega_{igt}} \left(\frac{w_{it}}{P_{ist}}\right)^{\omega_{ist}}.$$

On the technology side, for simplicity, assume that goods are produced using labor only; there are no intermediate goods. Therefore, the real wage in each sector is given by

$$\frac{w}{P_{ikt}} \propto \left(\frac{T_{ikt}}{\pi_{iikt}}\right)^{\frac{1}{\theta}}.$$

In autarky each sector's home trade share is 1, so the welfare gain (ratio of consumption in the baseline to that in autarky) is given by

$$\hat{W}_{it} = \left(\pi_{iigt}\right)^{-\frac{\omega_{igt}}{\theta}} \left(\pi_{iist}\right)^{-\frac{\omega_{ist}}{\theta}}.$$

Clearly, the gain depends on each sector's home trade share, the trade elasticity, and each sector's expenditure share. This is an example of the sufficient-statistics approach, popularized by Arkolakis, Costinot and Rodríguez-Clare (2012). In particular, holding fixed the sectoral home trade shares, as long as the service home trade share exceeds the goods home trade share, then structural change (increase in service expenditure share over time) implies declining gains from trade over time. Similarly, declining home trade shares over time imply increasing gains from trade.

The sufficient-statistics formula makes clear that the home trade shares alone are only one of the ingredients needed for measuring the gains from trade; One also needs to know each sector's share in final consumption, which endogenously depends on the degree of openness in our model. Even though our baseline model has a more complex structure of production and a generalized preference structure, the similar intuition goes through.

5.4 Projecting the future impact of structural change on trade

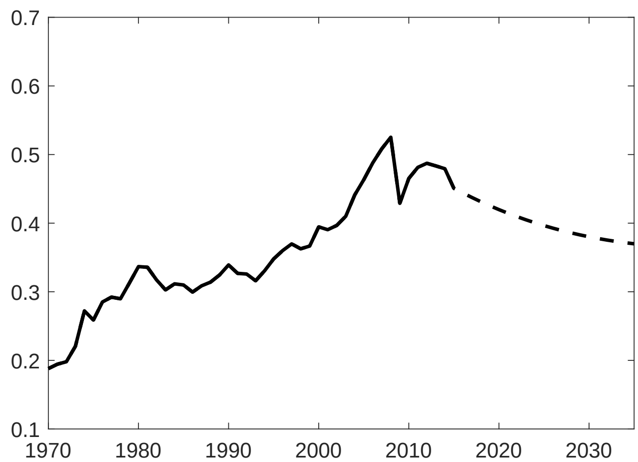
The recent slowdown in the growth of international trade has prompted careful consideration of the forces that might be holding back trade or no longer boosting it (IMF (2016b), Lewis and Monarch (2016)). While structural change has not been a stronger drag on trade growth recently than it was in preceding 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 possibility quantitatively through the lens of our model. Specifically, we extrapolate our sample of countries holding trade costs fixed at their 2015 value and letting goods and services productivity grow at their respective world average rates observed between 1970-2015.[11] Without additional factors boosting trade, our model implies that the ratio of trade to expenditure

[11] Goods productivity grows 14.1 percent and services grows 1.1 percent annually.

would fall from 45 percent in 2015 to 37 percent in 2035, in Figure 16.

Figure 16: World Trade to Expenditure Ratio, Projection



This quantitative example highlights the importance of paying attention to the role of the prevalent process of structural change when considering trade flows. Without incorporating structural change into the model, the downward pattern in the ratio of trade to GDP from Figure 16 would be attributed to rising trade costs. However, we find such a result even without any change in trade costs, as the effects of increased services consumption in a world without rapid trade growth materially affects the trajectory of global trade openness. In other words, it is perfectly within reason to imagine a decline in the ratio of trade to GDP, or even a decline in total trade flows, without any increased trade barriers. All that would be necessary is the combination of ongoing changes in services consumption along the lines of what we have seen in the past four decades with the continuation of current levels of trade openness. This is a notable policy implication worth being aware of in future years.

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 ratio of trade to GDP would be 23 percentage points higher than in the data (71 percent higher). 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 patters 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 slowdown in trade can be attributed to a lack of factors that have historically caused trade to rise relative to expenditure. Indeed, our paper demonstrates how unusual the 1990s and 2000s were: even as the share of services in 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 perhaps peaked, and similar patterns of structural change projected out to the future foreshadow declines in the ratio. Finally, one-sector models of trade overstate the gains from trade and can understate the reductions in trade costs necessary to rationalize observed trade flows.

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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".[12]

[12]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 γ_{ikn}, 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, λ_{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 ε, ω_i and σ, 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.

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 ν_{ik} using condition S2 and prices, P_{ik}, using condition S3. The prices in every sector and every country must determined as a simultaneous system of equations.
- Compute the sectoral bilateral trade shares π_{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:

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

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

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

  is the updated guess of wages and κ 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 17: Sectoral expenditure shares by Country

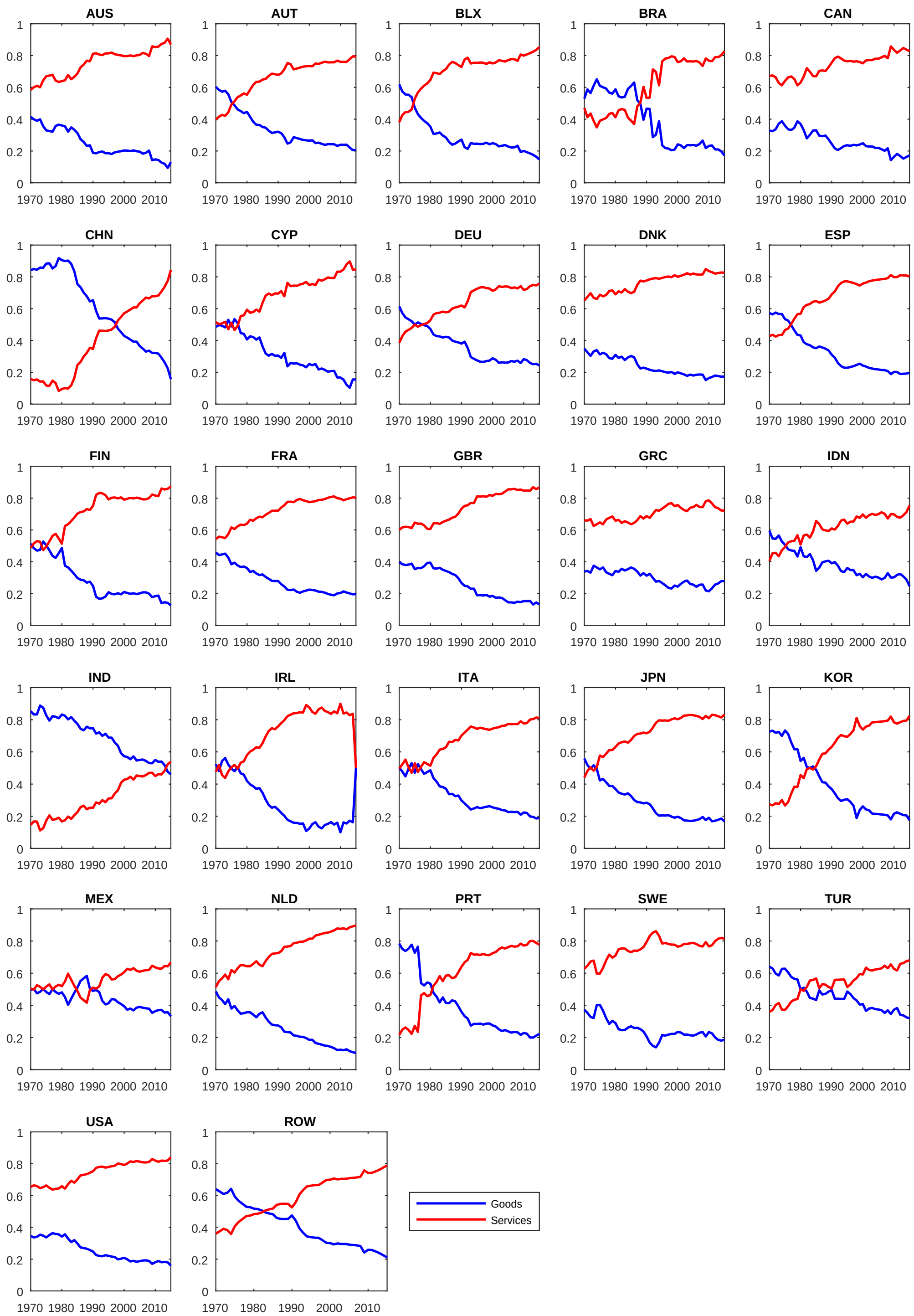

Figure 18: Trade to expenditure ratio by Country

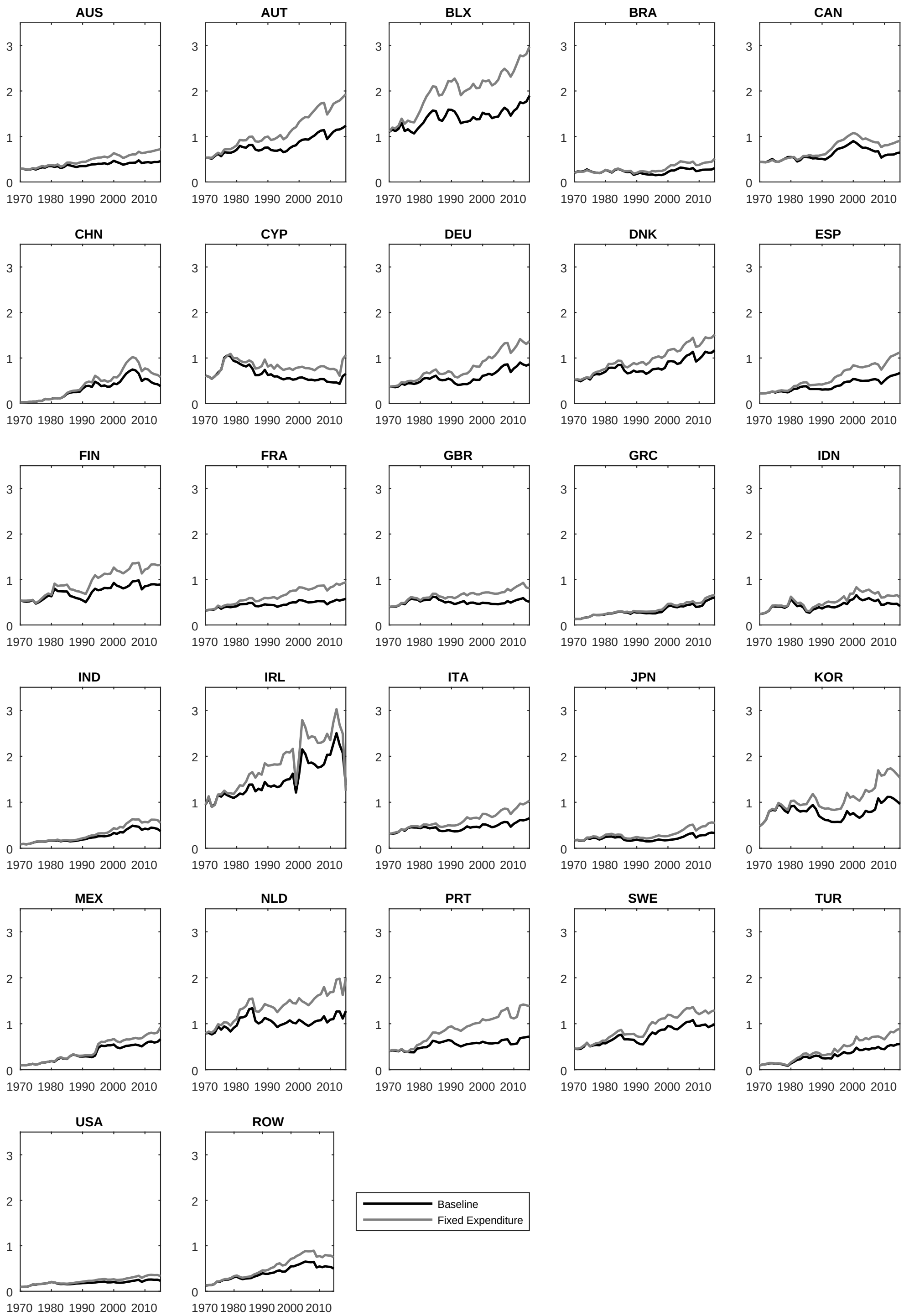

Table 5: Contributions to fixed expenditure counterfactual in 2015

Country	Expenditure Share	Trade Share	Contribution	Pct. Contribution
Australia	1.6%	1.7%	0.004	1.8%
Austria	0.4%	1.2%	0.003	1.2%
Belgium-Luxembourg	0.6%	2.3%	0.005	2.1%
Brazil	2.2%	1.5%	0.005	2.0%
Canada	2.1%	3.0%	0.006	2.4%
China	15.2%	12.8%	0.032	13.8%
Cyprus	0.0%	0.0%	0.000	0.0%
Germany	3.5%	6.6%	0.018	7.6%
Denmark	0.3%	0.9%	0.001	0.5%
Spain	1.5%	2.3%	0.007	2.8%
Finland	0.3%	0.5%	0.001	0.5%
France	3.1%	3.9%	0.011	4.7%
United Kingdom	3.6%	4.0%	0.009	4.0%
Greece	0.3%	0.3%	0.000	0.0%
Indonesia	1.2%	1.1%	0.003	1.1%
India	2.7%	2.3%	0.005	2.1%
Ireland	0.3%	1.0%	-0.001	-0.3%
Italy	2.2%	3.2%	0.009	3.7%
Japan	6.1%	4.5%	0.013	5.4%
Korea	1.6%	3.4%	0.010	4.1%
Mexico	1.5%	2.3%	0.004	1.9%
Netherlands	0.7%	1.9%	0.004	1.7%
Portugal	0.3%	0.4%	0.001	0.6%
Sweden	0.6%	1.2%	0.002	0.8%
Turkey	1.0%	1.2%	0.003	1.4%
United States	26.4%	13.5%	0.026	11.0%
Rest of World	20.9%	23.1%	0.054	22.9%
Total	100.0%	100.0%	0.236	100.0%