# Dissecting Structural Change in an Open Economy

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**Abstract**

This paper studies the role of trade and international borrowing in driving structural change. I decompose the change in manufacturing shares into contributions by sectoral expenditure shares, trade shares, and aggregate trade imbalances, and map these into structural primitives in a quantitative trade model with endogenous borrowing. Using data from twenty economies, I show that trade specialization and international borrowing explain 34% of the average change in the manufacturing share, half of the cross-country heterogeneity in the patterns of industrialization, half the dynamics in high-technology subsectors of manufacturing, and much of the China-driven deindustrialization and 'miracle' industrialization in South Korea.

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# 1 Introduction

Deindustrialization is in the news, again.[1] While the broad sweep of the changing sectoral composition of economies is typically attributed to closed economy forces (see Herrendorf et al. (2014)), it is the open economy angle – manufacturing 'going places' – that inspires the headlines. In this paper, I show how to quantify the contribution of two distinct types of openness – trade in goods and trade in assets – to the observed change in the relative size and the composition of countries' manufacturing, and use a structural model to link these effects to the underlying changes in preferences and technology. I use my framework to inspect the proximate and fundamental drivers of a host of structural change dynamics in the data, and show how it can be used to shed new light on the effect of China on global manufacturing and the export-led industrialization in South Korea.

First, using an accounting identity, I show that changes in sectoral value added shares can be broken down into three terms that arise due to (i) secular changes in sectoral demand (what goods do agents buy?), (ii) trade specialization (where do agents source these goods from?), and (iii) aggregate trade imbalances (who borrows and lends in a given period?). The decomposition relies on observable data alone, and offers a simple way to evaluate the distinct roles of trade in goods and assets in driving structural change.

Applying the decomposition to a sample of twenty economies, I show that trade specialization and international borrowing are responsible for 26% and 8% of the observed change in manufacturing shares between 1965 and 2011. The contribution of the two forces to the cross-country heterogeneity in the experiences of structural change, measured as the deviation of the change in manufacturing share from the group average, is larger still: at 40% and 14% respectively. Finally, I show that the role of the open economy forces, and trade specialization in particular, increases when looking beyond the aggregate manufacturing. As such, I find that trade specialization explains a third of the

[1]Over the last decade, the frequency in the use of the term in English language newspaper articles has almost tripled. No such increase is visible for GDP or 'economic growth'. Source: Dow Jones Factiva (2019).

changing composition of manufacturing in my sample, and is on par with secular forces in determining the relative size of the high-technology subsectors within manufacturing.

My accounting decomposition highlights the importance of taking openness into account when studying structural change. But what fundamental forces shape countries' specialization and borrowing behaviour? To address this question, I turn to a structural model, extending the closed economy setup of Comin et al. (2021) in two ways. First, I model manufacturing as a set of subsectors, each featuring a continuum of tradable varieties. Economies purchase varieties from the cheapest origin, giving rise to endogenous specialization subject to Ricardian comparative advantage. Second, households are forward looking and borrow and lend on international markets to smooth consumption subject to convex costs of imbalances. The model gives rise to a mapping between the terms of the decomposition and their fundamental drivers: preferences and technology.

Fully calibrated, the model matches the data by construction. This, in turn, enables me to study the fundamental drivers of structural change in the data and to use counterfactual exercises to revisit two long-standing questions linking trade and structural change – the impact of China on the evolution of manufacturing sectors around the world, and the role of trade in the 'miracle' industrialization of South Korea.

I show that between 2000 and 2011, China has put a squeeze on the manufacturing shares of all economies in my sample with two exceptions: South Korea and Taiwan. The decomposition by channel reveals that virtually all of this is attributable to specialization, with the borrowing channel playing a secondary role: current account surpluses in China made borrowing in the rest of the world cheaper, leading economies to shift towards the production of non-tradables. Furthermore, I find that trade specialization was important for China's effect on the *composition* of global manufacturing, pushing economies towards the specialization in low-technology subsectors of manufacturing.

Turning to South Korea, I show that trade specialization is the main force behind the doubling of its manufacturing share between 1965 and 2011. However, the aggregate conceals two distinct trends. First, trade cost declines prompted a dramatic reallocation of resources from the primary sector into the low-technology subsectors of manufacturing – mainly textiles. At the same time, South Korean productivity in high-technology sub-sectors – mainly electrical equipment – increased, drawing the resources from the low-technology subsectors. Thus, the 'miracle' industrialization hinged crucially on the combined effect of trade liberalization releasing labor into the manufacturing, and shifting comparative advantage *within* it.

**Literature review.** This paper is related to several strands in the literature. The first – focusing on structural change – has mostly relied on closed economy settings. Ngai and Pissarides (2007) study the role of substitution across sectoral goods due to shifting relative prices (price effect), whereas Boppart (2014); Comin et al. (2021) focus on the role of changes in expenditure shares due to the non-homotheticities in consumer preferences (income effect). Herrendorf et al. (2021); Garcia-Santana et al. (2021), in turn, emphasize the role of the sectoral composition of investment in driving structural change. Recently, Huneeus and Rogerson (2024) have used simulations to argue that the operation of price- and income effects in a closed economy environment is sufficient to explain much of cross-country heterogeneity in patterns of industrialization. By contrast, I use an accounting decomposition to show that changes in the sectoral expenditure shares – which nest both – explain only a half of the cross-country heterogeneity. In other words, ignoring openness to trade and borrowing risks overestimating the role of secular forces.

Structural change in an open economy has received relatively less attention. Uy et al. (2013); Święcki (2017) and Sposi et al. (2021) study the role of trade in driving structural change, but treat international capital flows as exogenous. Kehoe et al. (2018), in turn, study the role of endogenous borrowing in driving deindustrialization in the United States, but do not allow for specialization. By comparison, my accounting decomposition shows that openness to trade in goods and assets each play a distinct, quantitatively important role in explaining the patterns in the data. I therefore allow for both margins to evolve endogenously and study their joint contribution in driving structural change.

To do so, I build on the literature following the original Eaton and Kortum (2002) Ricardian model of trade. Here, my first contribution is to develop a novel way of calibrating the trade costs and sectoral productivities. Typically, these are recovered using the data on price series, as done in Uy et al. (2013); Świecki (2017) and Sposi et al. (2021). However, I show that such price-based productivity estimates imply patterns of specialization that are orthogonal to those observed in the data. By comparison, the calibration procedure developed in this paper – relying on sectoral trade flow data alone – generates patterns of specialization in line with the data. Moreover, as trade flow data of high quality exists for finer levels of sectoral disaggregation, the novel calibration enables me to go beyond the three-sector models of structural change typical of the literature. Second, while trade models increasingly feature endogenous borrowing, up until now the international capital has been assumed to be perfectly mobile. I show that this results in a wedge between the model predictions, where fast growing economies are expected to be borrowing heavily, and the data, where they rarely do. Frictions to international capital mobility introduced in this paper successfully dampen the model-generated capital flows, while remaining highly tractable and amenable to the 'hat-algebra' representation.

My analysis of the impact of China contributes to a relatively recent strand of literature studying the so-called 'China shock' using general equilibrium models of trade (Adao et al., 2019; Caliendo et al., 2019; Rodríguez-Clare et al., 2022; Galle et al., 2023). Here, the closest paper is Dix-Carneiro et al. (2023), who also study the joint role of trade specialization and endogenous trade imbalances in driving the sectoral reallocation following the rise of China. A surprising result in their paper is that impatience shocks which simulate the saving glut in China play a limited role in explaining the China-driven deindustrialization. While I confirm this result, I show that endogenous trade imbalances do in fact contribute to the China-driven deindustrialization. What resolves the seeming puzzle is that productivity growth in China is largely sufficient to generate much of its saving glut.

Finally, much of the analysis of the industrialization in South Korea has focused on the effect of industrial policies in promoting the growth of heavy industries (see Lane (2022) for an overview). Instead, I study the role of openness in driving South Korea's industrialization in a calibrated general equilibrium model, and uncover the complementary roles of trade liberalization and shifts in sectoral productivities in shaping the process.

**Outline** The rest of the paper is organized as follows. In section 2, I develop a decomposition of changes in sectoral shares into contributions of secular changes in sectoral demand, trade specialization, and international borrowing. In Section 3, I present the model where the terms of the decomposition arise endogenously. In Section 4, I discuss the implementation of the decomposition and the calibration of the model. In Section 5, I discuss the drivers of structural change, whereas in Section 6 I study China-induced deindustrialization and industrialization of South Korea. Finally, Section 7 concludes.

# 2 Accounting Decomposition

In a closed economy, the sectoral composition of production depends solely on the composition of domestic demand. In open economies, domestic consumption and production can diverge for two distinct reasons. First, economies can export and import different mixes of goods, thereby specializing. Second, economies can borrow and lend on international markets, eliminating the need for contemporaneous production of goods for domestic consumption. In this section, I develop an accounting decomposition that measures the role of these two forces in driving countries' sectoral composition in the data.

## 2.1 Derivation

Consider an economy $i$ that produces goods in sector $k$, with nominal sales $Y_{ik}$. For now, let there be no intermediate inputs in production. Let $j$ index the destination markets for $i$'s sales of sector $k$ goods (inclusive of the domestic market) and let $X_{jik}$ denote $j$'s demand for sector $k$ goods produced in $i$. Then,

$$Y_{ik} = \sum_j X_{jik}.$$

Multiplying and dividing $X_{jik}$, first, by $j$'s total expenditure on sector $k$ goods $\sum_i X_{jik}$, then by $j$'s total expenditure across sectoral goods $\sum_{i,k} X_{jik}$, and finally by $j$'s income $Y_j$, $X_{jik}$ can be rewritten as

$$X_{jik} = \frac{X_{jik}}{\sum_i X_{jik}} \frac{\sum_i X_{jik}}{\sum_{i,k} X_{jik}} \frac{\sum_{i,k} X_{jik}}{Y_j} Y_j = \Pi_{jik} \alpha_{jk} D_j Y_j.$$

Here, $\Pi_{jik}$ – the share of $j$'s consumption of sector $k$ goods originating in $i$ (trade share) – captures where the agents source the goods from, $\alpha_{jk}$ – the sectoral expenditure share – captures what goods the agents buy, and $D_j$ – the aggregate trade deficit – captures borrowing or lending on international markets in a given period. Economies that spend in excess of their income ($D_j > 1$) can only do so by running aggregate trade deficits. Economies that spend less than their income must run trade surpluses ($D_j < 1$). Finally, observe that in an economy with no intermediate inputs use, income is simply the sum of its sales across all sectors: $Y_j = \sum_k Y_{jk}$. Combining previous expressions, one obtains

$$Y_{ik} = \sum_j \Pi_{jik} \alpha_{jk} D_j \sum_k Y_{jk}.$$

Consider the total derivative of the sectoral sales. It is convenient to use changes with respect to the initial level, so denote $\tilde{x} = dx/x$, where $dx$ is an infinitesimal change. Then,

$$\tilde{Y}_{ik} = \sum_j \phi_{jik} \left( \tilde{\Pi}_{jik} + \tilde{\alpha}_{jk} + \tilde{D}_j + \sum_k va_{jk} \tilde{Y}_{jk} \right),$$

where $\phi_{jik} = X_{jik}/Y_{ik}$ is country $i$'s sector $k$ exposure to market $j$, and $va_{ik} = Y_{ik}/\sum_n Y_{in}$ is sector $k$'s share of the value added. In Appendix A.1 I show that changes in sectoral sales can be collected on the left hand side, such that

$$\tilde{Y}_{ik} = \sum_{jik} \varphi^{\Pi}_{jik} \tilde{\Pi}_{jik} + \sum_{jik} \varphi^{\alpha}_{jik} \tilde{\alpha}_{jk} + \sum_{jik} \varphi^{D}_{jik} \tilde{D}_{j} = \tilde{Y}_{ik}(\tilde{\Pi}) + \tilde{Y}_{ik}(\tilde{\alpha}) + \tilde{Y}_{ik}(\tilde{D}), \tag{1}$$

where $\tilde{Y}_{ik}(\cdot)$ terms are shorthand for the corresponding sums. Note that since $\tilde{va}_{ik} = \tilde{Y}_{ik} - \sum_n va_{in} \tilde{Y}_{in}$, changes in value added shares can be decomposed analogously:

$$\tilde{va}_{ik} = \tilde{va}_{ik}(\tilde{\Pi}) + \tilde{va}_{ik}(\tilde{\alpha}) + \tilde{va}_{ik}(\tilde{D}).$$

Finally, in Appendix A.1 I show that the above decomposition can be readily extended to accommodate intermediate inputs use. To do so, I first break down the demand terms into the final demand and intermediate inputs use across various sectors in $j$, $X_{jik} = X^{FC}_{jik} + \sum_n X^{II}_{jink}$, and, as before, rewrite each term as a product: $X^{FC}_{jk} = \Pi_{jik} \alpha_{jk} D_j Y_{jk}$ and $X^{II}_{jink} = \Pi_{jik} \beta_{jnk} Y_{jk}$, where $\alpha_{jk}$ is the sectoral expenditure share, $D_j$ is the total expenditure to GDP ratio, and $\beta_{jnk}$ is the intermediate inputs expenditure share. The resultant decomposition, as before, comprises three terms. However, the second term now reflects changes in both final and intermediate expenditure shares:

$$\tilde{va}_{ik} = \underbrace{\tilde{va}_{ik}(\tilde{\Pi})}_{specialization} + \underbrace{\tilde{va}_{ik}(\tilde{\alpha}, \tilde{\beta})}_{secular} + \underbrace{\tilde{va}_{ik}(\tilde{D})}_{borrowing}. \tag{1*}$$

Changes in sectoral value added shares can be attributed exactly to variation along three margins: international sourcing decisions, sectoral expenditure shares, and aggregate trade deficits. In Section 3 I show how these objects arise in general equilibrium via the optimizing behavior of firms and households. For now, I simply label the three as reflecting the effects of trade specialization, secular change in sectoral expenditures, and international borrowing, respectively, and ask: what was the contribution of these different margins to the observed changes in sectoral value added shares in the data?

## 2.2 Data Description

I use the World Input Output Database (WIOD) data on intermediate inputs use which varies by country and sector of origin and destination, $X^{II}_{jinkt}$, and final consumption series which vary by destination, sector and country of origin: $X^{FC}_{jikt}$. The dataset covers twenty economies and a rest-of-world aggregate, thirteen sectors (primary, eleven subsectors of manufacturing, and services), and covers the period between 1965 to 2011. The data description, cleaning and the construction of variables can be found in Appendix B.1

## 2.3 Implementing the Decomposition

To decompose the changes in sectoral shares, I first multiply both sides of the equation [1*] by the beginning of the period value added shares to obtain the change measured in percentage points. Second, I use the observed annual changes in trade shares, expenditure shares and aggregate trade deficits in place of the infinitesimal changes. This gives rise to an empirical counterpart of the decomposition [1*][2]:

$$\Delta va_{im,t} \approx \Delta va^{FO}_{im,t} = \Delta va_{im,t}(\Delta\Pi) + \Delta va_{im,t}(\Delta\alpha, \Delta\beta) + \Delta va_{im,t}(\Delta D). \qquad [1]$$

In order to economize on notation, from now on I also shorthand the three terms $va^{X}_{im,t}$, where $X = \{T, S, B\}$ stand for trade specialization, secular and borrowing respectively. Finally, in order to study the evolution of aggregate manufacturing shares over the long run, I aggregate the sector-year-level terms of decomposition [1] across the sub-sectors of manufacturing and across years:

$$\Delta va^{X}_{iM} = \sum_{t=1965}^{2011} \sum_{m \in M} \Delta va^{X}_{im,t} \quad \text{where } X = \{T, S, B\}. \qquad (2)$$

[2]Note that replacing infinitesimal changes with annual changes in [1*] gives rise to a first-order approximation of changes in sectoral shares. In practice, annual changes are small, so the correlation between the left and right hand sides of expression [1] is 0.997.

Here, $\Delta va_{iM}^{X}$ measures the *cumulative contribution* of $X$ as economies evolve.[3] An alternative is to use the long-run changes in [1]. The correlation between the components of the decomposition computed cumulatively and those using long-run changes is above 0.9 for all three terms. However, as the long-run changes are larger than annual, the approximation that uses long-run changes shows a poorer fit. Thus, in the rest of this section I focus on the cumulative contributions computed using equation (2).

## 2.4 Structural Change in Open Economies

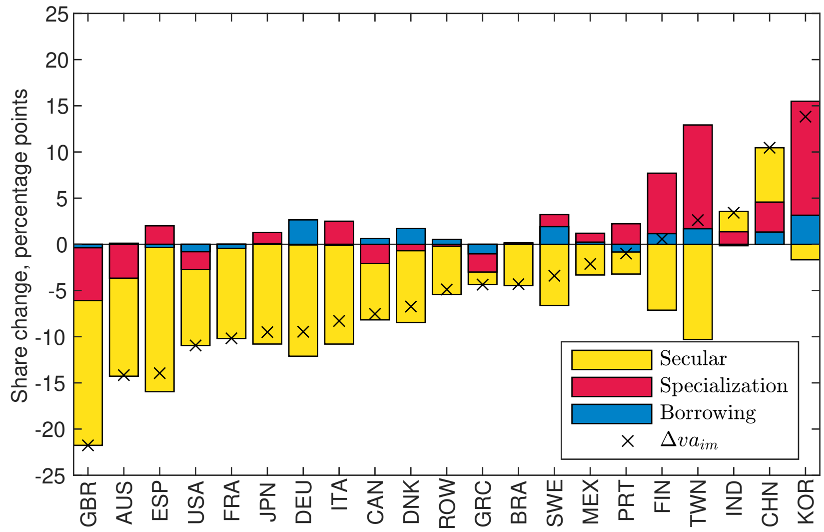
I now leverage decomposition [1] to make four empirical observations.

First, trade specialization and international borrowing are important in driving the evolution of manufacturing shares. To illustrate this, Figure 1 shows the results of decomposition [1] applied to the change in countries' manufacturing shares between 1965 and 2011. Computing the relative contribution of the components of decomposition [1] to the observed change in manufacturing shares over the entire period as $RC^{X} = \frac{\sum_i |\Delta va_{iM}^{X}|}{\sum_X \sum_i |\Delta va_{iM}^{X}|}$, where $X = \{T, S, B\}$, I find that the trade specialization and borrowing terms contribute 26% and 8%, respectively. Focusing on the more recent period spanning 1999 to 2011, the relative contribution of specialization and borrowing increases to 27% and 16% respectively. In other words, not only does openness matter and increasingly so, but, on top of that, trade in goods and trade in assets play distinct and quantitatively important roles.

Second, trade specialization and international borrowing matter for cross-country heterogeneity in patterns of (de)-industrialization. To see this, first note that one would expect similar compositional dynamics in economies at similar levels of development. Thus, I split my sample into two equally sized groups on the basis of their GDP per capita in 1965. For each, I break down the change in the aggregate manufacturing share compared

[3]Since the approximation in [1] is effectively exact, adding these terms across years likewise results in an effectively exact fit to the data ($\rho = 0.9999$).

Figure 1: Decomposing the Changes in Manufacturing Value Added Shares




*Note*: The crosses mark the change in the manufacturing value added share between 1965 and 2011. The bars correspond to the components of decomposition [1].

to the group average into the sum of de-meaned components of the equation [1]:

$$\Delta va_{iM} - \overline{\Delta va_M} = \Delta va^T_{iM} - \overline{\Delta va^T_M} + \Delta va^S_{iM} - \overline{\Delta va^S_M} + \Delta va^B_{iM} - \overline{\Delta va^B_M},$$

and compute the relative contributions of each term. Results can be seen in Table 1. For both groups, an average of 40% and 14% of the cross-country heterogeneity in changes in manufacturing shares is attributable to trade specialization and international borrowing.

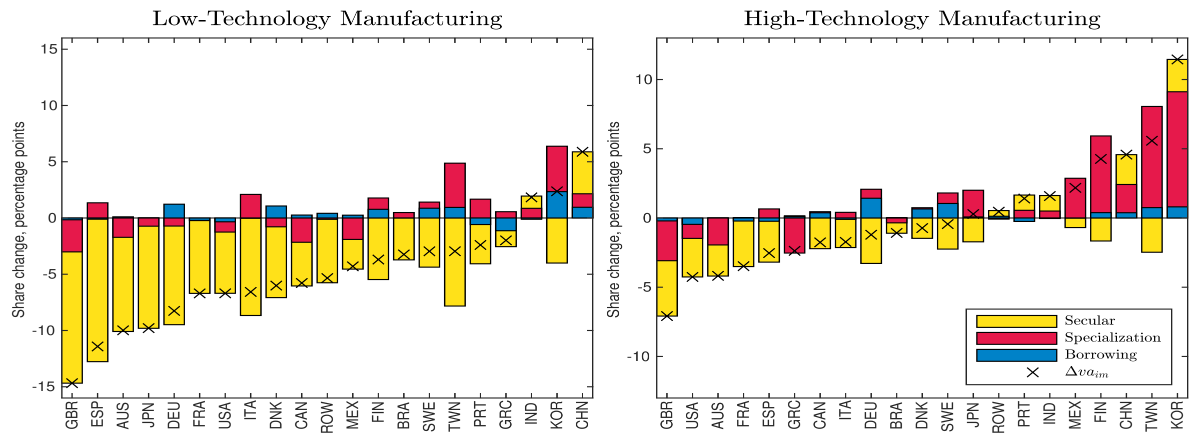
Third, trade specialization plays a greater role once the composition of manufactur-

Table 1: Relative Contributions to De-meaned Changes in Manufacturing Shares

| | Lower Income | Higher Income |
|---|---|---|
| Secular | 40 | 53 |
| Specialization | 43 | 37 |
| Borrowing | 17 | 11 |

*Note*: Lower income group: China, India, South Korea, Brazil, Taiwan, Portugal, Mexico, Japan, Greece and Spain. Higher income group: Italy, Finland, United Kingdom, Germany, Denmark, Australia, France, Canada, Sweden and United States. Values in percentage points.

Figure 2: Decomposing the Changes in Manufacturing Sub-Sector Value Added Shares




*Note*: The crosses mark the change in the manufacturing value added share between 1965 and 2011. The bars correspond to the components of decomposition [1].

ing is taken into account. To make this case, I apply the decomposition [1] to two-digit subsectors of manufacturing individually, and compute the relative contribution of the three margins of adjustment taking the compositional changes into account: $RC^X = \frac{\sum_{i,m} |\Delta va_{im}^X|}{\sum_X \sum_{i,m} |\Delta va_{im}^X|}$ for $X = \{T, S, B\}$. I find that trade specialization is responsible for 32%, and international borrowing for 7% of the churn within the aggregate manufacturing.

Finally, the drivers of structural change vary across the subsectors of manufacturing. To illustrate this, I split the aggregate manufacturing into low-technology and high-technology subsectors, and repeat the exercise.[4] Results in Figure 2 reveal stark heterogeneity between the two. For low-technology manufacturing, secular forces are the predominant driver – explaining 75% of the observed change and, in virtually all cases, causing deindustrialization. For high-technology manufacturing, on the other hand, trade specialization plays a key role, explaining 45% of the observed dynamics.

To sum up, both trade specialization and international borrowing need to be taken into account when studying structural change. In the following section, I construct a structural model where both of these margins operate endogenously.

[4]Two-digit industry results are in line with this grouping, see Figure B.2 in Online Appendix B.8.

# 3 Model

There are $I$ countries and $K$ sectors in the model. It is convenient to denote the first sector as $P$ for primary goods and the last sector as $S$ for services. The remainder of sectors, $k \in \{2, \ldots, K-1\}$, are subsectors of manufacturing, which produce aggregate manufacturing bundles. Due to this layered structure, I will use index $s \in \{P, M, S\}$ when agents make decisions that involve aggregate sectors, $m \in \{2, \ldots, K-1\}$ when considering choices over different types of manufacturing, and $k, n \in \{1, \ldots, K\}$ when discussing production, budgets and market clearing. While the model is dynamic, all variables with the exception of household expenditure are determined within a period. I thus suppress time indices where possible for ease of exposition.

**Producers.** Each sector $k$ in each country $i$ can produce any of a continuum of varieties $z \in [0, 1]$. Firms produce varieties with a Cobb-Douglas production function using labor $l_{ik}$ and intermediate inputs bundle $m_{ik}$, and are exogenously assigned a productivity level $a_{ik}(z)$:

$$y_{ik}(z) = a_{ik}(z) \left( \frac{l_{ik}(z)}{\omega_{ikL}} \right)^{\omega_{ikL}} \left( \frac{m_{ik}(z)}{1 - \omega_{ikL}} \right)^{1-\omega_{ikL}}, \tag{3}$$

where $\omega_{ikL} \in [0, 1]$. The intermediate input bundle, $m_{ik}$, is comprised of inputs from $K$ sectors, which are combined using a nested constant elasticity of substitution production function. The outer nest combines inputs from the aggregate sectors:

$$m_{ik}(z) = \left( \sum_s \omega_{iks}^{\frac{1}{\sigma_s}} m_{iks}(z)^{\frac{\sigma_s - 1}{\sigma_s}} \right)^{\frac{\sigma_s}{\sigma_s - 1}}, \quad \text{where } s \in \{P, M, S\}. \tag{4}$$

The inner nest combines inputs from the subsectors of manufacturing:

$$m_{ikM}(z) = \left( \sum_m \omega_{ikm}^{\frac{1}{\sigma_m}} m_{ikm}(z)^{\frac{\sigma_m - 1}{\sigma_m}} \right)^{\frac{\sigma_m}{\sigma_m - 1}}, \quad \text{where } m \in \{2, \ldots, K-1\}. \tag{5}$$

Firm profits satisfy:

$$\pi_{ik}(z) = p_{ik}(z)y_{ik}(z) - w_i l_{ik}(z) - \sum_{n\in K} P_{in} m_{ikn}(z), \tag{6}$$

where $P_{in}$ is the price index of the sector $n$ bundle in $i$.

*Assumption 1:* the productivity level $a_{ik}(z)$ is drawn, independently for each country and sector, from a Fréchet distribution with the following cumulative distribution function:

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

$A_{ik} > 0$ reflects the absolute advantage of country $i$ in producing sector $k$ goods: higher $A_{ik}$ makes high productivity draws for varieties more likely. $\theta_k > 1$ is inversely related to the productivity dispersion. If $\theta_k$ is high, productivity draws for any one country are more homogeneous.[5] $\gamma$ is introduced to simplify the notation in the rest of the model.[6]

Varieties can be shipped abroad with an iceberg cost $\tau_{ijk}$ ($\tau_{ijk}$ goods need to be shipped for one unit of good to arrive from $j$ to $i$; trade within an economy is costless: $\tau_{iik} = 1\ \forall i, k$). The final goods producer aggregates individual varieties into the sectoral good bundles in each economy using CES technology. Specifically,

$$Q_{ik} = \Big(\int_0^1 q_{ik}(z)^{(\xi-1)/\xi} dz\Big)^{\xi/(\xi-1)}, \quad \text{where} \quad q_{ik}(z) = \sum_{j\in I} q_{ijk}(z). \tag{7}$$

The profits of the final goods producer satisfy:

$$\pi_{ik} = P_{ik}Q_{ik} - \sum_{j\in I}\int_0^1 \tau_{ijk} p_{jk}(z) q_{ijk}(z) dz. \tag{8}$$

[5] As will be shown, the choice of the origin of a variety to be purchased will then be closely tied to the average productivity, costs of trade or costs of production in the exporter country. This means that changes in each of these will induce larger shifts in trade. In this sense, $\theta_k$ operates like trade elasticity in this model.

[6] $\Gamma$ stands for the gamma function. Absent normalization, $\gamma$ appears in the price equations as a shifter common across economies. The simplification is thus without loss of generality. I assume that $\theta_k > \xi - 1$. As long as this inequality is satisfied, the value of the parameter $\xi$ drops out of analysis.

**Households.** Country $i$ houses a population of identical households of mass $L_i$. Household preferences, like that of firms, are nested, with outer nest combining consumption bundles from three aggregate sectors, and inner nest combining bundles from subsectors of manufacturing. However, for the households, the outer nest is non-homothetic following Comin et al. (2021). In particular, household aggregate consumption $c_i$ is an implicit function of consumption of sectoral bundles:

$$\sum_s \Omega_{is}^{\frac{1}{\sigma_S}} \left( \frac{c_{is}}{c_i^{\epsilon_s}} \right)^{\frac{\sigma_S - 1}{\sigma_S}} = 1, \quad \text{where } s \in \{P, M, S\}, \tag{9}$$

and where manufacturing consumption $c_{iM}$ satisfies

$$c_{iM} = \left( \sum_m \Omega_{im}^{\frac{1}{\sigma_m}} c_{im}^{\frac{\sigma_m - 1}{\sigma_m}} \right)^{\frac{\sigma_m}{\sigma_m - 1}}, \quad \text{where } m \in \{2, \ldots, K-1\}. \tag{10}$$

The lifetime utility of the households is as follows:

$$U_i = \sum_{t=0}^{\infty} \rho^t \phi_{it} \ln c_{it}, \tag{11}$$

where $\phi_{it}$ is an impatience shifter, and $c_{it}$ is the household per-period aggregate consumption defined in equation (9). I assume that the households have perfect foresight.

Each household is endowed with one unit of labor which it supplies inelastically, such that the labor income of each household in $i$ is $w_i$. There are no other sources of income, but households can engage in international borrowing and lending through one-period bonds, which cost $\mu_t$ and pay out a unit in the next period. Since all economies interact in one international market and there is no risk, everyone faces the same price of bonds. Finally, borrowing and lending incurs quadratic transaction costs, paid as a share of income, which is fully rebated to the household as $T_{it}$.[7] Thus, the period budget constraint

[7] Here, rebating of $T_{ik}$ is introduced in order to match the data where the expenditure on sectoral goods is the only type of expenditure recorded.

of households is as follows:

$$e_{it} + \mu_{t+1} b_{it+1} + \frac{\kappa}{2} d_{it}^2 w_{it} = w_{it} + b_{it} + T_{it}, \quad d_{it} = \frac{e_{it} - w_{it}}{w_{it}}, \tag{12}$$

where $e_{it} = \sum_s P_{ist} c_{ist}$ is total expenditure, $b_{it}$ is this period's payment from bond holdings of the previous period, and $\mu_{t+1} b_{it+1}$ is the expenditure on bonds today. This setup follows closely that in Dix-Carneiro et al. (2023), but allows for frictions in the asset markets.

There are many impediments to borrowing and lending, such as the risk of default or informational frictions. The convex adjustment costs capture, in reduced form, the idea that further deviations of expenditure from income, $d_{it}$, become increasingly costly, while remaining highly tractable. Setting $\kappa = 0$ restores frictionless asset markets as in Eaton et al. (2016). The limit case of $\kappa$ approaching infinity, instead, rules out borrowing and produces a static environment as in Eaton and Kortum (2002). When $\kappa \in (0, \infty)$, households trade off the benefits of smoothing against the costs of borrowing and lending.

**Market clearing.** Markets for variety $z$ in any country and sector are perfectly competitive. Output of variety $z$ produced in $i, k$ satisfies demand for it across the economies:

$$y_{ik}(z) = \sum_{j \in I} \tau_{jik} q_{jik}(z). \tag{13}$$

Total demand needs to be satisfied by the final goods producer's output:

$$Q_{ik} = L_i c_{ik} + \sum_{k \in K} \int_0^1 m_{ik}(z) dz. \tag{14}$$

Labor demand needs to be satisfied by the domestic labor supply:

$$L_i = \sum_{k \in K} \int_0^1 l_{ik}(z) dz. \tag{15}$$

Bonds markets clear in all periods:

$$\sum_{i \in I} L_{it} b_{it} = 0. \tag{16}$$

Finally, prices are normalized such that

$$\sum_{i \in I} L_i P_{ik} c_{ik} = 1. \tag{17}$$

*Definition 1:* for a given set of exogenous variables $A_{ikt}, \tau_{ijkt}, \phi_{it}, \Omega_{ikt}, \omega_{iklt}, \omega_{iknt}, L_{it}$ and the initial level of bond holdings $b_{i0}$, the equilibrium is a set of quantities $y_{ikt}(z)$, $l_{ikt}(z)$, $m_{iknt}(z)$, $q_{ikt}(z)$, $Q_{ikt}$, $c_{ikt}$, $c_{it}$, $b_{it}$ and prices $p_{ikt}(z)$, $P_{ikt}$, $w_{it}$, $\mu_t$ for each $z \in [0, 1]$, $i \in I$, $k \in K$ and $t \in [0, \infty)$ such that (i) variety producers produce according to (3) - (5) and maximize profits (6); (ii) final good producers produce according to (7) and maximize profits (8); (iii) households maximize their utility (9) - (11) subject to period budget constraints (12); (iv) all markets clear: (13) - (16); and (v) normalization holds: (17).

**Interpreting the decomposition.** The accounting decomposition derived in Section 2 is a function of changes in trade shares, sectoral expenditure shares and aggregate trade deficits. All of these arise as equilibrium objects in the model. I discuss each in turn. As before, I abstract from the intermediate inputs use. See Appendix A.2 for the derivations.

Trade shares respond to the changes in the relative costs of production:

$$\tilde{\Pi}_{jik} = \theta_k \left( \tilde{A}_{ik} - \tilde{\tau}_{jik} - \tilde{w}_i - \sum_l \Pi_{jlk} \left( \tilde{A}_{lk} - \tilde{\tau}_{jlk} - \tilde{w}_l \right) \right).$$

Here, $i$'s trade share in $j$ increases if $i$'s productivity increases, or if its export costs or input costs decrease by more than that of its trade-share weighted average competitor in $j$. The setup naturally gives rise to specialization subject to comparative advantage.

Expenditure shares respond to the preference shifters, aggregate consumption and the relative prices:

$$\tilde{\alpha}_{in} = \begin{cases} \tilde{\Omega}_{iP} + (1-\sigma_s)\left[\tilde{P}_{iP} - \tilde{P}_i + (\epsilon_P - \epsilon_i)\,\tilde{c}_i\right], \text{ where } \quad \epsilon_i = \sum_s \alpha_{is}\epsilon_s, & \text{if } n = 1 \\ \tilde{\Omega}_{in} + (1-\sigma_s)\left[\tilde{P}_{iM} - \tilde{P}_i + (\epsilon_M - \epsilon_i)\,\tilde{c}_i\right] + (1-\sigma_m)\left(\tilde{P}_{in} - \tilde{P}_{iM}\right), & \text{if } 1 < n < K \\ \tilde{\Omega}_{iS} + (1-\sigma_s)\left[\tilde{P}_{iS} - \tilde{P}_i + (\epsilon_S - \epsilon_i)\,\tilde{c}_i\right], & \text{if } n = K. \end{cases}$$

If $\sigma_s < 1$, then price increase in $s$ compared to other aggregate sectors raises its expenditure share. Likewise, allocation of spending within aggregate manufacturing responds to the relative prices across the subsectors of manufacturing. If $\sigma_m < 1$, households direct their expenditure towards the subsectors with rising relative prices. Both of these represent the operation of the price effect. Furthermore, the expenditure share of sector $s$ increases if the aggregate consumption increases and the expenditure elasticity of sector $s$ is higher than $\epsilon_i$, the average expenditure elasticity in $i$, capturing the income effect.

Finally, households choose their aggregate trade deficits subject to their intertemporal optimization. If countries' net borrowing is small relative to their income, then

$$\tilde{D}_{it} = \tilde{E}_{it} - \tilde{w}_{it} \approx \frac{\tilde{\phi}_{it} - \tilde{\phi}_t}{1+\kappa} + \frac{\kappa \tilde{w}_{it}}{1+\kappa} + \frac{\tilde{e}_{it} - \tilde{e}_t}{1+\kappa} - \tilde{w}_{it}, \tag{18}$$

where $\tilde{e}_t = \sum_i L_i E_i \tilde{e}_{it}$ and $\tilde{\phi}_t = \sum_i L_i E_i \tilde{\phi}_{it}$. Suppose international borrowing is prohibitively costly: $\kappa \to \infty$. Then, $\tilde{E}_{it} = \tilde{w}_{it}$, agents spend exactly what they earn, and $\tilde{D}_{it} = 0$. If, instead, international borrowing is frictionless ($\kappa = 0$), then aggregate trade deficits increase if either: period income is low (consumption smoothing motive), period expenditure elasticity is high (increases contemporaneous returns to expenditure, and thus encourages borrowing), or, households experience an impatience shock (which makes consumption today relatively more attractive).[8]

[8] In the data, the aggregate expenditure reflects both the final consumption and investment. As modelling of investment is beyond the scope of this paper, I attribute its dynamics to the changes in consumer

The effect of changes in the aggregate trade deficits on economies' sectoral shares is compositional. To see this, consider an economy that borrows. This enables its households to temporarily expand consumption. Non-tradable sectors expand to meet the increase in demand. Tradable sectors, on the other hand, see their domestic demand increase, but the sales to the rest of world contract as the foreign lenders temporarily cut expenditure. As a result, borrowing props up the non-tradable sectors of the economy at the expense of the tradable ones, with lending having the opposite effect.

# 4 Calibration

## 4.1 Time-Invariant Parameter Values

There are seven time-invariant objects in the model: $\{\epsilon_P, \epsilon_M, \epsilon_S, \sigma_s, \sigma_m, \theta, b\}$.[9] I set the first four following Comin et al. (2021), who estimate a range of values for each. I set $\epsilon_P = 0.11$, $\epsilon_M = 1$, $\epsilon_S = 1.21$ and $\sigma_s = 0.5$, coming from the specification that features both developed and developing economies, as well as controls for trade. Under this parameterization, primary sector goods are necessity goods, services are luxury goods, and aggregate sectors are complements. Atalay (2017) estimates the elasticity of substitution across inputs from different industries using a wide range of specifications and identification strategies, consistently finding estimates below one. I set $\sigma_m = 0.38$, the estimate for the WIOD sample. I set trade elasticities, $\theta_k$, following Imbs and Mejean (2017).

Parameter $\kappa$, governing the cost of international borrowing, represents in reduced form a range of barriers to international capital flows, and as such, no direct counterpart is available. Instead, I use the Euler condition of the model to estimate $\kappa$ that minimizes the distance between the per capita expenditure changes under no impatience shifters

expenditure. Thus, an impatience shock should be interpreted as temporarily high returns on expenditure: consumption and investment, in a given economy. The clearing of global capital markets via bond prices then ensures that the return on such expenditure is equalized across the economies. See Herrendorf et al. (2021); Garcia-Santana et al. (2021) on the role of investment in structural change in a closed economy.

[9] While $\rho$, $\gamma$ and $\xi$ feature in the model setup, they drop out from the equilibrium conditions.

and that in the data. The procedure yields $\kappa = 7.6$ (see Appendix B.2 for details).

## 4.2 Shocks Series

I solve the model in 'hat-algebra' form (see Online Appendix B.6). As a result, simulations use the ratio of a given variable in period $t+1$ to its value in period $t$, $\hat{x} = x_{t+1}/x_t$, which I refer to as 'shocks'. The model retains the key property of Eaton and Kortum (2002): appropriately calibrated, it generates the paths of endogenous variables that exactly match those in the data. I discuss the calibration of each of the shock parameter series in turn.

**Population.** $\hat{L}$ can be obtained directly from the WIOD Socio-Economic Accounts.

**Productivity and trade cost shocks.** The trade shares in the 'hat-algebra' formulation of the model take the following form:

$$\hat{\Pi}_{jikt} = \left( \frac{\hat{\nu}_{ikt} \hat{\tau}_{jikt}}{\hat{A}_{ikt} \hat{P}_{jkt}} \right)^{-\theta_k}, \tag{19}$$

where $\nu_{ikt}$ is the cost of an input bundle. To proceed, I make use of the multiplicative form of the structural gravity equations, which I estimate using the Poisson pseudo-maximum likelihood method following Silva and Tenreyro (2006) (PPML from now onward). I assume that the bilateral trade cost changes can be represented as a product of the symmetric trade cost decline and an idiosyncratic term: $\hat{\tau}_{jikt} = \hat{\tau}_{jikt} \hat{\upsilon}_{jikt}$. Then, equation (19) can be rewritten as a product of exporter fixed effect $e_{ikt} = (\hat{\nu}_{ikt} / \hat{A}_{ikt})^{-\theta_k}$, importer fixed effect $m_{jkt} = \hat{P}^{\theta_k}_{jkt}$, symmetric trade cost decline $\hat{\tau}^{-\theta_k}_{jikt}$ and an error term $\varepsilon_{jikt} = \hat{\upsilon}^{-\theta_k}_{jikt}$, such that

$$\hat{\Pi}_{jikt} = m_{jkt} e_{ikt} \hat{\tau}^{-\theta_k}_{jikt} \varepsilon_{jikt}. \tag{20}$$

Following Head and Ries (2001a), $\hat{\tau}_{jikt}^{-\theta_k}$ can be recovered from the trade share changes:

$$\hat{\tau}_{jikt}^{-\theta_k} = \left( \frac{\hat{\Pi}_{jikt}\hat{\Pi}_{ijkt}}{\hat{\Pi}_{iikt}\hat{\Pi}_{jjkt}} \right)^{-1/2}.$$

Together with the destination and origin fixed effects by sector and year, these can be used to estimate the system. Note that this method amounts to requiring that asymmetric components of trade shocks have, on average, zero impact on trade shares.[10]

Silva and Tenreyro (2006) advocate the use of equal weights on all observations, which improves the efficiency of the estimation under the assumption of conditional variance being proportional to conditional mean. However, in the context of 'hat-algebra' specification, this assumption may be violated when economies transition from near-zero to positive, albeit negligible, trade flows: observations with near-zero denominators result in trade share changes significantly larger than the rest. For example, my sample includes 233 observations with $\hat{\Pi} > 10^6$. By contrast, the 90$^{\text{th}}$ percentile of trade share changes is 1.19. As the conditional variance of these observations is likely orders of magnitude higher than their conditional mean, unweighted PPML is likely to be extremely inefficient.[11] Since it is difficult to predict such transitions based on observables, I exclude observations with trade share changes above a certain threshold, effectively assigning them zero weight in the estimation. All other observations carry equal weight. In my baseline specification, I use the 95$^{\text{th}}$ percentile of the dependent variable for a given sector and year as the cutoff. However, results remain virtually unchanged if 90$^{\text{th}}$ or 97.5$^{\text{th}}$ percentile cutoff are used instead.

Once the model is estimated, I use the importer fixed effect to back out price deflators

[10]Specifically, estimation procedure picks fixed effects such as to ensure that $\sum_j \hat{\Pi}_{jikt} - \hat{\Pi}_{jikt}|_{\varepsilon=1} = 0$, where $\hat{\Pi}_{jikt}|_{\varepsilon=1} = m_{jkt} e_{ikt} \hat{\tau}_{jikt}^{-\theta_k}$ is the trade share change absent the asymmetric changes in trade costs.

[11]Intuitively, in a sample where each country has twenty trading partners, there are twenty data points that identify country-sector level fixed effects. If one of the trade share changes is six orders of magnitude larger than others, this observation will dominate the estimation. Given the extreme nature of these outliers, it is unlikely that the estimate would converge even if all global economies were included in the sample.

consistent with the model: $\hat{P}_{ikt} = m_{ikt}^{1/\theta_k}$. Since fixed effects are identified up to a sector-year multiplicative constant, I reflate all estimates so that the evolution of sectoral price deflators for the United States matches that from WIOD sectoral price index series. Finally, I combine the resultant price deflators with model-consistent changes in input costs $\hat{v}_{ikt}$ to back out sectoral productivity and trade cost shocks:

$$\hat{A}_{ikt} = \frac{\hat{v}_{ikt}}{\hat{P}_{ikt}} \hat{\Pi}_{iikt}^{1/\theta_k}, \quad \hat{\tau}_{jikt} = \frac{\hat{v}_{ikt}}{\hat{P}_{jkt}} \hat{\Pi}_{jikt}^{1/\theta_k}.$$

I discuss the construction of the input cost series in Appendix B.3.

**Preferences and production function shocks.** The model in changes links the changes in endogenous variables to their levels at the beginning of the period and changes in exogenous shocks. These conditions can be inverted: plugging in the observed changes in endogenous variables returns the changes in exogenous shocks consistent with patterns observed in the data. Thus, I use the data on final expenditure shares, household expenditures, wages and intermediate expenditure shares to infer household sectoral expenditure shocks $\hat{\Omega}$, impatience shocks $\hat{\phi}$, and firm intermediate input expenditure shocks $\hat{\omega}$. This completes the calibration of the model. I detail the calibration algorithm in Appendix B.3.

## 4.3 Simulating the model

In the following section, I use model simulations to study the fundamental forces behind the process of structural change. I now briefly discuss the exercise. First, I simulate the model with one type of shocks active at a time. The model is solved under general equilibrium, with all markets clearing and all prices determined endogenously. Such exercises then give rise to a counterfactual evolution of economies' sectoral compositions had only a subset of shocks operated over time. Adding up the results of such simulations gives rise to a decomposition of changes in sectoral shares into the contribution of shocks to productivity ($A$), trade costs ($\tau$), impatience ($\phi$), preferences ($\Omega$), production function

($\omega$), and population ($L$):

$$\Delta va_{ik} \approx \Delta va_{ik}(\hat{A}) + \Delta va_{ik}(\hat{\tau}) + \Delta va_{ik}(\hat{\phi}) + \Delta va_{ik}(\hat{\Omega}) + \Delta va_{ik}(\hat{\omega}) + \Delta va_{ik}(\hat{L}), \qquad [2]$$

where $\Delta va_{ik}(\hat{A})$ denotes the changes in sectoral shares in a simulation with sectoral productivities calibrated following the baseline and all other shocks set to no change: $\hat{x} = 1$.[12] To study the channels of operation of individual shock types, I apply the decomposition [1] to the simulated series. For example, for the 'productivity only' counterfactual,

$$\Delta va_{ik}(\hat{A}) \approx \Delta va_{ik}^{T}(\hat{A}) + \Delta va_{ik}^{S}(\hat{A}) + \Delta va_{ik}^{B}(\hat{A}), \qquad [3]$$

where, as before, $\{T, S, B\}$ denote trade specialization, secular and borrowing terms.

Finally, collecting the terms of the decomposition [1] across simulations with one type of shocks active at a time gives rise to the decomposition of individual terms of the decomposition [1] into contributing shock series, such that for each $X \in \{T, S, B\}$,

$$\Delta va_{ik}^{X} \approx \Delta va_{ik}^{X}(\hat{A}) + \Delta va_{ik}^{X}(\hat{\tau}) + \Delta va_{ik}^{X}(\hat{\phi}) + \Delta va_{ik}^{X}(\hat{\Omega}) + \Delta va_{ik}^{X}(\hat{\omega}) + \Delta va_{ik}^{X}(\hat{L}). \qquad [4]$$

### 4.4 Model Fit

In this section I discuss the properties of the shock series estimated in Section 4.2. Note that by construction, the model subject to baseline calibration matches the data exactly. Thus, simulation of the fully calibrated model is not a good test of the fit of the model. However, a model simulated with a subset of shocks operating at a time is not subject to the same restriction. In what follows, I use the ability of such partial model specifications to predict patterns in the data to assess the fit of the estimated shock series. Specifically, I simulate the model with one type of shocks active at a time and compare it with the

[12] Note that summing up the results of these simulations gives rise to an approximation of the changes in sectoral shares in the data. The reason for this is that simulations with only a subset of shocks 'on' fail to account for interactions between shocks. The simulation with all shocks 'on' restores the exact fit.

moments in the data. The moments I use are the changes in sectoral value added shares and their breakdown subject to the decomposition [1].

The results can be seen in Table 2. The first six columns record the correlation between the data and the simulations subject to my baseline calibration. Each shock series produces a correlation of between 0.24 and 0.8 with the changes in sectoral shares in the data.[13] Furthermore, individual shock series show a better fit with the components of decomposition that they affect directly. As such, the correlations between the trade specialization term in the data and that in the 'only productivity' and 'only trade costs' simulations are 0.46 and 0.61. The borrowing terms in the 'only impatience' counterfactual yield a correlation of 0.78, whereas the secular terms in the preference and production shifters specifications show correlations of 0.55 and 0.85 with that in the data.

This exercise also provides a framework for comparison with alternative shock specifications. In columns (7) and (8) I repeat the exercise using sectoral price deflators to identify trade cost- and sectoral productivity shocks, as is done in Uy et al. (2013); Święcki (2017) and Sposi et al. (2021). The deterioration of the fit, compared to my baseline calibration, is practically uniform. Crucially, the correlation of the 'productivities only' specification with the trade specialization term decreases to mere 0.03: productivities estimated using the price deflators give rise to patterns of specialization orthogonal to that in the data. One reason for this poor performance is the quality of the data: sectoral deflators at the two-digit level of disaggregation for a large sample of economies going back to 1965 are often not available. In these cases, missing price deflators in WIOD are obtained using extrapolation of available price series.[14] Secondly, price indices in the data reflect both differences in costs as well as differences in quality. In the world where quality differences across economies are important, price series need to be adjusted for quality before being used for estimation. The results suggest that the measurement error associated with

[13]The exception is the population shocks, which have no predictive power.

[14]If industry-level value added deflators are available, these are used in place of industry-level deflators. If these are unavailable, aggregate value added deflator is used as a proxy. For RoW, US deflators are used.

Table 2: Fit of the Shock Series

| | $\tau$ | $A$ | $\phi$ | $L$ | $\Omega$ | $\omega$ | $\tau^P$ | $A^P$ | $\phi^{fc}$ |
|---|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
| $\Delta va$ | 0.26 | 0.39 | 0.25 | 0.00 | 0.52 | 0.80 | 0.23 | 0.20 | 0.28 |
| $\Delta va^S$ | 0.32 | 0.49 | -0.02 | 0.10 | 0.55 | 0.85 | 0.26 | 0.60 | 0.22 |
| $\Delta va^T$ | 0.61 | 0.46 | 0.21 | 0.28 | 0.17 | 0.15 | 0.38 | 0.03 | 0.17 |
| $\Delta va^B$ | 0.16 | -0.04 | 0.78 | -0.11 | 0.04 | -0.02 | -0.01 | -0.03 | 0.25 |

*Note*: The table presents correlations between the objects in the data (rows), and the corresponding moments in a simulation with one set of shocks active at a time (columns). The correlations are computed over all countries, sectors and years (N = 12558). The first six columns use the shock series from the baseline calibration. The next two columns use shock series estimated using price deflators from the data. The last column uses impatience shocks estimated in a specification with free capital flows ($\kappa = 0$).

extrapolation and unaccounted quality differences might be considerable.

Finally, column (9) reports the fit of the impatience shocks series estimated under perfect capital mobility (imposing $\kappa = 0$). Note that the correlation between the borrowing terms in the data and the simulation that uses these shocks is 0.25. Thus, despite having a direct effect on borrowing, used alone, impatience shocks estimated this way do poorly in predicting the effects of borrowing. The deterioration of the fit is not coincidental: free capital flows specification predicts that the fast-growing economies should be borrowing aggressively. In the data, they rarely do. In order to reconcile the model and the data, this specification fits fast-growing economies with extreme patience, which, when modelled alone, results in large counterfactual surpluses. In comparison, the model with non-zero financial frictions rationalizes the lack of borrowing through high cost of engaging in international finance. As a result, recovered impatience series give rise to counterfactual simulations that show a better fit to the data.

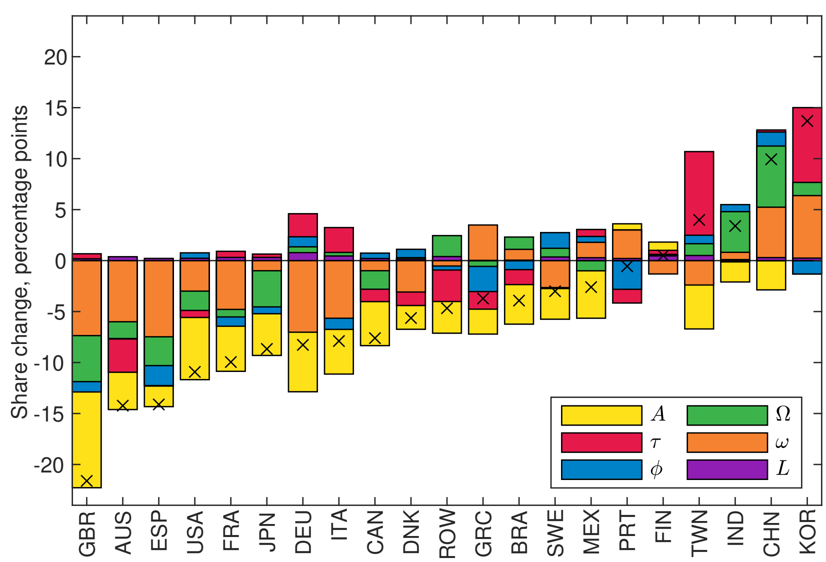
The summary statistics of trade cost and productivity shocks can be seen in Appendix B.7. I find that trade costs have declined by an average of 28% over my sample period. However, trade costs for China, Taiwan, South Korea, Brazil and India have declined almost twice as fast. South Korea saw the most rapid productivity growth, triple that of the United States, whereas Taiwan and Brazil saw the second and third biggest increases.

# 5 Fundamental Drivers of Structural Change

I now assess the fundamental drivers of structural change in my model. To do so, I conduct the decomposition [2] described in Section 4. The results can be seen in Figure 3. Computing the relative contribution as before, I find that the most important exogenous drivers are productivity shocks and production shifters, accounting for 30% of the change in aggregate manufacturing shares each. Trade cost shocks and preference shifters are the second in importance, explaining 15% of the change each. Impatience shocks account for 9%, whereas the role of the population change is negligible.

Next, I apply the decomposition [4] to see which exogenous shocks are responsible for the operation of each of the three margins of adjustment discussed in Section 2. The results can be seen in Table 3 (also see Figure B.1 in Online Appendix B.8). In line with the analysis in Section 3, I find that trade specialization is primarily driven by changes in sectoral productivities and trade costs. Both affect the relative costs of sourcing from different destinations, and, therefore, patterns of specialization. The secular channel is

Figure 3: Structural Drivers of Manufacturing Value Added Shares




*Note*: The crosses mark the change in the manufacturing value added share between 1965 and 2011. The bars correspond to the components of decomposition [2].

Table 3: Contribution of Shock Series

| | $A$ | $\tau$ | $\phi$ | $\Omega$ | $\omega$ | $L$ |
|---|---|---|---|---|---|---|
| $\Delta va_M$ | 30 | 15 | 9 | 15 | 30 | 2 |
| $\Delta va_M^S$ | 40 | 5 | 0 | 16 | 38 | 0 |
| $\Delta va_M^T$ | 40 | 40 | 5 | 4 | 6 | 5 |
| $\Delta va_M^B$ | 37 | 8 | 41 | 7 | 4 | 4 |

*Note*: The table presents the relative contribution of shock series to objects in the data: the long-run change in the manufacturing value added share and its breakdown into the secular, trade specialization and borrowing terms respectively. To measure the relative contribution of $X$ I simulate a model where only shocks $X$ follow the baseline, and all other shocks are set to 1. The values are in percentage points.

driven primarily by the changes in sectoral productivities: these affect both the relative prices of sectoral goods and incomes, thus bringing both price- and income effects into play. Meanwhile, the preference and production function shifters drive changes in sectoral expenditure shares over and above those that can be explained by changing prices and incomes. Finally, the borrowing term is driven by changing productivities and impatience shocks. The former render economies richer, which affects their saving behavior, whereas the latter capture the motives for saving beyond the consumption smoothing.

# 6 Case Studies

In this section, I show how the framework developed in this paper can be used to shed new light on the 'China shock' and the export-led industrialization in South Korea.

## 6.1 The rise of China

Between 2000 and 2011, China's economy tripled in size, jumping the ranks to second largest economy in the world. Following its accession to the WTO in 2001, China gained access to new markets, cementing its position as a key player in international trade. What would have happened had the productivity growth in China stalled or if the trade liberalization with China did not occur? How would global manufacturing patterns differ if

China had not ran up its current account surpluses?

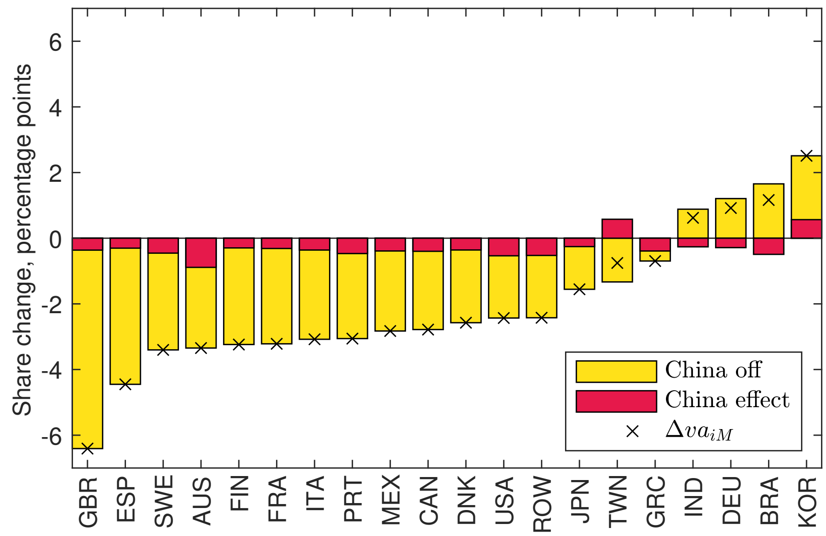
To answer these questions, I run a series of counterfactuals, beginning with a specification which I refer to as 'China off'. In this counterfactual, all exogenous shock series for economies other than China evolve as in the baseline. All shocks relating to China, in turn, are calibrated so that China remains 'frozen' in terms of both its exogenous processes and its endogenous outcomes – sectoral value added shares, sectoral expenditure shares, GDP, expenditures and aggregate trade deficit – at the level observed in 2000. This entails setting all China-related shocks to 1, and re-calibrating sectoral productivities and impatience shocks in China to ensure no changes in specialization or borrowing in the consecutive years.[15] The difference between this specification and the data, which I refer to as the 'China effect', isolates the total effect of China on the manufacturing shares around the world. In turn, taking the difference between a variation of the 'China off' simulation but now with a given exogenous series for China following the baseline and the 'China off' counterfactual identifies the contribution of a given exogenous shock series in China to the total 'China effect'. See Appendix B.4 for details.

Figure 4 shows that between 2000 and 2011, China drove a decline in manufacturing shares around the world, causing the manufacturing share in an average economy to contract by 0.31 percentage points, and contributing 15% of the change in manufacturing shares – a disproportionate effect given China's share of the global GDP of 3.5% in 2000. Note further that South Korea and Taiwan experienced China-driven *industrialization*.

Next, I apply decompositions [1] and [2] to dissect the aggregate 'China effect' into the operation of different margins of adjustment and exogenous shock series in China. Panel (a) in Figure 5 shows that trade specialization was the key channel for China-driven deindustrialization, responsible for 78% of the total effect, with changes in productivities and trade liberalization acting as the main exogenous drivers. Note further that the borrow-

[15] Note that setting changes in sectoral productivities to one in China does not preclude specialization as it is the *relative* changes in sectoral productivities that matter in (19). Likewise for borrowing, where the *relative* realizations of impatience shocks determine which economies borrow.

Figure 4: China-driven De-industrialization



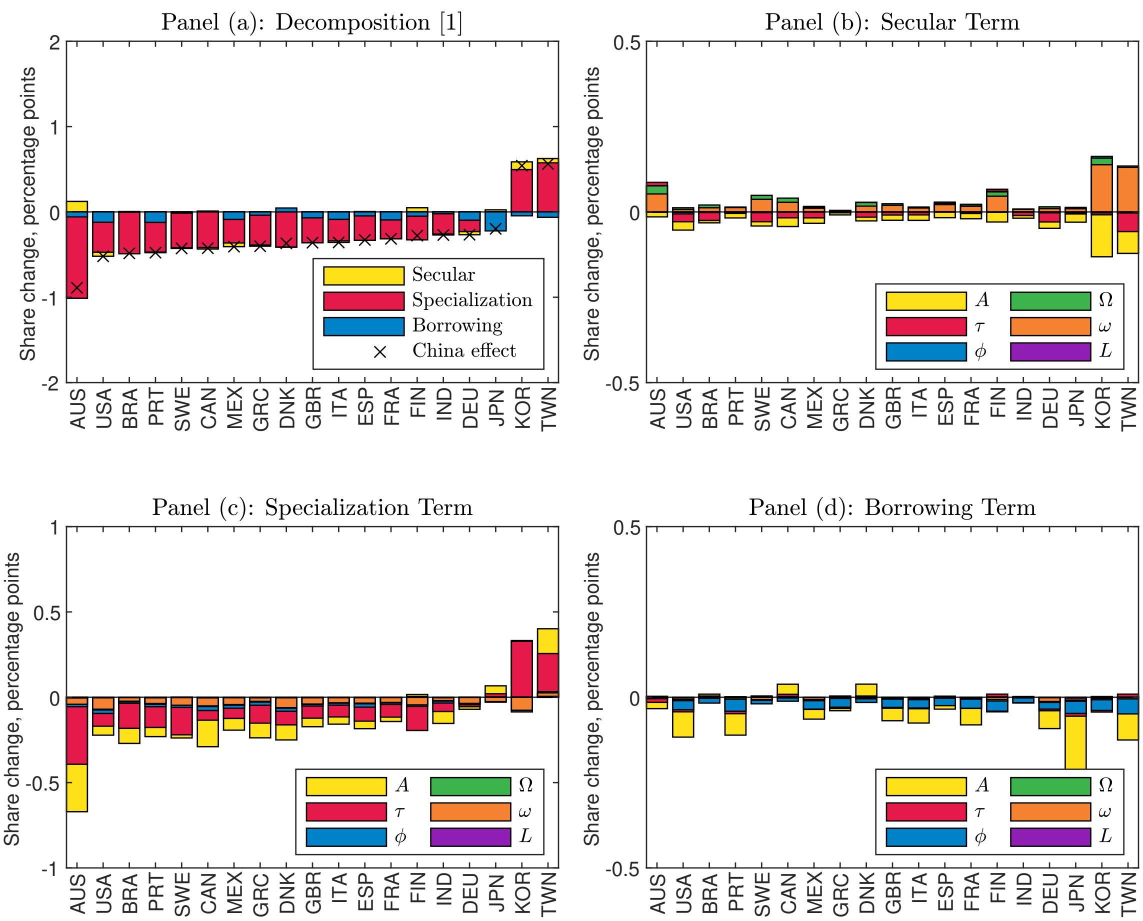

*Note*: The crosses mark the changes in aggregate manufacturing shares in the the data between 2000 and 2011. The yellow bars correspond to the change in manufacturing shares in the 'China off' counterfactual. The red bars are the complement of the yellow bars, and capture the 'China effect'.

ing channel played a secondary role – at 15% of the total. China ran large current account surpluses over the 2000-2011 period, which pushed the rest of the world towards borrowing. Lower aggregate trade balances meant that economies were spending more on domestic non-tradables, and made up for increases in demand for tradables by imports.

Figure 6 reveals that, while China had put a squeeze on both the low-technology and high-technology subsectors of manufacturing, it played a relatively more important role for the latter – explaining 28% of the observed change, with much of the impact occurring in a single subsector – electrical equipment (see Online Appendix B.8), where almost a half of the dynamics is attributable to China in this period (47%). Thus, in addition to causing a decline in the aggregate manufacturing shares, China caused a change in the global composition of manufacturing – away from the high-technology subsectors.

Two related papers merit discussion. Caliendo et al. (2019) study the effects of the China shock using a quantitative model of trade with rich labor market dynamics but no endogenous borrowing. Authors find that between 2000 and 2007, China has caused

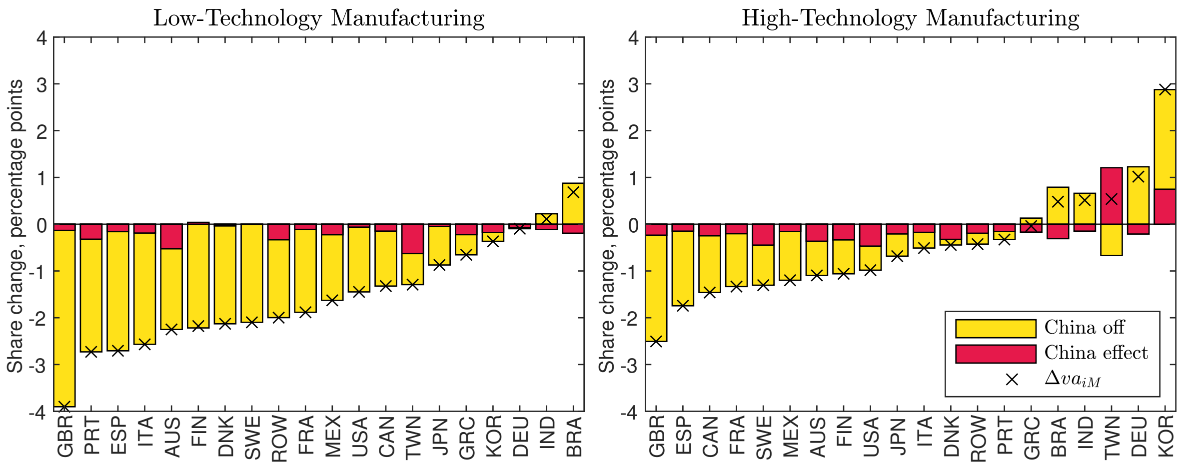
Figure 5: China-driven De-industrialization by Shock




*Panel (a)*: The crosses mark the changes in manufacturing shares driven by China between 2000 and 2011. The colored bars correspond to the components of decomposition [1] applied to the 'China effect' series. *Panels (b)-(d)*: Coloured bars correspond to contribution of individual shock series in China, computed using decomposition [2], to the operation of individual margins of adjustment in Panel (a).

the US manufacturing employment share to decline by 0.38 p.p., with most of the effect concentrated in the electrical equipment subsector. In a similar vein, I find that the trade specialization channel of the China shock has reduced the US manufacturing share by 0.35 p.p. with a matching pattern of sectoral reallocation. However, I further identify the operation of a second channel – international borrowing – which has contributed further 0.12 p.p. to the decline in the manufacturing share in the US, and played a quantitatively comparable role in Japan, Portugal, Germany, France, Mexico and Italy. In turn, Dix-Carneiro et al. (2023) study the joint role of trade specialization and endogenous trade imbalances

Figure 6: China-driven De-industrialization within Manufacturing



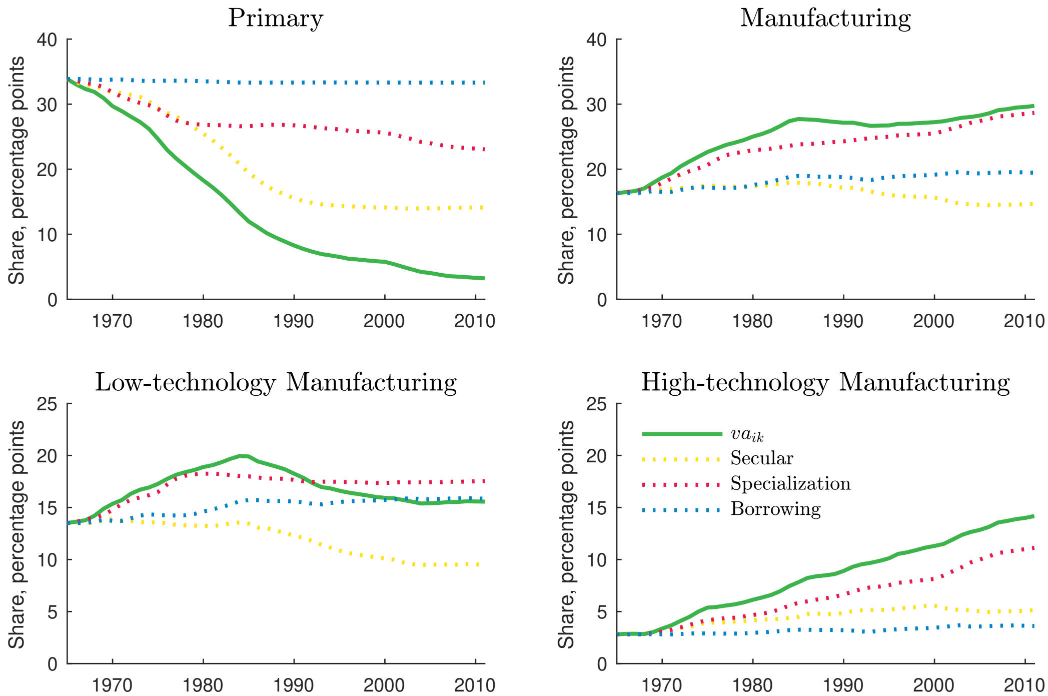

*Note*: The crosses mark the changes in sub-sectoral shares in the the data between 2000 and 2011. The yellow bars correspond to the change in sub-sectoral shares in the 'China off' counterfactual. The red bars are the complement of the yellow bars, and capture the 'China effect'.

in mediating the China shock. The authors argue that "shocks to Chinese productivity were responsible for the bulk of China's effect on the size of the U.S. employment in manufacturing. China's savings glut had a significant short-run negative effect, but this effect was completely undone by 2014." In comparison, I find that the China's saving glut played a quantitatively important role for a range of economies. Panel (d) of Figure 5 reconciles the seeming contradiction by showing that shocks to productivity were responsible for much of the endogenous trade imbalances dynamics seen in the data: as productivity grew in China, consumption smoothing motive resulted in a widening of the current account surpluses in China. In turn, these made borrowing in the rest of the world cheaper, leading economies to shift towards the production of non-tradables.

## 6.2 Industrialization in South Korea

Starting in 1960s, South Korea underwent one of the most rapid and successful episodes of industrialization in history, evolving from an agrarian economy into a leading global manufacturer. In this segment I ask: what role did openness play in this story?

Figure 7: Industrialization in South Korea

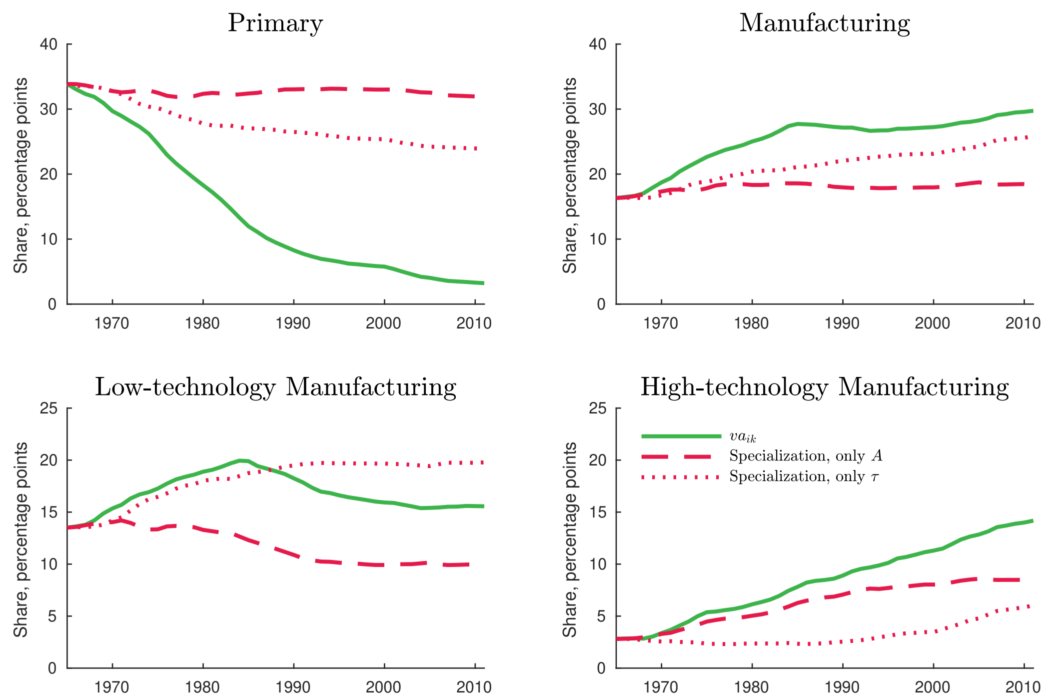



*Note*: Green line plots the value added share of the respective sector against time. Dashed lines correspond to the the cumulated contribution of the components of decomposition [1] applied to changes in sectoral shares in the data, computed as $va^X_{im,T} = va_{im,t} + \sum_{s\in\{1,..,T\}} \Delta va^X_{im,t+s}$ for $X \in \{S, T, B\}$.

Between 1965 and 2011, South Korea saw its manufacturing share almost double, from 16 to 30 percentage points. Figure 7 plots the evolution of the primary and manufacturing shares over time, alongside the split into the low- and high-technology subsectors of manufacturing. The figure makes clear that the structural transformation in South Korea featured a dramatic contraction in the primary share. Moreover, the patterns of industrialization within manufacturing were distinct, with the low-technology share peaking in the mid-1980s, and that of the high-technology subsectors rising throughout.

Decomposition [1] lends further insights into dynamics by decomposing the total change in each of the panels into the cumulative contributions of secular, trade specialization and borrowing terms respectively. The figure makes clear that virtually all of the increase in the manufacturing share in South Korea can be attributed to trade specializa-

Figure 8: Industrialization in South Korea, by Shock Series




*Note*: The green lines plot the value added share of the sector. The red lines correspond to the the cumulated contribution of the specialization components of the decomposition [1] applied to the sectoral shares in the 'only sectoral productivities' and 'only trade liberalization' in South Korea counterfactuals.

tion, with the borrowing term playing a secondary role.

To shed light on this process, I repeat the exercise in the previous section, this time 'freezing' and, shock by shock, 'unfreezing' South Korea, while letting the rest of the world evolve following the baseline calibration. The difference between the specification with South Korean productivities following the baseline and 'South Korea off' captures the counterfactual evolution of the sectoral shares in South Korea had only productivities evolved between 1965 and 2011, and likewise for other exogenous series. Finally, to study the drivers behind the South Korean specialization, I decompose these counterfactual series using expression [3]. The results can be seen in Figure 8.

First, I find that the main force that pushed South Korea to move resources out of the primary sector and into manufacturing was trade liberalization. Note that this process reflected the initial patterns of comparative advantage, South Korea being a net importer of agricultural goods already in 1965.[16] However, this aggregate picture conceals two distinct trends. First note that trade liberalization has pushed resources into the low-technology subsectors of manufacturing – mainly into textiles (see Figure B.4 in Online Appendix B.8). However, at the same time, the evolution of sectoral productivities in South Korea has favoured high-technology subsectors of manufacturing. Thus, just as the trade liberalization has pushed the resources into the low-technology subsectors, there were concurrent outflows towards the high-technology subsectors – mainly electrical equipment – due to the shift in South Korea's relative productivities. In short, 'miracle' industrialization in South Korea would not have been possible without both.

# 7 Conclusion

In this paper I develop a methodology to study structural change in an open economy that enables me to dissect changes in sectoral shares *as observed in the data* into the contribution of different margins of adjustment and exogenous drivers. The key methodological innovations in my analysis are (i) the accounting decomposition developed in Section 2, (ii) the introduction of frictions in international financial markets that give rise to plausible aggregate trade imbalances dynamics developed in Section 3, and (iii) the identification of sectoral productivities in datasets with no reliable sectoral deflator series developed in Section 4. In turn, this enables me to go further than previous studies in identifying the relative importance of trade in assets as well as trade in goods, and move beyond aggregate manufacturing. As a result, in this paper I show that trade specialization and international borrowing are two quantitatively important yet distinct mechanisms of structural change, that much of the structural change in open economies happens within manu-

[16] A similar point is made in Uy et al. (2013), who construct a two-country, three-sector model to study industrialization in South Korea. The authors show that compared to autarky, an open economy setup generates faster industrialization, with both trade cost and sectoral productivities playing important roles.

facturing, and that paying attention to these dynamics can yield novel insights into the long-standing questions at the intersection of trade and structural change.

More broadly, this paper makes a methodological contribution. In it, I have shown how to interpret changing patterns of global production through the lens of a calibrated general equilibrium model with realistic dynamics of aggregate trade imbalances. The setup enables granular understanding of effects of fundamental shocks and the mechanisms of their operation, with the link between the two modes of analysis spelled out explicitly and grounded in theory. The mapping between the decompositions and objects in the data, in turn, makes quantification exercises transparent and easy to interpret. The model is easy to calibrate for any number of countries and at an arbitrary level of disaggregation, whereas its modular nature makes it possible to introduce further frictions to address a wider range of questions. As the twenty first century marks a backlash against globalization and a renewed interest in industrial policy, I suggest a framework to think through the potential effects of such policies in a quantitatively rigorous manner.

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# A Mathematical Appendix

## A.1 Derivation of Decomposition 1*

Consider the market clearing condition,

$$Y_{ik} = \sum_j \Pi_{jik} \left( \alpha_{jk} D_j Y_j + \sum_n \beta_{jnk} Y_{jn} \right), \tag{21}$$

where $D_i = e_i/w_i = d_i + 1$ is the aggregate deficit and $Y_j = \sum_n \beta_{jnl} Y_{jn} = \sum_n V_{jn}$ is the country's GDP. Let $V_{ik}$ be value added in country $i$'s sector $k$. This expression can be rewritten in matrix form:

$$\mathbf{Y} = \mathbf{\Pi A D \Sigma V} + \mathbf{\Pi B Y},$$

where $\mathbf{\Pi}$ is a block matrix of dimensions $IK$ by $IK$, with blocks in position $i, j$ represented by a diagonal matrix of sectoral trade shares $\Pi_{jik}$, matrices $\mathbf{D}$ and $\mathbf{A}$ are diagonal matrices with aggregate deficits and final expenditure shares $D_i$ and $\alpha_{ik}$ in positions $(i-1)K + k$, $\mathbf{\Sigma}$ is a block diagonal matrix of $K$ by $K$ matrices of one, and $\mathbf{B}$ is a block diagonal matrix of countries' intermediate input expenditure share matrices. $\mathbf{Y}$ and $\mathbf{V}$ are vectors of sectoral sales and value added stacked by country.

Collecting the sales on the left hand side and multiplying by a diagonal matrix of sectoral labor shares $\mathbf{B_l}$, obtain a vector of sectoral value added in levels:

$$\mathbf{V} = \mathbf{B_l L \Pi A D \Sigma V} = \mathbf{\Phi V},$$

where $\mathbf{L} = (\mathbf{I} - \mathbf{\Pi B})^{-1}$ is the Leontief inverse. This system has infinitely many solutions. Normalize the value added of the last country and sector, $V_{IK} = 1$. Let $\mathbf{\Phi}_{IK-1}$ stand for the first $IK - 1$ rows and columns of matrix $\mathbf{\Phi}$ and $\phi$ for the first $IK - 1$ elements of the last column of matrix $\mathbf{\Phi}$. The normalized system is then:

$$\mathbf{V}_{IK-1} = \mathbf{\Phi_{IK-1}}\mathbf{V}_{IK-1} + \phi, \quad \mathbf{V}_{IK-1} = (\mathbf{I} - \mathbf{\Phi_{IK-1}})^{-1}\phi.$$

Totally differentiating $\mathbf{\Phi}$ with respect to elements in $\mathbf{\Pi}$, $\mathbf{B_I}$, $\mathbf{B}$ and $\mathbf{A}$, and $\mathbf{D}$, yields

$$\begin{aligned}
\mathbf{\Phi}^T =& \mathbf{B_I}\mathbf{L}\tilde{\mathbf{\Pi}} \odot \mathbf{\Pi}\mathbf{A}\mathbf{D}\mathbf{\Sigma} + \mathbf{B_I}\mathbf{L}\tilde{\mathbf{\Pi}} \odot \mathbf{\Pi}\mathbf{B}\mathbf{L}\mathbf{\Pi}\mathbf{A}\mathbf{D}\mathbf{\Sigma}, \\
\mathbf{\Phi}^S =& \tilde{\mathbf{B}}_\mathbf{I}\mathbf{B_I}\mathbf{L}\mathbf{\Pi}\mathbf{A}\mathbf{D}\mathbf{\Sigma} + \mathbf{B_I}\mathbf{L}\mathbf{\Pi}\tilde{\mathbf{B}} \odot \mathbf{B}\mathbf{L}\mathbf{\Pi}\mathbf{A}\mathbf{D}\mathbf{\Sigma} + \mathbf{B_I}\mathbf{L}\mathbf{\Pi}\tilde{\mathbf{A}}\mathbf{A}\mathbf{D}\mathbf{\Sigma}, \\
\mathbf{\Phi}^B =& \mathbf{B_I}\mathbf{L}\mathbf{\Pi}\mathbf{A}\tilde{\mathbf{D}}\mathbf{D}\mathbf{\Sigma},
\end{aligned}$$

where $\odot$ stands for element-wise multiplication and matrices with tilde collect infinitesimal changes from level. Let $\mathbf{\Phi}^X_{IK-1}$ stand for the first $IK-1$ rows and columns of matrix $\mathbf{\Phi}^X$ and $\phi^X$ for the first $IK-1$ elements of the last column of matrix $\mathbf{\Phi}^X$.

Let $\oslash$ denote element-wise division. Then,

$$\begin{aligned}
\tilde{\mathbf{V}}^T_{IK-1} &= \left[(\mathbf{I} - \mathbf{\Phi_{IK-1}})^{-1}\mathbf{\Phi^T_{IK-1}}(\mathbf{I} - \mathbf{\Phi_{IK-1}})^{-1}\phi + (\mathbf{I} - \mathbf{\Phi_{IK-1}})^{-1}\phi^T\right] \oslash \mathbf{V}_{IK-1}, \\
\tilde{\mathbf{V}}^S_{IK-1} &= \left[(\mathbf{I} - \mathbf{\Phi_{IK-1}})^{-1}\mathbf{\Phi^S_{IK-1}}(\mathbf{I} - \mathbf{\Phi_{IK-1}})^{-1}\phi + (\mathbf{I} - \mathbf{\Phi_{IK-1}})^{-1}\phi^S\right] \oslash \mathbf{V}_{IK-1}, \\
\tilde{\mathbf{V}}^B_{IK-1} &= \left[(\mathbf{I} - \mathbf{\Phi_{IK-1}})^{-1}\mathbf{\Phi^B_{IK-1}}(\mathbf{I} - \mathbf{\Phi_{IK-1}})^{-1}\phi + (\mathbf{I} - \mathbf{\Phi_{IK-1}})^{-1}\phi^B\right] \oslash \mathbf{V}_{IK-1}
\end{aligned}$$

collect deviations from level in sectoral value added as a function of deviations from level in trade shares, final and intermediate expenditure shares, and aggregate trade deficits respectively. The summands in equation (1) in Section 2 represent the element in position $(i-1)K+k$ in vectors $\tilde{\mathbf{V}}^T_{IK-1}$, $\tilde{\mathbf{V}}^S_{IK-1}$ and $\tilde{\mathbf{V}}^B_{IK-1}$ respectively.

The change in sectoral value added shares can be computed as follows:

$$\tilde{va}^X_{ik} = \tilde{V}^X_{ik} - \sum_n va_{in}\tilde{V}^X_{in} \quad \text{for } X \in \{T, S, B\}.$$

No input-output version is as above, with $\mathbf{B_I} = \mathbf{L} = \mathbf{I}$, where $\mathbf{I}$ is an identity matrix.

## A.2 Linking Endogenous Variables and Exogenous Shocks

**Trade shares and prices.** First, apply total differentiation to trade shares:

$$d\Pi_{jik} = -\theta_k \Big(\frac{w_i \tau_{jik}}{A_{ik} P_{jk}}\Big)^{-\theta_k - 1} \left( \frac{dw_i \tau_{jik}}{A_{ik} P_{jk}} + \frac{w_i d\tau_{jik}}{A_{ik} P_{jk}} - \frac{w_i \tau_{jik} dA_{ik}}{A_{ik}^2 P_{jk}} - \frac{w_i \tau_{jik} dP_{jk}}{A_{ik} P_{jk}^2} \right) =$$
$$-\theta_k \Pi_{jik} \left( \frac{dw_i}{w_i} + \frac{d\tau_{jik}}{\tau_{jik}} - \frac{dA_{ik}}{A_{ik}} - \frac{dP_{jk}}{P_{jk}} \right) \quad \rightarrow \quad \tilde{\Pi}_{jik} = \theta_k \left( \tilde{A}_{ik} - \tilde{\tau}_{jik} - \tilde{w}_i - \tilde{P}_{jk} \right).$$

Applying total differentiation to the price index yields

$$dP_{ik} = \left[ \sum_l \Big( \frac{w_l \tau_{ilk}}{A_{lk}} \Big)^{-\theta_k} \right]^{-\frac{1}{\theta_k} - 1} \sum_l \Big( \frac{w_l \tau_{ilk}}{A_{lk}} \Big)^{-\theta_k} \Big( \frac{dw_l}{w_l} + \frac{d\tau_{ilk}}{\tau_{ilk}} - \frac{dA_{lk}}{A_{lk}} \Big) =$$
$$P_{ik} \sum_l \Pi_{ilk} \Big( \frac{dw_l}{w_l} + \frac{d\tau_{ilk}}{\tau_{ilk}} - \frac{dA_{lk}}{A_{lk}} \Big) \quad \rightarrow \tilde{P}_{ik} = \sum_l \Pi_{ilk} \left( \tilde{w}_l + \tilde{\tau}_{ilk} - \tilde{A}_{lk} \right).$$

**Expenditure shares.** Applying total differentiation to expenditure shares yields

$$d\alpha_{in} = \begin{cases} \alpha_{iP} \left[ \dfrac{d\Omega_{iP}}{\Omega_{iP}} + (1-\sigma_s) \left( \dfrac{dP_{iP}}{P_{iP}} - \dfrac{de_i}{e_i} + \dfrac{dc_i}{c_i} \epsilon_P \right) \right], & \text{if } n = 1 \\[2ex] \alpha_{in} \Big[ \dfrac{d\Omega_{iM}}{\Omega_{iM}} + (1-\sigma_s) \left( \dfrac{dP_{iM}}{P_{iM}} - \dfrac{de_i}{e_i} + \dfrac{dc_i}{c_i} \epsilon_M \right) + & \\ \qquad \dfrac{d\Omega_{in}}{\Omega_{in}} + (1-\sigma_m) \left( \dfrac{dP_{in}}{P_{in}} - \dfrac{dP_{iM}}{P_{iM}} \right) \Big], & \text{if } 1 < n < K \\[2ex] \alpha_{iS} \left[ \dfrac{d\Omega_{iS}}{\Omega_{iS}} + (1-\sigma_s) \left( \dfrac{dP_{iS}}{P_{iS}} - \dfrac{de_i}{e_i} + \dfrac{dc_i}{c_i} \epsilon_S \right) \right], & \text{if } n = K, \end{cases}$$

Totally differentiating the per-period utility as a function of expenditure and prices

$$\sum_s \alpha_{is} \left( \frac{d\Omega_{is}}{\Omega_{is}} + (1-\sigma_s) \frac{dP_{is}}{P_{is}} - (1-\sigma_s) \frac{de_i}{e_i} + (1-\sigma_s) \epsilon_s \frac{dc_i}{c_i} \right) = 0.$$

Expenditure weights $\Omega$ are invariant to uniform scaling, in terms of the resulting observables. Thus, I pick the scaling such that $\sum_s \alpha_{is} \dfrac{d\Omega_{is}}{\Omega_{is}} = 0$ and $\sum_m \alpha_{im} \dfrac{d\Omega_{im}}{\Omega_{im}} = 0$. Plugging into the expenditure share changes and rewriting in tilde notation yields:

$$\tilde{\alpha}_{in} = \begin{cases} \tilde{\Omega}_{iP} + (1-\sigma_s)\left[\tilde{P}_{iP} - \tilde{P}_i + (\epsilon_P - \epsilon_i)\,\tilde{c}_i\right], & \text{if } n = 1 \\ (1-\sigma_s)\left[\tilde{P}_{iM} - \tilde{P}_i + (\epsilon_M - \epsilon_i)\,\tilde{c}_i\right] + \tilde{\Omega}_{in} + (1-\sigma_m)\left(\tilde{P}_{in} - \tilde{P}_{iM}\right), & \text{if } 1 < n < K \\ \tilde{\Omega}_{iS} + (1-\sigma_s)\left[\tilde{P}_{iS} - \tilde{P}_i + (\epsilon_S - \epsilon_i)\,\tilde{c}_i\right], & \text{if } n = K, \end{cases}$$

where $\tilde{P}_i = \sum_s \alpha_{is}\tilde{P}_{is}$, $\tilde{P}_{iM} = \sum_m \alpha_{im}\tilde{P}_{im}$, and $\tilde{c}_i = \dfrac{\tilde{e}_i - \sum_s \alpha_{is}\tilde{P}_{is}}{\sum_s \alpha_{is}\epsilon_s}$.

**Expenditure.** Finally, totally differentiating the Euler equation,

$$\rho\frac{d\phi_{it}}{\phi_{it-1}} = \rho\frac{\phi_{it}}{\phi_{it-1}}\left[\frac{d\mu_t}{\mu_t} + \frac{\kappa dd_{it}}{1+\kappa d_{it-1}} + \frac{de_{it}}{e_{it}} + \frac{d\epsilon_{it}}{\epsilon_{it}}\right] \quad \rightarrow \quad \tilde{e}_{it} = \tilde{\phi}_{it} - \tilde{\mu}_t - \frac{\kappa d_{it}\tilde{d}_{it}}{1+\kappa d_{it-1}} - \tilde{\epsilon}_{it},$$

where $\tilde{d}_{it} = \dfrac{e_{it}(\tilde{e}_{it} - \tilde{w}_{it})}{w_{it}d_{it}}$. Multiplying both sides by $E_{it}$ and summing across the economies,

$$\tilde{\mu}_t = \sum_i E_{it}\tilde{\phi}_{it} - \sum_i E_{it}\frac{\kappa d_{it}\tilde{d}_{it}}{1+\kappa d_{it-1}} - \sum_i E_{it}\tilde{e}_{it} - \sum_i E_{it}\tilde{\epsilon}_{it}.$$

$\sum_i E_{it}\tilde{e}_{it} = 0$ due to normalization. Plugging back in,

$$\tilde{e}_{it} = \tilde{\phi}_{it} - \tilde{\phi}_t - \left(\frac{\kappa d_{it}\tilde{d}_{it}}{1+\kappa d_{it-1}} - \sum_i E_{it}\frac{\kappa d_{it}\tilde{d}_{it}}{1+\kappa d_{it-1}}\right) - (\tilde{\epsilon}_{it} - \tilde{\epsilon}_t),$$

where $\sum_i E_{it}\tilde{\phi}_{it} = \tilde{\phi}_t$ and $\sum_i E_{it}\tilde{\epsilon}_{it} = \tilde{\epsilon}_t$. Finally, suppose $D_{it} \approx 1$, or $e_{it} \approx w_{it}$. Then,

$$\frac{\kappa d_{it}\tilde{d}_{it}}{1+\kappa d_{it-1}} \approx \kappa(\tilde{e}_{it} - \tilde{w}_{it}) \quad \text{and} \quad \sum_i E_{it}\frac{\kappa d_{it}\tilde{d}_{it}}{1+\kappa d_{it-1}} \approx 0.$$

Plugging in and solving out,

$$\tilde{e}_{it} \approx \frac{\tilde{\phi}_{it} - \tilde{\phi}_t}{1+\kappa} + \frac{\kappa\tilde{w}_{it}}{1+\kappa} + \frac{\tilde{\epsilon}_{it} - \tilde{\epsilon}_t}{1+\kappa}.$$

# B Online Appendix

## B.1 Data

**List of countries:** Australia, Brazil, Canada, China , Germany, Denmark, Spain, Finland, France, United Kingdom, Greece, India, Italy, Japan, Republic of Korea, Mexico, Portugal, Sweden, Taiwan, United States.[17]

**List of sectors:** *Primary:* Agriculture, Hunting, Forestry and Fishing; Mining and Quarrying. *Manufacturing:* Food, Beverages and Tobacco; Textile, Leather and Footwear; Pulp, Paper, Printing and Publishing; Coke, Petroleum and Nuclear Fuel; Chemicals and Chemical Products; Rubber and Plastics; Other Non-Metallic Mineral; Basic Metals and Fabricated Metal; Machinery; Electrical and Optical Equipment; Transport Equipment. *Services:* Manufacturing n.e.c. & Recycling[18]; Electricity, Gas and Water Supply; Construction; Wholesale and Retail Trade; Hotels and Restaurants; Transport and Storage; Post and Telecommunications; Financial Intermediation; Real Estate, Renting and Business Activities; Community Social and Personal.

**Data cleaning**. I do minimal cleaning of the dataset. First, as I am focusing on the long run processes, I smooth the data using a moving average of the series with a window length of 10 years. This removes the jumps in the data while keeping the long run trends intact. Second, the consumption reported in WIOD includes inventories and thus can take negative values. I subtract inventories from sectoral sales such that my measure of output is now akin to 'goods used'. This alteration leaves all other intermediate and final

[17] I exclude Austria, Belgium, Hong Kong, Ireland and Netherlands from the analysis as the time series for these countries feature abnormalities. Austria and Netherlands series feature structural breaks in years 1995 and 1969 respectively. Hong Kong series show zero final or intermediate consumption of textiles, but positive production throughout the period. Belgium and Ireland do not show a clear structural break, but feature self-shares that dip down to zero for consecutive years absent a corresponding drop in sectoral sales. Since domestic sales in the dataset are obtained as a residual between output and exports, I interpret these observations as reflective of a measurement error in either the sales or the exports series.

[18] I include Manufacturing, n.e.c. & Recycling into the services sector. This sector contains manufacturing of jewellery, musical instruments, games equipment, and toys; and recycling of metal- and non-metal scrap. Thus, this sector combines both manufacturing production, but also the provision of the service of recycling. I attribute it wholly to services.

use categories intact and the dataset remains internally consistent. In order to extend the sample length, I merge the Long Run (1965-2000) and 2013 Release (1995-2011) vintages of the dataset. See Woltjer et al. (2021) for the original dataset construction.

**Solving for the paths of endogenous variables**. Annual values for all endogenous variables can be derived as follows:

$$X_{ijk} = X_{ijk}^{FC} + \sum_n X_{ijnk}^{II}, \quad Y_{ik} = \sum_j X_{jik}, \quad \Pi_{ijk} = \frac{X_{ijk}}{\sum_l X_{ilk}},$$
$$\beta_{ikn} = \frac{\sum_j X_{ijkn}^{II}}{Y_{ik}}, \quad \beta_{ikl} = 1 - \sum_n \beta_{ikn}, \quad e_i = \sum_{j,k} X_{ijk}^{FC} / L_i, \quad \alpha_{ik} = \frac{\sum_j X_{ijk}^{FC}}{L_i e_i}.$$

## B.2 Calibration of $\kappa$

1. Take the Euler condition from the changes formulation of the model,

$$\hat{e}_{it} = \rho \hat{\phi}_{it} \frac{1}{\mu_{t+1}} \frac{1 + \kappa d_{it}}{1 + \kappa d_{it} \hat{d}_{it}} \frac{1}{\hat{\epsilon}_{it}}, \quad \hat{\epsilon}_{it} = \frac{\sum_s \alpha_{ist} \hat{\alpha}_{ist} \epsilon_s}{\sum_s \alpha_{ist} \epsilon_s}, \quad \hat{d}_{it} = \left( \frac{e_{it} \hat{e}_{it}}{w_{it} \hat{w}_{it}} - 1 \right) \frac{1}{d_{it}}, \quad \text{[EE]}$$

   together with the market clearing condition (31) at $t+1$.

2. Impose $\hat{\phi}_{it} = 1 \, \forall i \in I, t \in T$.

3. Set $\hat{w}_{it}$, $e_{it}$ and $w_i$ as observed in the data.

4. Search over $\kappa$ as to minimize

$$\sum_{i,t} (L_{it} \hat{e}_{it} - L_{it} \hat{e^*}_{it})^2,$$

   where $\hat{e}_{it}$ is the change in household expenditure in the data and $\hat{e^*}_{it}$ is the solution to EE under restrictions imposed in steps 1-3.

## B.3 Calibration of Exogenous Shocks

The model is calibrated by inverting the equilibrium conditions in Appendix B.6:

1. Construct the changes in wages from the data on GDP and population: $\hat{w}_i = \hat{Y}_i / \hat{L}_i$.

2. Normalize $\hat{\Omega}_{iM} = \hat{\omega}_{ikM} = 1$ and $\prod_i \hat{\phi}_i^{1/I} = 1$.

3. Use observed $\beta_{ikl}$, $\beta_{ikn}$, $\alpha_{ik}$, $\hat{\beta}_{ikl}$, $\hat{\beta}_{ikn}$, $\hat{\alpha}_{ik}$ and $\hat{E}_i$, as well as sectoral price changes $\hat{P}_{ik}$ obtained in Section 4.2 to solve $[\text{iii}] - [\text{vi}]$ and $[\text{x}]$ in Appendix B.6 for the full set of $\hat{\phi}_i$, $\hat{\Omega}_{ik}$, $\hat{\omega}_{ikl}$ and $\hat{\omega}_{ikn}$ for all $i \in I$ and $k, n \in K$.

4. Use $\hat{\omega}_{ikl}$ and $\hat{\omega}_{ikn}$ series as well as wage changes $\hat{w}_i$ to solve for input costs $\hat{v}_{ik}$.

5. Use input costs $\hat{v}_{ik}$, price changes $\hat{P}_{ik}$ and observed changes in trade shares $\hat{\Pi}_{ijk}$ to solve for sectoral productivity and trade cost shocks $\hat{A}_{ik}$ and $\hat{\tau}_{ijk}$ for all $i, j \in I$ and $k \in K$.

## B.4 Switching Countries Off

In Section 6 I conduct a series of exercises which involve 'switching off' of individual economies. I do so as follows. Let the country to be switched off be indexed $i$. First, I let all exogenous shock series for economies other than $i$ evolve as estimated in Section 4.2. Second, all shock series relating to $i$, other than sectoral productivities and discount factor shocks, are set to no-change: $\hat{\tau}_{ijkt} = \hat{\tau}_{jikt} = \hat{\Omega}_{ikt} = \hat{\omega}_{iknt} = \hat{\omega}_{ikLt} = \hat{L}_{it} = 1$ for all $j$, $k$, $n$ and $t$. Third, sectoral productivity and discount factor shocks are set such that expenditure and sectoral value added in $i$ remain unchanged. This ensures that changes in global international markets do not induce $i$ to borrow or lend and that there is no spurious specialization.[19] Finally, I replace the per-period utility function and production

[19] In the model, it is not the level of $\hat{\phi}$ that determines borrowing, but its relative size relative to that of the other economies. Thus, setting $\hat{\phi} = 1$ is not sufficient to preclude $i$ from borrowing. Likewise, setting $\hat{A}_{ikt} = 1$ does not preclude specialization: when all other countries' productivities evolve, no change in $i$'s productivity still entails evolution in relative productivities, and therefore, in comparative advantage of $i$.

functions for $i$ by appropriately re-calibrated Cobb-Douglas functions. This is necessary since even absent the evolution of $i$'s own exogenous variables, as long as $i$ is open, evolving productivities elsewhere in the world result in changes in sectoral prices and therefore changes in sectoral expenditures and wages in $i$. The outcome of this specification is the economy $i$ 'frozen in time' at the level of the initial year $t$. Changes in sectoral shares in all other economies in this specification register the evolution in sectoral composition that would have occurred had $i$ remained static in terms of both its exogenous processes and its endogenous outcomes. In turn, the difference between the '$i$ off' specification and the data is the isolated effect of $i$ on the global economies. I refer to this difference as '$i$ on'. Note that this difference captures the contribution of individual exogenous series in $i$, as well as of the interactions between them. Finally, observe that $i$ can be partially switched back on by bringing shock series in $i$ to baseline, one at a time. The difference between this specification and '$i$ off' isolates the effect of the given shock series.

## B.5 Derivations of the Equilibrium Conditions

**Trade shares.** Perfect competition in production of varieties ensures that each variety can be offered at most at its marginal cost. Taking transportation costs into account, the price of receiving in $i$ a unit of variety $z$ from $j$ is

$$p_{ijk}(z) = \frac{\nu_{jk}\tau_{ijk}}{a_{jk}(z)}.$$

Since bundle producer views varieties $z$ produced anywhere as perfectly substitutable, the price it pays is the minimal of prices by origin:

$$p_{ik}(z) = \min_{i} \left\{ \frac{\nu_{jk}\tau_{ijk}}{a_{jk}(z)} \right\}.$$

CES production function of the bundle producer results in the following price of a bundle:

$$P_{ik} = \left( \int_0^1 p_{ik}(z)^{1-\xi} dz \right)^{1/(1-\xi)}.$$

*Assumption 1* ensures that aggregation over varieties gives rise to trade shares in (22).

**Firm problem.** Consider the following maximization problem,

$$\max_{l(z)_{ik}, k(z)_{ik}, m_{ikn}(z)} \pi_{ik}(z) = p_{ik}(z) q_{ik}(z) - w_i l_{ik}(z) - \sum_{n \in K} P_{in} m_{ikn}(z),$$

$$q_{ik}(z) = a_{ik}(z) \left( \frac{l_{ik}(z)}{\omega_{ikL}} \right)^{\omega_{ikL}} \left( \frac{m_{ik}(z)}{1 - \omega_{ikL}} \right)^{1-\omega_{ikL}},$$

$$m_{ik}(z) = \left( \omega_{ikP}^{\frac{1}{\sigma_S}} m_{ikP}(z)^{\frac{\sigma_S - 1}{\sigma_S}} + \omega_{ikM}^{\frac{1}{\sigma_S}} \left( \sum_m \omega_{ikm}^{\frac{1}{\sigma_m}} m_{ikm}(z)^{\frac{\sigma_m - 1}{\sigma_m}} \right)^{\frac{\sigma_m(\sigma_S - 1)}{\sigma_S(\sigma_m - 1)}} + \omega_{ikS}^{\frac{1}{\sigma_S}} m_{ikS}(z)^{\frac{\sigma_S - 1}{\sigma_S}} \right)^{\frac{\sigma_S}{\sigma_S - 1}}.$$

First order conditions with respect to inputs are as follows:

$$\text{FOC}_{l(z)_{ik}} : \omega_{ikL} p_{ik}(z) y_{ik}(z) = w_i l_{ik}(z),$$

$$\text{FOC}_{m_{ikP}(z)} : (1 - \omega_{ikL}) p_{ik}(z) y_{ik}(z) \omega_{ikP}^{\frac{1}{\sigma_S}} \left( \frac{m_{ikP}(z)}{m_{ik}(z)} \right)^{\frac{\sigma_S - 1}{\sigma_S}} = m_{ikP}(z) P_{iP},$$

$$\text{FOC}_{m_{ikm}(z)} : (1 - \omega_{ikL}) p_{ik}(z) y_{ik}(z) \omega_{ikM}^{\frac{1}{\sigma_S}} \left( \frac{m_{ikM}(z)}{m_{ik}(z)} \right)^{\frac{\sigma_S - 1}{\sigma_S}} \omega_{ikm}^{\frac{1}{\sigma_m}} \left( \frac{m_{ikm}(z)}{m_{ikM}(z)} \right)^{\frac{\sigma_m - 1}{\sigma_m}} = m_{ikm}(z) P_{im},$$

$$\text{FOC}_{m_{ikS}(z)} : (1 - \omega_{ikL}) p_{ik}(z) y_{ik}(z) \omega_{ikS}^{\frac{1}{\sigma_S}} \left( \frac{m_{ikS}(z)}{m_{ik}(z)} \right)^{\frac{\sigma_S - 1}{\sigma_S}} = m_{ikS}(z) P_{iS}.$$

The cost of production and input expenditure shares (23)-(25) obtain by combining these first order conditions with the production function defined in (3)-(5).

**Household problem.** First, for a given expenditure $e_i$, solve

$$\max_{c_{ik}} c_i, \quad \text{where } \sum_s \Omega_{is}^{\frac{1}{\sigma_s}} \left( \frac{c_{is}}{c_i^{\epsilon_s}} \right)^{\frac{\sigma_s - 1}{\sigma_s}} = 1 \text{ and } c_{iM} = \left( \sum_m \Omega_{im}^{\frac{1}{\sigma_m}} c_{im}^{\frac{\sigma_m - 1}{\sigma_m}} \right)^{\frac{\sigma_m}{\sigma_m - 1}} \quad \text{s.t. } \sum_k P_{ik} c_{ik} = e_i.$$

First order conditions with respect to sectoral consumption are as follows:

$$\begin{aligned}
\mathrm{FOC}_{c_{iP}}: \quad & \frac{dc_i}{dc_{iP}} = \Omega_{iP}^{\frac{1}{\sigma_s}} \left(\frac{c_{iP}}{c_i^{\epsilon_s}}\right)^{\frac{\sigma_s-1}{\sigma_s}} \left(\sum_s \Omega_{is}^{\frac{1}{\sigma_s}} \left(\frac{c_{is}}{c_i^{\epsilon_s}}\right)^{\frac{\sigma_s-1}{\sigma_s}} \epsilon_s\right)^{-1} \frac{c_i}{c_{iP}} = \lambda_i P_{iP}, \\
\mathrm{FOC}_{c_{im}}: \quad & \frac{dc_i}{dc_{im}} = \Omega_{iM}^{\frac{1}{\sigma_s}} \left(\frac{c_{iM}}{c_i^{\epsilon_s}}\right)^{\frac{\sigma_s-1}{\sigma_s}} \left(\sum_s \Omega_{is}^{\frac{1}{\sigma_s}} \left(\frac{c_{is}}{c_i^{\epsilon_s}}\right)^{\frac{\sigma_s-1}{\sigma_s}} \epsilon_s\right)^{-1} \frac{c_i}{c_{iM}} \Omega_{im}^{\frac{1}{\sigma_m}} \left(\frac{c_{iM}}{c_{im}}\right)^{\frac{1}{\sigma_m}} = \lambda_i P_{im}, \\
\mathrm{FOC}_{c_{iS}}: \quad & \frac{dc_i}{dc_{iS}} = \Omega_{iS}^{\frac{1}{\sigma_s}} \left(\frac{c_{iS}}{c_i^{\epsilon_s}}\right)^{\frac{\sigma_s-1}{\sigma_s}} \left(\sum_s \Omega_{is}^{\frac{1}{\sigma_s}} \left(\frac{c_{is}}{c_i^{\epsilon_s}}\right)^{\frac{\sigma_s-1}{\sigma_s}} \epsilon_s\right)^{-1} \frac{c_i}{c_{iS}} = \lambda_i P_{iS},
\end{aligned}$$

which pin down the consumption expenditure shares in (26).

Next, consider the following intertemporal problem:

$$\max_{e_{it}, B_{it+1}} \sum_{t=0}^{\infty} \rho^t \phi_{it} \ln c_{it}(e_{it}, \mathbf{P}_{it}) \quad \text{s.t.} \;\; e_{it} + \mu_{t+1} b_{it+1} + \frac{\kappa}{2} d_{it}^2 w_i = w_i + b_{it} + T_{it}, \quad d_{it} = \frac{e_{it} - w_i}{w_i},$$

where $\mathbf{P}_{it}$ is a vector of prices and the full sequence of incomes $\{w_i\}$ is known in advance. The associated first order conditions,

$$\begin{aligned}
\mathrm{FOC}_{e_{it}}: \quad & \rho^t \phi_{it} \frac{1}{c_{it}} \frac{dc_{it}}{de_{it}} = \lambda_{it}(1 + \kappa d_{it}), \quad \text{where } \frac{1}{c_{it}} \frac{dc_{it}}{de_{it}} = \left(e_{it} \sum_s \alpha_{ist} \epsilon_s\right)^{-1}, \\
\mathrm{FOC}_{B_{it+1}}: \quad & \lambda_{it} \mu_{t+1} = \lambda_{it+1},
\end{aligned}$$

give rise to the Euler equation (27).

**Equilibrium of the model.** Trade shares satisfy:

$$\Pi_{jik} = \left(\frac{c_{ik} \tau_{jik}}{A_{ik} P_{jk}}\right)^{-\theta_k}, \quad \text{where } P_{ik} = \left[\sum_l \left(\frac{\nu_{lk} \tau_{ilk}}{A_{lk}}\right)^{-\theta_k}\right]^{-\frac{1}{\theta_k}} \tag{22}$$

and $\nu_{ik}$ is the cost of production of a firm in $i, k$ with a unit productivity:

$$\nu_{ik} = w_{ik}^{\omega_{ikL}} \left(\sum_s \omega_{iks} P_{iks}^{1-\sigma_s}\right)^{\frac{1-\omega_{ikL}}{1-\sigma_s}}, \tag{23}$$

where $P_{ikP} = P_{iP}$, $P_{ikM} = \left(\sum_m \omega_{ikm} P_{im}^{1-\sigma_m}\right)^{1/(1-\sigma_m)}$ and $P_{ikS} = P_{iS}$.

Firms spend $\beta_{ikL}$ on labor,

$$\beta_{ikL} = \frac{w_{it} l_{ik}(z)}{p_{ik}(z) y_{ik}(z)} = \omega_{ikL}, \tag{24}$$

and a fraction $\beta_{ikn}$ of their revenue on inputs from sector $n$:

$$\beta_{ikn} = \frac{P_{in} m_{ikn}(z)}{p_{ik}(z) y_{ik}(z)} = \begin{cases} (1-\omega_{ikL}) \dfrac{\omega_{ikP} P_{iP}^{1-\sigma_s}}{\sum_s \omega_{iks} P_{iks}^{1-\sigma_s}}, & \text{if } n = 1 \\ (1-\omega_{ikL}) \dfrac{\omega_{ikM} P_{ikM}^{1-\sigma_s}}{\sum_s \omega_{iks} P_{iks}^{1-\sigma_s}} \dfrac{\omega_{ikm} P_{im}^{1-\sigma_m}}{\sum_m \omega_{ikm} P_{im}^{1-\sigma_m}}, & \text{if } 1 < n < K \\ (1-\omega_{ikL}) \dfrac{\omega_{ikS} P_{iS}^{1-\sigma_s}}{\sum_s \omega_{iks} P_{iks}^{1-\sigma_s}}, & \text{if } n = K. \end{cases} \tag{25}$$

Household sectoral expenditure shares depend on prices, per-period aggregate consumption $c_i$, and household expenditure $e_i = \sum_{k \in K} P_{ik} c_{ik}$:

$$\alpha_{in} = \frac{P_{in} c_{in}}{e_i} = \begin{cases} \Omega_{iP} \left(\dfrac{P_{iP}}{e_i}\right)^{1-\sigma_s} c_i^{(1-\sigma_s)\epsilon_P}, & \text{if } n = 1 \\ \Omega_{iM} \left(\dfrac{P_{iM}}{e_i}\right)^{1-\sigma_s} c_i^{(1-\sigma_s)\epsilon_M} \dfrac{\Omega_{im} P_{im}^{1-\sigma_m}}{\sum_m \Omega_{im} P_{im}^{1-\sigma_m}}, & \text{if } 1 < n < K \\ \Omega_{iS} \left(\dfrac{P_{iS}}{e_i}\right)^{1-\sigma_s} c_i^{(1-\sigma_s)\epsilon_S}, & \text{if } n = K, \end{cases} \tag{26}$$

where $c_i$ is defined implicitly:

$$\sum_s \Omega_{is}^{\frac{1}{\sigma_s}} \left(\frac{c_{is}}{c_i^{\epsilon_s}}\right)^{\frac{\sigma_s - 1}{\sigma_s}} = 1, \quad \text{with } c_{iP} = \frac{\alpha_{iP} e_i}{P_{iP}},\ c_{iM} = \frac{\alpha_{iM} e_i}{P_{iM}},\ c_{iS} = \frac{\alpha_{iS} e_i}{P_{iS}},$$

and where manufacturing consumption bundle price $P_{iM}$ satisfies

$$P_{iM} = \left( \sum_m \Omega_{im} P_{im}^{1-\sigma_m} \right)^{1/(1-\sigma_m)}.$$

Household consumption smoothing problem gives rise to the following Euler condition:

$$\rho \frac{\phi_{it}}{\phi_{it-1}} = \mu_t \frac{1+\kappa d_{it}}{1+\kappa d_{it-1}} \frac{e_{it}\epsilon_{it}}{e_{it-1}\epsilon_{it-1}}, \tag{27}$$

where $d_{it} = \dfrac{e_{it} - w_{it}}{w_{it}}$ and $\epsilon_{it} = \sum_s \alpha_{ist}\epsilon_s$.
Sectoral bundle market clearing in $i, k$ satisfies

$$X_{ik} = \alpha_{ik} L_i e_i + \sum_{n \in K} \beta_{ink} \int_0^1 p_{in}(z) y_{in}(z) = \alpha_{ik} L_i e_i + \sum_{n \in K} \beta_{ink} Y_{in}, \tag{28}$$

where $Y_{ik}$ denotes the sales of all varieties in $i, k$: $Y_{ik} = \int_0^1 p_{in}(z) y_{in}(z)$.

Sectoral sales are a sum of what is demanded by each trading partner:

$$Y_{ik} = \sum_j \Pi_{jik} X_{jk}. \tag{29}$$

Labour markets clear

$$w_i L_i = \sum_{k \in K} \int_0^1 w_i l_{ik}(z) dz = \sum_{k \in K} \beta_{ikL} Y_{ik}, \tag{30}$$

Finally, the bond market clearing together with normalization require

$$\sum_i L_{it} e_{it} = \sum_i L_{it} w_{it} = 1. \tag{31}$$

## B.6 Model in Changes

Suppose that base year values of endogenous variables $Y_{ik}$, $\Pi_{jik}$, $\alpha_{ik}$, $\beta_{ikL}$, $\beta_{ikn}$, $e_i$, $w_i$, $L_i$ for all $i, j \in I$ and $k, n \in K$, are known. Equations [i] to [x] constitute the equilibrium of the changes formulation of the model and can be used to solve for all the endogenous objects in the next period as a function of the exogenous shocks:

[i] Changes in trade shares and price indices can be derived from (22):

$$\hat{\Pi}_{jik} = \left(\frac{\hat{v}_{ik}\hat{\tau}_{jik}}{\hat{A}_{ik}\hat{P}_{jk}}\right)^{-\theta_k}, \quad \hat{P}_{ik} = \left[\sum_l \Pi_{ilk}\left(\frac{\hat{v}_{lk}\hat{\tau}_{ilk}}{\hat{A}_{lk}}\right)^{-\theta_k}\right]^{-\frac{1}{\theta_k}}.$$

[ii] Changes in production costs can be derived from (23):

$$\hat{v}_{ik} = \hat{w}_i^{\beta_{ikL}}\left(\sum_s \frac{\beta_{iks}}{\sum_s \beta_{iks}}\hat{\omega}_{iks}\hat{P}_{iks}^{1-\sigma_s}\right)^{\frac{1-\beta_{ikL}}{1-\sigma_s}},$$

where $\hat{P}_{ikP} = \hat{P}_{iP}$, $\hat{P}_{ikM} = \left(\sum_m \frac{\beta_{ikm}}{\sum_m \beta_{ikm}}\hat{\omega}_{ikm}\hat{P}_{im}^{1-\sigma_m}\right)^{1/(1-\sigma_m)}$ and $\hat{P}_{ikS} = \hat{P}_{iS}$.

[iii] Changes in the labour share are immediate from (24):

$$\hat{\beta}_{ikL} = \hat{\omega}_{ikL}.$$

[iv] Changes in the intermediate input shares can be derived from (25):

$$\hat{\beta}_{ikn} = \begin{cases} \frac{1-\beta_{ikL}\hat{\omega}_{ikL}}{1-\beta_{ikL}} \frac{\hat{\omega}_{ikP}\hat{P}_{ikP}^{1-\sigma_s}}{\sum_s \frac{\beta_{iks}}{\sum_s \beta_{iks}}\hat{\omega}_{iks}\hat{P}_{iks}^{1-\sigma_s}}, & \text{if } n = 1 \\ \frac{1-\beta_{ikL}\hat{\omega}_{ikL}}{1-\beta_{ikL}} \frac{\hat{\omega}_{ikM}\hat{P}_{ikM}^{1-\sigma_s}}{\sum_s \frac{\beta_{iks}}{\sum_s \beta_{iks}}\hat{\omega}_{iks}\hat{P}_{iks}^{1-\sigma_s}} \frac{\hat{\omega}_{ikm}\hat{P}_{ikm}^{1-\sigma_m}}{\sum_m \frac{\beta_{ikm}}{\sum_m \beta_{ikm}}\hat{\omega}_{ikm}\hat{P}_{ikm}^{1-\sigma_m}}, & \text{if } 1 < n < K \\ \frac{1-\beta_{ikL}\hat{\omega}_{ikL}}{1-\beta_{ikL}} \frac{\hat{\omega}_{ikS}\hat{P}_{ikS}^{1-\sigma_s}}{\sum_s \frac{\beta_{iks}}{\sum_s \beta_{iks}}\hat{\omega}_{iks}\hat{P}_{iks}^{1-\sigma_s}}, & \text{if } n = K. \end{cases}$$

[v] Changes in the final expenditure shares can be derived from condition (26):

$$\hat{\alpha}_{in} = \begin{cases} \hat{\Omega}_{iP}\left(\frac{\hat{P}_{iP}}{\hat{e}_i}\right)^{1-\sigma_s}\hat{c}_i^{(1-\sigma_s)\epsilon_P}, & \text{if } n=1 \\ \hat{\Omega}_{iM}\left(\frac{\hat{P}_{iM}}{\hat{e}_i}\right)^{1-\sigma_s}\hat{c}_i^{(1-\sigma_s)\epsilon_M}\frac{\hat{\Omega}_{im}\hat{P}_{im}^{1-\sigma_m}}{\sum_m \frac{\alpha_{im}}{\sum_m \alpha_{im}}\hat{\Omega}_{im}\hat{P}_{im}^{1-\sigma_m}}, & \text{if } 1<n<K \\ \hat{\Omega}_{iS}\left(\frac{\hat{P}_{iS}}{\hat{e}_i}\right)^{1-\sigma_s}\hat{c}_i^{(1-\sigma_s)\epsilon_S}, & \text{if } n=K, \end{cases}$$

where $\hat{c}_i$ satisfies:

$$\sum_s \alpha_{is}\hat{\Omega}_{is}\left(\frac{\hat{P}_{is}}{\hat{e}_i}\right)^{1-\sigma_s}\hat{c}_i^{(1-\sigma_s)\epsilon_s} = 1.$$

[vi] Changes in the household expenditure can be derived from (27):

$$\hat{e}_{it} = \rho\hat{\phi}_{it}\frac{1}{\mu_{t+1}}\frac{1+\kappa d_{it}}{1+\kappa d_{it}\hat{d}_{it}}\frac{1}{\hat{\epsilon}_{it}}, \quad \hat{\epsilon}_{it} = \frac{\sum_s \alpha_{ist}\hat{\alpha}_{ist}\epsilon_s}{\sum_s \alpha_{ist}\epsilon_s}, \quad \hat{d}_{it} = \left(\frac{e_{it}\hat{e}_{it}}{w_{it}\hat{w}_{it}} - 1\right)\frac{1}{d_{it}}.$$

[vii] $\hat{X}_{ik}$ satisfies the sectoral bundle market clearing condition (28):

$$X_{ik}\hat{X}_{ik} = \alpha_{ik}L_i e_i\hat{\alpha}_{ik}\hat{L}_i\hat{e}_i + \sum_{n\in K}\beta_{ink}Y_{in}\hat{\beta}_{ink}\hat{Y}_{in}.$$

[viii] $\hat{Y}_{ik}$ satisfies the sectoral market clearing condition (29):

$$Y_{ik}\hat{Y}_{ik} = \sum_j \Pi_{jik}X_{jk}\hat{\Pi}_{jik}\hat{X}_{jk}.$$

[ix] Wages change as to clear the labor market (30):

$$w_i L_i\hat{w}_i\hat{L}_i = \sum_{k\in K}\beta_{ikL}Y_{ik}\hat{\beta}_{ikL}\hat{Y}_{ik}.$$

[x] Finally, $\mu_{t+1}$ satisfies (31):

$$\sum_i L_{it}\hat{L}_{it}e_{it}\hat{e}_{it} = 1.$$

## B.7 Shock Summary Statistics

Table B.1: Inward Trade Cost Shocks, 1965-2011

| | Primary | Food | Textiles | Pulp & Paper | Coke & Petroleum | Chemicals | Rubber & Plastics | Non-Metallic Mineral | Basic/Fabricated Metal | Machinery, n.e.c. | Electrical & Optical | Transport Equipment | Services | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Australia | 0.70 | 0.90 | 0.89 | 0.76 | 0.57 | 0.71 | 0.77 | 0.67 | 0.74 | 0.73 | 0.77 | 0.77 | – | 0.76 |
| Brazil | 0.76 | 0.79 | 0.60 | 0.42 | 0.42 | 0.65 | 0.43 | 0.53 | 0.63 | 0.61 | 0.68 | 0.62 | – | 0.64 |
| Canada | 0.89 | 0.79 | 0.80 | 0.87 | 0.57 | 0.76 | 0.82 | 0.77 | 0.92 | 0.77 | 0.80 | 0.81 | – | 0.83 |
| China | 0.58 | 0.68 | 0.64 | 0.50 | 0.31 | 0.55 | 0.46 | 0.21 | 0.63 | 0.42 | 0.52 | 0.55 | – | 0.55 |
| Germany | 0.79 | 0.70 | 0.76 | 0.70 | 0.87 | 0.70 | 0.74 | 0.84 | 0.73 | 0.80 | 0.84 | 0.87 | – | 0.77 |
| Denmark | 0.90 | 0.75 | 0.74 | 0.80 | 0.59 | 0.71 | 0.70 | 0.72 | 0.82 | 0.77 | 0.82 | 0.81 | – | 0.78 |
| Spain | 0.74 | 0.76 | 0.61 | 0.72 | 0.44 | 0.67 | 0.55 | 0.64 | 0.65 | 0.78 | 0.75 | 0.62 | – | 0.67 |
| Finland | 0.61 | 0.75 | 0.72 | 0.80 | 0.59 | 0.68 | 0.61 | 0.61 | 0.78 | 0.81 | 0.76 | 0.84 | – | 0.72 |
| France | 0.82 | 0.78 | 0.77 | 0.85 | 0.62 | 0.70 | 0.77 | 0.84 | 0.87 | 0.86 | 0.83 | 0.82 | – | 0.79 |
| United Kingdom | 0.79 | 0.83 | 0.79 | 0.91 | 0.58 | 0.69 | 0.70 | 0.80 | 0.86 | 0.82 | 0.83 | 0.78 | – | 0.80 |
| Greece | 0.63 | 0.75 | 0.67 | 0.67 | 0.48 | 0.59 | 0.59 | 0.50 | 0.71 | 0.57 | 0.69 | 0.70 | – | 0.65 |
| India | 0.63 | 0.70 | 0.73 | 0.72 | 0.43 | 0.63 | 0.54 | 0.55 | 0.61 | 0.69 | 0.68 | 0.62 | – | 0.64 |
| Italy | 0.74 | 0.74 | 0.78 | 0.79 | 0.67 | 0.74 | 0.73 | 0.79 | 0.80 | 0.83 | 0.87 | 0.84 | – | 0.77 |
| Japan | 0.85 | 1.03 | 0.90 | 0.93 | 0.68 | 0.83 | 0.65 | 0.75 | 0.89 | 0.81 | 0.82 | 0.75 | – | 0.85 |
| Republic of Korea | 0.56 | 0.63 | 0.74 | 0.53 | 0.45 | 0.56 | 0.40 | 0.42 | 0.64 | 0.59 | 0.66 | 0.59 | – | 0.59 |
| Mexico | 0.57 | 0.59 | 0.65 | 0.56 | 0.47 | 0.69 | 0.34 | 0.56 | 0.58 | 0.61 | 0.60 | 0.56 | – | 0.58 |
| Portugal | 0.77 | 0.74 | 0.67 | 0.61 | 0.65 | 0.72 | 0.56 | 0.51 | 0.70 | 0.68 | 0.74 | 0.63 | – | 0.69 |
| Sweden | 0.73 | 0.77 | 0.74 | 0.85 | 0.64 | 0.74 | 0.74 | 0.76 | 0.91 | 0.87 | 0.83 | 0.95 | – | 0.82 |
| Taiwan | 0.50 | 0.81 | 0.60 | 0.47 | 0.54 | 0.62 | 0.46 | 0.48 | 0.60 | 0.69 | 0.73 | 0.71 | – | 0.58 |
| United States | 0.82 | 0.96 | 0.76 | 1.01 | 0.94 | 0.72 | 0.78 | 0.79 | 0.94 | 0.84 | 0.83 | 0.90 | – | 0.87 |
| RoW | 0.88 | 0.84 | 0.76 | 0.80 | 0.79 | 0.75 | 0.75 | 0.80 | 0.82 | 0.78 | 0.81 | 0.83 | – | 0.83 |

*Note*: Trade costs are computed by first obtaining an import-share weighted average inward trade cost shock, and then multiplying these over time to obtain change over the whole period. The total is computed by first obtaining yearly tradable sector sales-share weighted average inward trade cost shocks, and then multiplying these over time to obtain change over the whole period.

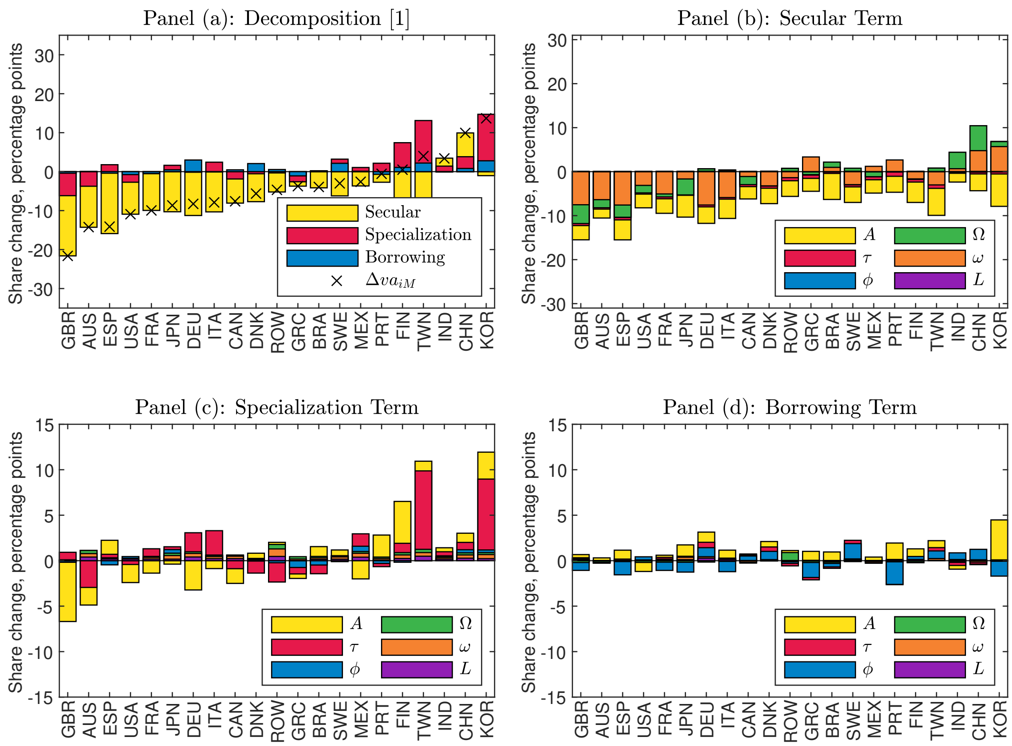
Table B.2: Sectoral Productivity Shocks, 1965-2011

| | Primary | Food | Textiles | Pulp & Paper | Coke & Petroleum | Chemicals | Rubber & Plastics | Non-Metallic Mineral | Basic/Fabricated Metal | Machinery, n.e.c. | Electrical & Optical | Transport Equipment | Services | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Australia | 1.64 | 1.54 | 2.13 | 2.21 | 0.62 | 1.35 | 1.99 | 2.60 | 1.70 | 1.67 | 8.17 | 1.86 | 2.14 | 2.04 |
| Brazil | 2.77 | 2.16 | 3.50 | 3.96 | 0.79 | 1.84 | 3.31 | 3.43 | 2.32 | 2.28 | 7.70 | 2.01 | 3.43 | 3.08 |
| Canada | 1.42 | 1.56 | 2.00 | 1.42 | 0.59 | 1.12 | 1.97 | 1.67 | 1.35 | 1.59 | 5.90 | 1.58 | 2.06 | 1.85 |
| China | 2.78 | 2.61 | 2.30 | 2.39 | 1.01 | 1.61 | 3.05 | 3.08 | 2.19 | 2.14 | 6.08 | 1.93 | 2.86 | 2.68 |
| Germany | 1.46 | 1.89 | 2.15 | 1.77 | 0.46 | 1.29 | 2.36 | 2.02 | 1.70 | 1.68 | 9.08 | 1.86 | 2.73 | 2.41 |
| Denmark | 1.78 | 1.62 | 2.20 | 1.89 | 0.70 | 1.41 | 2.40 | 2.44 | 1.91 | 1.88 | 8.98 | 1.69 | 2.28 | 2.17 |
| Spain | 2.51 | 1.91 | 2.38 | 2.23 | 0.56 | 1.80 | 2.72 | 3.16 | 2.04 | 1.97 | 8.39 | 1.93 | 2.79 | 2.54 |
| Finland | 2.02 | 1.74 | 2.71 | 1.59 | 0.91 | 1.74 | 3.11 | 2.89 | 1.84 | 2.30 | 9.36 | 1.96 | 2.25 | 2.21 |
| France | 1.48 | 1.74 | 1.95 | 1.56 | 0.39 | 1.13 | 2.17 | 1.70 | 1.58 | 1.46 | 6.72 | 1.43 | 2.11 | 1.92 |
| United Kingdom | 1.95 | 1.70 | 2.05 | 1.66 | 0.44 | 1.16 | 1.82 | 1.63 | 1.41 | 1.51 | 6.56 | 1.57 | 2.16 | 1.99 |
| Greece | 2.26 | 1.84 | 2.66 | 2.07 | 0.80 | 1.34 | 2.68 | 3.07 | 1.73 | 1.66 | 8.37 | 3.32 | 3.12 | 2.82 |
| India | 1.75 | 1.87 | 1.92 | 1.57 | 0.81 | 1.25 | 2.12 | 2.01 | 1.47 | 1.57 | 5.40 | 1.69 | 1.84 | 1.80 |
| Italy | 1.90 | 1.93 | 2.39 | 1.74 | 0.39 | 1.27 | 2.08 | 2.21 | 1.82 | 1.68 | 8.28 | 1.71 | 2.54 | 2.27 |
| Japan | 2.25 | 2.35 | 2.47 | 1.78 | 0.91 | 1.68 | 2.50 | 1.98 | 1.83 | 2.21 | 7.93 | 1.86 | 3.26 | 2.76 |
| Republic of Korea | 5.57 | 2.19 | 2.64 | 2.98 | 1.23 | 2.61 | 3.79 | 4.97 | 2.41 | 4.06 | 7.29 | 3.40 | 5.88 | 4.42 |
| Mexico | 1.85 | 1.61 | 1.98 | 1.58 | 0.56 | 1.12 | 2.11 | 2.34 | 1.44 | 1.55 | 5.04 | 1.72 | 2.57 | 2.20 |
| Portugal | 2.32 | 1.84 | 2.21 | 2.56 | 0.88 | 1.46 | 3.65 | 3.27 | 2.18 | 1.84 | 5.48 | 1.42 | 2.88 | 2.62 |
| Sweden | 1.50 | 1.75 | 1.91 | 1.38 | 0.68 | 1.50 | 2.09 | 1.71 | 1.46 | 1.39 | 6.32 | 1.65 | 1.69 | 1.73 |
| Taiwan | 2.85 | 1.97 | 2.62 | 2.95 | 1.29 | 1.98 | 2.15 | 3.63 | 2.19 | 1.77 | 6.18 | 2.95 | 5.24 | 3.59 |
| United States | 1.10 | 1.44 | 1.67 | 1.23 | 0.42 | 1.07 | 1.59 | 1.31 | 1.25 | 1.26 | 5.68 | 1.31 | 1.62 | 1.54 |
| RoW | 1.88 | 2.03 | 2.30 | 1.89 | 0.51 | 1.40 | 2.18 | 2.31 | 1.65 | 1.75 | 6.49 | 1.75 | 2.07 | 1.99 |

*Note*: Sectoral productivities are obtained by multiplying yearly changes over time to obtain change over the whole period. The total is computed by first obtaining yearly sectoral sales-share weighted average change in productivity, and then multiplying these over time to obtain change over the whole period.

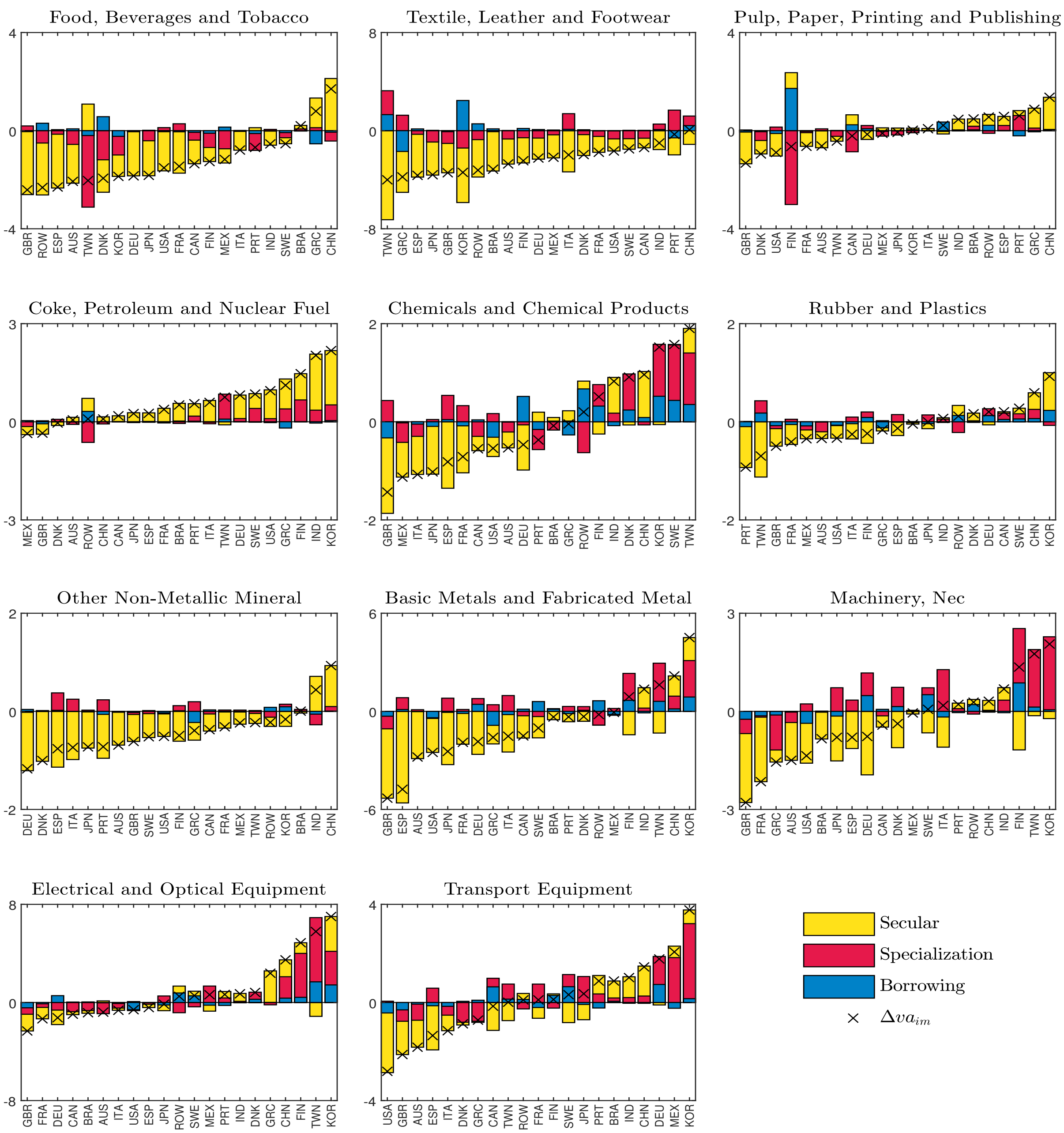
## B.8 Additional Figures

Figure B.1: Mechanisms of Manufacturing Value Added Shares by Shock



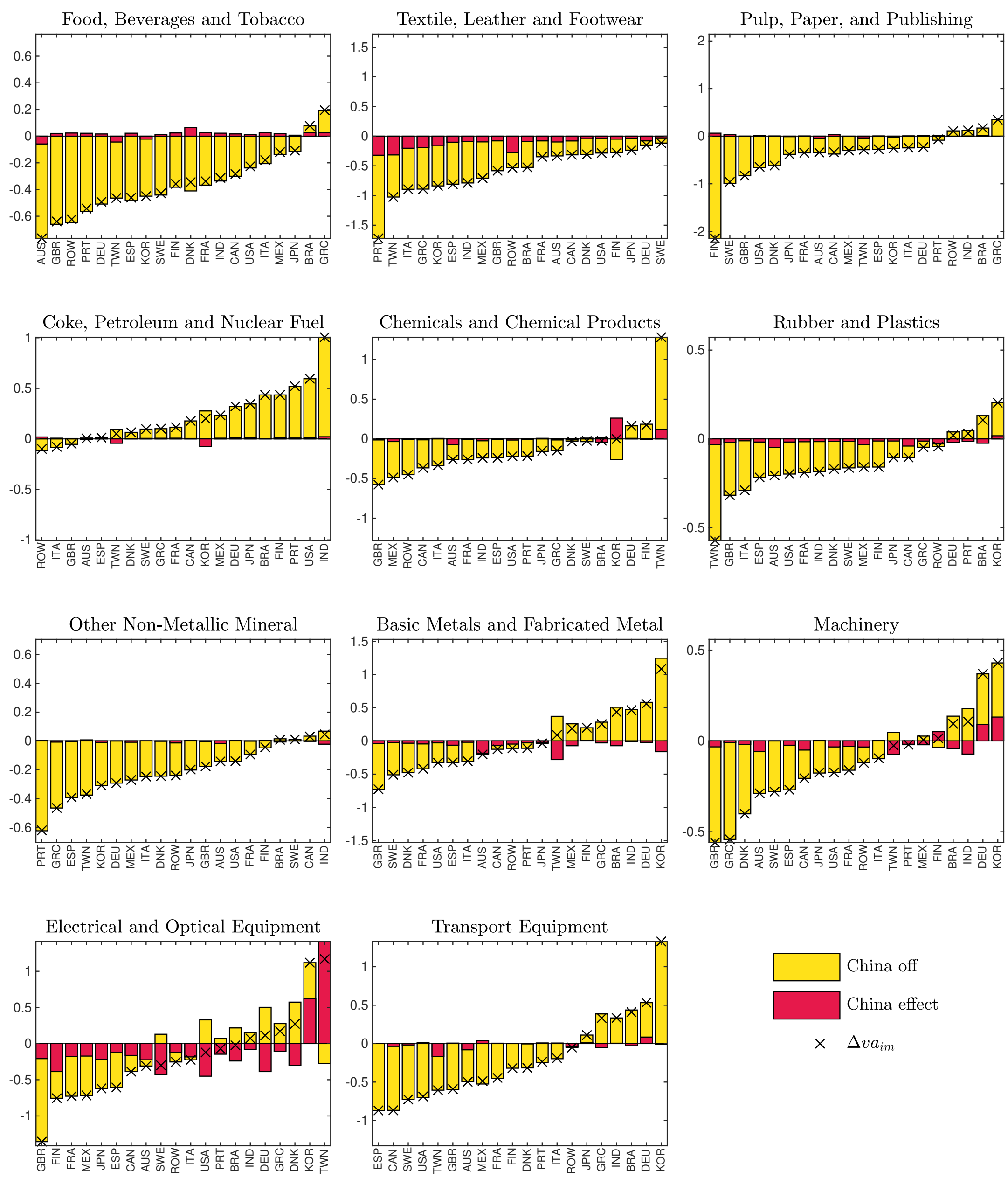

*Note*: The crosses mark the change in the manufacturing value added share between 1965 and 2011. The bars correspond to the components of decompositions [1] in Panel (a) and [4] in Panels (b)–(d).

Figure B.2: Mechanisms of Structural Change within Manufacturing




*Note*: The crosses mark the change in the manufacturing value added share between 1965 and 2011. The bars correspond to the components of decomposition [1].

Figure B.3: China-driven De-industrialization by Industry




*Note*: The crosses mark the change in the manufacturing value added share between 2000 and 2011. The yellow bars represent the value added changes in the simulation with all non-China shocks unconstrained, and China shocks calibrated such that $\hat{\tau}_{ijkt} = \hat{\tau}_{jikt} = \hat{\Omega}_{ikt} = \hat{\omega}_{iknt} = \hat{\omega}_{ikLt} = \hat{L}_{it} = 1$ for all $j \in I$, $k, n \in K$ and $t \in T$, where $i$ indexes China. Additionally, $\hat{\phi}_{it}$ and $\hat{A}_{ikt}$ for China is calibrated so that there is no change in China's expenditure and sectoral value added. The red bars depict the difference between this calibration and the simulation subject to baseline calibration.

Figure B.4: Industrialization in South Korea, by Industry


*Note*: The green lines plot the value added share of the sector. The red lines correspond to the the cumulated contribution of the specialization components of the decomposition [1] applied to the sectoral shares in the 'only sectoral productivities' and 'only trade liberalization' in South Korea counterfactuals.