Structural Change in an Open Economy

Lidia Smitkova[1]

November 27, 2023

Abstract

This paper studies the role of trade and international borrowing in driving structural change. I decompose the change in manufacturing shares into three terms driven by (i) sectoral expenditure shares (what goods do agents buy?), (ii) trade shares (where do agents source these goods from?), and (iii) aggregate trade deficits (who borrows in a given period?), and map the reduced-form terms of the decomposition into structural primitives using a calibrated quantitative model of trade with non-homothetic preferences and endogenous borrowing. Using data from twenty economies between 1965 and 2011, I show that trade specialization and international borrowing explain 23% and 17% of observed change in manufacturing shares, half of cross-country heterogeneity in patterns of industrialization, half the dynamics in high-technology subsectors of manufacturing, and are indispensable for understanding the effect of China on global manufacturing and 'miracle' industrialization in South Korea.

1. Department of Economics, University of Oxford (e-mail: lidia.smitkova@economics.ox.ac.uk). I am grateful to Charles Brendon, Tiago Cavalcanti and Giancarlo Corsetti for support and guidance. I also thank Timo Boppart, Doug Gollin, Joe Kaboski, Pete Klenow, Andrés Rodríguez-Clare and Thomas Sampson for helpful discussions and suggestions. I have benefited from valuable comments by participants at the GEP/CEPR Trade Workshop, Annual Meeting of the CEPR Macroeconomics and Growth Programme, CEP-LSE Junior Trade Workshop, European Summer Symposium in International Macroeconomics, and the Society for Economic Dynamics Meeting.

1 Introduction

Structural change is the process of shifts in the sectoral composition of economies as they mature. Much has been written on its drivers in a closed economy (see overview in Herrendorf, Rogerson, and Valentinyi (2014)). But does openness matter for structural change? If so, is it openness to trade in goods, in assets, or both? Should we expect the effects to be uniform across the subsectors of manufacturing? And how do we understand the cases of export-led industrialization (e.g. South Korea) and import-driven deindustrialization (e.g. so-called 'China shock')? In this paper I address these questions in a unified framework.

I do so by employing a structural decomposition. 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 changes in (i) sectoral expenditure shares (what goods do agents buy?), (ii) trade shares (where do agents source these goods from?), and (iii) aggregate trade deficits (who borrows in a given period?). In turn, I interpret the three as capturing the contribution of secular changes in sectoral demand, trade specialization, and international borrowing. The decomposition is independent of micro-level specification of the model, and relies on observable data alone. Later on, I map the reduced-form terms of the decomposition into structural primitives using a calibrated quantitative model of trade with non-homothetic preferences and endogenous borrowing. The decomposition offers a simple way to evaluate the role of trade specialization and international borrowing in driving structural change.

Applying the decomposition to changes in manufacturing value added shares in twenty economies between 1965 and 2011, I show that trade specialization and international borrowing are quantitatively important drivers of structural change. Specifically, the two are responsible for 23% and 17% of observed changes in manufacturing shares in my sample. However, the level of disaggregation matters: taking the *composition* of manufacturing into account, I find that the relative importance of specialization increases to 31%. In other words, economies specialize within manufacturing rather than in manufacturing as a whole.

Second, I show that trade specialization and international borrowing are crucial drivers of the heterogeneity in countries' experiences of structural change. In particular, I find that trade specialization explains a quarter of the deviation of countries' change in manufacturing shares from the average for their income group. International borrowing explains a further quarter. Moreover, I argue that polarization is inherent to the operation of these two forces. When one economy specializes in manufacturing – its exports increase as a share of its trading partner's expenditures. On the flip side, the export shares of its competitors, necessarily, decline – resulting in 'de-specialization'. In turn, economies that borrow see their non-tradable sectors expand. This effect is compositional: as borrowing domestic households increase their expenditure, non-tradable services expand to meet the demand. Tradable sectors, on the other hand, see their sales to domestic households increase, but the sales to rest of world contract as the foreign lenders temporarily cut expenditure. Thus, borrowing props up the non-tradable sectors of the economy at the expense of the tradables. By similar logic, the economies that lend see their tradables share expand.

Finally, I show that subsectors within manufacturing follow very different dynamics. As economies mature, both the aggregate manufacturing and its low-technology subsectors' shares initially increase and then contract – exhibiting the co-called 'hump-shaped' pattern. The high-technology manufacturing, on the other hand, exhibits no such 'hump'. Applying the decomposition to the two subsectors separately reveals the origin of the discrepancy: whereas the low-technology subsectors are mainly driven by the secular changes in sectoral demand, the high-technology manufacturing is primarily shaped by trade specialization.

The decomposition highlights the fact that in order to understand structural change in open economies we need to take seriously the patterns of specialization within manufacturing and countries' engagement in international borrowing and lending. With that in mind, I extend a closed economy model of structural change following Comin, Lashkari, and Mestieri (2021) in two ways. First, I model manufacturing as comprising of 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 à la Eaton and Kortum (2002). Second, households are forward looking and borrow and lend on international markets to smooth consumption subject to convex costs of imbalances. I calibrate the model and use it 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 manufacturing shares of virtually all economies in my sample. However, while trade specialization played an important role for a handful of economies, for others – including the United States – the main channel at play was, instead, borrowing. Inasmuch as large current account surpluses in China made borrowing in the rest of the world cheaper, this led to a global shift towards the production of non-tradables. In turn, I find that trade specialization was important for China's effect on the *composition* of global manufacturing, pushing economies towards the production of low-technology varieties. 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 evolved, increasingly favouring high-technology sub-sectors – automotive, electrical and machinery – which drew on resources from the low-technology subsectors. Thus, the 'miracle' industrialization hinged crucially on the interaction of trade liberalization releasing labour into the manufacturing, and shifting comparative advantage *within* it.

This paper is related to several strands in the literature. First – focusing on structural change – has mostly been analysed in a closed economy context. Ngai and Pissarides (2007) and Acemoglu and Guerrieri (2008) study the role of substitution across sectoral goods due to shifting relative prices (price effect), whereas Kongsamut, Rebelo, and Xie (2001), Boppart (2014), and Comin, Lashkari, and Mestieri (2021) focus on the role of changes in expenditure shares due to non-homotheticities in consumer preferences (income effect). Herrendorf, Rogerson, and Valentinyi (2021) and Garcia-Santana, Pijoan-Mas, and Villacorta (2021), in turn, emphasize the role of sectoral composition of investment in driving structural change. Recently, Huneeus and Rogerson (2020) 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. Instead, I use a model-free 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.

Meanwhile, structural transformation in an open economy received relatively less attention. A number of papers leverage calibrated models of trade to study the importance of different drivers of structural change. Uy, Yi, and Zhang (2013) and Kehoe, Ruhl, and Steinberg (2018) do so in the context of South Korea and United States. Świecki (2017) and a recent working paper by Sposi, Yi, and Zhang (2021), instead, study structural change in a large sample of economies and consider the operation of multiple exogenous drivers. The latter, moreover, document a novel stylised fact: increase in the variance in manufacturing shares over time. Both find that imposing autarky leads to the deterioration of the fit between the model and the data and that, therefore, openness matters for structural change.

In comparison, in this paper, I show that the effect of openness is comprised of two distinct mechanisms: trade specialization and international borrowing. While the idea of (de)-industrialization due to shifts in comparative advantage is as old as Ricardo, the quantitative importance of this mechanism, up until now, was unknown. In turn, the role of international borrowing in driving structural change – increasingly important in a world of tight financial integration – has up until now been overlooked altogether. The accounting decomposition allows me to measure the relative role of the two. I find that both margins are critical for understanding a drove of structural change dynamics.

To account for these forces, I develop a structural model with intra-industry specialization and imperfect international capital mobility. Here, I contribute to a considerable literature building on the original Eaton and Kortum (2002) quantitative Ricardian model. First, I develop a novel way of calibrating trade costs and sectoral productivities that only requires trade flow data as an input. This enables me to calibrate the model at a two-digit level of disaggregation and thus move beyond the aggregate manufacturing, and towards dynamics within it. Second, while endogenous borrowing is increasingly used in quantitative trade models, international capital is typically assumed to be perfectly mobile. 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 amenable to the 'hat-algebra' representation commonly used in this literature.

Finally, my analysis of the impact of China and industrialization in South Korea contributes to two well-established strands of literature. Much of the former has leveraged cross-regional heterogeneity in exposure to competition from China to identify impact (see Autor, Dorn, and Hanson (2016) for an overview). However, within-country cross-regional studies miss the country-level impact by construction.[2] In comparison, general equilibrium setup used in this paper gives rise to country-level estimates of impact. Modelling the operation of multiple channels at the same time, in turn, enables me to contrast the effects of competition from China, which mainly affected the composition of manufacturing, with the operation of the borrowing channel – the key driver behind the China-driven deindustrialization. Meanwhile, much of the analysis of the industrialization in South Korea has focused on the effect of industrial policies in promoting the expansion of heavy industries (see Lane (2022) for an overview). In this paper, I study the role of openness in driving South Korea's industrialization in a calibrated general equilibrium model, and discover the complementary roles of trade liberalization and shifts in sectoral productivities in shaping the process.

Outline The organization of this paper is as follows. In section 2, I develop an accounting 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 transformation in my sample, whereas in Section 6 I focus on the case studies of China and South Korea. Finally, Section 7 concludes.

2. Cross-regional studies identify the difference between affected and unaffected regions, but are silent on the general equilibrium effects common to both.

2 Accounting Decomposition

In this section, I show how to break down changes in manufacturing value added shares into three terms driven by secular changes in sectoral demand, trade specialization, and international borrowing, respectively. For ease of exposition, I begin by assuming that no intermediate inputs are used in production. I relax this assumption later on.

Derivation. Consider an economy i that produces goods in sector k, with nominal sales denoted as Y_{ik}. 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, Π_{jik} – the share of j's consumption of sector k goods originating in i (trade share) – captures where the agents source the goods from, α_{jk} – sectoral expenditure share – captures what goods the agents buy, and D_j – aggregate trade deficit – captures borrowing/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, the reverse is true for economies with $D_j < 1$. Finally, observe that in an economy with no intermediate inputs use, income is simply the sum of its sales across all sectors: $Y_j = \sum_k Y_{jk}$. Plugging all in,

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

Consider the total derivative of sectoral sales with respect to the full set of changes in trade shares, sectoral expenditure shares and aggregate trade deficits. It is convenient to use changes with respect to 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 $va_{ik} = Y_{ik}/\sum_k Y_{ik}$ is sector k's share of the value added. In Appendix A.1 I show changes in sectoral sales can be collected on the left hand side, such that

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

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

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

Interpretation. I interpret $\tilde{va}_{ik}(\tilde{\Pi})$ as capturing the effect of *trade specialization*:

$$\tilde{va}_{ik}(\tilde{\Pi}) = \sum_j \phi_{jik} \tilde{\Pi}_{jik} - \sum_n va_{in} \sum_j \phi_{jin} \tilde{\Pi}_{jin} + \sum_j \left(\phi_{jik} - \overline{\phi_{ji}} \right) \tilde{Y}_j(\tilde{\Pi}).$$

The direct effect (captured by the first two terms) is positive if either domestic or foreign households switch towards i as a supplier of sector k goods, *and* this effect is stronger than that in other sectors. Thus, its operation reflects specialization in production of given sectoral goods as compared to other producers and as opposed to production in other sectors. The indirect effect (captured in the last term), in turn, accounts for changes in countries' incomes due to shifting patterns of specialization, with the sign of the effect depending on the sector's exposure to a given market compared to the economy average. Sectors that are above average exposed to an economy that grew – expand.

I interpret $\tilde{va}_{ik}(\tilde{\alpha})$ as capturing the effect of *secular changes in sectoral demand*:

$$\tilde{va}_{ik}(\tilde{\alpha}) = \sum_j \phi_{jik} \tilde{\alpha}_{jk} - \sum_n va_{in} \sum_j \phi_{jin} \tilde{\alpha}_{jn} + \sum_j \left(\phi_{jik} - \overline{\phi_{ji}} \right) \tilde{Y}_j(\tilde{\alpha}).$$

The direct effect is positive if either domestic or foreign households switch their expenditures towards consumption of sector k goods. The indirect effect operates as before, this time reflecting changes in incomes that arise due to shifts in spending patterns. I label the contribution of this effect 'secular' as it encompasses the sweeping, long-term changes in sectoral consumption shares typically associated with development process.

Finally, $\tilde{va}_{ik}(\tilde{D})$ captures the effect of changes in countries' *international borrowing*:

$$\tilde{va}_{ik}(\tilde{D}) = \sum_j \left(\phi_{jik} - \overline{\phi_{ji}}\right) \tilde{D}_j + \sum_j \left(\phi_{jik} - \overline{\phi_{ji}}\right) \tilde{Y}_j(\tilde{D}).$$

Suppose home increases its borrowing, so that $\tilde{D}_i > 0$, and let k be non-tradable. Then, k is more exposed to domestic demand than an average sector in the economy: $\phi_{iik} = 1 > \overline{\phi_{ii}}$. Thus, the direct effect of borrowing is positive for non-tradables. In essence, international borrowing temporarily alters the sectoral composition of demand for domestically produced goods: as borrowing domestic households increase their expenditure, non-tradable services expand to meet the demand. Tradable sectors, on the other hand, see their sales to domestic households increase, but the sales to rest of world contract as the foreign lenders temporarily cut expenditure. Thus, borrowing props up the non-tradable sectors of the economy at the expense of the tradables. International lending has the opposite effect. Finally, the indirect effect now reflects changes in countries' incomes due to shifts in international borrowing.

Intermediate inputs. Use of intermediate inputs is readily accommodated in the analysis. In Appendix A.1 I show that breaking down the demand terms into final demand and intermediate inputs use across various sectors in j, $X_{jik} = X_{jik}^{FC} + \sum_n X_{jink}^{II}$, and further breaking down intermediate inputs use into a product of the trade share, intermediate inputs expenditure share, and sectoral sales such that $X_{jink}^{II} = \Pi_{jik}\beta_{jnk}Y_{jk}$ gives rise to a decomposition analogous to the one with no intermediate inputs, where the secular term of the decomposition now includes changes in both final and intermediate expenditure shares:

$$\tilde{va}_{ik} = \tilde{va}_{ik}(\tilde{\Pi}) + \tilde{va}_{ik}(\tilde{\alpha}, \tilde{\beta}) + \tilde{va}_{ik}(\tilde{D}). \qquad [1^*]$$

Note that the decomposition is model-free and relies on observable data alone. In the next section, I interpret the reduced-form terms of the decomposition using a structural model.

3 Model

In this section, I first outline a Ricardian model of trade with non-homothetic preferences and endogenous borrowing, and then use it to give a structural interpretation to the terms of the decomposition developed in the previous section. Two points on notation are in order.

Sectors: there are I countries and K sectors in the model. In what follows, 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. When aggregated, these produce aggregate manufacturing bundles for final and intermediate use. Due to this layered structure, I will use index $s \in \{P, M, S\}$ when agents make decisions that involve aggregate sectors, and $m \in \{2, \ldots, K-1\}$ when considering choices over different types of manufacturing. When discussing production, budgets and market clearing where no such distinction is necessary, I will be indexing sectors by $k, n \in \{1, \ldots, K\}$.

Timing: the model is dynamic, where production and consumption evolve subject to changes in six types of exogenous processes, which include sectoral productivities, trade costs, household impatience, preference and production function shifters, and country populations. Households have perfect foresight of the future evolution of these variables. However, with the exception of the level of household expenditure, all variables are determined within a period. I thus suppress time indices where possible.

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

$$y_{ik}(z) = a_{ik}(z) \left(\frac{l_{ik}(z)}{\omega_{ikl}} \right)^{\omega_{ikl}} \left(\frac{m_{ik}(z)}{1-\omega_{ikl}} \right)^{1-\omega_{ikl}}, \quad \text{where} \quad \omega_{ikl} \in [0,1]. \tag{1}$$

Intermediate input bundle, m_{ik}, is comprised of inputs from K sectors, which are combined using a nested constant elasticity of substitution production structure. The outer nest combines inputs from three aggregate sectors:

$$m_{ik}(z) = \left(\sum_s \omega_{iks}^{\frac{1}{\sigma_s}} m_{iks}(z)^{\frac{\sigma_s - 1}{\sigma_s}} \right)^{\frac{\sigma_s}{\sigma_s - 1}}, \quad \text{where } s \in \{P, M, S\}. \tag{2}$$

The inner nest combines inputs from subsectors of manufacturing:

$$m_{ikM}(z) = \left(\sum_m \omega_{ikm}^{\frac{1}{\sigma_m}} m_{ikm}(z)^{\frac{\sigma_m - 1}{\sigma_m}} \right)^{\frac{\sigma_m}{\sigma_m - 1}}, \quad \text{where } m \in \{2, \dots, K-1\}. \tag{3}$$

Firm profits satisfy:

$$\pi_{ik}(z) = p_{ik}(z) y_{ik}(z) - w_i l_{ik}(z) - \sum_{n \in K} P_{in} m_{ikn}(z). \tag{4}$$

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

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

$A_{ik} > 0$ reflects the absolute advantage of country i in producing sector k goods: higher A_{ik} means that high productivity draws for varieties in i, k are more likely. $\theta_k > 1$ is inversely related to the productivity dispersion. If θ_k is high, productivity draws for any one country are more homogeneous.[3] γ is introduced to simplify the notation in the rest of the model.[4]

Varieties can be shipped abroad with an iceberg cost τ_{ijk} (τ_{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,

$$Q_{ik} = \Big(\int_0^1 q_{ik}(z)^{(\xi-1)/\xi} dz \Big)^{\xi/(\xi-1)}, \quad \text{where} \quad q_{ik}(z) = \sum_{j \in I} q_{ijk}(z). \tag{5}$$

3. 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, θ_k operates like trade elasticity in this model.

4. Γ stands for the gamma function. Absent normalization, γ appears in the price equations as a shifter common across economies. The simplification is thus without loss of generality. I assume that $\theta_k > \xi - 1$. As long as this inequality is satisfied, the value of the parameter ξ does not matter for the analysis and need not be estimated.

Final goods producer profits satisfy:

$$\pi_{ik} = P_{ik}Q_{ik} - \sum_{j\in I} \int_0^1 \tau_{ijk} p_{jk}(z) q_{ijk}(z) dz. \tag{6}$$

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, Lashkari, and Mestieri (2021). In particular, household aggregate consumption C_i is an implicit function of consumption of sectoral bundles:

$$\sum_s \Omega_{is}^{\frac{1}{\sigma_s}} \left(\frac{C_{is}}{C_i^{\epsilon_s}}\right)^{\frac{\sigma_s-1}{\sigma_s}} = 1, \quad \text{where } s \in \{P, M, S\}, \tag{7}$$

and where manufacturing consumption C_{iM} satisfies

$$C_{iM} = \left(\sum_m \Omega_{im}^{\frac{1}{\sigma_m}} C_{im}^{\frac{\sigma_m-1}{\sigma_m}}\right)^{\frac{\sigma_m}{\sigma_m-1}}, \quad \text{where } m \in \{2, \ldots, K-1\}. \tag{8}$$

Lifetime utility of households is as follows:

$$U_i = \sum_{t=0}^{\infty} \rho^t \phi_{it} \ln C_{it}, \tag{9}$$

where ρ is the discount factor, ϕ_{it} is the impatience shifter,[5] and C_{it} is per-period household utility defined in equation (7).

Each household is endowed with one unit of labor which it supplies inelastically, such that labor income of each household in i is w_i. Households also receive a rebate T_{it}, to be defined shortly. There are no other sources of income, but households can engage in international borrowing and lending through Arrow-Debreau bonds, which cost μ_t, and pay out a unit in the next period. Since all economies interact in one international market and

5. The impatience shifters capture all the reasons that economies might want to lend or borrow aside from the consumption smoothing motive, such as the cross-country differences in demographics, risk-profiles, or development of the financial system that can give rise to international capital flows.

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}. Thus, the period budget constraint of households is as follows:

$$E_{it} + \mu_{t+1} B_{it+1} + \frac{b}{2} d_{it}^2 w_i = w_i + B_{it} + T_{it}, \quad d_{it} = \frac{E_{it} - w_i}{w_i}, \tag{10}$$

where $E_{it} = \sum_s P_{ist} C_{ist}$ is the 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 sale of bonds which mature next period.

There are many impediments to international capital flows, such as risk of default or informational frictions. The convex adjustment costs capture, in reduced form, the idea that further deviation of expenditure from income, d_{it}, becomes increasingly costly, while remaining highly tractable. Setting $b = 0$ restores frictionless asset markets as in Eaton et al. (2016). The limit case of b approaching infinity, instead, rules out international borrowing and produces a static environment as in Eaton and Kortum (2002). When b takes an intermediate value, 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 economies, taking into account the transportation costs:

$$y_{ik}(z) = \sum_{j \in I} \tau_{jik} q_{jik}(z). \tag{11}$$

Goods markets clear when the final producer's sectoral bundles output equals the final and intermediate demand for sectoral bundles:

$$Q_{ik} = L_i C_{ik} + \sum_{k \in K} \int_0^1 m_{ik}(z) dz. \tag{12}$$

Labor demand needs to be satisfied by domestic labor supply:

$$L_i = \sum_{k \in K} \int_0^1 l_{ik}(z) dz. \tag{13}$$

Bonds markets clear in all periods:

$$\sum_{i \in I} L_{it} B_{it} = 0. \tag{14}$$

Finally, prices are normalized such that

$$\sum_{i \in I} L_i P_{ik} C_{ik} = 1. \tag{15}$$

Definition 1: for a given evolution 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}, μ_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 (1) - (3) and maximize profits (4); (ii) final good producers produce according to (5) and maximize profits (6); (iii) households maximize their utility (7) - (9) subject to per-period budget constraints (10); (iv) all markets clear: (11) – (14); and (v) normalization holds: (15).

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, for ease of exposition I suppress the input-output structure. See Appendix A.3 for the derivations, including the model with a fully flexible input-output structure.

First, trade shares respond to changes in costs of production vis-à-vis the competitors:

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

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, in short, naturally gives rise specialization subject to comparative advantage.

Second, final expenditure shares respond to preference shifters, as well as to changes in relative prices and aggregate consumption, which capture the operation of price- and income effects:

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

Note that if $\sigma_s < 1$, then price increase in s compared to other aggregate sectors leads to higher expenditure shares. Likewise, expenditure share of sector s increases if the aggregate consumption increases, and the expenditure elasticity of sector s is higher than the average expenditure elasticity in i. In turn, allocation of spending within the 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.

Finally, households choose their aggregate trade deficits subject to their intertemporal optimization. If countries' net borrowing is small relative to their income ($D_{it} \approx 1$), then

$$\tilde{D}_{it} = \tilde{E}_{it} - \tilde{w}_{it} \approx \frac{\tilde{\phi}_{it} - \tilde{\phi}_t}{1+b} + \frac{b\tilde{w}_{it}}{1+b} + \frac{\tilde{e}_{it} - \tilde{e}_t}{1+b} - \tilde{w}_{it}, \tag{16}$$

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: $b \to \infty$. Then, $\tilde{E}_{it} = \tilde{w}_{it}$, agents spend exactly what they earn, and $\tilde{D}_{it} = 0$. If, instead, international borrowing is frictionless ($b = 0$), then aggregate trade deficits respond to changes in incomes – the consumption smoothing motive, to impatience shifters, and to the shifts in the average expenditure elasticity. A higher average expenditure elasticity today increases contemporaneous returns to expenditure, and thus encourages borrowing.

In short, the terms of the accounting decomposition [1*] summarize the effects of movements in trade shares, expenditure shares and aggregate trade deficits which are brought into motion by distinct mechanisms in the model. Thus, the three terms of the decomposition [1*] comprise distinct channels of structural change.

4 Implementation

In this section, I discuss the calibration of the structural model developed in Section 3 and the implementation of the decomposition [1*] in the data. I begin by describing the data.

4.1 Data Description

I use the World Input Output Database (WIOD) as a source of data on annual intermediate inputs use which varies by country and sector of both origin and destination, X^{II}_{jinkt}, and consumption series which vary by destination, sector and country of origin: X^{FC}_{jikt}.[6] Furthermore, I obtain the data on country-level population and sectoral price deflators from the WIOD Socio-Economic Accounts. In order to extend the sample length, I merge the Long Run (1965-2000) and 2013 Release (1995-2011) vintages of the dataset.

The dataset covers twenty five economies and an aggregate rest of the world region over years 1965 to 2011. I restrict my analysis to twenty economies, and group the remaining five together with the rest of the world. The sectoral coverage is at a two digit level and is subject to ISIC rev. 3.1 industrial classification. There are twenty three sectors in the data, thirteen of which are tradable: agriculture, mining, and eleven sectors that produce different manufacturing goods. I group agriculture and mining into one primary goods sector, and aggregate the ten services sectors into one. I keep manufacturing sectors disaggregated. The data description, cleaning and the construction of variables can be found in Appendix B.1

4.2 Implementing the Decomposition

To break down changes in sectoral shares into the operation of different channels, I first multiply both sides of the decomposition [1*] by the beginning of the period value added shares to obtain changes measured in percentage points. Second, I use 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*]:

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

6. See Woltjer, Gouma, and Timmer (2021) for the dataset construction.

Note that, compared to [1*] which holds exactly, decomposition [1] is a first-order approximation. The imprecision arises from the absence of interaction terms. These can be ignored in decomposition [1*], as the changes considered are infinitesimal. In the meantime, the empirical counterparts are not, leading to non-zero second- and higher-order terms. Incorporating interaction terms in [1] yields an exact match with the data. In practice, however, annual changes are small enough to ensure a remarkably close fit between the left and right hand sides of expression [1], with correlation of 0.997. Thus, in the following sections, I apply the decomposition to the first order approximation terms Δva_{im}^{FO}, as opposed to the changes in sectoral shares in the data. Finally, to economize on notation, in the rest of the paper I will be denoting $\Delta va_{im}(\Delta\alpha, \beta)$ as Δva_{im}^{S} for secular changes in sectoral demand, $\Delta va_{im}(\Delta\Pi)$ as Δva_{im}^{R} for (Ricardian) specialization, and $\Delta va_{im}(\Delta D)$ as Δva_{im}^{B} for international borrowing.

4.3 Time-Invariant Parameter Values

There are seven time-invariant objects in the model: $\{\epsilon_P, \epsilon_M, \epsilon_S, \sigma_s, \sigma_m, \theta, b\}$.[7] I set the first four following Comin, Lashkari, and Mestieri (2021), who estimate a range of values for each. I pick $\epsilon_P = 0.11$, $\epsilon_M = 1$, $\epsilon_S = 1.21$ and $\sigma_s = 0.5$ 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, identification strategies and samples, consistently finding estimates below one. I set $\sigma_m = 0.38$ following his estimate for WIOD sample. I set trade elasticities, θ_k, following Imbs and Mejean (2017).

Parameter b, 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 b that minimizes the distance between the expenditure changes under no impatience shifters and that in the data. The procedure yields $b = 7.5$ (see Appendix B.2 for details).

7. While ρ, γ and ξ feature in the model setup, they are not necessary for solving the model.

4.4 Calibration of the Shocks Series

I rewrite the model in hat-algebra form (see Appendix A.4). As a result, simulations use the changes of exogenous variables from level, $\hat{x} = x_{t+1}/x_t$. Moreover, the model retains the key property of Eaton and Kortum (2002) setup: appropriately calibrated, it generates paths of endogenous variables that match those in the data. Moreover, since the model now evolves as a function of changes in exogenous variables, I will refer to the 'hat' objects as 'shocks'. $\hat{L} = L_{t+1}/L_t$ can be obtained for directly from the data. I discuss the calibration of $\hat{A}, \hat{\tau}, \hat{\phi}, \hat{\Omega}, \hat{\omega}$ in turns.

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

$$\hat{\Pi}_{jikt} = \left(\frac{\hat{c}_{ikt}\hat{\tau}_{jikt}}{\hat{A}_{ikt}\hat{P}_{jkt}} \right)^{-\theta_k}. \tag{17}$$

However, trade share data is insufficient to uniquely identify trade costs and productivities.

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: $\hat{\tau}_{jikt} = \hat{\boldsymbol{\tau}}_{jikt}\hat{\upsilon}_{jikt}$. Then, equation (17) can be rewritten as a product of exporter fixed effect $e_{ikt} = (\hat{c}_{ikt}/\hat{A}_{ikt})^{-\theta_k}$, importer fixed effect $m_{jkt} = \hat{P}_{jkt}^{\theta_k}$, symmetric trade cost decline $\hat{\boldsymbol{\tau}}_{jikt}^{-\theta_k}$ and an error term $\varepsilon_{jikt} = \hat{\upsilon}_{jikt}^{-\theta_k}$, such that

$$\hat{\Pi}_{jikt} = m_{jkt} e_{ikt} \hat{\boldsymbol{\tau}}_{jikt}^{-\theta_k} \varepsilon_{jikt}. \tag{18}$$

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

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

Together with destination and origin fixed effects by sector and year, these can then be used to estimate the model. Note that this method amounts to requiring that estimated asymmetric components of trade shocks have, on average, zero impact on trade shares.[8]

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 current context, 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 513 observations with $\hat{\Pi} > 10^3$ and 233 with $\hat{\Pi} > 10^6$. In contrast, the 90^{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.[9] 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^{th} percentile of the dependent variable for a given sector and year as the cutoff. However, results remain virtually unchanged if 90^{th} or 97.5^{th} percentile cutoff are used instead.

Once the model is estimated, I use the importer fixed effect to back out model-consistent price deflators: $\hat{P}_{ikt} = m_{ikt}^{1/\theta_k}$. 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 $\hat{c}_{ikt}$ to back out sectoral productivity and trade cost shocks:

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

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

I report the summary statistics of trade cost and productivity shock estimates in Ap-

8. 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.

9. 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.

pendix B.4. I find that trade costs have declined over the period, by 37% on average. However, trade costs for China, Taiwan, South Korea, Brazil and India have declined more rapidly, more than halving over the period. In contrast, United States saw only a 20% decline. South Korea saw the most rapid productivity growth over the period, triple that of the United States; Taiwan and Brazil saw the second and third biggest increases.

Preferences and production function shocks. The model in changes links changes in endogenous variables to their levels in 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 data on final expenditure shares, household expenditure and 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.

4.5 Model Fit

While the model can be inverted to obtain a set of restrictions on exogenous shocks that ensure exact fit between the model and the data, these restrictions are insufficient to identify the shock series uniquely. In turn, different additional identifying assumptions give rise to different shock series estimates. For example, instead of using the PPML procedure, it is common to identify trade cost and productivity series by requiring that the model-generated sectoral price deflators equal those in the data. Likewise, calibration of the model with perfect capital mobility, $b = 0$, yields impatience shocks that differ from the ones calibrated with $b > 0$. Which ones should be used? In this subsection, I use the fit between the partial specification of the model and the data to select between different shock series estimates. Specifically, I simulate the model with one type of shocks active at a time and compare it with the moments in the data. The moments I use are the changes in sectoral value added shares and their breakdown subject to decomposition [1]. Results can be seen in Table 1.

The first six columns record the correlation between the data and the simulation with column shock series subject to baseline calibration, and all other shock series set to 1. Each shock series produces a correlation of between 0.24 and 0.55 with the changes in sectoral shares in the data.[10] Furthermore, individual shock series show a better fit with those 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 0.44 and 0.56. The borrowing terms in the 'only impatience' counterfactual yield a correlation of 0.69, whereas the secular terms in the preference and production shifters specifications show correlations of 0.24 and 0.55 with that in the data.

In columns (7) and (8) I present the correlations between the objects in the data and in partial specifications that use sectoral price deflators to identify trade cost and productivities. The deterioration of the fit, compared to the baseline, is practically uniform. Crucially, the correlation of the 'productivities only' specification with the trade specialization term decreases to mere 0.08. In other words, productivities estimated using price deflators have essentially no bearing on the specialization patterns observed in the data.

Finally, column (9) reports the fit of the impatience shocks series estimated under perfect capital mobility. Note that the correlation between the borrowing terms in the data and the simulation that uses these shocks is 0.14. 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 these economies with extreme patience, which, when modelled alone, results in large counterfactual surpluses in the fast-growing economies. In comparison, the model with financial frictions rationalizes the lack of borrowing through its high costs, resulting in a better fit to the data.

4.6 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. To study the relative importance of different exogenous drivers, I simulate the model with one type of shocks active at a time. Adding up the results of such simulations gives rise to a decomposition of

10. The exception is population shocks, which have no predictive power.

	τ	A	ϕ	L	Ω	ω	τ^P	A^P	ϕ^{fc}
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Δva	0.28	0.29	0.27	-0.02	0.24	0.55	0.21	0.20	0.26
Δva^S	0.32	0.35	0.03	-0.07	0.28	0.62	0.25	0.32	0.20
Δva^R	0.59	0.44	0.20	0.15	0.21	0.02	0.40	0.08	0.05
Δva^B	0.30	0.04	0.69	0.00	0.11	-0.16	0.18	0.01	0.14

Table 1: Fit of the Shock Series

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, in turn, uses impatience shocks estimated in a specification with free capital flows ($b = 0$).

changes in sectoral shares into contributing shock series:

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

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: $\hat{x} = 1$.[11] In turn, to learn which fundamental drivers are responsible for the operation of each of the channels of structural change, I apply the decomposition [1] to the simulated series. Collecting the results across the simulations then enables me to break down the operation of individual channels into the contribution of fundamental drivers.

Finally, to obtain the decomposition at longer time horizons I add up the results in [1] and [2] across years. For changes in the aggregate manufacturing share, I sum across the subsectors of manufacturing.

11. Note that summing up the results of these simulations gives rise to a first order 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. Simulation with all shocks active restores the exact match.

5 Results

In this section, I apply the results from Sections 2, 3 and 4 to study the dynamics of structural transformation. In Section 5.1 I discuss the relative importance of mechanisms and structural shocks in driving manufacturing shares in my sample. In Section 5.2, I focus on the origins of cross-country heterogeneity in patterns of industrialization. Finally, in Section 5.3 I discuss the heterogeneous patterns across the subsectors of manufacturing.

5.1 Drivers of Manufacturing Shares

Figure 1 below presents the decomposition [1], applied to the aggregate manufacturing shares between years 1965 and 2011.

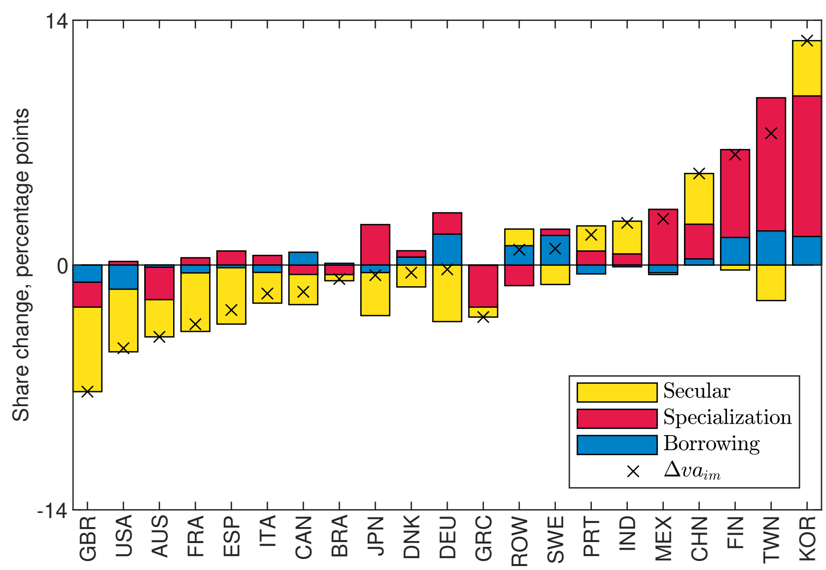

Figure 1: Mechanisms of Changes in Manufacturing Value Added Shares

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].

First, note that the secular component, capturing changes in final and intermediate expenditure shares, is the key driver behind the changes in aggregate manufacturing shares in this period. To quantify this statement, I compute the relative contribution of the components of decomposition [1] to the observed change in manufacturing shares as follows:

$$RC^X = \frac{\sum_i |\Delta va_{im}^X|}{\sum_X \sum_i |\Delta va_{im}^X|}, \quad \text{where} \quad X = \{R, S, B\}.$$

I find that the secular component accounts for 60% of the observed change in aggregate manufacturing shares. In turn, trade specialization and borrowing terms contribute 23% and 17%, respectively. In other words, not only does openness matter, but, on top of that, trade in goods and trade in assets play distinct, quantitatively important roles, and thus should not be ignored when modelling structural change.

Next, I turn to the structural shocks behind the mechanisms of structural change discussed in the previous segment. To do so, I simulate the model with one set of shocks subject to baseline calibration, and all other shocks set to 'no change', i.e. $\hat{x} = 1$. I repeat this exercise for each of $\hat{A}, \hat{\tau}, \hat{\phi}, \hat{\Omega}, \hat{\omega}, \hat{L}$, and record the simulated changes in sectoral shares. I plot the results in Figure 2.

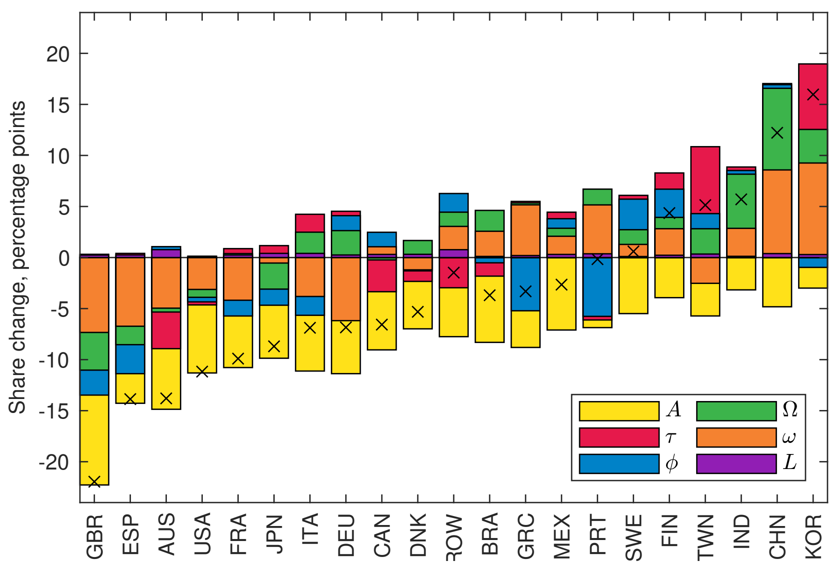

Figure 2: Structural Drivers of Manufacturing Value Added Shares

Note: The crosses mark the change in the manufacturing value added share between 1965 and 2011. The bars correspond to the changes in manufacturing value added shares in simulations with one type of shocks active at a time.

Computing the relative contribution as before, I find that the most important exogenous driver are productivity shocks, accounting for 33% of the changes in aggregate manufacturing shares. Production and preference shifters are the second and third in importance, explaining 27% and 14% of the change respectively. Impatience and trade cost shocks account for the remaining 12% and 11%. The contribution of changes in population is negligible.

Finally, I apply the decomposition [1] to the simulated series to see which structural shocks are responsible for the operation of each of the mechanisms. The results can be seen in Table 2 (also see Figure C.1 in Appendix C.1). In line with the analysis in Section 3, I find that trade specialization is primarily driven by changes in sectoral productivities and trade costs. Changes in these series affect the relative costs of sourcing from different destinations, and, therefore, patterns of specialization. Note, additionally, that impatience shocks, too, matter for specialization. Their role is mediated via the changes in cost of labour: an economy that borrows experiences a temporary boom which raises its wages, and, through them, the price of its exports. As a result, some of its customers switch towards alternative suppliers. The secular channel, in turn, is driven primarily by 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, preference and production function shifters drive changes in sectoral expenditure shares that are unrelated to changing prices and incomes. Finally, the borrowing term is due to two factors: changing productivities and impatience shocks. The former render economies richer, which affects the saving behavior, whereas the latter capture changing motives for saving that go beyond the consumption smoothing.

	A	τ	ϕ	Ω	ω	L
Δva	33	11	12	14	27	2
Δva^S	43	6	1	16	33	1
Δva^R	24	47	9	5	8	7
Δva^B	38	6	45	3	5	3

Table 2: Contribution of Shock Series

Note: The table presents the relative contribution of shock series (columns) to objects in the data (rows). To measure relative contribution of shock series 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.

5.2 Cross-Country Heterogeneity

It is clear from Figure 1 that both trade specialization and international borrowing are important for explaining the cross-country heterogeneous in patterns of industrialization. To make this statement concrete, notice first that one would expect similar compositional dynamics in economies at similar levels of development: their income levels should imply similar composition of consumption baskets, their comparative advantage is likely to be centered on similar sectors, and, they should find themselves at the same end of global capital flows. Thus, to study cross-country heterogeneity in patterns of structural change, I split my sample into two equally sized groups on the basis of their GDP per capita in 1965. For each of the groups, I break down the the change in the aggregate manufacturing share compared to the group average into a sum of de-meaned components of decomposition [1]:

$$\Delta va_{im} - \overline{\Delta va_m} = \Delta va_{im}^R - \overline{\Delta va_m^R} + \Delta va_{im}^S - \overline{\Delta va_m^S} + \Delta va_{im}^B - \overline{\Delta va_m^B},$$

and compute the relative contributions of each term. The results can be seen in Table 3.

	Lower Income	Higher Income
Secular	56	46
Specialization	26	27
Borrowing	18	27

Table 3: Relative Contributions to De-meaned Changes in Manufacturing Shares

Note: Values in percentage points. 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.

Observe that secular changes in sectoral demand, although still the primary contributor, matter less for heterogeneity than for overall changes in manufacturing shares. Instead, around half of the dynamics is now due to trade specialization and international borrowing.

A related point is made in Sposi, Yi, and Zhang (2021), who document the *increase* in variance of the logarithm of manufacturing shares over time and argue that this is an open economy phenomenon: the authors calibrate a multi-country, open economy model of structural change, and show that a counterfactual simulation with countries in autarky shows no such increase. To shed light on the open economy drivers of this pattern, I use the decomposition [1] to break down the evolution of manufacturing shares into contributions of the secular, specialization, and borrowing terms, and then plot the variance of the logarithm of the resultant series. Results can be seen in Figure 3.

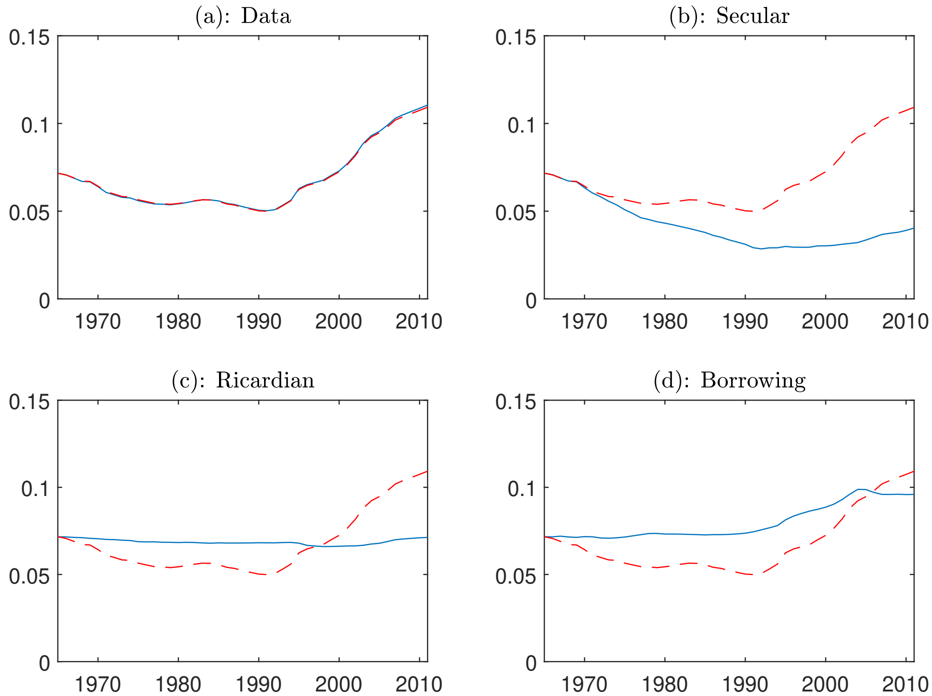

Figure 3: Industry Polarization by Mechanism

Note: Red dashed line in all panels represents the unconditional variance of the logarithm of manufacturing value added shares in my sample in a given year. The blue lines represent, respectively, the variance of the logarithm of manufacturing shares computed as $va^X_{im,T} = va_{im,t} + \sum_{s \in \{1,..,T\}} \Delta va^X_{im,t+s}$ for $X \in \{S, R, B\}$. When all three components are added jointly (Panel (a)), the series tracks the data by construction.

I find that most of the polarization is due to the borrowing channel. In turn, trade specialization played no role, and secular forces pushed against industry polarization. Note that this is in no contradiction to the results earlier in this section: both secular forces and trade specialization matter for heterogeneity, but not more so today than previously. However, international borrowing did increase between 1965 and 2011, driving industry polarization.

Finally, Figure 1 can shed light on industrialization experiences of individual economies. For example, most of the change in manufacturing shares in Taiwan and South Korea, two economies with the highest industrialization rates between 1965 and 2011, can be attributed to trade specialization. This occurred during a time of deindustrialization for most economies, highlighting the transformative power of export-led industrialization. Likewise, losses in comparative advantage contributed to two of the most rapid deindustrialization experiences in my sample – those of the United Kingdom and Australia. In turn, international borrowing channel is the sole reason high-income, surplus economies like Sweden and Finland experienced an increase in manufacturing shares during this period. Similarly, Germany's ability to maintain a relatively high manufacturing share despite its high income can be credited to its status as a lender. Contrast this with the United States and the United Kingdom, where aggregate trade deficits have acted to speed up the process of deindustrialization.

5.3 Cross-Sector Heterogeneity

It is common to treat manufacturing as one homogeneous sector. However, it is unlikely that sectors such as textiles behave very similarly to the electrical equipment production; or that minerals production is responding to the same drivers as the automotive industry. In this subsection, I investigate the heterogeneity in sectoral dynamics within manufacturing.

Following Herrendorf, Rogerson, and Valentinyi (2013), I first find the best quadratic fit between the countries' manufacturing shares and log-GDP per capita. However, instead of treating manufacturing as homogeneous, I break it up into two sub-sectors: low-technology (LT) and high-technology manufacturing (HT). Results can be seen in Figure 4.

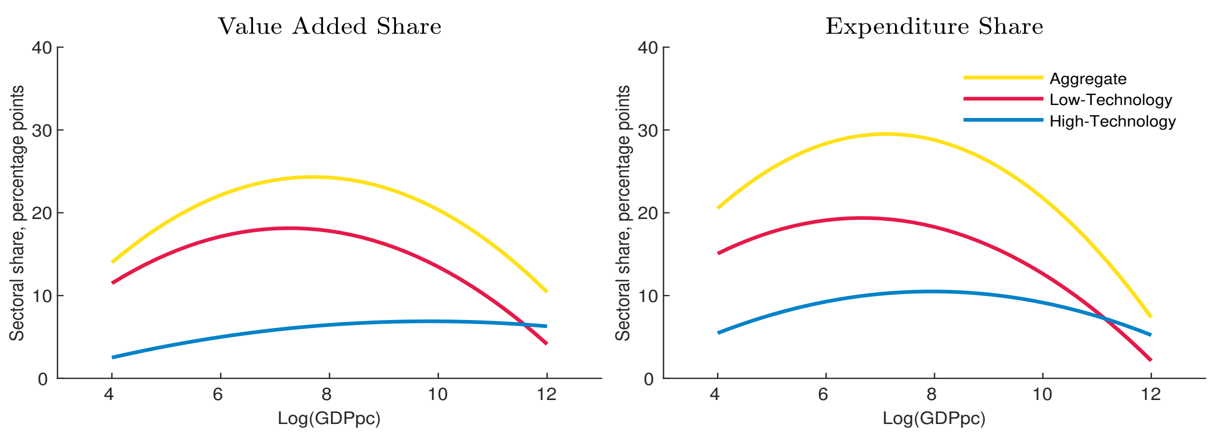

Figure 4: Structural Change within Manufacturing

Note: Panels present the fitted quadratic relationship between log-GDP per capita and the sectoral share.

First, note that both the aggregate and the low-technology manufacturing shares exhibit the so-called 'hump-shaped' pattern. Economies initially industrialize, and then undergo deindustrialization, as they develop. At the same time, however, the share of high-technology subsectors essentially flattens out as incomes grow. Moreover, income is only a weak predictor of high-technology manufacturing shares, with the R^2 of the quadratic relationship of 0.06. On the other hand, final expenditure shares on both low- and high-technology manufacturing exhibit a 'hump'. Thus, while households eventually switch out of high-technology manufacturing expenditure, this does not feed through into the production structure of the economies. What, then, determines the relative size of the high-technology subsectors?

To address this question, I repeat the decomposition exercise for the two subsectors. Results can be seen in Figure 5 (see Figure C.2 in Appendix C.1 for industry-level results).

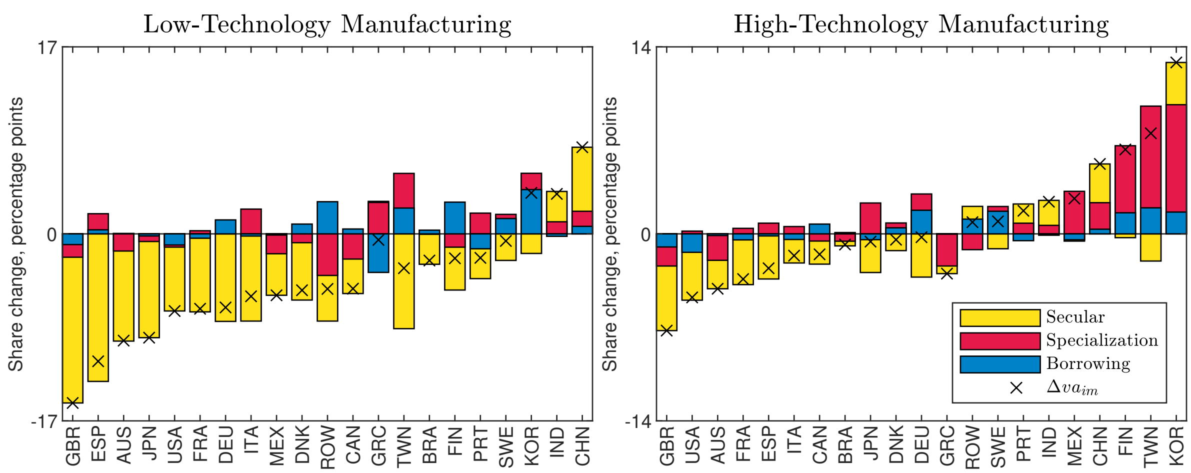

Figure 5: Mechanisms of Structural Change across Sectors

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].

The figure reveals stark heterogeneity in the patterns of industrialization between the two. For low-technology manufacturing, secular forces are the predominant force and, in virtually all cases, cause deindustrialization. For high-technology manufacturing, on the other hand, secular forces are no longer the most important driver; instead, their role is comparable to that of trade specialization. Furthermore, whereas low-technology manufacturing shares displayed a global trend, high-technology manufacturing shares, instead, diverged, with a small subset of economies increasingly dominant.

6 Case Studies

In the previous section, I argued that modelling intra-industry specialization and international borrowing and lending is critical for understanding structural change in an open economy. In this section, I use this insight 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.

6.1 The rise of China

Between 2000 and 2011, China's economy tripled in size, jumping the ranks from seventh 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. How did this growing presence affect manufacturing industries across the globe?

To answer this question, 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 shock series relating to China, in turn, are calibrated so that China remains 'frozen in time' (see Appendix B.5 for details). The difference between this specification and the data, which I refer to as 'China on', isolates the effect of China on manufacturing shares around the world. The results can be seen in Figure 6.

First, note that, between 2000 and 2011, China did, in fact, cause a decline in manufacturing shares around the world, causing the manufacturing share in an average economy to contract by 0.36 percentage points (contributing 18% of the change in manufacturing shares). Note that, at the time, Chinese economy constituted mere 3.5% of the global GDP. In other words, its effect went well beyond what could be suggested by its size.

Next, I turn to dissecting the aggregate 'China effect' into mechanisms and structural drivers. Results can be seen in Figure 7. First, note that trade specialization was the key channel for China-driven deindustrialization. However, much of this effect was concentrated in a handful of economies: Australia, Brazil, Canada, and India. For the others – including the United States – the main channel at play was, instead, borrowing. China ran large

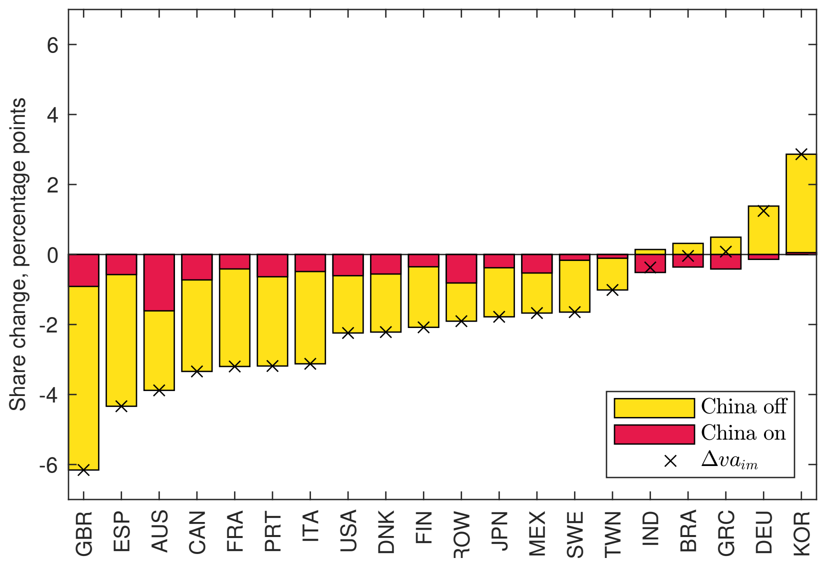

Figure 6: China-driven De-industrialization

Note: The crosses mark the changes in manufacturing shares in the 'China on' counterfactual, 2000-2011. The colored bars correspond to the components of decomposition [1] applied to 'China on' counterfactual.

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, ultimately from China. Breaking up the operation of channels into contributing shocks lends further insights. For example, Panel (c) shows that the trade specialization channel was responding, first and foremost, to changes in Chinese sectoral productivities. Declines in trade costs were important as well, but to a lesser degree. Note that this account adds nuance to the received wisdom regarding the 'China shock', which typically posits that the declining costs of trade with China meant deindustrialization due to the loss of comparative advantage. Instead, I show that, first, for many economies, it was China-induced borrowing that played the primary role, and second, that inasmuch as economies lost comparative advantage in manufacturing to China, much of it was a function of evolving productivities in China since the entry into the WTO, as opposed to declining trade costs.

Next, I turn to analysis at the level of individual subsectors. First, as before, I break down manufacturing into low-technology and high-technology subsectors and repeat the exercise. Results can be seen in Figure 8. I find that China has caused a decline in both

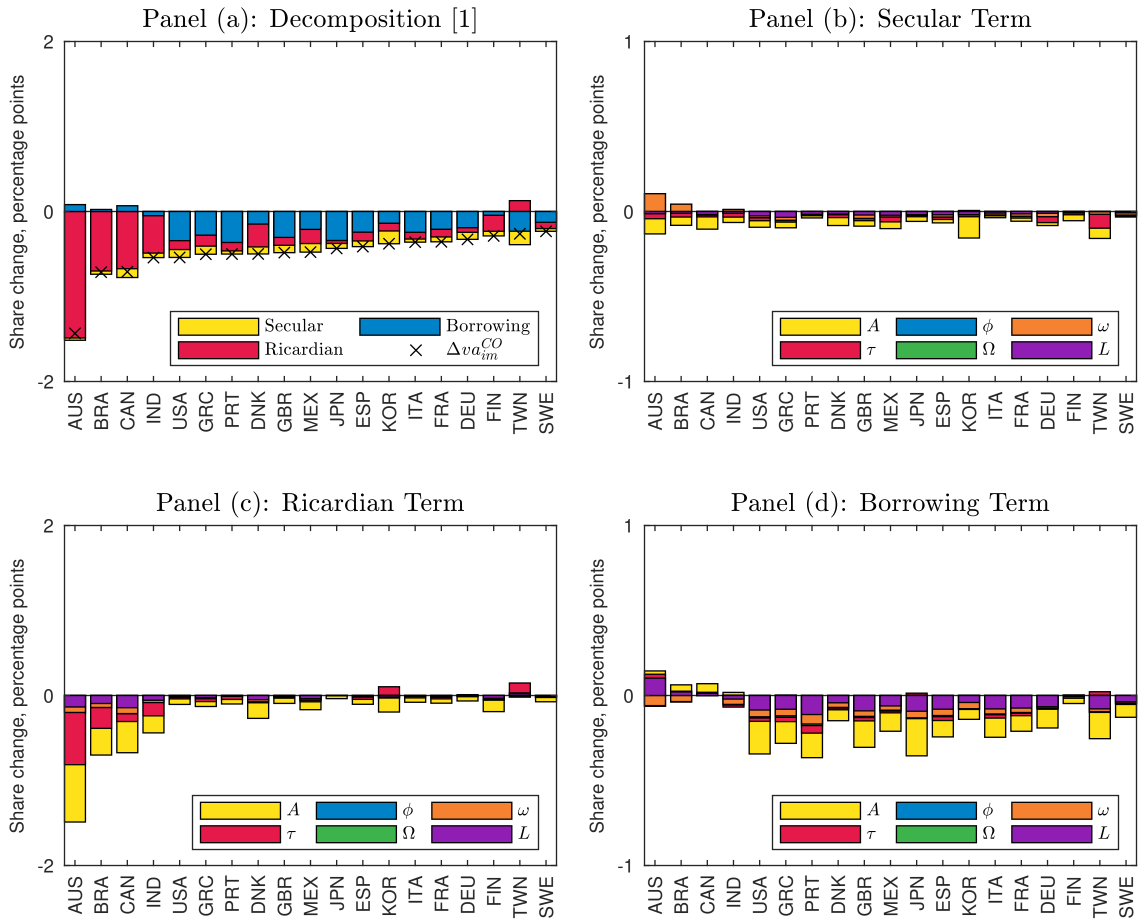

Figure 7: China-driven De-industrialization by Shock

Panel (a): The crosses mark the changes in manufacturing shares in the 'China on' counterfactual between years 2000 and 2011. The colored bars correspond to the components of decomposition [1] applied to 'China on' counterfactual. *Panels (b)-(d)*: Coloured bars correspond to contribution of individual shock series, marked in the legend, to the components of decomposition [1] applied to the 'China on' counterfactual.

low-technology and high-technology manufacturing shares in most economies. However, surprisingly, the effects in the high-technology manufacturing were larger – at 33% of the observed change. Industry-level analysis in C.3 in Appendix C.2 locates much of this effect in a single subsector – electrical equipment.

In Figure 9, I show that China-induced decline in electrical equipment shares was mostly due to the trade specialization channel which, in turn, was driven by the evolution of sectoral productivities – as China's productivity profile has evolved, it put pressure on China's competitors. Indeed, close competitors in the electrical equipment industry – Finland, Sweden,

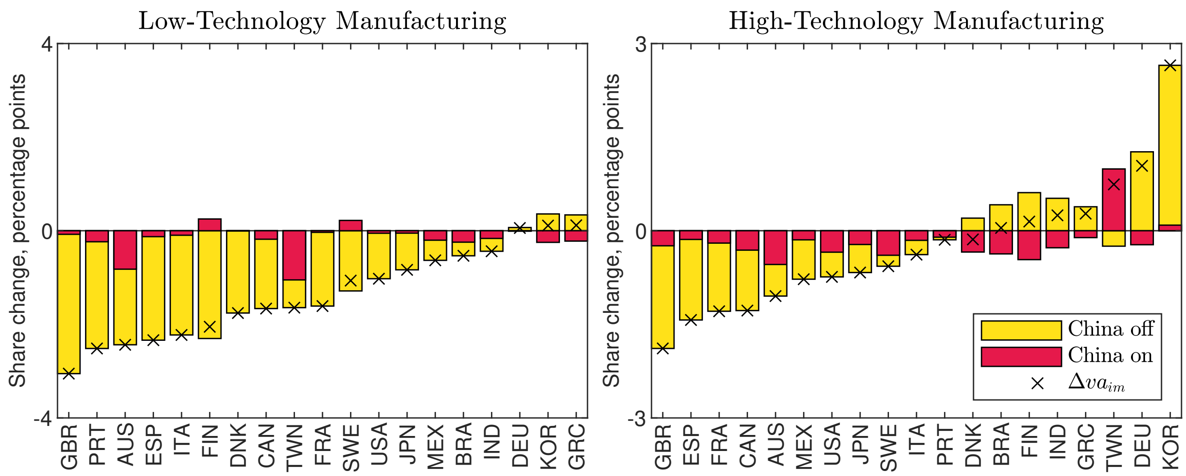

Figure 8: China-driven De-industrialization within Manufacturing

Note: The crosses mark the changes in manufacturing shares in the 'China on' counterfactual, 2000-2011. The colored bars correspond to the components of decomposition [1] applied to 'China on' counterfactual.

Germany, and Denmark – suffered the biggest declines. Likewise, trade cost declines have led to further losses in the electronics shares around the world. The two exceptions from this pattern are South Korea and Taiwan, who have benefited from close proximity with China and expanded access to its markets.

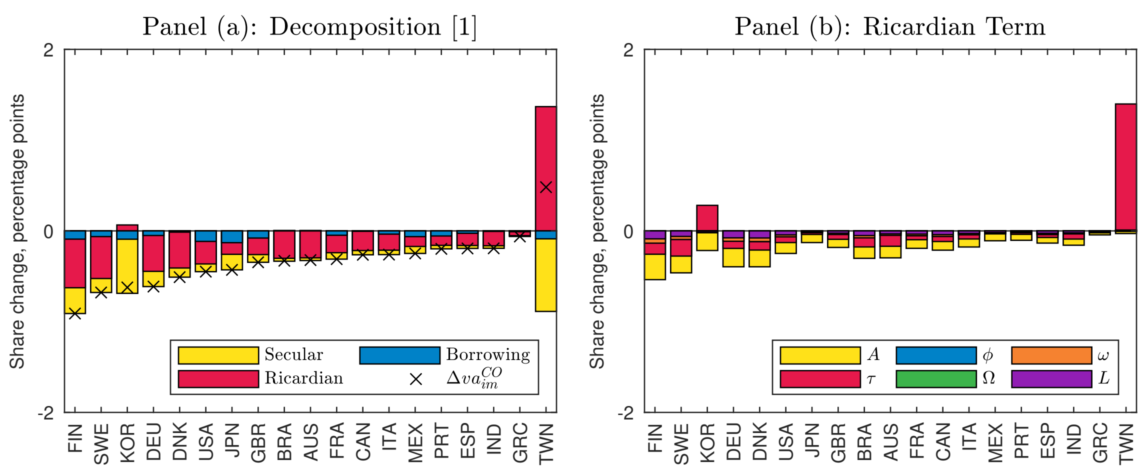

Figure 9: China-driven De-industrialization in Electrical Equipment

Panel (a): The crosses mark the changes in electrical equipment shares in the 'China on' counterfactual between years 2000 and 2011. The colored bars correspond to the components of decomposition [1] applied to 'China on' counterfactual. *Panel (b)*: Coloured bars correspond to contribution of individual shock series, marked in the legend, to the Ricardian component of the 'China on' counterfactual.

6.2 Industrialization in South Korea.

Next, I shift my focus to the remarkable industrialization of South Korea and its implications for understanding structural change. From the 1960s to the 1990s, South Korea underwent one of the most rapid and successful industrial transformations in history, evolving from an agrarian economy into a leading global manufacturer. In this segment I ask: what was the contribution of trade to this dramatic transformation?

Between 1965 and 2011, South Korea saw its manufacturing share double, from 17 to 33 percentage points. Figure 10 offers an insight into the dynamics behind this increase by plotting the evolution of primary and manufacturing shares over time, alongside the split by low- and high-technology subsectors of manufacturing. In each panel, the total is further decomposed into the contributions of specialization, secular, and borrowing terms. The figure reveals that the increase in the manufacturing share resulted from a mix of all three, with trade specialization explaining the majority of the increase.

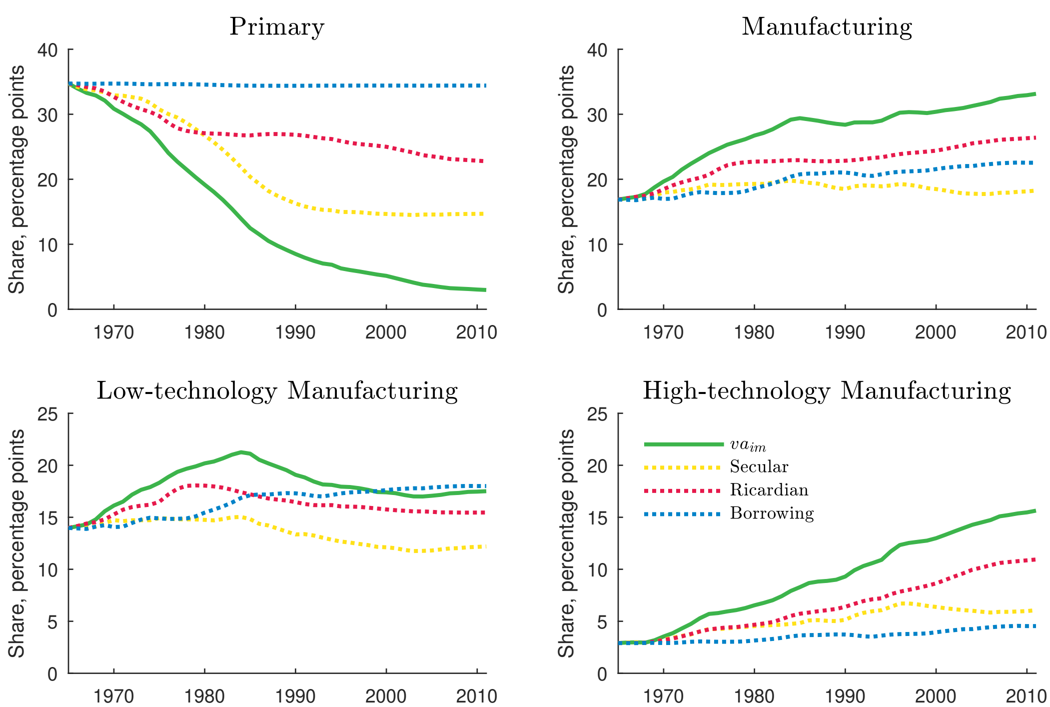

Figure 10: Industrialization in South Korea

Note: Green line marks the value added share of the sector. Dashed lines correspond to the the respective components of decomposition [1], computed as $va^X_{im,T} = va_{im,t} + \sum_{s\in\{1,..,T\}} \Delta va^X_{im,t+s}$ for $X \in \{S, R, B\}$.

To shed light on this process, I 'freeze' and, shock by shock, 'unfreeze' South Korea. Figure 11 presents the results, focusing on the contribution of the evolution of sectoral productivities and trade costs to the specialization term in the decomposition [1]. I find that, first, trade cost declines enabled South Korea to specialize in manufacturing by moving resources out of the primary sector and into the low-technology manufacturing. Note that this move reflects the patterns of comparative advantage already in place in 1965, when South Korea relied on imports of agricultural goods. A decline in trade costs permitted it to move resources away from the relatively unproductive agriculture, and into the relatively more productive low-technology manufacturing, mainly textiles (see Figure C.4 in Appendix C.2). Turning to the effect of changes in sectoral productivities reveals the second trend: over the period, South Korea experienced a shift in its comparative advantage – away from low-technology and towards the high-technology manufacturing. Thus, high-technology manufacturing was able to grow by drawing on the resources from the low-technology subsectors.

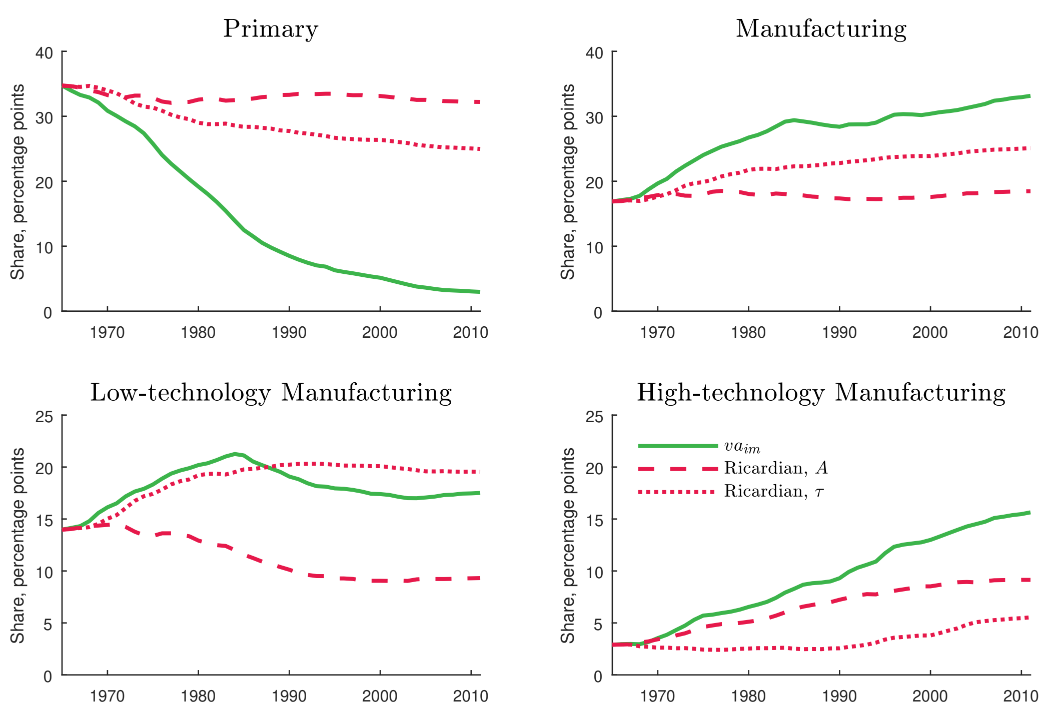

Figure 11: Industrialization in South Korea, by Shock Series

Note: Green line marks the value added share of the sector. Red lines correspond to the the Ricardian components of decomposition [1], computed as $va^R_{im,T} = va_{im,t} + \sum_{s\in\{1,..,T\}} \Delta va^R_{im,t+s}$, in the 'South Korea on' simulation with only South Korean productivities and trade costs evolving, respectively.

7 Conclusion

In this paper, I have argued that openness to international trade and capital flows is important for understanding structural change over the long run in a large sample of economies. By employing structural decompositions, the analysis showed that trade specialization and international borrowing are important drivers of structural change. This study highlighted the importance of these mechanisms not only in explaining the dynamics of aggregate manufacturing shares but also for thinking about heterogeneous experiences across economies and shifts in the composition of manufacturing broadly defined. Furthermore, I have argued that both are central to understanding the impact of China on the evolution of manufacturing sectors worldwide and the industrialization of South Korea.

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 general equilibrium model. 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 exact 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, all the while retaining its benefits: exact mapping to data and general equilibrium linkages across the economies. As twenty first century marks a backlash against globalization and a renewed interest in industrial policy, the present paper offers a framework to think through the potential effects of such policies in a quantitatively rigorous manner.

References

Acemoglu, Daron, and Veronica Guerrieri. 2008. "Capital Deepening and Nonbalanced Economic Growth." *Journal of Political Economy* 116 (3): 467–498.

Atalay, Enghin. 2017. "How Important Are Sectoral Shocks?" *American Economic Journal: Macroeconomics* 9 (4): 254–280.

Autor, David H, David Dorn, and Gordon H Hanson. 2016. "The China Shock: Learning from Labor-Market Adjustment to Large Changes in Trade." *Annual Review of Economics* 8:205–240.

Boppart, Timo. 2014. "Structural Change and the Kaldor Facts in a Growth Model with Relative Price Effects and Non-Gorman Preferences." *Econometrica* 82 (6): 2167–2196.

Comin, Diego, Danial Lashkari, and Martí Mestieri. 2021. "Structural Change with Long-run Income and Price Effects." *Econometrica* 89 (1): 311–374.

Eaton, Jonathan, and Samuel Kortum. 2002. "Technology, Geography, and Trade." *Econometrica* 70 (5): 1741–1779.

Eaton, Jonathan, Samuel Kortum, Brent Neiman, and John Romalis. 2016. "Trade and the Global Recession." *American Economic Review* 106 (11): 3401–3438.

Garcia-Santana, Manuel, Josep Pijoan-Mas, and Lucciano Villacorta. 2021. "Investment Demand and Structural Change." *Econometrica* 89 (6): 2751–2785.

Head, Keith, and John Ries. 2001. "Increasing Returns Versus National Product Differentiation as an Explanation for the Pattern of US–Canada Trade." *American Economic Review* 91 (4): 858–876.

Herrendorf, Berthold, Richard Rogerson, and Akos Valentinyi. 2013. "Two Perspectives on Preferences and Structural Transformation." *The American Economic Review* 103 (7): 2752–2789.

———. 2014. *Growth and Structural Transformation.* 2:855–941.

Herrendorf, Berthold, Richard Rogerson, and Akos Valentinyi. 2021. "Structural Change in Investment and Consumption—A Unified Analysis." *The Review of Economic Studies* 88 (3): 1311–1346.

Huneeus, Federico, and Richard Rogerson. 2020. *Heterogeneous paths of industrialization.* Technical report. National Bureau of Economic Research.

Imbs, Jean, and Isabelle Mejean. 2017. "Trade Elasticities." *Review of International Economics* 25 (2): 383–402.

Kehoe, Timothy J, Kim J Ruhl, and Joseph B Steinberg. 2018. "Global Imbalances and Structural Change in the United States." *Journal of Political Economy* 126 (2): 761–796.

Kongsamut, Piyabha, Sergio Rebelo, and Danyang Xie. 2001. "Beyond Balanced Growth." *The Review of Economic Studies* 68 (4): 869–882.

Lane, Nathan. 2022. "Manufacturing Revolutions: Industrial Policy and Industrialization in South Korea." *Available at SSRN 3890311.*

Ngai, L. Rachel, and Christopher A Pissarides. 2007. "Structural Change in a Multisector Model of Growth." *American Economic Review* 97 (1): 429–443.

Silva, JMC Santos, and Silvana Tenreyro. 2006. "The Log of Gravity." *The Review of Economics and Statistics* 88 (4): 641–658.

Sposi, Michael, Kei-Mu Yi, and Jing Zhang. 2021. *Deindustrialization and Industry Polarization.* Technical report. National Bureau of Economic Research.

Święcki, Tomasz. 2017. "Determinants of Structural Change." *Review of Economic Dynamics* 24:95–131.

Uy, Timothy, Kei-Mu Yi, and Jing Zhang. 2013. "Structural Change in an Open Economy." *Journal of Monetary Economics* 60 (6): 667–682.

Woltjer, PJ, Reitze Gouma, and Marcel P Timmer. 2021. "Long-run World Input-Output Database: Version 1.0 Sources and Methods."

A Mathematical Appendix

A.1 Derivation of Decomposition 1*

Consider the market clearing condition,

$$Y_{ik} = \sum_{j} \Pi_{jik} \left(\alpha_{jk} D_j Y_j + \sum_{n} \beta_{jnk} Y_{jn} \right),$$

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 Π_{jik}, matrices $\mathbf{D}$ and $\mathbf{A}$ are diagonal matrices with aggregate deficits and final expenditure shares D_i and α_{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, respectively, 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 $\boldsymbol{\phi}$ for the first $IK - 1$ elements of the last column of matrix $\mathbf{\Phi}$. The normalized system is then:

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

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

$$
\begin{aligned}
\mathbf{\Phi}^R =& \mathbf{B_l L \tilde{\Pi} \odot \Pi A D \Sigma + B_l L \tilde{\Pi} \odot \Pi B L \Pi A D \Sigma},\\
\mathbf{\Phi}^S =& \mathbf{\tilde{B}_l B_l L \Pi A D \Sigma + B_l L \Pi \tilde{B} \odot B L \Pi A D \Sigma + B_l L \Pi \tilde{A} A D \Sigma},\\
\mathbf{\Phi}^B =& \mathbf{B_l L \Pi A \tilde{D} D \Sigma},
\end{aligned}
$$

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 $\boldsymbol{\phi}^X$ for the first $IK-1$ elements of the last column of matrix $\mathbf{\Phi}^X$.

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

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

collect percent changes in sectoral value added as a function of percent changes in trade shares, final and intermediate expenditure shares, and aggregate trade deficits respectively. The change in sectoral value added shares can be computed as follows:

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

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

A.2 Derivations of the Equilibrium Conditions

Equilibrium. Eaton and Kortum (2002) show that if *Assumption 1* holds, then sector-level price indices and expenditures can be solved for in closed form. Together with intertemporal optimization of households, this yields the following set of equilibrium conditions (see derivations in Appendix A.2).

Trade shares, that is the expenditures on imports from any given destination as a share of the total spending on the sectoral bundle, satisfy:

$$\Pi_{jik} = \left(\frac{c_{ik}\tau_{jik}}{A_{ik}P_{jk}}\right)^{-\theta_k}, \quad \text{where } P_{ik} = \left[\sum_l \left(\frac{c_{lk}\tau_{ilk}}{A_{lk}}\right)^{-\theta_k}\right]^{-\frac{1}{\theta_k}} \tag{19}$$

is the price of the sector k bundle in country i, and c_{ik} is the cost of production of a firm in i, k with a unit productivity

$$c_{ik} = w_{ik}^{\omega_{ikl}} \left(\sum_s \omega_{iks} P_{iks}^{1-\sigma_s}\right)^{\frac{1-\omega_{ikl}}{1-\sigma_s}}, \tag{20}$$

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 optimally spend a fraction β_{ikl} of their revenue on labor:

$$\beta_{ikl} = \frac{w_i l_{ik}(z)}{p_{ik}(z) y_{ik}(z)} = \omega_{ikl}, \tag{21}$$

and a fraction β_{ikn} of their revenue on inputs from sector n:

$$\beta_{ikn} = \frac{P_{in} m_{ikn}(z)}{p_{ik}(z) y_{ik}(z)} = \begin{cases} (1-\omega_{ikl}) \dfrac{\omega_{ikP} P_{iP}^{1-\sigma_s}}{\sum_s \omega_{iks} P_{iks}^{1-\sigma_s}}, & \text{if } n = 1 \\ (1-\omega_{ikl}) \dfrac{\omega_{ikM} P_{ikM}^{1-\sigma_s}}{\sum_s \omega_{iks} P_{iks}^{1-\sigma_s}} \dfrac{\omega_{ikm} P_{im}^{1-\sigma_m}}{\sum_m \omega_{ikm} P_{im}^{1-\sigma_m}}, & \text{if } 1 < n < K \\ (1-\omega_{ikl}) \dfrac{\omega_{ikS} P_{iS}^{1-\sigma_s}}{\sum_s \omega_{iks} P_{iks}^{1-\sigma_s}}, & \text{if } n = K. \end{cases} \tag{22}$$

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

$$\alpha_{in} = \frac{P_{in} C_{in}}{E_i} = \begin{cases} \Omega_{iP} \left(\dfrac{P_{iP}}{E_i}\right)^{1-\sigma_s} C_i^{(1-\sigma_s)\epsilon_P}, & \text{if } n = 1 \\ \Omega_{iM} \left(\dfrac{P_{iM}}{E_i}\right)^{1-\sigma_s} C_i^{(1-\sigma_s)\epsilon_M} \dfrac{\Omega_{im} P_{im}^{1-\sigma_m}}{\sum_m \Omega_{im} P_{im}^{1-\sigma_m}}, & \text{if } 1 < n < K \\ \Omega_{iS} \left(\dfrac{P_{iS}}{E_i}\right)^{1-\sigma_s} C_i^{(1-\sigma_s)\epsilon_S}, & \text{if } n = K, \end{cases} \tag{23}$$

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:

$$\rho \frac{\phi_{it}}{\phi_{it-1}} = \mu_t \frac{1+bd_{it}}{1+bd_{it-1}} \frac{E_{it}\epsilon_{it}}{E_{it-1}\epsilon_{it-1}}, \quad \text{where} \quad d_{it} = \frac{E_{it}-w_i}{w_i} \text{ and } \epsilon_{it} = \sum_s \alpha_{ist}\epsilon_s. \tag{24}$$

Sectoral bundle market clearing in i, k satisfies

$$X_{ik} = \alpha_{ik} L_i E_i + \sum_{n \in K} \beta_{ink} \int_0^1 p_{in}(z) y_{in}(z) = \alpha_{ik} L_i E_i + \sum_{n \in K} \beta_{ink} Y_{in}, \tag{25}$$

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:

$$Y_{ik} = \sum_j \Pi_{jik} X_{jk}. \tag{26}$$

Labour market clears

$$wL_i = \sum_{k \in K} \int_0^1 w l_{ik}(z) dz = \sum_{k \in K} \beta_{ikl} Y_{ik}. \tag{27}$$

Finally, bond market clearing together with normalization require

$$\sum_i L_{it} E_{it} = \sum_i L_{it} w_{it} = 1. \tag{28}$$

Trade shares. The setup of international trade follows directly from Eaton and Kortum (2002). Since the proof is lengthy, and not new to this paper, I present the stylised argument and refer the reader to detailed proofs in Eaton and Kortum (2002) and Eaton et al. (2016).

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 would be

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

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

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

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 (19).

Firm problem. Consider the following maximization,

$$\max_{l(z)_{ik}, m_{ikn}(z)} \pi_{ik}(z) = p_{ik}(z) a_{ik}(z) \left(\frac{l_{ik}(z)}{\omega_{ikl}} \right)^{\omega_{ikl}} \left(\frac{m_{ik}(z)}{1-\omega_{ikl}} \right)^{1-\omega_{ikl}} - w_i l_{ik}(z) - \sum_{n \in K} P_{in} m_{ikn}(z),$$

where

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

First order conditions with respect to inputs are as follows:

$$\mathrm{FOC}_{l(z)_{ik}}: \quad \omega_{ikl} p_{ik}(z) y_{ik}(z) = w_i l_{ik}(z),$$

$$\mathrm{FOC}_{m_{ikP}(z)}: \quad (1-\omega_{ikl}) p_{ik}(z) y_{ik}(z) \omega_{ikP}^{\frac{1}{\sigma_s}} \left(\frac{m_{ikP}(z)}{m_{ik}(z)}\right)^{\frac{\sigma_s - 1}{\sigma_s}} = m_{ikM}(z) P_{iP},$$

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

$$\mathrm{FOC}_{m_{ikS}(z)}: \quad (1-\omega_{ikl}) p_{ik}(z) y_{ik}(z) \omega_{ikS}^{\frac{1}{\sigma_s}} \left(\frac{m_{ikS}(z)}{m_{ik}(z)}\right)^{\frac{\sigma_s - 1}{\sigma_s}} = m_{ikS}(z) P_{iS}.$$

The unit cost of production (20) obtains by combining these first order conditions with intermediate input cost function and production function defined in (1)–(3). The input expenditure shares (21) and (22) obtain by combining these first order conditions with intermediate input cost function, production function defined in (1)–(3), and by defining appropriate price indices.

Household problem. Household problem can be solved in two steps. First, for a given expenditure E_i, solve

$$\max_{C_{ik}} C_i, \quad \text{where} \quad \sum_s \Omega_{is}^{\frac{1}{\sigma_s}} \left(\frac{C_{is}}{C_i^{\epsilon_s}}\right)^{\frac{\sigma_s - 1}{\sigma_s}} = 1 \text{ and } C_{iM} = \left(\sum_m \Omega_{im}^{\frac{1}{\sigma_m}} C_{im}^{\frac{\sigma_m - 1}{\sigma_m}}\right)^{\frac{\sigma_m}{\sigma_m - 1}}$$

$$\text{s.t.} \quad \sum_k P_{ik} C_{ik} = E_i.$$

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

$$\mathrm{FOC}_{C_{iP}}: \quad \frac{dC_i}{dC_{iP}} = \Omega_{iP}^{\frac{1}{\sigma_s}} \left(\frac{C_{iP}}{C_i^{\epsilon_s}}\right)^{\frac{\sigma_s - 1}{\sigma_s}} \left(\sum_s \Omega_{is}^{\frac{1}{\sigma_s}} \left(\frac{C_{is}}{C_i^{\epsilon_s}}\right)^{\frac{\sigma_s - 1}{\sigma_s}} \epsilon_s\right)^{-1} \frac{C_i}{C_{iP}} = \lambda_i P_{iP},$$

$$\mathrm{FOC}_{C_{im}}: \quad \frac{dC_i}{dC_{im}} = \Omega_{iM}^{\frac{1}{\sigma_s}} \left(\frac{C_{iM}}{C_i^{\epsilon_s}}\right)^{\frac{\sigma_s - 1}{\sigma_s}} \left(\sum_s \Omega_{is}^{\frac{1}{\sigma_s}} \left(\frac{C_{is}}{C_i^{\epsilon_s}}\right)^{\frac{\sigma_s - 1}{\sigma_s}} \epsilon_s\right)^{-1} \frac{C_i}{C_{iM}} \Omega_{im}^{\frac{1}{\sigma_m}} \left(\frac{C_{iM}}{C_{im}}\right)^{\frac{1}{\sigma_m}} = \lambda_i P_{im},$$

$$\mathrm{FOC}_{C_{iS}}: \quad \frac{dC_i}{dC_{iS}} = \Omega_{iS}^{\frac{1}{\sigma_s}} \left(\frac{C_{iS}}{C_i^{\epsilon_s}}\right)^{\frac{\sigma_s - 1}{\sigma_s}} \left(\sum_s \Omega_{is}^{\frac{1}{\sigma_s}} \left(\frac{C_{is}}{C_i^{\epsilon_s}}\right)^{\frac{\sigma_s - 1}{\sigma_s}} \epsilon_s\right)^{-1} \frac{C_i}{C_{iS}} = \lambda_i P_{iS},$$

where λ_i is the Lagrange multiplier on the budget constraint. Final consumption expenditure shares in (23) obtain by substituting expenditures from these first order conditions into the budget constraint to solve for λ_i, and then plugging λ_i back in.

Next, consider the following intertemporal problem:

$$\max_{E_{it},B_{it+1}} \sum_{t=0}^{\infty} \rho^t \phi_{it} \ln C_{it}(E_{it}, \mathbf{P}_{it}) \quad \text{s.t.} \quad E_{it} + \mu_{t+1} B_{it+1} + \frac{b}{2} \left(\frac{E_{it} - w_i}{w_i} \right)^2 w_i = w_i + B_{it} + T_{it},$$

where $\mathbf{P}_{it}$ is a vector of prices faced at t.

$$\text{FOC}_{E_{it}}: \quad \rho^t \phi_{it} \frac{1}{C_{it}} \frac{dC_{it}}{dE_{it}} = \lambda_{it}(1 + bd_{it}),$$

$$\text{FOC}_{B_{it+1}}: \quad \lambda_{it}\mu_{t+1} = \lambda_{it+1},$$

where $d_{it} = \dfrac{E_{it} - w_i}{w_i}$ and where λ_{it} is the Lagrange multiplier associated with the budget constraint in period t. Optimality conditions obtained in the previous segment can be used to derive

$$\frac{1}{C_{it}} \frac{dC_{it}}{dE_{it}} = \left(E_{it} \sum_s \alpha_{ist} \epsilon_s \right)^{-1}.$$

Plugging in and substituting for λ_{it} and λ_{it+1} gives rise to the Euler equation (24).

A.3 Linking Endogenous Variables and Exogenous Shocks

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

$$d\Pi_{jik} = -\theta_k \Big(\frac{w_i\tau_{jik}}{A_{ik}P_{jk}}\Big)^{-\theta_k-1} \left(\frac{dw_i\tau_{jik}}{A_{ik}P_{jk}} + \frac{w_i d\tau_{jik}}{A_{ik}P_{jk}} - \frac{w_i\tau_{jik}dA_{ik}}{A_{ik}^2 P_{jk}} - \frac{w_i\tau_{jik}dP_{jk}}{A_{ik}P_{jk}^2}\right) =$$
$$-\theta_k \Pi_{jik} \left(\frac{dw_i}{w_i} + \frac{d\tau_{jik}}{\tau_{jik}} - \frac{dA_{ik}}{A_{ik}} - \frac{dP_{jk}}{P_{jk}}\right),$$

which can be rewritten as

$$\tilde{\Pi}_{jik} = \theta_k \left(\tilde{A}_{ik} - \tilde{\tau}_{jik} - \tilde{w}_i - \tilde{P}_{jk}\right).$$

Applying total differentiation to the price index yields

$$dP_{ik} = -\frac{1}{\theta_k}\left[\sum_l \Big(\frac{w_l\tau_{ilk}}{A_{lk}}\Big)^{-\theta_k}\right]^{-\frac{1}{\theta_k}-1} - \theta_k \sum_l \Big(\frac{w_l\tau_{ilk}}{A_{lk}}\Big)^{-\theta_k}\Big(\frac{dw_l}{w_l} + \frac{d\tau_{ilk}}{\tau_{ilk}} - \frac{dA_{lk}}{A_{lk}}\Big) =$$
$$P_{ik}\sum_l \Big(\frac{w_l\tau_{ilk}}{A_{lk}P_{ik}}\Big)^{-\theta_k}\Big(\frac{dw_l}{w_l} + \frac{d\tau_{ilk}}{\tau_{ilk}} - \frac{dA_{lk}}{A_{lk}}\Big) = P_{ik}\sum_l \Pi_{ilk}\Big(\frac{dw_l}{w_l} + \frac{d\tau_{ilk}}{\tau_{ilk}} - \frac{dA_{lk}}{A_{lk}}\Big),$$

or

$$\tilde{P}_{ik} = \sum_l \Pi_{ilk}\left(\tilde{w}_l + \tilde{\tau}_{ilk} - \tilde{A}_{lk}\right).$$

Expenditure shares. Applying total differentiation to expenditure shares yields

$$d\alpha_{in} = \begin{cases} \alpha_{iP}\left[\frac{d\Omega_{iP}}{\Omega_{iP}} + (1-\sigma_s)\left(\frac{dP_{iP}}{P_{iP}} - \frac{dE_i}{E_i} + \frac{dC_i}{C_i}\epsilon_P\right)\right], & \text{if } n = 1 \\ \alpha_{in}\Big[\frac{d\Omega_{iM}}{\Omega_{iM}} + (1-\sigma_s)\left(\frac{dP_{iM}}{P_{iM}} - \frac{dE_i}{E_i} + \frac{dC_i}{C_i}\epsilon_M\right) + & \\ \qquad \frac{d\Omega_{in}}{\Omega_{in}} + (1-\sigma_m)\left(\frac{dP_{in}}{P_{in}} - \frac{dP_{iM}}{P_{iM}}\right)\Big], & \text{if } 1 < n < K \\ \alpha_{iS}\left[\frac{d\Omega_{iS}}{\Omega_{iS}} + (1-\sigma_s)\left(\frac{dP_{iS}}{P_{iS}} - \frac{dE_i}{E_i} + \frac{dC_i}{C_i}\epsilon_S\right)\right], & \text{if } n = K, \end{cases}$$

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

$$\sum_s \alpha_{is} \left(\frac{d\Omega_{is}}{\Omega_{is}} + (1-\sigma_s)\frac{dP_{is}}{P_{is}} - (1-\sigma_s)\frac{dE_i}{E_i} + (1-\sigma_s)\epsilon_s \frac{dC_i}{C_i} \right) = 0.$$

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

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

where $\tilde{P}_i = \sum_s \alpha_{is}\tilde{P}_{is}$, $\tilde{P}_{iM} = \sum_m \alpha_{im}\tilde{P}_{im}$, and

$$\tilde{C}_i = \frac{\tilde{E}_i - \sum_s \alpha_{is}\tilde{P}_{is}}{\sum_s \alpha_{is}\epsilon_s}.$$

Expenditure. Finally, totally differentiating the Euler equation,

$$\rho\frac{d\phi_{it}}{\phi_{it-1}} = \rho\frac{\phi_{it}}{\phi_{it-1}}\left[\frac{d\mu_t}{\mu_t} + \frac{bdd_{it}}{1+bd_{it1}} + \frac{dE_{it}}{E_{it}} + \frac{d\epsilon_{it}}{\epsilon_{it}}\right],$$

or in tilde notation,

$$\tilde{E}_{it} = \tilde{\phi}_{it} - \tilde{\mu}_t - \frac{bd_{it}\tilde{d}_{it}}{1+bd_{it1}} - \tilde{\epsilon}_{it}, \quad \text{where } \tilde{d}_{it} = \frac{E_{it}(\tilde{E}_{it} - \tilde{w}_{it})}{w_{it}d_{it}}.$$

Multiplying both sides by E_{it} and summing across the economies,

$$\tilde{\mu}_t = \sum_i E_{it}\tilde{\phi}_{it} - \sum_i E_{it}\frac{bd_{it}\tilde{d}_{it}}{1+bd_{it1}} - \sum_i E_{it}\tilde{E}_{it} - \sum_i E_{it}\tilde{\epsilon}_{it}.$$

$\sum_i E_{it}\tilde{E}_{it} = 0$ due to normalization. Denoting $\sum_i E_{it}\tilde{\phi}_{it} = \tilde{\phi}_t$ and $\sum_i E_{it}\tilde{\epsilon}_{it} = \tilde{\epsilon}_t$ and plugging back in,

$$\tilde{E}_{it} = \tilde{\phi}_{it} - \tilde{\phi}_t - \left(\frac{bd_{it}\tilde{d}_{it}}{1 + bd_{it1}} - \sum_i E_{it} \frac{bd_{it}\tilde{d}_{it}}{1 + bd_{it1}} \right) - (\tilde{\epsilon}_{it} - \tilde{\epsilon}_t).$$

Finally, suppose $D_{it} \approx 1$, or $E_{it} \approx w_{it}$. Then,

$$\frac{bd_{it}\tilde{d}_{it}}{1 + bd_{it1}} \approx b(\tilde{E}_{it} - \tilde{w}_{it}) \quad \text{and} \quad \sum_i E_{it} \frac{bd_{it}\tilde{d}_{it}}{1 + bd_{it1}} \approx 0.$$

Plugging in and solving out,

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

A.4 Model in Changes

Suppose that base year values of endogenous variables Y_{ik}, Π_{jik}, α_{ik}, β_{ikl}, β_{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 conditions (19):

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

[ii] Changes in production costs can be derived from (20):

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

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 labour shares are immediate from (21):

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

[iv] Changes in intermediate input shares can be derived from (22):

$$\hat{\beta}_{ikn} = \begin{cases} \dfrac{1-\beta_{ikl}\hat{\omega}_{ikl}}{1-\beta_{ikl}} \dfrac{\hat{\omega}_{ikP}\hat{P}_{ikP}^{1-\sigma_s}}{\sum_s \frac{\beta_{iks}}{\sum_s \beta_{iks}}\hat{\omega}_{iks}\hat{P}_{iks}^{1-\sigma_s}}, & \text{if } n = 1 \\[2ex] \dfrac{1-\beta_{ikl}\hat{\omega}_{ikl}}{1-\beta_{ikl}} \dfrac{\hat{\omega}_{ikM}\hat{P}_{ikM}^{1-\sigma_s}}{\sum_s \frac{\beta_{iks}}{\sum_s \beta_{iks}}\hat{\omega}_{iks}\hat{P}_{iks}^{1-\sigma_s}} \dfrac{\hat{\omega}_{ikm}\hat{P}_{ikm}^{1-\sigma_m}}{\sum_m \frac{\beta_{ikm}}{\sum_m \beta_{ikm}}\hat{\omega}_{ikm}\hat{P}_{ikm}^{1-\sigma_m}}, & \text{if } 1 < n < K \\[2ex] \dfrac{1-\beta_{ikl}\hat{\omega}_{ikl}}{1-\beta_{ikl}} \dfrac{\hat{\omega}_{ikS}\hat{P}_{ikS}^{1-\sigma_s}}{\sum_s \frac{\beta_{iks}}{\sum_s \beta_{iks}}\hat{\omega}_{iks}\hat{P}_{iks}^{1-\sigma_s}}, & \text{if } n = K. \end{cases}$$

[v] Changes in the final expenditure shares can be derived from condition (23):

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

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 household expenditure can be derived from (24):

$$\hat{E}_{it} = \rho\hat{\phi}_{it}\frac{1}{\mu_{t+1}}\frac{1+bd_{it}}{1+bd_{it}\hat{d}_{it}}\frac{1}{\hat{\epsilon}_{it}},$$

where $\hat{\epsilon}_{it} = \frac{\sum_s \alpha_{ist}\hat{\alpha}_{ist}\epsilon_s}{\sum_s \alpha_{ist}\epsilon_s}$, $d_{it} = \frac{E_{it} - w_i}{w_i}$, and $\hat{d}_{it} = \left(\frac{E_{it}\hat{E}_{it}}{w_{it}\hat{w}_{it}} - 1\right)\frac{1}{d_{it}}$.

[vii] $\hat{X}_{ik}$ satisfies the sectoral bundle market clearing condition (25):

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

[viii] $\hat{Y}_{ik}$ satisfies the sectoral market clearing condition (26):

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

[ix] Wages change as to clear the labor market (27):

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

[x] Finally, μ_{t+1} satisfies (28):

$$\sum_i L_{it}\hat{L}_{it}E_{it}\hat{E}_{it} = 1.$$

B Calibration 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.[12]

List of sectors: see Table B.1.

ISIC Rev. 3.1 Title	Type
Agriculture, Hunting, Forestry and Fishing	Primary
Mining and Quarrying	Primary
Food, Beverages and Tobacco	Manufacturing
Textile, Leather and Footwear	Manufacturing
Pulp, Paper, Printing and Publishing	Manufacturing
Coke, Petroleum and Nuclear Fuel	Manufacturing
Chemicals and Chemical Products	Manufacturing
Rubber and Plastics	Manufacturing
Other Non-Metallic Mineral	Manufacturing
Basic Metals and Fabricated Metal	Manufacturing
Machinery, Nec	Manufacturing
Electrical and Optical Equipment	Manufacturing
Transport Equipment	Manufacturing
Manufacturing, Nec; Recycling	Services
Electricity, Gas and Water Supply	Services
Construction	Services
Wholesale and Retail Trade	Services
Hotels and Restaurants	Services
Transport and Storage	Services
Post and Telecommunications	Services
Financial Intermediation	Services
Real Estate, Renting and Business Activities	Services
Community Social and Personal Services	Services

Table B.1: Sectors in Long Run WIOD

12. 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.

Note: I include Manufacturing, Nes; 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.

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, I force no trade in the services sectors. While some services are tradable in practice, in WIOD services export values are not compiled from raw trade data and instead are imputed as a residual. Since these values are unlikely to match the true trade in services, I attribute all domestic absorption to domestic sales. Finally, 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 use categories intact and the dataset remains internally consistent.

Solving for paths of endogenous variables. Annual values for all endogenous variables can be derived using data on final and intermediate expenditures, along with population time series data, 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 Parameter b

In the changes formulation of the model, the relationship between the change in the total expenditure and the changes in income is defined implicitly:

$$\hat{E}_{it} = \rho\hat{\phi}_{it}\frac{1}{\mu_{t+1}}\frac{1+bd_{it}}{1+bd_{it}\hat{d}_{it}}\frac{1}{\hat{\epsilon}_{it}}, \qquad \text{[EE]}$$

where $\hat{\epsilon}_{it} = \frac{\sum_s \alpha_{ist}\hat{\alpha}_{ist}\epsilon_s}{\sum_s \alpha_{ist}\epsilon_s}$, $d_{it} = \frac{E_{it} - w_i}{w_i}$, and $\hat{d}_{it} = \left(\frac{E_{it}\hat{E}_{it}}{w_{it}\hat{w}_{it}} - 1\right)\frac{1}{d_{it}}$. b is calibrated as follows:

1. Back out μ_{t+1} using the normalization $\prod_i \hat{\phi}_i^{1/I} = 1$.

2. Plug in μ_{t+1}, as well as $\hat{w}_{it}$, E_{it} and w_i as observed in the data, into equation EE.

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

4. Search over b as to minimize

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

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 A.4 as follows:

1. Construct changes in wages from observed changes in 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 β_{ikl}, β_{ikn}, α_{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 4.4 to solve [iii] $-$ [vi] and [x] in Appendix A.4 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 $\hat{c}_{ik}$.
5. Use input costs $\hat{c}_{ik}$, 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 Shock Summary Statistics

	Primary	Food	Textiles	Pulp & Paper	Coke & Petroleum	Chemicals	Rubber & Plastics	Non-Metallic Mineral	Basic/Fabricated Metal	Machinery, Nec	Electrical & Optical	Transport Equipment	Services	Total
Australia	0.67	0.90	0.78	0.75	0.57	0.62	0.77	0.69	0.69	0.59	0.60	0.62	NaN	0.71
Brazil	0.72	0.73	0.37	0.41	0.37	0.55	0.39	0.52	0.55	0.43	0.42	0.38	NaN	0.52
Canada	0.89	0.75	0.63	0.83	0.53	0.67	0.79	0.76	0.92	0.63	0.62	0.65	NaN	0.77
China	0.55	0.68	0.39	0.48	0.26	0.43	0.41	0.25	0.54	0.24	0.24	0.30	NaN	0.44
Germany	0.77	0.63	0.49	0.69	0.83	0.59	0.69	0.82	0.64	0.68	0.66	0.74	NaN	0.67
Denmark	0.89	0.70	0.43	0.74	0.56	0.59	0.64	0.71	0.75	0.64	0.63	0.60	NaN	0.70
Spain	0.69	0.70	0.36	0.68	0.39	0.56	0.47	0.61	0.56	0.64	0.52	0.38	NaN	0.55
Finland	0.56	0.70	0.51	0.79	0.47	0.59	0.56	0.60	0.69	0.70	0.54	0.66	NaN	0.65
France	0.77	0.72	0.53	0.84	0.57	0.59	0.73	0.82	0.83	0.74	0.64	0.67	NaN	0.70
United Kingdom	0.75	0.77	0.57	0.92	0.55	0.56	0.65	0.78	0.81	0.69	0.59	0.59	NaN	0.70
Greece	0.63	0.77	0.50	0.83	0.53	0.59	0.80	0.76	0.81	0.55	0.60	0.48	NaN	0.65
India	0.55	0.65	0.53	0.77	0.35	0.50	0.48	0.55	0.52	0.55	0.43	0.40	NaN	0.54
Italy	0.70	0.69	0.59	0.77	0.62	0.64	0.68	0.78	0.73	0.71	0.72	0.68	NaN	0.68
Japan	0.80	1.04	0.75	0.79	0.65	0.77	0.60	0.72	0.82	0.70	0.64	0.55	NaN	0.75
Republic of Korea	0.51	0.56	0.55	0.52	0.38	0.41	0.35	0.42	0.54	0.38	0.39	0.32	NaN	0.47
Mexico	0.60	1.07	1.08	0.59	0.38	0.72	0.33	0.81	0.90	0.66	0.42	0.49	NaN	0.72
Portugal	0.71	0.71	0.42	0.63	0.62	0.62	0.52	0.51	0.62	0.51	0.52	0.42	NaN	0.59
Sweden	0.69	0.73	0.50	0.85	0.60	0.65	0.72	0.77	0.89	0.78	0.65	0.90	NaN	0.76
Taiwan	0.47	0.76	0.34	0.43	0.46	0.50	0.38	0.44	0.47	0.59	0.43	0.52	NaN	0.44
United States	0.82	0.96	0.55	0.94	0.94	0.62	0.76	0.77	0.92	0.75	0.66	0.79	NaN	0.80
Rest of World	0.84	0.80	0.55	0.79	0.75	0.62	0.72	0.79	0.75	0.65	0.58	0.68	NaN	0.75

Table B.2: Inward Trade Cost Shocks, 1965-2011

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.

	Primary	Food	Textiles	Pulp & Paper	Coke & Petroleum	Chemicals	Rubber & Plastics	Non-Metallic Mineral	Basic/Fabricated Metal	Machinery, Nec	Electrical & Optical	Transport Equipment	Services	Total
Australia	12.9	9.5	13.1	15.6	6.6	10.5	13.9	16.8	12.1	12.4	62.6	13.9	10.8	11.9
Brazil	22.5	14.7	25.5	28.8	8.4	13.6	24.6	22.2	17.9	18.7	69.1	19.9	19.1	20.3
Canada	11.3	10.2	12.7	10.6	6.8	7.9	14.4	11.5	9.7	11.8	43.0	13.0	10.7	11.3
China	19.8	16.5	18.2	17.1	12.1	13.0	22.8	19.3	18.1	19.7	58.7	19.6	10.9	16.3
Germany	12.0	12.9	11.0	13.2	5.5	9.0	17.5	14.1	12.7	11.8	67.2	14.1	15.1	15.1
Denmark	15.0	10.0	9.4	13.8	7.6	10.1	17.3	16.1	15.0	13.2	72.5	10.2	13.9	14.3
Spain	20.2	12.5	15.1	16.3	6.2	13.1	20.2	21.3	15.4	14.4	67.6	14.8	16.1	16.7
Finland	17.0	11.8	17.5	12.0	12.9	13.5	24.2	19.8	14.4	20.0	96.8	17.3	13.8	15.6
France	12.2	11.3	11.7	11.5	4.4	8.0	15.5	12.0	11.7	10.3	50.2	10.5	12.8	12.8
United Kingdom	16.6	11.3	11.3	11.9	4.5	7.8	13.2	11.5	10.2	10.0	42.0	10.2	12.1	12.5
Greece	14.9	11.0	15.1	12.9	9.2	9.9	15.1	14.4	12.1	12.2	31.4	22.7	13.6	14.2
India	15.2	12.6	15.0	12.3	11.4	11.2	16.5	14.0	12.4	15.8	62.2	19.1	9.3	12.4
Italy	15.4	13.0	16.5	13.0	4.1	9.2	15.3	15.0	14.2	12.3	63.3	11.9	14.2	14.4
Japan	19.3	15.2	14.1	12.6	10.5	12.2	18.9	13.8	14.1	15.5	62.7	14.9	21.1	19.2
Republic of Korea	45.6	14.6	19.6	22.8	16.2	22.5	29.1	33.9	20.9	46.6	85.0	43.9	32.2	31.1
Mexico	13.6	10.3	13.3	10.9	6.5	7.2	14.7	13.5	10.1	11.5	43.2	16.9	9.6	11.6
Portugal	19.6	11.9	17.2	19.0	10.8	11.2	27.0	22.0	17.1	15.5	48.1	12.4	16.9	17.6
Sweden	12.4	11.5	10.0	10.3	8.1	11.4	15.2	11.6	10.8	9.9	48.4	12.6	10.3	11.5
Taiwan	20.9	12.5	16.3	21.5	16.2	15.3	15.8	24.9	18.5	17.7	46.5	27.1	26.5	23.0
United States	9.3	9.6	10.5	9.0	4.9	7.7	11.6	9.4	9.4	8.7	43.0	9.0	10.0	10.3
Rest of World	14.7	12.2	15.1	14.1	5.7	10.3	15.7	15.5	12.9	14.0	55.0	14.2	11.9	13.4

Table B.3: Sectoral Productivity Shocks, 1965-2011

Note: Sectoral productivities in the table 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.5 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 4.4. 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, year-by-year. This ensures that changes in global international markets do not induce i to borrow or lend and that there is no spurious specialization.[13] Finally, I replace the per-period utility function and production functions for i by appropriately re-calibrated Cobb-Douglas functions. This ensures that i's expenditure shares do not respond to changing prices of imports. The outcome of this specification is the economy i ‘frozen in time’. Changes in sectoral shares in all other economies in this specification register the evolution in sectoral composition that would have occurred had i remained fixed. 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’. Finally, observe that i can be partially switched back on by bringing shock series in i back to baseline, one at a time. The difference between this specification and the ‘i off’, then, isolates its effect.

13. 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.

C Results Appendix

C.1 Additional Figures for Section 5

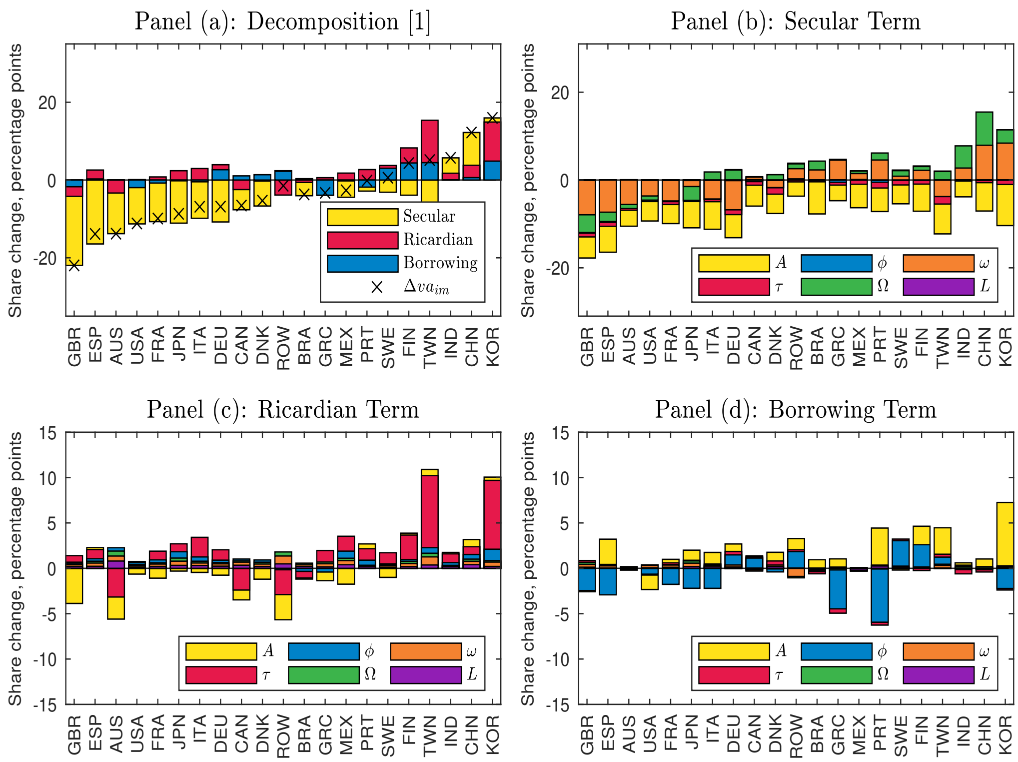

Figure C.1: Mechanisms of Manufacturing Value Added Shares by Shock

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 [2] as it applies to individual terms of [1] in Panels (b)–(d).

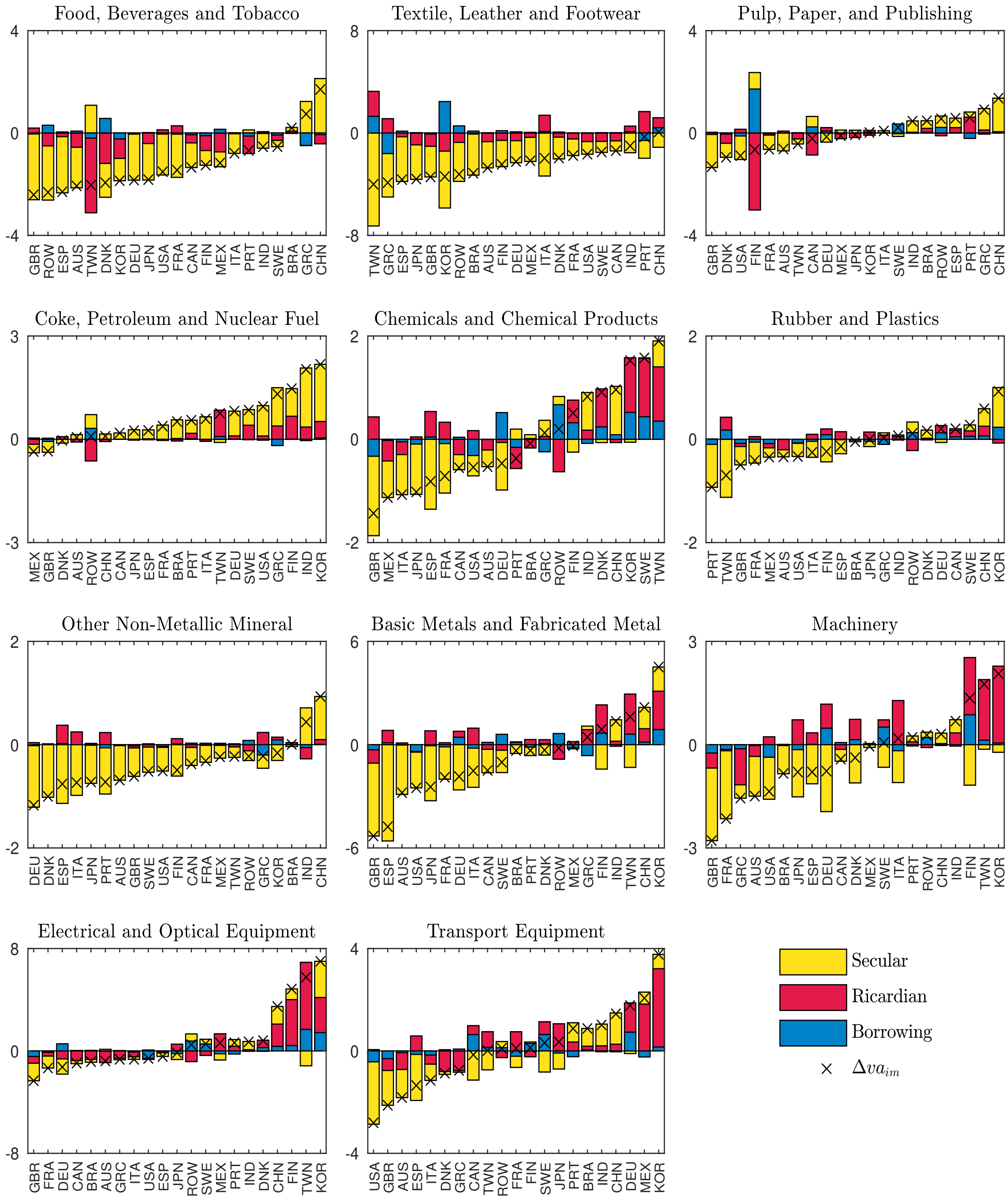

Figure C.2: Mechanisms of Structural Change within Manufacturing

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].

C.2 Additional Figures for Section 6

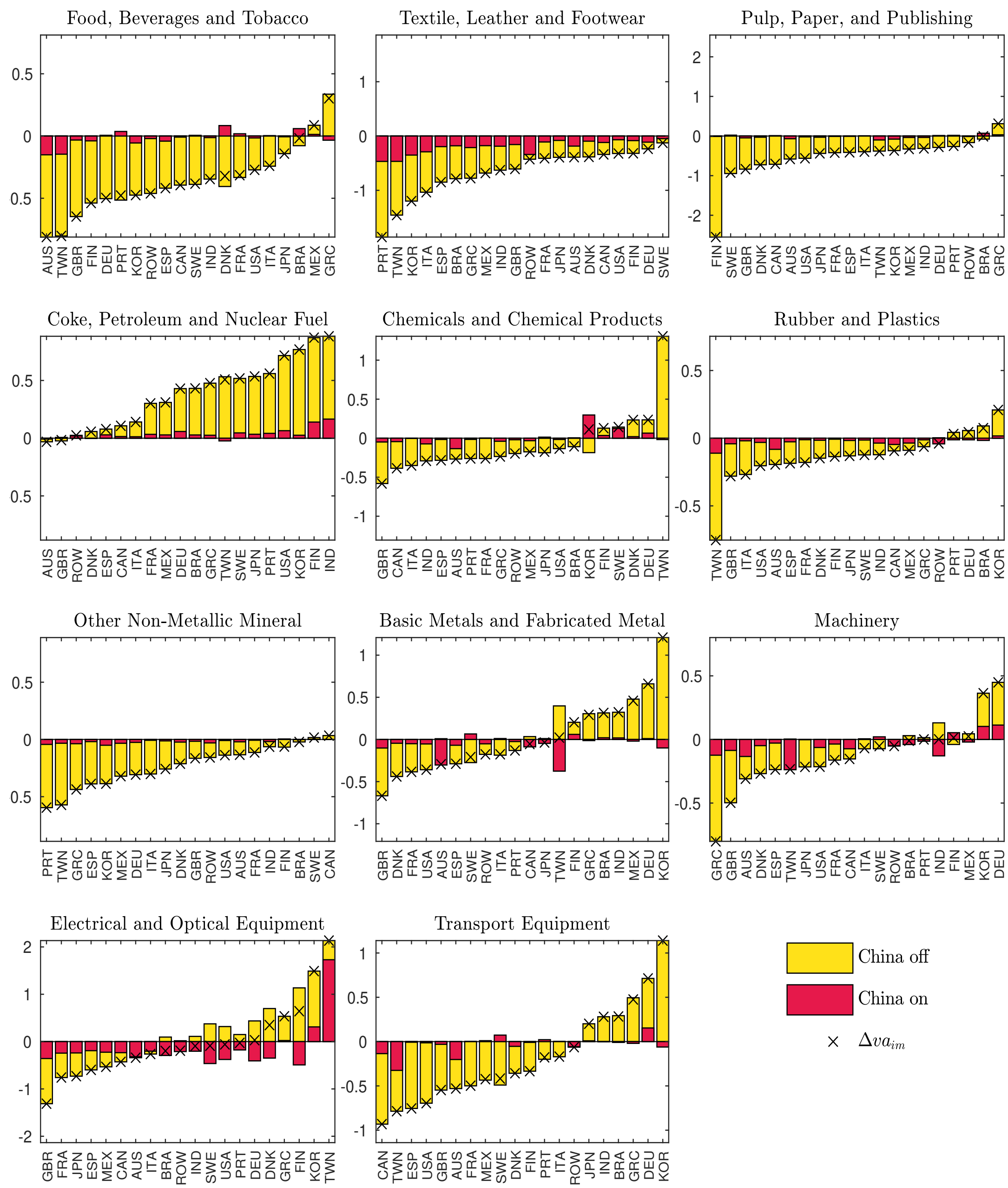

Figure C.3: China-driven De-industrialization by Industry

Note: The crosses mark the change in the manufacturing value added share between 1998 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.

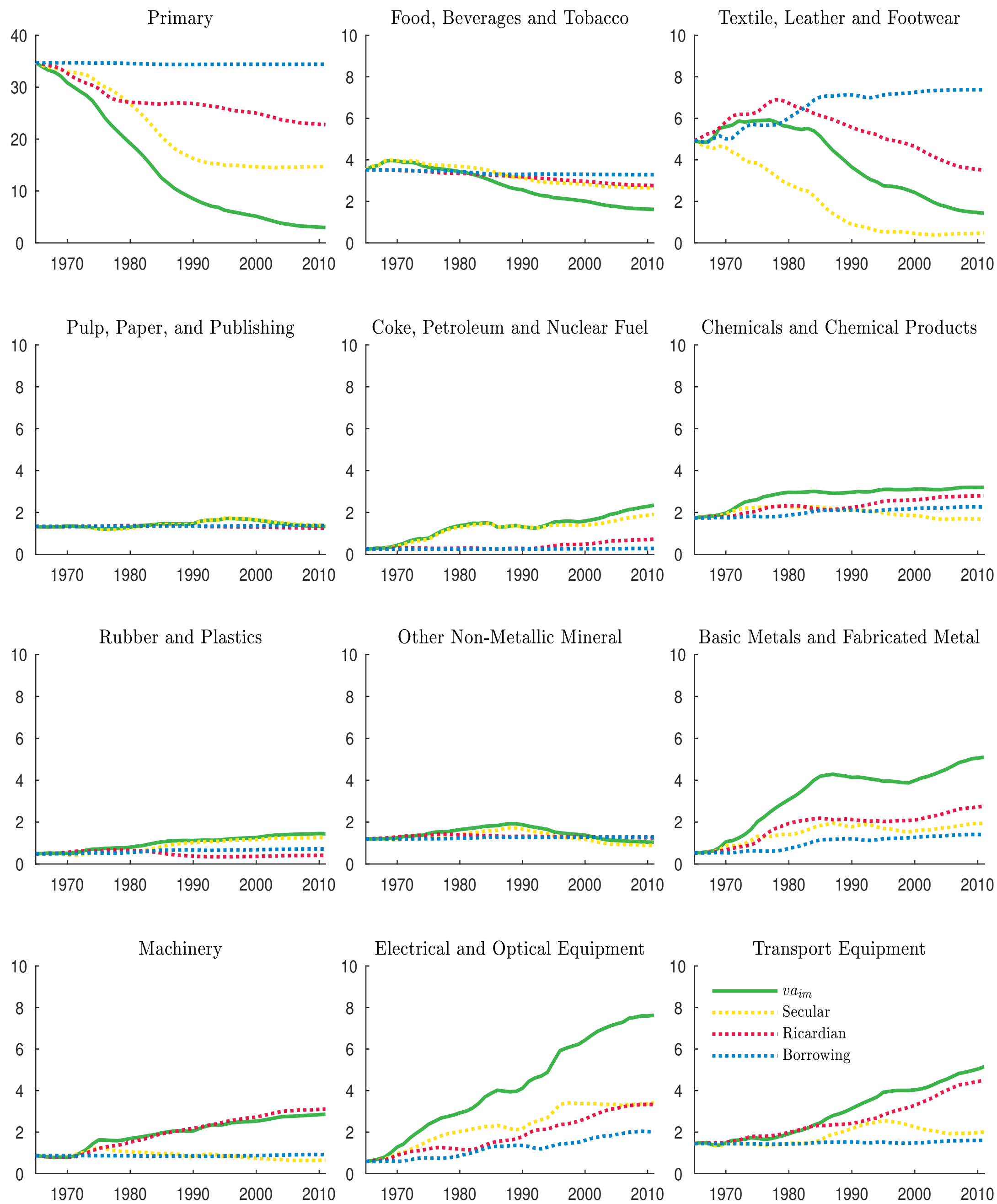

Figure C.4: Industrialization in South Korea, by Industry

Note: Green line marks the value added share of the sector. The yellow, red, and blue lines correspond to the components of decomposition [1], added to the beginning of the year value added share.