

Does Openness Matter for Structural Change?

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Abstract

This paper develops a novel framework to assess the contribution of openness and trade to structural change. I develop an identity-based decomposition to study the evolution of the share of manufacturing value added at country level, and apply it to a sample of 20 large manufacturing exporters relying on sectoral data from the World Input-Output Database for the years 1995-2007. The analysis features two new mechanisms of structural change, arising from changes in sectoral competitiveness in international markets, and changes in the size of the foreign market. The average contribution of these channels to structural change is 33 and 34 percent, respectively. This suggests that, by omitting trade, closed economy analyses may be severely limited. To investigate the driving forces underlying structural change, I rely on a quantitative model building on Eaton and Kortum (2002) and simulate the effects of shocks to trade costs and trade deficits on the manufacturing value added shares of China, Germany, the United Kingdom and the United States. I find that shocks to trade costs and trade imbalances play a key role as drivers of structural change. They explain most of the change in the manufacturing value added shares in China and the United States. They contribute significantly, alongside shocks to sectoral productivity levels, in Germany and the United Kingdom.

1 Introduction

Structural change is defined as long-run shifts in the relative sizes of major sectors of the economy (Kuznets (1973)). Initially, structural change involves the decline of agricultural sector, in relative terms, and the rise of the manufacturing sector. As growth continues, manufacturing gives place to services. This pattern is ubiquitous: Herrendorf et al. (2013) document sectoral transformations of this kind for a large set of countries using historical data. The remarkable regularity of this process has sparked much debate regarding its origins.

The contributions to the literature on structural change can be broadly divided into two categories. “Price-effect” models emphasize the reallocation of consumption expenditure in response to changes in the relative prices of sectoral goods (Ngai and Pissarides (2007) and Acemoglu and Guerrieri (2008)). “Income-effect” models focus on shifts in expenditure patterns associated with income growth (Kongsamut et al. (2001) and Foellmi and Zweimüller (2008)). The two types of models have much in common: both have sectoral productivity growth as the exogenous driver and both see the optimal adjustment of the consumption portfolio by households as the mechanism that brings about structural change. Overwhelmingly, these are closed economy models.

Abstracting from trade is not innocuous. Once countries produce and trade the same varieties of goods, they enter into direct competition with each other. This means that even in the absence of changes in expenditure patterns, a sector can grow at the expense of its foreign rivals by capturing a larger share of domestic and international markets. This mechanism can only operate in an open economy and can run simultaneously with and contrary to closed economy forces. Employing a closed economy framework to study structural change can thus lead to a misattribution of the effects of shifts in competitiveness. Moreover, once international trade is brought into picture, factors that affect competitiveness become relevant. Absent trade, the role of trade costs, trade deficits and sectoral productivity growth abroad in determining the sectoral composition of the home economy is inevitably overlooked.

In order to measure the relative contribution of the different mechanisms that produce structural change, I develop an identity-based decomposition of sectoral value added share. In a closed economy setting, movements in value added can be traced back to the changes in final expenditures or in the use of intermediate inputs in production. Once an open economy framework is considered, a further two mechanisms appear. The first operates as sectors become relatively more or less competitive. The second arises due to changes in the size of the foreign market vis-a-vis the domestic productive capacity.

The decomposition can be employed to interpret the manufacturing value added share changes in the data as arising via one of the four channels described. Since competitiveness and foreign market size channels only operate in an open economy setting, this analysis can serve as a preliminary test for the relevance of openness for structural change.

Applying this decomposition to manufacturing value added data from World Input-Output Database (WIOD) for a sample of 20 economies yields three new qualifiers for the study of structural change. First, the average contribution of the competitiveness and the foreign market size channels is shown to be 33% and 34% respectively. This shows that the traditional focus on domestic demand as the driver of structural change is missing a key contribution of trade to the changes in sectoral shares. Second, 22% of the value added share change in an average economy is shown to be attributable to the change in the use of intermediate inputs. Therefore, the changes in production technology, and in particular in the use of the intermediate inputs, have to be part and parcel of studying the evolution of sectoral value added. Finally, on average only 12% of the observed change is due to changes in consumption expenditure shares. This result is at odds with the view held in much of the literature that structural change arises either via relative price or via income effects, both ultimately operating through shifts in sectoral expenditure. The contribution of sectoral final demand is small because once the use of intermediate inputs is allowed, any fall in the spending on final manufacturing goods is partially offset by the rise in the use of manufacturing as an intermediate input into production of services. Thus, any study of structural change that ignores intermediate inputs use will also overestimate the importance of shifts in final spending. To overcome these shortcomings, the rest of the paper considers structural change in an open economy with an input-output structure. The modelling of changes in technology is beyond the scope of the present work and is currently not considered.

To investigate the driving forces behind structural change in an open economy a quantitative model of trade is employed. A multi-sector Eaton and Kortum (2002) model is combined with the nonhomothetic CES preferences studied by Comin et al. (2015). The Eaton and Kortum (2002) model is selected as a natural setup to study international competition in manufacturing production. This model is extended to allow for the use of intermediate inputs and exogenous trade imbalances. The Comin et al. (2015) preference structure permits the operation of the usual channels of structural change: adjustment of sectoral spending in response to changing sectoral prices and household income. The model can therefore be seen as a multi-country extension of a closed-economy model of structural change, with open economy channels operating alongside the classical, closed

economy forces.

The model is solved using the Dekle et al. (2007) "exact hat algebra" approach with changes in endowments of labour and capital, trade costs, sectoral productivity levels and trade deficits acting as the exogenous driving forces. The model is simulated for a sample of 20 economies. The contribution of the shocks is studied by running counterfactual simulations where only a subset of shocks is active at a time. For each simulated series a decomposition of value added shares is applied to explore the transmission channels of the shocks. Among the 20 economies simulated, the experiences of China, Germany, the United Kingdom and the United States are highlighted to exemplify the contribution and transmission mechanisms of the shocks under consideration.

The results show that for China and the United States, the trade costs and trade imbalances explain much of the manufacturing value added share evolution over the 1995 to 2007 period. For Germany and the United Kingdom, both played a role alongside the shocks to sectoral productivity. The shocks to trade costs and trade imbalances have mainly operated via the competitiveness channel, while productivity growth has had an effect via both competitiveness and foreign market size channels. Thus, in addition to the open economy channels being key in producing structural change, the shocks to trade costs and trade deficits play a substantial role as drivers of the structural change.

This paper draws on two broad strands of literature: the literature on structural change and the applications of the Eaton and Kortum (2002) model. In the structural change literature, this paper builds on works that model structural change in a closed economy as arising due to the households' response to the changes in relative prices of sectoral goods (Ngai and Pissarides (2007), Acemoglu and Guerrieri (2008)) or in income (Kongsamut et al. (2001), Foellmi and Zweimüller (2008)). Following Boppart (2014) and Herrendorf et al. (2013), who argue that both channels are important drivers of structural change, the nonhomothetic CES preference structure that permits both is used, specifically the utility specification first applied in a structural change setting by Comin et al. (2015). This specification shows a good fit to the data and is highly tractable. The contribution of the present work is to allow for international trade and the use of intermediate inputs. The inclusion of intermediate goods in the analysis of structural change is also the subject of a recent contribution by Sposi (2015), who however does not discuss changes in the intermediate inputs use over time and is not focusing on trade. From a trade perspective, the literature used in this paper is one following the original Eaton and Kortum (2002) publication. In particular, this paper's multi-sector setup is similar to the one used in Caliendo and Parro (2015), while the changes formulation is adapted from the Dekle et al. (2007).

Other works have also investigated the contribution of trade to structural change. Matsuyama (2009) builds a model where structural change can arise due to shifts in competitiveness in international markets. Uy et al. (2013) apply the Eaton and Kortum (2002) model to show that falling trade costs have contributed to the industrialisation of South Korea. Cravino and Sotelo (2017) is the closest paper to the present work. It investigates the effects of falling trade costs on the manufacturing value added shares and the skill-premium. However, this paper differs from Cravino and Sotelo (2017) in a number of dimensions. First, in addition to falling trade costs the effects of growing trade imbalances and the sectoral productivity growth are investigated. Second, using the value added share change decomposition allows one to pin down the channels in operation during the process of structural change. Contrary to the Cravino and Sotelo (2017) interpretation of expenditure shares shifts as the driving mechanism behind trade-induced de-industrialisation, this study finds that it is the changes in trade, operating through competitiveness and foreign market size channels, that explain most of the manufacturing shares evolution.

The rest of this paper is organised as follows. Section 2 derives and applies an identity-based decomposition to changes in value added shares of manufacturing. Section 3 introduces the model and shows how it can be reformulated in changes. Section 4 discusses the calibration of the parameters of the model and derives the shock series used for counterfactuals. In Section 5 the counterfactuals are used to study the contribution of the growth of resources, trade cost shocks, trade imbalances and productivity growth to the manufacturing shares change. The conclusion then sums up the work.

2 Effects of trade: a simple exercise

2.1 Identity-based decomposition

A simple accounting exercise can be used to separate the effects of changes in competitiveness from changes in expenditure patterns.

Consider the link between the household expenditure and sectoral output in a model of a closed economy with no intermediate inputs. Let X_{im} be the manufacturing expenditure by households in country i . By market clearing condition, sectoral output (denoted as VA_{im} since it is also the sectoral value added in absence of intermediate inputs) will equal sectoral final expenditure:

$$VA_{im} = X_{im}.$$

To obtain value added share, divide through by income:

$$va_{im} = \frac{VA_{im}}{Y_i} = \frac{X_{im}}{Y_i} = S_{im}.$$

In this simple setting the expenditure share (S_{im}) and value added share (va_{im}) are equal. Thus, trivially, the period change (from now on denoted as Δ) in the two equals too:

$$\Delta va_{im} = \Delta S_{im}. \quad (1)$$

Following changes in the expenditure shares due to either changing relative prices or incomes, value added share will move one for one.

Now suppose countries engage in trade. The households will be purchasing manufacturing both domestically and from abroad. The manufacturing expenditure can then be rewritten as a sum of amounts spent on domestic manufacturing and on the goods from each of the trading partners:

$$X_{im} = \sum_j X_{ijm}, \quad i \in j,$$

where X_{ijm} stands for the value of manufacturing that i purchased from j . As in Eaton and Kortum (2002), let Π_{ijm} denote the share of i 's manufacturing expenditure that is covered by imports from j (from now on referred to as "import shares"). Manufacturing spending can then be rewritten:

$$X_{im} = \sum_j \Pi_{ijm} X_{im}, \quad \text{where} \quad \Pi_{ijm} = \frac{X_{jim}}{X_{im}} \quad \text{and} \quad \sum_j \Pi_{ijm} = 1.$$

Naturally, openness also means that the home producers sell domestically as well as abroad. By the market clearing condition,

$$VA_{im} = \sum_j X_{jim}, \quad i \in j,$$

and using the import shares representation,

$$VA_{im} = \sum_j \Pi_{jim} X_{jm}.$$

Thus, country i produces as much as it and its trading partners are willing to purchase from i to cover their manufacturing consumption. Rewrite manufacturing expenditure

of j as a share S_{jm} of j 's income and divide through by the output in i to obtain value added shares:

$$va_{im} = \sum_j X_{jim}/Y_i = \sum_j \Pi_{jim} S_{jm} \frac{Y_j}{Y_i}.$$

To separate the effects of changing expenditure shares and competitiveness, the above expression can be rewritten in changes (see Appendix A for derivation). The first-order terms of the changes formulation provide a first-order approximation of the change in the sectoral value added:

$$\Delta va_{im} \approx \underbrace{\sum_j \psi_{jim}^{\Pi} \Delta \Pi_{jim}}_{(C)} + \underbrace{\sum_j \psi_{jim}^S \Delta S_{jm}}_{(ES)} + \underbrace{\sum_j \psi_{jim}^Y \Delta \left(\frac{Y_j}{Y_i}\right)}_{(FM)}, \quad (2)$$

where Δ terms denote period differences and ψ_{jims} are weights. The sum denoted by (ES) stands for the expenditure share channel. It reflects the operation of the relative price and income effects, the staple forces of the classical structural change literature. Compared to equation (1), changes in the spending behavior abroad affect the domestic value added shares, feeding in through the change in demand for manufacturing exports.

However, changes in final consumption are just part of the story. Compared to equation (1), equation (2) features two extra terms. The first term, denoted by (C), is the part of the change in the sectoral value added that accrues due to the changes in sectoral competitiveness. Recall that Π_{jim} stands for the share of the manufacturing consumption of country j covered by imports from i . Positive $\Delta \Pi_{jim}$ thus means that i has captured a larger share of j 's manufacturing market. (C) captures the shifts in competitiveness of i in all markets where it sells. The other term, denoted by (FM), denotes the change occurring due to the shifts in the size of the foreign market vis-a-vis the domestic productive capacity. The operation of this channel is similar to the effect of transfers in Dornbusch et al. (1977): if trading partners are becoming relatively richer, the demand for the tradeable produce of the home country outpaces the demand for the non-tradeables, and vice versa. Thus, (FM) reflects the movements in the absorption capacity of the markets that i sells to. Note that these terms are inherently an open economy phenomenon: Appendix A shows that in absence of trade, equation (2) collapses to equation (1) precisely. Thus, backing out (C) and (FM) from the data is a simple way of testing the quantitative importance of the openness for structural change.

One final step remains before (2) can be taken to the data. So far the use of intermediate inputs has been left out of the analysis in the interest of conciseness. However, more manufacturing is used as intermediate inputs than for final consumption. Appendix

A shows how equation (2) can be expanded to account for the use of intermediate inputs. The resulting approximation is as follows:

$$\Delta va_{im} \approx \sum_{j,k} \psi_{jik}^{\beta} \Delta \beta_{jnk} + \sum_{j,k} \psi_{jik}^{\Pi} \Delta \Pi_{jik} + \sum_{j,k} \psi_{jik}^S \Delta S_{jk} + \sum_{j,k} \psi_{jik}^Y \Delta \left(\frac{Y_j}{Y_i} \right). \quad (3)$$

(II) (C) (ES) (FM)

The differences between equations (2) and (3) are multiple. First, each of the terms is now summing over all sectors. The reason is that manufacturing output now depends indirectly on demand for other sectoral goods, via the intermediate inputs it supplies for their production. Second, a new term appears. (II) is the change in the sectoral value added arising through the shifts in the use of the intermediate inputs in production. If manufacturing loses importance as an input, the manufacturing value added share will shrink even in absence of changes in final demand. The interpretation of the other mechanisms is largely as before.

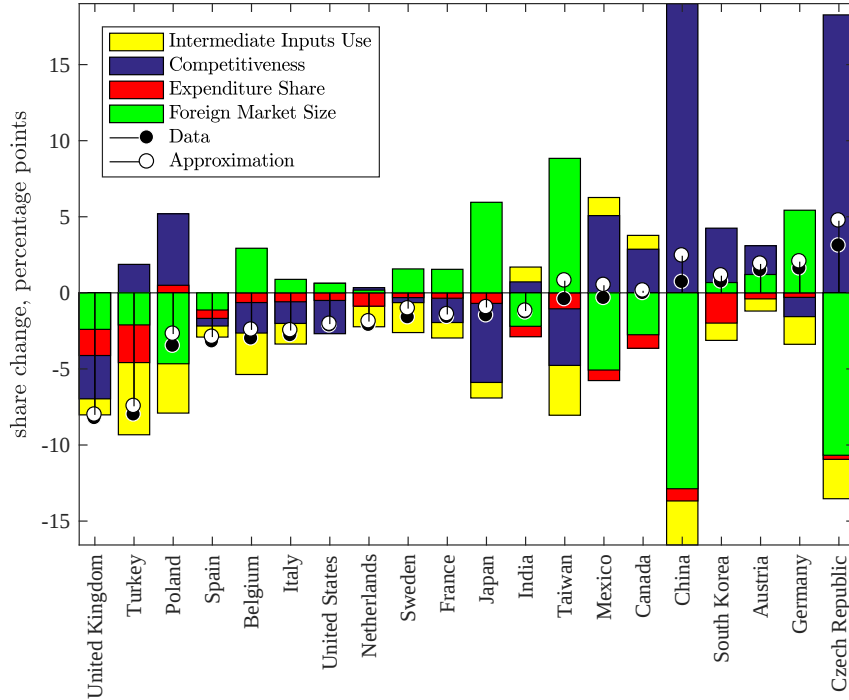
Having allowed for both trade and intermediate inputs use, equation (3) can be taken to the real world data. In what follows, (3) will be used to decompose the changes in the manufacturing value added share into contributions of different channels. The full decomposition would have to feature second- and higher-order terms, but as will be discussed further, all but one interaction terms can be disregarded without much consequence.

2.2 Application to WIOD sectoral data

Figure 1 shows the decomposition of the manufacturing value added share change between 1995 and 2007 for a sample of 20 countries. The sectoral trade flows, consumption expenditure, intermediate inputs use and output are taken from the World Input-Output Database. The 20 selected countries are the largest manufacturing exporters in the sample. The dataset features 35 industries. These are aggregated into three sectors: agriculture (includes agriculture and food production), manufacturing (includes mining and 14 industries that fall into the manufacturing category according to ISIC rev. 4 classification) and services (everything else). The list of the countries used and the sectoral mapping can be found in Table II in Appendix B.

The coloured bars in Figure 1 correspond to the four components highlighted in equation (3). The black stems mark the change in the manufacturing value added share in the data, while the white stems mark the first-order approximation. The fit is not exact: second- and higher-order terms are missing from the approximation. Countries with the poorest fit are China, Czech Republic and Taiwan.

Figure 1: Manufacturing Value Added Share Changes Decomposition, 1995 to 2007



Note: Bars correspond to the terms (II), (C), (ES) and (FM) in equation (3).

The red bars show the change in the manufacturing value added due to the changing expenditure shares. For all countries, the contribution of this channel has been negative and of about equal magnitude, averaging at -0.76 percentage points over the period. Thus, the pressure on the manufacturing emanating from shifts in the spending behaviour is roughly uniform around the world. Note that the contribution of this channel falls considerably short of the overall change seen in the data. The reason for this is that the decomposition employed models the input-output structure of the economy explicitly. Once the use of intermediate inputs is allowed, any fall in the spending on final manufacturing goods is partially offset by the rise in the use of manufacturing as an intermediate input into production of services.

The yellow bars represent the contribution of changing intermediate inputs use. Note that this channel too has decreased manufacturing share for all countries except Mexico. The effect of this channel has been larger in magnitude than that of the changes in final expenditure, with the average contribution of -1.43 percentage points. This suggests that the decreased use of manufacturing as an intermediate input has played a

larger role in the global deindustrialization than the changes in expenditure patterns.

The blue bars show the change in manufacturing share occurring due to the change in competitiveness. Since the decomposition takes into account the input-output structure of the economy, this channel reflects both changes in competitiveness of the manufacturing produce as well as changes in competitiveness of other sectoral goods insofar as they rely on manufacturing inputs. The contribution of this channel has been sizeable and varied in both magnitude and direction across countries. The countries with the biggest drops in competitiveness were Japan, United Kingdom and Taiwan, while the biggest gainers were China, Czech Republic and South Korea.

Finally, the green bars denote the contribution of the changes in the size of the foreign market. This effect similarly has been large and worked in opposite directions for the economies in the sample. The slowest growing economies, Taiwan, Japan and Germany all saw the rise of the foreign market rise size relative to that of the domestic economy, putting an upward pressure on the manufacturing share. The opposite has been the case for China, Czech Republic and Poland.

The changes decomposition offers an insight into what affects the manufacturing sector the most and why the experiences of the countries differ. To gauge the relative importance of different channels, compute the relative contributions of each of the components:

$$rc_x(\%) = \frac{|(x)|}{|(II)| + |(C)| + |(ES)| + |(FM)|}.$$

For an average country, changes in expenditure shares explain just 12% of the change. Therefore, for the sample at hand, classical channels of relative price and income have played a minor role in driving the manufacturing share. Changes in the use of the intermediate inputs are responsible for 22% of the change. Thus, the advances in the production techniques warrant a focus no less than the consumer spending behavior. Changes in competitiveness and in the size of the foreign market account for 33% and 34% of the movements in industrialization, respectively. Since these two effects are only relevant in the presence of trade, much of what is driving structural change can only be understood in an open economy setting.

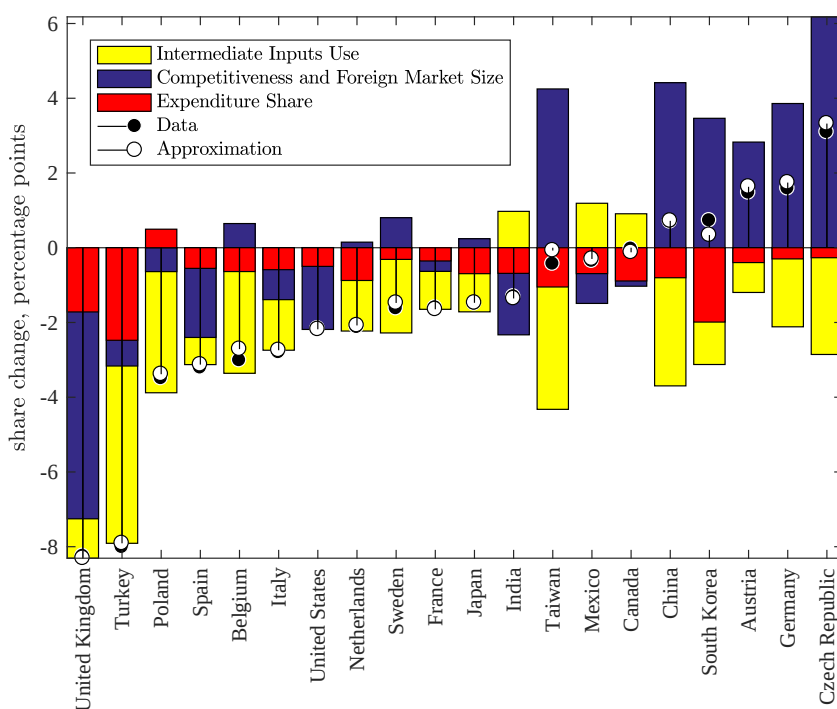
One issue with comparing the contributions of different channels in isolation is that they are, in fact, correlated. In practice, the only two terms with correlation in excess of ± 0.2 are (C) and (FM): $corr((C), (FM)) = -0.88$. This is hardly surprising: comovement in components is structural. Suppose a country experiences an exogenous shock to manufacturing productivity. This will both reduce the price of manufacturing and increase income, leading to a gain in manufacturing share via the competitiveness

channel and a loss via the foreign market size effect. To check whether the two cancel out consider Figure 2. The red and yellow bars are as before, and the blue bars now stand for the sum of (C), (FM) as well as their interaction term:

$$(C \times FM)_{ik} = \sum_{j,n} \psi_{jin}^{\Pi Y} \Delta \Pi_{jin} \Delta \left(\frac{Y_j}{Y_i} \right). \quad (4)$$

First, note that the two do not cancel out: together, they are still responsible for 37% of the manufacturing share change of an average country. Second, observe that the two forces seem to explain much of the difference in the industrialization experiences in the sample: the only countries to maintain their industrialization levels did so via the open economy channels. Finally, introducing the interaction term $(C \times FM)$ makes for an almost perfect fit.

Figure 2: Manufacturing Value Added Share Changes Decomposition, 1995 to 2007



Note: Bars correspond to the terms (II), (ES), and a sum of (C), (FM) and $(C \times FM)$ in equations (3) and (4).

The results of the decompositions yield three new qualifiers for the study of structural change. First, the importance of the open economy channels (C) and (FM) means

that the traditional use of the closed economy framework misses a key contribution of trade to the process of structural change. Second, the prominent role of the changes in the use of intermediate inputs on manufacturing shares suggests that changes in production technology have to be part and parcel of studying the evolution of sectoral value added. Finally, the surprisingly small contribution of changes in final expenditure to driving the manufacturing share imply that to understand structural change, the input-output structure of the economy has to be modelled explicitly.

To overcome these shortcomings, the rest of the paper considers structural change in an open economy with an input-output structure.

The decomposition presented is a reduced form analysis: each of the effects discussed thus far is a result of the responses of the economic agents to underlying economic shocks. But what are these shocks and how exactly do they bring about structural change? Closed economy models tend to rely on sectoral productivity growth as the exogenous driver of sectoral shifts. However, openness means that other factors such as changes in trade costs and trade deficits can play a role. The rest of the paper discusses the contribution of these two factors to structural change.

3 Model

To investigate the effects of changing trade costs and trade deficits on the structural change in an open economy a quantitative model of trade is needed. The Eaton and Kortum (2002) model (from now on referred to as EK) provides a natural setup for international competition: countries are capable of producing the exact same varieties, but only those who manage to sell at the lowest price end up producing. On the demand side, non-homothetic CES preferences studied in Comin et al. (2015) are employed. This preference structure shows a good fit to the data and features relative price and income effects in a highly tractable manner. The setup is extended to allow for the use of intermediate inputs and exogenous trade imbalances, and is solved in changes, all following Eaton et al. (2016). But first the model is laid out in levels to display its building blocks.

3.1 Model in levels

The model comprises a series of static equilibria; time subscripts are suppressed for ease of exposition.

3.1.1 Production

There are I countries in the model. There are three sectors in each producing agricultural, manufacturing and services goods, subscripted by $k \in \{a, m, s\}$ respectively. In each sector k of each country i a continuum of varieties $z \in [0, 1]$ can be produced. Firms produce using a Cobb-Douglas production function and are exogenously assigned a productivity level $a_{ik}(z)$. The inputs are labour L_{ik} , capital K_{ik} and intermediate inputs in form of sectoral aggregates M_{ikn} . Output of a firm z in country i and sector k is therefore as follows:

$$y_{ik}(z) = a_{ik}(z) L_{ik}^{\beta_{ikL}}(z) K_{ik}^{\beta_{ikK}}(z) \prod_n M_{ikn}^{\beta_{ikn}}(z),$$

where

$$\beta_{ikL} + \beta_{ikK} + \sum_n \beta_{ikn} = 1 \quad \text{and} \quad \beta_{ikx} \geq 0 \quad \forall \quad x \in \{L, K, n\}.$$

The production functions are country and sector specific. Note that the combination of Cobb-Douglas production functions and time-invariant production parameters means that the operation of the intermediate inputs use channel (II) is shut down by construction. This is done to abstract from modelling the evolution of production technology¹. As noted in Section 2.2, the contribution of this channel to structural change is considerable and warrants separate investigation.

The productivity level $a_{ik}(z)$ is drawn, independently for each country, from a Frechet distribution² with the following cumulative distribution function:

$$F_{ik}(a) = \exp \left[- \left(\frac{a}{\gamma A_{ik}} \right)^{\theta_k} \right], \quad \gamma = \left[\Gamma \left(\frac{\theta_k - \xi + 1}{\theta_k} \right) \right]^{1/(1-\xi)}.$$

$A_{ik} > 0$ reflects the absolute advantage of country i in producing sector k goods: higher A_{ik} means that high productivity draws for varieties in i, k are more likely. $\theta_k > 1$ is inversely related to the productivity dispersion. If θ_k is high, productivity draws for any one country are more homogenous. The choice of the origin of a variety to be purchased then will have less to do with productivity and more with costs of trade or input costs in the exporter country. Changes in trade and production costs will induce larger shifts

¹While one could pick a functional form of production such that intermediate input shares vary endogenously, it is likely that they also vary exogenously over time as technology improves. The production side of the model is kept simple to avoid taking a stance on the latter.

²Kortum (1997) shows that if the sectoral productivities are an outcome of search for the new production techniques and the ideas are Pareto distributed, the distribution of the technological frontier (best ideas found so far) is Frechet.

in trade. In this sense, θ_k operates as the trade elasticity in this model. γ is introduced to simplify the notation in the rest of the model³.

Varieties can be shipped abroad with an iceberg cost of d_{ijk} incurred when shipping a variety from sector k from country i to j (d_{ijk} goods need to be shipped for one unit of good to arrive to j). It is assumed that these costs capture transportation, tariff and non-tariff barriers to trade. Trade within an economy is assumed to be costless: $d_{iik} = 1$ for all i, k .

3.1.2 Households

Country i houses a population of a mass L_i . Households are identical and are maximizing the aggregate consumption, defined, following Comin et al. (2015), as an implicit function of agricultural, manufacturing and services consumption aggregates:

$$\sum_{k \in K} \Omega_{ik}^{\frac{1}{\sigma}} C_i^{\frac{\epsilon_k - \sigma}{\sigma}} C_{ik}^{\frac{\sigma - 1}{\sigma}} = 1. \quad (5)$$

This preference specification uniquely features a constant elasticity of relative demand with respect to aggregate consumption:

$$\frac{\partial \log(C_{ik}/C_{in})}{\partial \log C_i} = \epsilon_k - \epsilon_n,$$

as well as a constant elasticity of substitution between sectoral goods:

$$\frac{\partial \log(C_{ik}/C_{in})}{\partial \log(P_{ik}/P_{in})} = \sigma.$$

The former is the source of nonhomotheticity in the model: as real consumption grows, demand for a sectoral good with higher income elasticity rises relatively more. The latter, σ , governs the response to relative price movements. If $\sigma < 1$, an empirically relevant case as will be shown later, the sectoral goods are complements and the expenditure on the good whose relative price is falling will be decreasing.

Demand functions and price index associated with this preference structure are as follows:

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

³ Γ stands for the gamma function. Absent normalization γ appears in the price equations as a shifter common across economies. The simplification is thus without loss of generality.

$$P_i \equiv \frac{E_i}{C_i} = \frac{1}{C_i} \left[\sum_{k \in K} \Omega_{ik} C_i^{\epsilon_k - \sigma} P_{ik}^{1-\sigma} \right]^{\frac{1}{1-\sigma}}, \quad (7)$$

where P_{ik} is the price index of sector k good in country i (see Comin et al. (2015) for details and derivations).

Each household is endowed with one unit of labour which it supplies inelastically. Capital stock, K_i , comes in a form of endowment. Returns to capital are divided equally among households. Like in Dornbusch et al. (1977) and Dekle et al. (2007), trade imbalance is modelled as an exogenous lump-sum transfer D_i with the requirement that global trade is balanced: $\sum_i D_i = 0$. The trade imbalance is too shared equally among households. Thus, the budget constraint faced by a household is equal to

$$E_i = \sum_{n \in K} P_{in} C_{in} = P_i C_i = w_i + r_i \frac{K_i}{L_i} + \frac{D_i}{L_i}, \quad (8)$$

where w_i and r_i stand for the wage and interest rate in country i .

3.1.3 Markets

Markets for variety z in any sector are perfectly competitive: price of a variety z equals its marginal cost corrected for the cost of shipping:

$$p_{ijk}(z) = \frac{d_{ijk} c_{jk}}{A_{jk}(z)},$$

where

$$c_{ik} = \left(\frac{w_{ik}}{\beta_{ikL}} \right)^{\beta_{ikL}} \left(\frac{r_{ik}}{\beta_{ikK}} \right)^{\beta_{ikK}} \prod_n \left(\frac{P_{in}}{\beta_{ikn}} \right)^{\beta_{ikn}}, \quad (9)$$

is the unit cost function of a firm with a unit productivity. Up to this point the model is completely standard: households maximize utility subject to the budget constraint, firms minimize the cost of production, perfect competition yields variety prices at marginal costs. Suppose that a variety z purchased from country i is a perfect substitute for the same variety purchased from any other country. In this case buyers choose to purchase variety z from a country with lowest price, so price paid in i for variety z of sector k is $p_{ik}(z) = \min_j \{p_{ijk}(z)\}$. The EK insight is that, with production efficiencies stochastic and Frechet distributed, the distribution of such minimal prices can be solved for. If in

addition the sectoral aggregator is CES, the price index for a sectoral good equals

$$P_{ik} = \left[\sum_l \left(\frac{c_{lk} d_{ilk}}{A_{lk}} \right)^{-\theta_k} \right]^{-\frac{1}{\theta_k}}. \quad (10)$$

Note that the price is decreasing in the average productivities accessible in the world markets, and increases in production and trade costs.

EK also show that the import shares take the following form:

$$\Pi_{jik} = \frac{(c_{ik} d_{jik} / A_{ik})^{-\theta_k}}{\sum_l (c_{lk} d_{jlk} / A_{lk})^{-\theta_k}} = \left(\frac{c_{ik} d_{jik}}{A_{ik} P_{jk}} \right)^{-\theta_k}. \quad (11)$$

It can be seen that the import share increases in the trade partner's technology relative to technologies available in other countries, and decreases in production and trade costs, again, relative to production and trade costs in other countries.

Labour and capital market clearing conditions are (combined with variety cost minimization) as follows:

$$w_i L_i = \sum_{k \in K} \int_0^1 w_i L_{ik}(z) dz = \sum_{k \in K} \beta_{ikL} Y_{ik}, \quad (12)$$

$$r_i K_i = \sum_{k \in K} \int_0^1 K_{ik}(z) dz = \sum_{k \in K} \beta_{ikK} Y_{ik}. \quad (13)$$

The normalization in this model is by setting the global GDP to 1: $\sum_i L_i P_{ik} C_{ik} = 1$.

Country i demands for all varieties are combined with a CES aggregator, and are used up on final consumption and as an intermediate factor of production:

$$x_{ik} = \left(\int_0^1 x_{ik}(z)^{(\xi-1)/\xi} dz \right)^{\xi/(\xi-1)} = L_i C_{ik} + \sum_{n \in K} \int_0^1 M_{ink}(z) dz.$$

Combined with variety cost minimization condition it can be rewritten as total sectoral expenditure:

$$X_{ik} = L_i P_{ik} C_{ik} + \sum_{n \in K} \beta_{ink} Y_{in}. \quad (14)$$

Finally, the value of sector k output in country i is a sum of each trading partners and its own expenditure on its good:

$$Y_{ik} = \sum_{j \in I} \Pi_{jik} X_{jk}. \quad (15)$$

Together, equations (5) - (15) constitute the equilibrium of the model for a given time period. The parameters of the model are $\{\beta_{ikL}, \beta_{ikK}, \beta_{ikn}, \theta_k, \epsilon_k, \sigma, \Omega_{ik}\}$. Exogenous shocks are $\{A_{ik,t}, d_{ijk,t}, L_{i,t}, K_{ik,t}, D_{i,t}\}$ for $i, j \in I, k \in K$ and $t = 1, \dots, T$.

3.2 Model in changes

Instead of solving the EK model in levels, Dekle et al. (2007) and Eaton et al. (2016) show how it can be recast in changes. The changes formulation uses “exact hat algebra”, meaning that the equilibrium conditions can be rewritten to provide solution to outcomes in changes as a function of shocks in changes, where change is in comparison to the previous period value: $\hat{x}_{t+1} = \frac{x_{t+1}}{x_t}$ (note that under this notation, $\hat{x}_{t+1} = 1$ means no change). The benefit of this approach is a much smaller set of data required to parameterize the model. In particular, the changes specification does not require the knowledge of $K_{i,t}, w_{i,t}, r_{i,t}$ and $P_{ik,t}$ in levels.

The transformation from levels to changes is possible by using endogenous variables $Y_{ik,t}$ and $\Pi_{ijk,t}$ as well as employment $L_{ik,t}$ in levels as the initial condition⁴. These variables contain the information on the levels of exogenous shocks $K_{i,t}, A_{ik,t}, d_{ijk,t}$ up to the initial period. Thus, only the changes in these shocks, $\hat{K}_{i,t+1}, \hat{A}_{ik,t+1}, \hat{d}_{ijk,t+1}$, are needed to solve for the next period endogenous variables. Together with the level of trade deficit, $D_{i,t+1}$ and the change in employment $\hat{L}_{i,t+1}$, these shocks constitute the exogenous drivers of the model in changes: $\hat{\Psi}_t = \{\hat{L}_{i,t}, \hat{K}_{i,t}, \hat{A}_{ik,t}, \hat{d}_{ijk,t}, D_{i,t}\}$. $\hat{\Psi}_{t+1}$ can be used to solve for period $t+1$ values of $Y_{ik,t+1}, \Pi_{ijk,t+1}$ and $L_{ik,t+1}$. Using these as the new initial condition together with $\hat{\Psi}_{t+2}$, the procedure can be repeated. In this manner the model can be solved recursively.

The estimation of $\hat{\Psi}$ is discussed in the next section. For now, suppose that the initial period $Y_{ik,t}, \Pi_{ijk,t}$ and $L_{ik,t}$ as well as $\hat{\Psi}_{t+1}$ are known. Equations (16) to (25) constitute the equilibrium of the changes formulation of the model:

[i] Change in import shares, $\hat{\Pi}_{ijk,t+1}$ satisfies

$$\hat{\Pi}_{jik,t+1} = \left(\frac{\hat{c}_{ik,t+1} \hat{d}_{jik,t+1}}{\hat{A}_{ik,t+1} \hat{P}_{jk,t+1}} \right)^{-\theta_k}, \quad (16)$$

a changes equivalent of equation (11).

⁴These variables are exogenous from the perspective of the future periods as there are no forward looking relations in this model. In particular, capital accumulation is assumed to be exogenous. This is not a limitation of the model, EKRN show how to introduce endogenous investment decisions into the model. In the present version of the model investment decisions are not modelled for the sake of conciseness.

[ii] From equations (10) and (11), price changes $\hat{P}_{ik,t+1}$ satisfy

$$\hat{P}_{ik,t+1} = \left[\sum_l \Pi_{ilk,t} \left(\frac{\hat{c}_{lk,t+1} \hat{d}_{ilk,t+1}}{\hat{A}_{lk,t+1}} \right)^{-\theta_k} \right]^{-\frac{1}{\theta_k}}, \quad (17)$$

where $\hat{c}_{ik,t+1}$, based on equation (9), equals

$$\hat{c}_{ik,t+1} = \hat{w}_{ik,t+1}^{\beta_{ikL}} \hat{r}_{ik,t+1}^{\beta_{ikK}} \prod_n \hat{P}_{in,t+1}^{\beta_{ikn}}. \quad (18)$$

[iii] Using equations (12) and (13), wages and interest rates change as to clear labour and capital markets at $t+1$:

$$\hat{w}_{i,t+1} \hat{L}_{i,t+1} \sum_{k \in K} \beta_{ikL} Y_{ik,t} = \sum_{k \in K} \beta_{ikL,t+1} Y_{ik,t+1}, \quad (19)$$

$$\hat{r}_{i,t+1} \hat{K}_{i,t+1} \sum_{k \in K} \beta_{ikK} Y_{ik,t} = \sum_{k \in K} \beta_{ikK,t+1} Y_{ik,t+1}. \quad (20)$$

[iv] From equations (6) and (7), the household consumption satisfies:

$$C_{ik,t+1} = \Omega_{ik} \left(\prod_{\tau=0}^{t+1} \hat{P}_{ik,\tau} \right)^{-\sigma} E_{i,t+1}^{\sigma} C_{i,t+1}^{\epsilon_k - \sigma}, \quad (21)$$

where $C_{i,t+1}$ and $E_{i,t+1}$ can be obtained by manipulating equations (5) and (7),

$$\sum_{k \in K} \Omega_{ik} \left(\prod_{\tau=0}^{t+1} \hat{P}_{ik,\tau} \right)^{1-\sigma} E_{i,t+1}^{\sigma-1} C_{i,t+1}^{\epsilon_k - \sigma} = 1, \quad (22)$$

and equations (8), (12) and (13):

$$E_{i,t+1} = \frac{(\beta_{ikL} + \beta_{ikK}) Y_{i,t+1} + D_{i,t+1}}{L_{i,t} \hat{L}_{i,t+1}}. \quad (23)$$

[v] Finally, $Y_{ik,t+1}$ should satisfy the sectoral market clearing condition (15):

$$Y_{ik,t+1} = \sum_{j \in I} \Pi_{jik,t} \hat{\Pi}_{jik,t+1} X_{jk,t+1}, \quad (24)$$

where

$$X_{ik,t+1} = L_{i,t} \hat{L}_{i,t+1} \left(\prod_{\tau=0}^{t+1} \hat{P}_{ik,\tau} \right) C_{ik,t+1} + \sum_{n \in K} \beta_{ink} Y_{in,t+1}. \quad (25)$$

3.2.1 Interpretation of the model in changes

Before turning to the estimation of shocks and parameters it is worthwhile discussing the effects that each type of shock has in the model. All shocks have direct effects as well as indirect, general equilibrium effects. Equations (16) - (25) can be used to examine the direct effects of shocks $\hat{L}_{i,t}$, $\hat{K}_{i,t}$, $\hat{A}_{ik,t}$, $\hat{d}_{ijk,t}$, $D_{i,t}$ occurring in country i and trace it to the sectoral output of i where possible.

Consider the resource shocks $\hat{L}_{i,t}$ and $\hat{K}_{i,t}$. The direct effect of rising employment, $\hat{L}_{i,t} > 1$, is threefold: to reduce wages via (19), to increase aggregate demand via (25) and to reduce the household income via (23). Like in Dornbusch et al. (1977), lower wages result in lower production costs and hence higher competitiveness, increasing the size of the tradeable sector and, among tradeable sectors, of the one using labour relatively more intensively. Rising capital endowment, $\hat{K}_{i,t} > 1$, via (20) puts a downward pressure on the interest rate. Analogously to the falling wage rate, it decreases production costs and promotes the tradeable sectors and in particular the sector that relies on capital relatively more.

The direct effect of a fall in export costs in sector k , $\hat{d}_{ijk,t+1} < 1$, is to increase the import shares from i via (16). Equation (24) implies that sector k output increases. The fall in import costs, $\hat{d}_{ijk,t+1} < 1$, makes k cheaper via (17). Cheaper imports compete with domestic production and $\hat{\Pi}_{iik,t}$ decreases via (16), reducing the sectoral output. In addition, since sectoral goods are assumed to be complements, the falling relative price induces the households to spend relatively less on k (the expenditure share falls because the rise in consumption is less than the fall in price if goods are complements), reducing the output share of k even further.

Rising productivity, $\hat{A}_{ik,t} > 1$, makes k more competitive. The import shares from i , $\Pi_{jik,t}$ rise via (16), and via (24) the output of k rises. Another effect is to reduce the sectoral price of k via (17), again, decreasing the sector k consumption expenditure share.

Finally, suppose the deficit grows: $D_{t+1} > D_t$. This directly increases disposable income via (23) and through (25) the final demand for all goods. Like in Dornbusch et al. (1977), growing trade imbalance puts a squeeze on the tradeable sector. The reason is that the extra income is spent predominantly domestically, pushing up the factor prices and reducing competitiveness in the international markets. Another effect is via (21).

The expenditure share of a sector with higher income elasticity expands.

4 Calibration

Before the model can be used to study the effects of shocks to trade costs and trade deficits on the size of the manufacturing sector, it needs to be calibrated. In this section I first estimate the parameter values in Θ and then back out the shock series in $\hat{\Psi}$. The data used is the yearly observations of sectoral output, trade flows, consumption and inputs expenditure from the WIOD for the period from 1995 to 2007 aggregated as discussed in Section 2.

4.1 Parameter values

From the producer cost minimization condition, input cost share equals its production function exponent. Thus, β_{ikL} is calculated as the average ratio of the country i 's sector k labour compensation to sector k total factor expenditure across years 1995 to 2007. Similarly, β_{ikn} is calculated as the average sector k 's expenditure on sector n intermediate inputs, divided by sector k total costs. β_{ikK} is taken to be a residual consistent with constant returns to scale production:

$$\beta_{ikK} = 1 - \beta_{ikL} - \sum_n \beta_{ikn}.$$

The resulting input shares can be found in Table III in Appendix C.

The sectoral elasticity of trade, θ_k , is taken directly from the literature. Simonovska and Waugh (2014) and Donaldson (2010) both estimate the trade elasticity of manufacturing, θ_m , of around 4. The same value is used for services. For the primary sector a value of 5.33 is used, a simple average of the estimates for agriculture and food production in Caliendo and Parro (2015).

Preference parameters ϵ_k , σ , and Ω_{ik} are obtained by a non-linear least squares minimization procedure. Appendix C shows how, subject to parameter values, sectoral expenditure shares can be computed based on sectoral prices and income. Parameters are then chosen as to minimize the distance to the expenditure shares observed in the data. This procedure yields $\sigma = 0.4$. Thus, sectoral goods are complements, a typical result in the literature. A set of income elasticities for country i , $\{\epsilon_k\}_i$ can only be identified up to a scale α . Since equilibrium expenditure shares are independent of α , the income elasticity of services ϵ_{is} is normalized to unity for each country without loss of generality. The resulting income elasticities of agriculture and manufacturing are

$\epsilon_a = 0.27$ and $\epsilon_m = 0.84$. These results square well with the estimates obtained in Comin et al. (2015): $(\epsilon_a - \epsilon_m)/(\epsilon_s - \epsilon_m) = -3.7$ in Comin et al. (2015) (Table 2 column (2) estimates for the OECD sample) and -3.6 in the present work⁵.

4.2 Shocks estimation

Values of $\hat{L}_{i,t}$, $\hat{K}_{i,t}$ come directly from the data on employment and capital stock available in the WIOD Socio-Economic Accounts data. Trade deficit, $D_{i,t}$, is calculated as total imports less total exports.

Eaton et al. (2016) show how the trade cost and productivity shocks series can be backed out by combining equations (16) and (18) to obtain

$$\hat{A}_{ik,t+1} = \hat{\Pi}_{ik,t+1}^{\frac{1}{\theta_k}} \frac{\hat{C}_{ik,t+1}}{\hat{P}_{ik,t+1}}.$$

and

$$\hat{d}_{ijk,t+1} = \frac{\hat{\Pi}_{ijk,t+1}}{\hat{\Pi}_{jjk,t+1}}^{-\frac{1}{\theta_k}} \frac{\hat{P}_{ik,t+1}}{\hat{P}_{jk,t+1}}.$$

Instead of relying on the price data, the Head and Ries (2001) method can be used to back out the trade costs using the trade flows data only. Employing the assumption of the symmetry for the trade costs,

$$\hat{d}_{ijk}\hat{d}_{jik} = \hat{d}_{ijk}^2 = \left(\frac{\hat{\Pi}_{ijk,t+1}\hat{\Pi}_{jik,t+1}}{\hat{\Pi}_{iik,t+1}\hat{\Pi}_{jjk,t+1}} \right)^{\frac{1}{\theta_k}}. \quad (26)$$

Table 1 presents the summary statistics for the backed out shock values. The average employment growth, weighted by the world GDP share, was 1 percent per year in the period between 1995 and 2007. Meanwhile, the average capital stock growth constituted 3 percent per year. Thus, the overall quantity of resources grew, with capital accumulation outpacing the employment growth in all but one country (Mexico).

The next set of columns shows the average change in the trade costs by sector⁶. The world as a whole experienced a decline in the costs of trade, with an average yearly fall of 2 percent in each of the three sectors. All countries in the sample experienced a period of trade liberalisation. Poland, India, China and Austria have seen the largest

⁵The ratio is used to cancel out the different normalization of α in the two sets of estimates.

⁶Since the trade costs shocks are country-pair specific they are averaged across trading partners in a model consistent way: $\hat{d}_{ik,t} = \left(\sum_{j \neq i} \frac{X_{ijk,t} + X_{jik,t}}{\sum_{j \neq i} (X_{ijk,t} + X_{jik,t})} \hat{d}_{ijk,t}^{-\theta_k} \right)^{-1/\theta_k}$, where X stands for value traded.

decline in the manufacturing trade costs.

Finally, the last column displays the average yearly change in the trade deficit to GDP ratio. Most values are non-zero, meaning that countries saw a trend in their trade imbalance with either exports increasingly exceeding imports, or the other way around. The countries with increasingly unfavorable trade balance include Spain, Italy and Poland, while the countries that have seen their surpluses grow the most were Czech Republic, Germany, Austria and China. Thus, in addition to trade liberalization, there has been ever tighter financial integration, with countries running increasingly large trade surpluses and deficits.

According to the model presented in Section 3, both trade liberalization and growing trade imbalances depicted in Table 2 can have an effect on the relative sizes of the manufacturing sectors around the world. The next section is concerned with how much movement in the manufacturing shares can be generated by these shock series.

5 Counterfactuals

Now that the model is parameterized and the shock series are backed out, we can use the model to consider the impact that the falling costs of trade and rising trade imbalances had on the manufacturing shares around the world. To concretize the discussion, I will be focusing on the experiences of four countries. China, Germany, the United Kingdom and the United States are among the largest manufacturing exporters in the world and have shown markedly different patterns of industrialization over the period: while the United Kingdom and the United States have seen their manufacturing value added shares decline by 8.1 and 2.9 percentage points respectively, a fall of a whopping 43 and 21 percent from the year 1995 levels, China and Germany were among the few countries to expand their manufacturing shares, by 0.2 and 2 percentage points respectively, or 0.7 and 9 percent up since the beginning of the period.

The contribution of the shocks will be assessed by running counterfactual simulations with selected sets of shocks active, keeping levels of all other shocks at their 1995 level. The simulations will model the 20 largest manufacturing exporters in the sample and an aggregate of the rest of the world. The importance of shock series for driving manufacturing shares will be judged by testing the counterfactual simulations against two benchmarks.

5.1 Benchmark scenarios

The first benchmark is the “No Shocks” scenario: in absence of any type of shocks all manufacturing shares stay stable between 1995 and 2007. The further away is a counterfactual from the “No Shocks” benchmark, the bigger is the effect of that shock on value added shares.

The second benchmark is the “All Shocks” scenario. Recall that a considerable part of the manufacturing share declines around the world is attributable, as shown in decompositions in Section 2, to the falling use of manufacturing intermediate inputs in production. The model described in Section 3 has abstracted from modelling this source of structural change by assuming time-invariant Cobb-Douglas production functions. To be able to make consistent comparisons between the data and the model, the “All Shocks” scenario is computed by purging the manufacturing value added share in the data of the contribution of this channel. This amounts to subtracting the first- and higher-order terms containing $\Delta\beta_{ik,t}$ that appear in the full manufacturing value added share change decomposition from the data. The closer is a counterfactual to the “All Shocks” benchmark, the more it can explain of the manufacturing share evolution in a particular country.

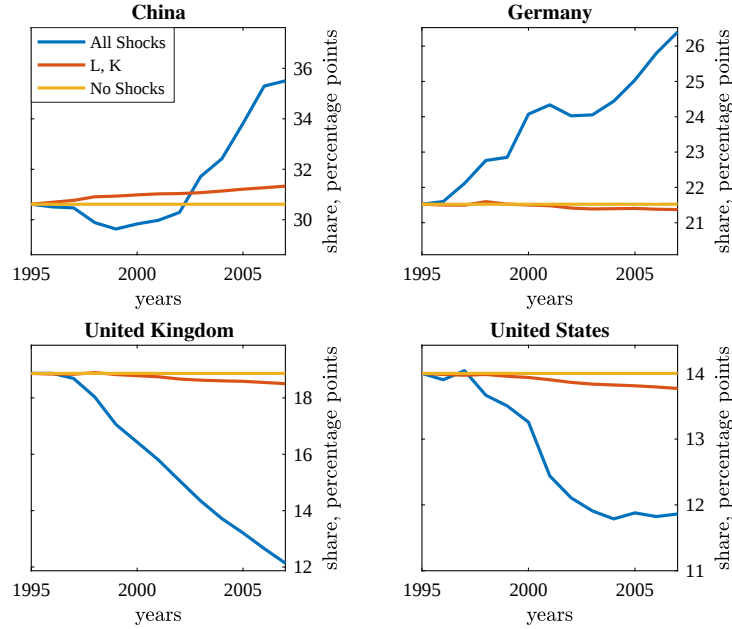
5.2 Contribution of shocks to employment and capital stock

Figure 3 presents the counterfactual evolution of manufacturing value added shares in the four economies if the only thing to evolve around the world were employment levels and the capital stocks. For all four economies the contribution of these shocks is rather limited: the distance between the counterfactual and the “No Shocks” scenario is less than a percentage point in the end of the period.

5.3 Contribution of trade cost shocks

Next, suppose that on top of the employment and capital stock shocks, the trade costs too were evolving. From Figure 4 it can be seen that trade costs do much better in explaining the change in the value added shares in manufacturing for each of the four economies. For China and the US, the changes in trade costs are sufficient to hit the “All Shocks” benchmark suggesting that much of the experience of the manufacturing in these countries can be understood as an outcome of trade liberalization. Note that for China the steep rise of the manufacturing shares happens just after 2001, the year in which China joined the WTO. For Germany and the UK trade cost shocks seem to explain about a third of the manufacturing shares evolution.

Figure 3: Manufacturing Value Added: Effects of Employment and Capital Stock Shocks

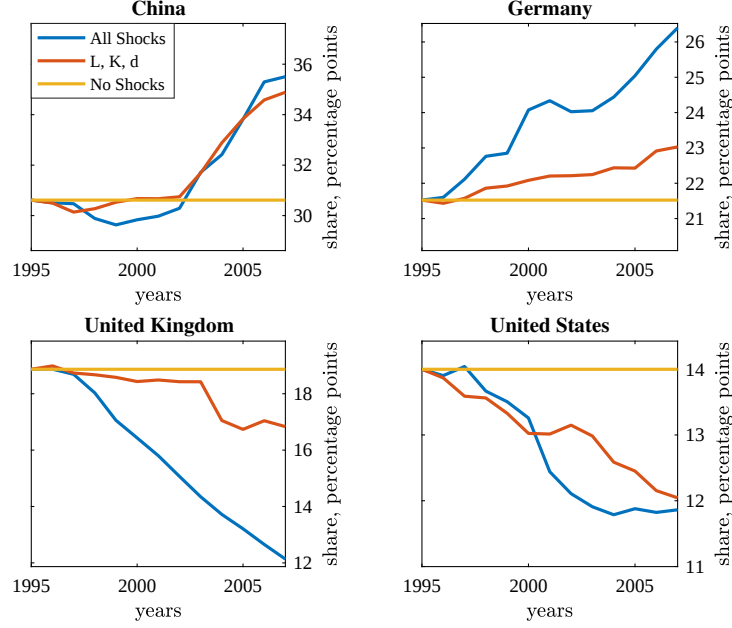


Note: Line “L, K” represents the counterfactual manufacturing value added shares with the paths of $\hat{L}$, $\hat{K}$ shocks at their calibrated values and all other shocks at 1 (meaning no change). “All Shocks” is the value added share from data purged of the changes in the intermediate inputs use, “No Shocks” is the value added share in a counterfactual where all shocks are set to 1.

5.4 Contribution of trade deficit shocks

Suppose now that the trade costs stayed still over the period, but all countries experienced exogenous shocks to their trade deficits of the magnitude observed in the data. Figure 5 shows that for the four economies, the trade imbalances have had the effect in line with predictions of the theory: surplus countries (China and Germany) industrialize in response to the growing trade imbalances, while the deficit countries (UK and the US) see a fall in the manufacturing value added share. Once again, the magnitude of the effect is sizeable: in China the trade surpluses produce industrialization of the scale observed in the “All Shocks” scenario, and in the United States the trade deficits go more than half way in hitting the target. The effect of trade imbalances on the manufacturing in Germany and the United Kingdom is considerable, but again, falls short of explaining the full evolution of manufacturing shares.

Figure 4: Manufacturing Value Added: Effects of Trade Cost Shocks



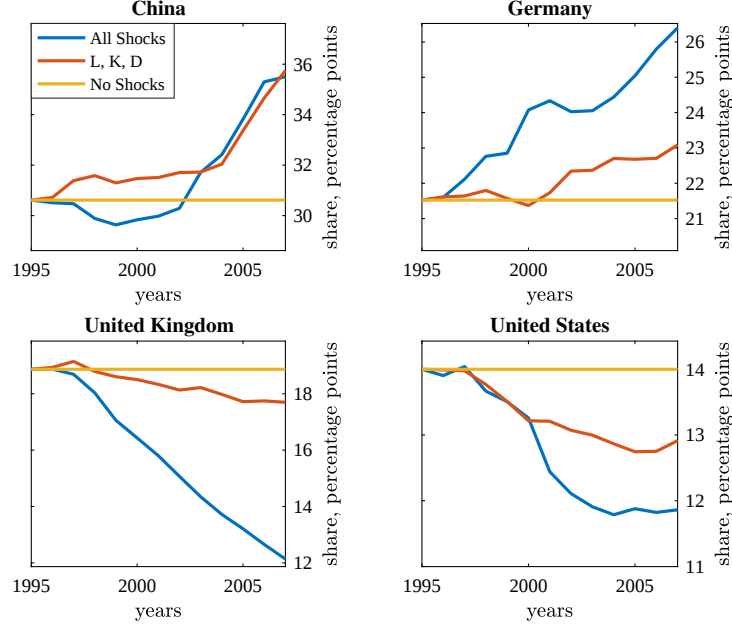
Note: Line “L, K, d” represents the counterfactual manufacturing value added shares with the paths of $\hat{L}$, $\hat{K}$ and $\hat{d}$ shocks at their calibrated values and all other shocks at 1 (meaning no change). “All Shocks” is the value added share from data purged of the changes in the intermediate inputs use, “No Shocks” is the value added share in a counterfactual where all shocks are set to 1.

5.5 Transmission channels

To see how exactly the shocks to trade costs and trade deficits have affected manufacturing in the countries under consideration, apply the decomposition developed in Section 2 to the counterfactuals. This procedure allows one to break down the evolution of the manufacturing value added into three components: a part that occurs via the competitiveness channel, (C), a part that occurs via the expenditure shares channel, (ES), and one that is due to the changes in the size of the foreign market, (FM). This allows one to track the transmission of the shocks in the economy.

As can be seen from Figures 4 and 5, the shocks to trade costs have been affecting the manufacturing in each of the economies in a manner similar to that of the trade deficit shocks. Appendix E contains the decompositions of the counterfactuals for each of these shock series separately. The decompositions show that the transmission of these shocks is also similar. Thus, in what follows the effects of the two types of shocks will be considered together.

Figure 5: Manufacturing Value Added: Effects of Trade Deficit Shocks



Note: Line “L, K, D” represents the counterfactual manufacturing value added shares with the paths of $\hat{L}$, $\hat{K}$ and $\hat{D}$ shocks at their calibrated values and all other shocks at 1 (meaning no change). “All Shocks” is the value added share from data purged of the changes in the intermediate inputs use, “No Shocks” is the value added share in a counterfactual where all shocks are set to 1.

Figures 6a - 6d show the manufacturing shares evolution and its decomposition into three channels for the two benchmark scenarios and a counterfactual with $\hat{L}$, $\hat{K}$, $\hat{d}$ and D shocks in operation.

Recall that the model described in Section 3 allowed for five types of shocks: $\hat{L}$, $\hat{K}$, $\hat{A}$, $\hat{d}$, D . By comparing the simulation where only $\hat{L}$, $\hat{K}$, $\hat{d}$ and D are present with “All Shocks” scenario we can infer the contribution of the missing sectoral productivity shock $\hat{A}$ to the manufacturing shares evolution.

5.5.1 China

For China, the combination of employment growth, capital stock growth, falling trade costs and rising trade surpluses contributed to a swift industrialization, with a 7 percentage point increase over the period. The growth occurred via the increased competitiveness of Chinese manufacturing produce, as seen in panel (C) of the figure, and was partially offset by the shrinking of the relative size of the foreign market for China. The

changes in expenditure played a minimal role in this process. It is notable that the “All Shocks” scenario is actually below the counterfactual with four sets of shocks. This is informative of the role of the sectoral productivity shocks for the Chinese manufacturing. As can be seen from panels (C) and (FM), suppressing productivity growth results in lower competitiveness than the “All Shocks” benchmark and in a relatively smaller drop via the foreign market size effect. This suggests that the Chinese productivity growth made for a more competitive manufacturing, but also fueled an economic growth so rapid that the productive capacity of the Chinese economy outgrew the foreign demand.

5.5.2 Germany

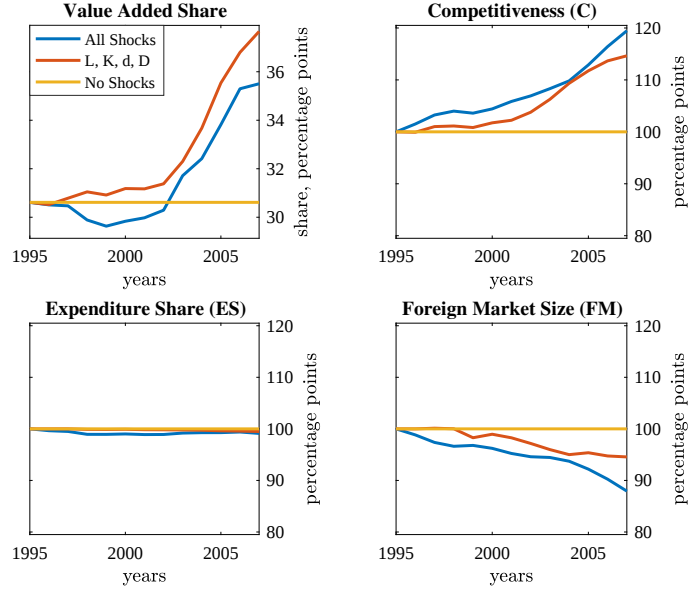
For Germany the joint contribution of the four shocks falls somewhat short of the “All Shocks” benchmark. However, the decomposition reveals that the counterfactual is in fact widely off target. First observe that behind the industrialization in the counterfactual scenario stands increased competitiveness in manufacturing. But competitiveness plays no role in the “All Shocks” benchmark. Instead, the industrialization is solely an outcome of the growth of the foreign market size. This paints a rich picture of the German experience: growing trade surpluses and falling trade costs have made its manufacturing more competitive, but German productivity failed to match that of the trading partners, rendering these gains undone. At the same time, the outside world has been showing stronger growth than the German economy, translating into strong growth in demand for German manufacturing, pushing up its share in the economy.

5.5.3 United Kingdom

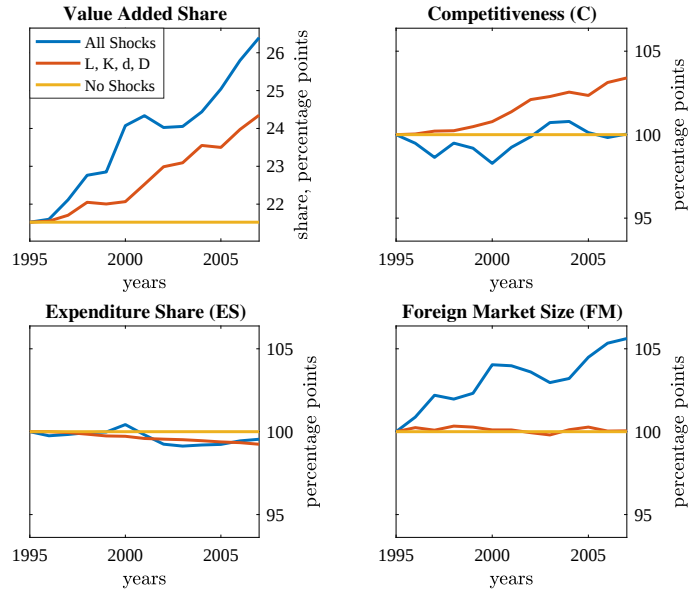
Figure 6c shows that the falling trade costs and growing trade deficits are not sufficient to explain the rapid deindustrialization of the United Kingdom between 1995 and 2007. While the two have decreased the competitiveness of its manufacturing, the four sets of shocks fail to generate the decreases that occurred via the competitiveness and the foreign market size channels in the “All Shocks” scenario. The difference must be due to the sectoral productivity growth. In particular, the drop in competitiveness suggests that the UK manufacturing productivity growth was weak, while the fall in the size of the foreign market size indicates that the rest of the economy saw rapid growth, which in turn resulted in the export-serving share of the economy shrink in relative terms.

Figure 6: Counterfactual Simulations, Decomposition by Channel

(a) China



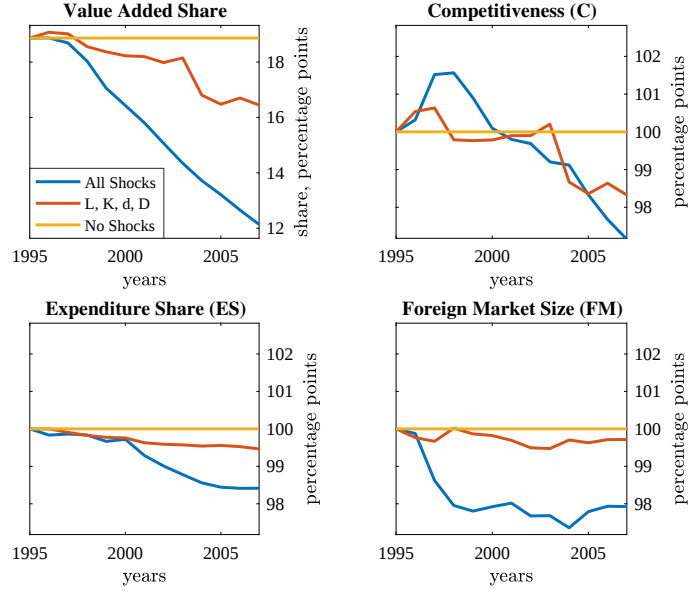
(b) Germany



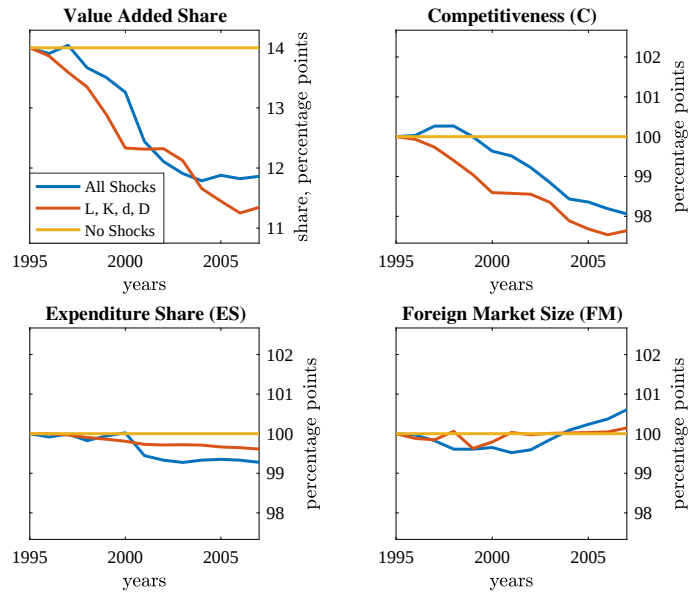
Note: Line “L, K, d, D” represents the counterfactual manufacturing value added shares with the paths of $\hat{L}$, $\hat{K}$, $\hat{d}$ and $\hat{D}$ shocks at their calibrated values and all other shocks at 1 (meaning no change). “All Shocks” is the value added share from data purged of the changes in the intermediate inputs use, “No Shocks” is the value added share in a counterfactual where all shocks are set to 1. The series in panels (C), (ES) and (FM) are by cumulating the respective terms from equation (3) over time.

Figure 6: Counterfactual Simulations, Decomposition by Channel

(c) United Kingdom



(d) United States



Note: Line “L, K, d, D” represents the counterfactual manufacturing value added shares with the paths of $\hat{L}$, $\hat{K}$, $\hat{d}$ and $\hat{D}$ shocks at their calibrated values and all other shocks at 1 (meaning no change). “All Shocks” is the value added share from data purged of the changes in the intermediate inputs use, “No Shocks” is the value added share in a counterfactual where all shocks are set to 1. The series in panels (C), (ES) and (FM) are by cumulating the respective terms from equation (3) over time.

5.5.4 United States

Finally, Figure 6d shows that the shocks to trade costs and trade deficits have resulted in a loss of competitiveness of the US manufacturing produce, leading to a decline in its share in the economy. Note that the loss in competitiveness can be attributed to these shocks alone: the sectoral productivity growth played a minor role. The expenditure share and foreign market size channels have also been of minor importance for the decline of US manufacturing. Thus, unlike in the United Kingdom, in the United States the falling trade costs and rising trade surplus are responsible for most of the deindustrialization.

5.6 Discussion

Figures 6a - 6d suggest that shocks to trade costs and trade deficits play a substantial role in driving structural change in China, Germany, the United Kingdom and the United States. In particular, for China and the United States, the two types of shocks, combined with the growth in employment and the capital stocks, produce counterfactual value added share evolutions that are similar in magnitude and in composition (in terms of contributions of different channels). For Germany and the United Kingdom these shocks seem to be responsible for part of the change occurring via the competitiveness and expenditure shares channels. For all four countries the bulk of the contribution of these shocks occurred by rendering the manufacturing produce more or less competitive in the world markets. These results suggest that the shocks to trade costs and trade imbalances are important as drivers of structural change.

The extent to which the simulations fail to reproduce the changes in value added and their decomposition is informative about the role of sectoral productivity growth in driving manufacturing shares in these countries. In particular, both Germany and United Kingdom saw their manufacturing shares change due to the mismatch between the growth in domestic income and that of the trading partners. This suggests a new role for productivity growth in causing structural change, in addition to the classical relative price and income effects.

This work is meant to sketch out a way of thinking about structural change in an open economy. The main contribution is the identity-based decomposition as a handy tool for thinking about structural change. By accounting for all moving parts that can lead to shifts in relative sizes of sectors it helps put different channels and drivers into perspective. Thus, for the period between 1995-2007, shifts in final expenditure played a minor role in evolution of manufacturing shares. The three main contributors, instead,

were the changes in the use of intermediate inputs, and the open economy channels of competitiveness and foreign market size effect. In addition, it is useful for disciplining the analysis of the counterfactual simulations. Recall that in Figure 6b the simulated value added shares square well with the benchmark but do a very poor job in matching the decomposition. This is an example where good fit is by luck rather than by construction. By matching multiple benchmark series it is possible to control for such errors.

This work can be expanded in multiple directions. First, the series considered are both very short and recent. It would be interesting to see a similar decomposition carried out over longer periods of time. Second, the prominent role of changes in the use of manufacturing intermediate inputs calls for a separate investigation. Finally, an assumption of exogenous trade imbalances, albeit common, is likely inappropriate in the context of structural change. It would be good to see how endogenous trade deficits could be fitted into the model.

6 Conclusion

This paper has documented the contribution of trade to the evolution of manufacturing value added shares over the years 1995-2007, by analyzing World Input-Output Database sectoral data. First, an identity-based decomposition was applied to the changes in manufacturing value added shares. It has been shown that an open economy framework features two new mechanisms of structural change arising due to changes in sectoral competitiveness in international trade and in the size of the foreign market. For a sample of the 20 largest manufacturing exporters, the average contribution of these channels was shown to be 33 and 34 percent, respectively, suggesting that the traditional use of closed economy framework misses a key contribution of trade to the process of structural change. Second, this paper has investigated the driving forces behind structural change. For China and the United States, the shocks to trade costs and trade deficits explained most of the change in the manufacturing value added shares. For Germany and the United Kingdom, the two types of shocks played a substantial role alongside the shocks to the sectoral productivity levels. Thus, the shocks to trade costs and trade imbalances are important as drivers of structural change.

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A Manufacturing Value Added Share Decomposition

A.1 Full changes decomposition

Take equation for the value added share for time t :

$$va_{im,t} = \sum_j \Pi_{jim,t} S_{jm,t} \frac{Y_j,t}{Y_i,t}.$$

Take a difference between dates T and t :

$$va_{im,T} - va_{im,t} = \sum_j (\Pi_{jim,T} S_{jm,T} \frac{Y_j,T}{Y_i,T} - \Pi_{jim,t} S_{jm,t} \frac{Y_j,t}{Y_i,t}).$$

Rewrite all time T variables as $x_T = x_t + \Delta x_t$, where Δ stands for period change:

$$\Delta va_{im,t} = \sum_j ((\Pi_{jim,t} + \Delta \Pi_{jim,t})(S_{jm,t} + \Delta S_{jm,t})(\frac{Y_j,t}{Y_i,t} + \Delta \frac{Y_j,t}{Y_i,t}) - \Pi_{jim,t} S_{jm,t} \frac{Y_j,t}{Y_i,t}).$$

Multiply out the brackets and cancel $\Pi_{jim,t} S_{jm,t} \frac{Y_j,t}{Y_i,t}$:

$$\begin{aligned} \Delta va_{im,t} = & \sum_j (\Delta \Pi_{jim,t} S_{jm,t} \frac{Y_j,t}{Y_i,t} + \Pi_{jim,t} \Delta S_{jm,t} \frac{Y_j,t}{Y_i,t} + \Pi_{jim,t} S_{jm,t} \Delta \frac{Y_j,t}{Y_i,t} + \\ & \Delta \Pi_{jim,t} \Delta S_{jm,t} \frac{Y_j,t}{Y_i,t} + \Delta \Pi_{jim,t} S_{jm,t} \Delta \frac{Y_j,t}{Y_i,t} + \Pi_{jim,t} \Delta S_{jm,t} \Delta \frac{Y_j,t}{Y_i,t} + \\ & \Delta \Pi_{jim,t} \Delta S_{jm,t} \Delta \frac{Y_j,t}{Y_i,t}). \end{aligned}$$

The terms on the first line are the first-order terms, on the second line are the second-order terms, on the third line are the third-order terms.

A.2 The closed economy case of equation (2)

Take the first-order approximation:

$$\Delta va_{im,t} = \sum_j (\Delta \Pi_{jim,t} S_{jm,t} \frac{Y_j,t}{Y_i,t} + \Pi_{jim,t} \Delta S_{jm,t} \frac{Y_j,t}{Y_i,t} + \Pi_{jim,t} S_{jm,t} \Delta \frac{Y_j,t}{Y_i,t})$$

Suppose the economy is closed. In that case, $\Pi_{iik} = 1$ and $\Pi_{jik} = 0$ for all $j \neq i$, so $\Delta \Pi_{jik} = 0$ for all time periods. Furthermore, $\frac{Y_i,t}{Y_i,t} = 1$ and $\Delta \frac{Y_i,t}{Y_i,t} = 0$. Plugging in

obtain

$$\Delta va_{im,t} = \Delta S_{im,t}.$$

A.3 Decomposition with intermediate inputs use

Rewrite sectoral output as a sum of demands, breaking down total demand into the final consumption expenditure X_{jk} and intermediate inputs use $\beta_{jnk}Y_{jn}$, where β_{jnk} is the expenditure share of country j sector n on intermediate inputs from sector k :

$$Y_{ik} = \sum_j \Pi_{jik}(X_{jk} + \sum_n \beta_{jnk}Y_{jn}).$$

Stack up in a matrix form, such that Y and X are vectors of length IK listing country-sector output and final demands respectively,

$$Y = \Pi_{FC}X + \Pi_{II}BY,$$

where Π_{FC} is an IK by IK matrix constructed of blocks of sectoral import shares matrices Π_k on the diagonal and blocks of zeros off the diagonal, Π_{II} is an IK by IK matrix constructed of blocks of sectoral import shares matrices Π_k and B is an IK by IK matrix constructed of rows of stacked intermediate input use intensities β_{ikn} . Collect factors on the left-hand side:

$$(I - \Pi_{II}B)Y = \Pi_{FC}X,$$

where I is an identity matrix of dimensions IK by IK . Premultiply both sides by a Leontief inverse:

$$Y = (I - \Pi_{II}B)^{-1}\Pi_{FC}X.$$

Premultiply by B_{VA} , a diagonal matrix with $\beta_{VA,ik} = \beta_{ikL} + \beta_{ikK}$ elements on the diagonal to obtain sectoral value added:

$$VA = B_{VA}(I - \Pi_{II}B)^{-1}\Pi_{FC}X.$$

Finally, divide through by incomes to obtain value added shares, and break down X into the expenditure share S and income such that:

$$va = B_{VA}(I - \Pi_{II}B)^{-1}\Pi_{FC}(Y/Y)X.$$

By subtracting va_t from va_T and following the procedure outlined in A.3, find that to a first-order approximation,

$$\begin{aligned}\Delta va = & \Delta B_{VA}(I - \Pi_{II}B)^{-1}\Pi_{FC}(Y/Y)S + B_{VA}\Delta(I - \Pi_{II}B)^{-1}\Pi_{FC}(Y/Y)S + \\ & B_{VA}(I - \Pi_{II}B)^{-1}\Delta\Pi_{FC}(Y/Y)S + B_{VA}(I - \Pi_{II}B)^{-1}\Pi_{FC}\Delta(Y/Y)S + \\ & B_{VA}(I - \Pi_{II}B)^{-1}\Pi_{FC}(Y/Y)\Delta S.\end{aligned}$$

Finally, changes in Leontief inverse can be approximated too to distinguish between changes in the intermediate input use and import shares:

$$\Delta(I - \Pi_{II}B)^{-1} = (I - \Pi_{II}B)^{-1}(\Delta\Pi_{II}B + \Pi_{II}\Delta B)(I - \Pi_{II}B)^{-1}.$$

B Data Description

List of countries: Austria, Belgium, Canada, China , Czech Republic, Germany, Spain, Finland, France, United Kingdom, India, Italy, Japan, Republic of Korea, Mexico, Netherlands, Poland, Sweden, Turkey, Taiwan, US.

Rest of the world: Australia, Bulgaria, Brazil, Cyprus, Denmark, Estonia, Greece, Hungary, Indonesia, Ireland, Lithuania, Luxembourg, Latvia, Malta, Portugal, Romania, Russia, Slovak Republic, Slovenia, RoW.

For sector mapping see Table I.

C Calibration

To find parameters of the utility function,

- [i] Guess $\{\epsilon_k, \sigma, \Omega_{ik}\}$ for $k = a, m$, for all i .
- [ii] Set $\epsilon_s = 1, \Omega_{is} = 1$ for all i .
- [iii] Using price series from WIOD Socio-Economic Accounts dataset, $P_{ik,t}$, and final consumption sectoral expenditure from WIOD tables, $E_{i,t+1}$, solve for aggregate consumption for all time periods $t = \{1995, \dots, 2007\}$:

$$\sum_{k \in K} \Omega_{ik} P_{ik,t}^{1-\sigma} E_{i,t+1}^{\sigma-1} C_{i,t}^{\epsilon_k - \sigma} = 1.$$

- [iv] Compute model-implied expenditure shares:

$$\omega_{ik,t} = \Omega_{ik} P_{ik,t}^{1-\sigma} E_{i,t}^{\sigma-1} C_{i,t}^{\epsilon_k - \sigma}.$$

- [v] Solve for $\{\epsilon_k, \sigma, \Omega_{ik}\}$ that minimise the squared distance between the resulting expenditure shares and the ones obtained from the WIOD tables, $exp_{ik,t}$:

$$\min_{\{\epsilon_k, \sigma, \Omega_{ik}\}} \sum_i \sum_k \sum_t (\omega_{ik,t} - exp_{ik,t})^2.$$

Table 1: Estimated Shocks: Labour and Capital Supply, Sectoral Trade Costs and Overall Trade Deficits, Average over 1995-2007

	$\hat{L}_i$	$\hat{K}_i$	$\hat{d}_{ia}$	$\hat{d}_{im}$	$\hat{d}_{is}$	$\Delta \frac{D_i}{Y_i}$
Austria	1.009	1.023	0.957	0.970	0.990	0.686
Belgium	1.010	1.030	0.980	0.987	0.992	-0.093
Canada	1.019	1.032	0.977	0.995	0.990	-0.132
China	1.010	1.043	0.972	0.962	0.957	0.662
Czech Republic	1.001	1.029	0.975	0.953	0.994	0.824
Germany	1.005	1.023	0.973	0.976	0.976	0.732
Spain	1.036	1.042	0.976	0.975	0.966	-0.446
Finland	1.016	1.025	0.976	0.983	0.982	-0.204
France	1.011	1.016	0.988	0.986	0.999	-0.269
UK	1.010	1.035	0.983	0.988	0.973	-0.210
India	1.016	1.074	0.946	0.959	0.946	-0.143
Italy	1.012	1.021	0.980	0.987	0.991	-0.301
Japan	0.997	1.000	0.981	0.990	0.982	0.065
Korea	1.012	1.046	0.972	0.986	0.985	0.313
Mexico	1.028	0.993	0.966	0.974	0.996	-0.259
Netherlands	1.016	1.026	0.978	0.992	0.989	0.189
Poland	1.003	1.037	0.969	0.952	0.959	-0.376
Sweden	1.008	1.033	0.970	0.988	0.978	0.058
Turkey	1.001	1.044	0.995	0.963	0.957	-0.280
Taiwan	1.008	1.057	0.982	0.979	0.991	0.627
US	1.011	1.040	0.988	0.989	0.987	-0.277
RoW	0.998	1.035	0.980	0.977	0.980	0.276
Average	1.007	1.032	0.981	0.983	0.982	0.000

Note: Trade costs are calculated as a weighted average across trading partners, see Footnote 5. Trade deficit change is computed as the yearly difference of the trade deficit to GDP ratio. The values in the last row are the GDP-weighted averages of the country-level shocks.

Table I: Sectors mapping

Sector	OECD Description
Primary	Agriculture, Hunting, Forestry and Fishing
Manufacturing	Mining and Quarrying
Primary	Food, Beverages and Tobacco
Manufacturing	Textiles and Textile Products
Manufacturing	Leather, Leather and Footwear
Manufacturing	Wood and Products of Wood and Cork
Manufacturing	Pulp, Paper, Paper , Printing and Publishing
Manufacturing	Refined Petroleum and Nuclear Fuel
Manufacturing	Chemicals and Chemical Products
Manufacturing	Rubber and Plastics
Manufacturing	Other Non-Metallic Mineral
Manufacturing	Basic Metals and Fabricated Metal
Manufacturing	Machinery, Nec
Manufacturing	Electrical and Optical Equipment
Manufacturing	Transport Equipment
Manufacturing	Manufacturing, Nec; Recycling
Manufacturing	Electricity, Gas and Water Supply
Services	Construction
Services	Sale, Maintenance and Repair of Motor Vehicles and Motorcycles; Retail Sale of Fuel
Services	Wholesale Trade and Commission Trade, Except of Motor Vehicles and Motorcycles
Services	Retail Trade, Except of Motor Vehicles and Motorcycles; Repair of Household Goods
Services	Hotels and Restaurants
Services	Inland Transport
Services	Water Transport
Services	Air Transport
Services	Other Supporting and Auxiliary Transport Activities; Activities of Travel Agencies
Services	Post and Telecommunications
Services	Financial Intermediation
Services	Real estate activities
Services	Renting of machines and equipment and other business activities
Services	Public Administration and Defence, Compulsary Social Security
Services	Education
Services	Health and Social Work
Services	Other Community, Social and Personal Services
Services	Private Households with Employed Persons

Table III: Production Function Parameters

	β_{iaL}	β_{imL}	β_{isL}	β_{iaK}	β_{imK}	β_{isK}	β_{iaa}	β_{ima}	β_{isa}	β_{iam}	β_{imn}	β_{ism}	β_{ias}	β_{ims}	β_{iss}
Austria	0.433	0.274	0.407	0.000	0.143	0.229	0.254	0.034	0.017	0.091	0.315	0.080	0.222	0.234	0.2682
Belgium	0.158	0.202	0.365	0.135	0.133	0.200	0.360	0.031	0.017	0.084	0.388	0.070	0.264	0.245	0.3478
Canada	0.175	0.189	0.387	0.295	0.179	0.258	0.239	0.063	0.017	0.082	0.358	0.077	0.209	0.211	0.2611
China	0.360	0.118	0.232	0.140	0.156	0.231	0.291	0.091	0.056	0.119	0.491	0.269	0.090	0.145	0.2109
Germany	0.294	0.307	0.395	0.079	0.106	0.245	0.256	0.021	0.015	0.100	0.329	0.072	0.271	0.237	0.2733
Spain	0.205	0.208	0.377	0.178	0.134	0.213	0.326	0.038	0.033	0.082	0.384	0.097	0.210	0.237	0.2805
Finland	0.317	0.194	0.391	0.099	0.172	0.216	0.295	0.062	0.022	0.074	0.356	0.117	0.214	0.216	0.2547
France	0.223	0.213	0.370	0.144	0.116	0.244	0.303	0.029	0.016	0.086	0.356	0.062	0.244	0.286	0.3091
United Kingdom	0.188	0.261	0.381	0.245	0.152	0.197	0.254	0.030	0.031	0.100	0.339	0.076	0.213	0.219	0.3155
India	0.374	0.102	0.357	0.244	0.175	0.287	0.212	0.088	0.030	0.065	0.401	0.150	0.105	0.234	0.1758
Ireland	0.231	0.146	0.363	0.115	0.237	0.180	0.379	0.028	0.016	0.102	0.331	0.096	0.173	0.258	0.3447
Italy	0.296	0.214	0.382	0.112	0.126	0.227	0.297	0.030	0.023	0.062	0.389	0.090	0.233	0.241	0.278
Japan	0.207	0.214	0.379	0.229	0.147	0.239	0.279	0.025	0.019	0.095	0.420	0.100	0.191	0.194	0.2627
Republic of Korea	0.455	0.177	0.476	0.000	0.130	0.123	0.387	0.047	0.011	0.078	0.513	0.147	0.080	0.133	0.2422
Mexico	0.127	0.109	0.259	0.426	0.216	0.441	0.219	0.125	0.007	0.081	0.392	0.105	0.148	0.158	0.188
Netherlands	0.177	0.216	0.386	0.215	0.152	0.194	0.295	0.061	0.023	0.070	0.294	0.074	0.243	0.278	0.3237
Sweden	0.263	0.206	0.361	0.208	0.175	0.220	0.242	0.046	0.011	0.088	0.331	0.090	0.199	0.243	0.3187
Taiwan	0.271	0.166	0.403	0.124	0.124	0.225	0.321	0.033	0.009	0.085	0.498	0.131	0.199	0.180	0.2317
United States	0.161	0.214	0.384	0.187	0.131	0.254	0.324	0.040	0.016	0.113	0.406	0.076	0.217	0.210	0.2712
RoW	0.292	0.190	0.343	0.214	0.152	0.262	0.244	0.101	0.035	0.079	0.362	0.113	0.171	0.195	0.2475
Average	0.260	0.196	0.370	0.169	0.153	0.234	0.289	0.051	0.021	0.087	0.383	0.105	0.195	0.218	0.270