Beyond the Hump:
Structural Change in an Open Economy

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Abstract

This paper investigates the role of trade in driving structural change. First, I attribute change in manufacturing shares to adjustments in international sourcing decisions, sectoral expenditure shares, and aggregate trade deficits. Using a structural model, I interpret these as endogenous responses to exogenous shocks. Applying the decomposition to data from twenty economies between 1965 and 2011, I find that 40% of the observed change in manufacturing shares was due to specialization subject to comparative advantage and compositional effects due to international borrowing. Moreover, these mechanisms were key in driving both the cross-country heterogeneity and churn within the aggregate manufacturing. Finally, I inspect two popular narratives thank link industrialization and trade. I show that China has caused global deindustrialization via the borrowing channel and pushed economies towards low-technology manufacturing. In South Korea, trade specialization was responsible for both its rapid industrialization, and its shift towards high-technology manufacturing.

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1 Introduction

Structural transformation – the process of shifts in the relative sizes of major sectors of the economy – goes hand in hand with economic development. Much has been written on its determinants in a closed economy (see Herrendorf, Rogerson, and Valentinyi (2014)). But how does openness to trade affect structural transformation? What are the mechanisms in operation, and what fundamental shocks bring them into motion? Which countries have seen their manufacturing contract due to open economy forces, and which ones saw it grow? Were the effects uniform across the subsectors of manufacturing? And how to 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.

To do this, I proceed in two steps. First, using an accounting identity, I show that changes in manufacturing shares can be attributed exactly to variation along three margins: shifts in sectoral expenditure shares (as in closed economy models), changes in international sourcing decisions, and changes in aggregate trade deficits. Second, using a quantitative model of trade with non-homothetic preferences and endogenous borrowing, I interpret the three mechanisms as endogenous responses to changes in sectoral productivity, trade costs, and preference shifters. The mapping between the calibrated version of the model, accounting decompositions, and the data is exact. This enables me to interpret patterns as observed in the data through the lens of the model. Once the model is set up, I take it to a sample of twenty developed and developing economies between 1965 and 2011.

First, I show that 40% of the observed change in manufacturing shares in my sample was unrelated to standard closed economy drivers of structural transformation – price effect (substitution across sectoral goods in presence of shifting relative prices) and income effect (changes in expenditure shares due to non-homotheticities in consumer preferences). Instead, it was driven by specialization subject to comparative advantage, and compositional effects as countries engaged in international lending and borrowing. Next, I argue that these two mechanisms are key for understanding structural change beyond the hump-shaped pattern in manufacturing shares: both in terms of heterogeneous experiences across economies at similar levels of development, and in terms of heterogeneous behaviour of individual subsectors within manufacturing. Finally, I argue that both the effect of the rise of China on the manufacturing around the world, and industrialization in South Korea cannot be satisfactorily understood without sizing up the open economy channels of structural change and without going beyond the aggregate manufacturing.

To study how trade affects structural change, I build on a multi-sector Eaton and Kortum (2002) model. Sectoral varieties are produced using labor and intermediate inputs and are subject to Pareto productivity draws. Varieties can be shipped abroad after paying iceberg trade costs. Economies are in direct competition with each other in supplying sectoral varieties. Sectoral varieties are combined into sectoral bundles, which are then consumed by the households and used as intermediate inputs in production. Non-unitary elasticity of substitution across sectoral goods among households and producers ensure that final- and intermediate expenditure shares respond to changes in the relative prices of sectoral goods. Non-homotheticicities in the household preferences, in turn, mean that household expenditure patterns are affected by changes in incomes. Finally, households are forward looking, have perfect foresight, and borrow and lend to smooth consumption over time, subject to convex costs of imbalances. The model is dynamic, where changes in sectoral productivities, sectoral trade costs, impatience shocks, preference- and production technology shifters, as well as countries' populations determine the full path of countries' sectoral composition over time.

Using the market clearing conditions, I show that the change in sectoral value added shares can be attributed exactly to variation along three margins: changes in international sourcing decisions, shifts in sectoral expenditure shares, and changes aggregate trade deficits. The structural model enables me to interpret the three terms as distinct mechanisms of structural change. First, as costs of production and trade costs evolve, countries change their sourcing decisions by redirecting their spending towards suppliers that offer sectoral goods at a lower price. This leads to specialization subject to comparative advantage. I refer to this mechanism as 'Ricardian'. Second, changes in incomes and in relative prices of sectoral goods induce households and producers to alter their sectoral expenditure shares. Since both of these forces have typically been proposed as long-run determinants of sectoral makeup of closed economies, I label the changes in sectoral shares they cause as 'Secular'. Third, in the model, households lend and borrow to smooth consumption subject to changes in income and impatience shocks. Economies that run aggregate trade surpluses temporarily transfer the purchasing power away from domestic households, and to those abroad. In turn, this affects the sectoral makeup of economies by shifting the composition of demand for domestically produced goods, and in particular tilting it towards those that are most reliant on exports. Thus, 'Borrowing' is the third mechanism of structural change.

I calibrate the model using data on sector-level bilateral trade flows, consumption and intermediate inputs use from Groningen Growth and Development Centre World Input Output Database. I focus on twenty developed and developing economies, covering 80% of the global GDP. The series runs from 1965 to 2011, and features thirteen tradable sectors, eleven of which are subsectors of manufacturing. I retain this level of disaggregation throughout. Once the model is calibrated, I take my decompositions to the data.

First, I find that the secular channel is the key determinant of changes in manufacturing shares in my sample, responsible for 60% of the change between 1965 and 2011. Ricardian and borrowing channels, in turn, explain 23% and 17% respectively. Thus, trade specialization and international borrowing are quantitatively important drivers of structural change.

Second, I turn to the relative importance of the three channels in explaining the heterogeneous experiences of structural change across countries. To do so, I split the sample into lower and higher income groups and apply the decomposition to the change in manufacturing shares compared to the group average. Measured in this way, the contribution of the secular channel declines: to 56% for the lower income group, and to 46% for the higher income group. Instead, for both groups, around a quarter now is due to Ricardian specialization. In particular, trade specialization has given a sizeable boost to the manufacturing shares in South Korea and Taiwan, respectively, making for some of the highest rates of industrialization in my sample. In the higher income group, loss of comparative advantage has contributed to record deindustrialization rates in United Kingdom and Australia. International borrowing explains the remaining quarter of the deviation from the group trend, with widening aggregate trade imbalances leading to further deindustrialization in the deficit economies (United Kingdom and United States), and to the maintenance of the unusually high manufacturing shares in high-income, surplus economies (Sweden, Finland, and Germany).

Third, I go beyond the aggregate and study separately the low- and high-technology subsectors within manufacturing. I find that the hump-shaped pattern in the aggregate manufacturing derives mainly from the low-technology subsectors. The high-technology manufacturing share, on the other hand, exhibits no such hump and is only weakly predicted by income. Instead, I show that high-technology manufacturing is to a large extent shaped by trade specialization. Furthermore, whereas low-technology manufacturing shares follow a global trend, high-technology manufacturing shares, instead, diverge, with a small subset of countries showing increased specialization in high-technology subsectors.

Finally, I apply my methodology to revisit two popular narratives that link trade and industrialization. First, I ask: what was the role of the rise of China in shaping the production structure of economies around the world? I show that between 2000 and 2011, China has put a squeeze on the aggregate manufacturing shares of virtually all economies in my sample, causing an average decline of 0.36 percentage points – 18% of the overall change in the period. However, while I find that Ricardian forces 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. Going beyond the aggregate reveals that, surprisingly, much of the 'China shock' was concentrated in the high-technology subsectors of manufacturing, with Ricardian forces explaining most of the dynamics. In other words, I find that China induced a two-fold effect on global manufacturing: a broad-based deindustrialization via the borrowing channel, as well as a shift of production away from the high-technology subsectors within manufacturing.

Turning to export-led industrialization in South Korea, I show that between 1965 and 2011, manufacturing share in South Korea has doubled. Decomposition by channels attributes 57% of this increase to trade specialization. Breaking down the contribution of this mechanism into contributing shocks, I show that the aggregate conceals two distinct trends. First, trade cost declines prompted a dramatic reallocation of resources from the primary sector to low-technology subsectors of manufacturing – mainly textiles. In turn, the evolution of comparative advantage favored high-technology sub-sectors of machinery production, electrical, and transport equipment, which in turn acted to draw resources from the low-technology subsectors of manufacturing.

To sum up, in this paper I propose a novel methodology for dissecting changes in manufacturing shares into contributing shocks and mechanisms. I show that open economy mechanisms are key for understanding the process of structural change, as well as for unpacking the cross-country and cross-sector heterogeneity in patterns of industrialization. Conducting analysis at a two-digit level of disaggregation, I reveal rich dynamics that is lost in the aggregate. Finally, I show how the methodology developed in this paper can be used to gain granular insight into economic events at the intersection of trade and structural change.

1.1 Related Literature

Much of the literature has studied structural transformation in a closed economy. Two mechanisms in particular have been emphasized: the price- and income effects. The former has been studied in Ngai and Pissarides (2007) and Acemoglu and Guerrieri (2008), whereas the latter has been discussed in Kongsamut, Rebelo, and Xie (2001), Boppart (2014), and Comin, Lashkari, and Mestieri (2021). Two recent contributions, Herrendorf, Rogerson, and Valentinyi (2021) and Garcia-Santana, Pijoan-Mas, and Villacorta (2021), point out that price- and income effects also affect the demand for sectoral investment goods. Here, I allow for price effect in both household and firm behaviour, and follow Comin, Lashkari, and Mestieri (2021) in modelling non-homothetic preferences of the households.

Among the closed economy studies, the paper most closely related to mine is that of Huneeus and Rogerson (2020). The authors study the cross-country heterogeneity in patterns of industrialization, and argue that much of it can be attributed to the differences in sectoral growth rates. Notably, in a closed economy, these operate exclusively through price- and income effects, and are thus contained in the 'Secular' component in my decompositions. In turn, my accounting shows that this mechanism is responsible for at most half of the cross-country heterogeneity in industrialization experiences. In other words, ignoring the openness to trade risks overestimating the importance of secular forces.

Structural transformation in an open economy received relatively less attention. A number of papers have focused on the operation of individual shocks and on the experiences of individual economies, such as Uy, Yi, and Zhang (2013), who study the contribution of falling trade costs and changing sectoral productivity to the industrialization of South

Korea, Kehoe, Ruhl, and Steinberg (2018), who study how international borrowing affected manufacturing employment share in the United States, or Cravino and Sotelo (2019), who study the effect of changes in trade costs on sectoral shares and skill-bias. Świecki (2017) and Sposi, Yi, and Zhang (2021), instead, study how trade affects the process of structural transformation in a large sample of economies and consider the operation of multiple shocks simultaneously. Both argue that asymmetric productivity shocks, operating through the price effect, are the key driver behind structural change, whereas trade cost shocks, which drive trade specialization, are helpful in explaining cross-country heterogeneity. Since the modelling setup in these papers is similar to mine, I discuss the difference in more detail.

The first key difference is that I treat mechanisms and shocks as distinct. Far from being a matter of semantics, this separation is crucial for accurately attributing drivers of structural change. Both Świecki (2017) and Sposi, Yi, and Zhang (2021) use simulations with individual shock series to study the drivers of structural change. In both cases, the link between shocks and mechanisms – the mapping from asymmetric productivity to price effect and from trade costs to specialization – is implicit. However, since the true mapping between shocks and mechanisms is many-to-many, such exercises are prone to mismeasurement and misattribution. For example, I show that a sizeable chunk of the effect of asymmetric productivity growth operates through trade specialization. Attributing it to price effect results in overestimation of the importance of this mechanism. Conversely, I show that trade specialization is to a large extent driven by changes in productivity and that excluding this contribution results in understating the role of trade specialization by a half. Instead, I argue that the accounting decomposition developed in this paper is the correct measurement of the mechanisms of structural change, as it captures *distinct* margins of adjustment by agents in the economy with respect to *all* relevant shocks. Using this novel methodology, I am able to, for the first time, size up the relative role of drivers of structural change while avoiding both the conflation of unrelated mechanisms and exclusion of relevant contributing shocks that is characteristic of simulation-based methods.

Second, while previous literature typically features borrowing, its role is usually restricted to ensuring the match between simulations and the data. In contrast, this is the first paper to outline the borrowing mechanism of structural change and to quantify its contribution. I show that borrowing is a quantitatively important driver of structural change. Moreover, overlooking borrowing is not merely a matter of missing an important determinant of structural change. Since it is typical to leave the borrowing margin active in counterfactual simulations, failure to account for its own effect can lead to misinterpretation of results. For example, I repeat the analysis in Sposi, Yi, and Zhang (2021) and show that increase in the variance in manufacturing shares that they document is almost entirely due to increase in borrowing. Instead, the authors attribute it to trade specialization. The misattribution, once again, is an outcome of an inaccurate mapping between simulations and mechanisms. The methodology developed in this paper can be used to test which mechanism is at play and therefore precludes misattribution when multiple shock series are considered jointly.

The third key difference concerns the calibration of the shock series. Świecki (2017) and Sposi, Yi, and Zhang (2021) rely on sectoral deflators to identify sectoral productivity shocks. In turn, Eaton et al. (2016) and Sposi, Yi, and Zhang (2021) calibrate impatience shocks in a setup with no capital flow frictions. I use the fit between the model simulated with only these shock series in operation and the data to assess the quality of the respective series. I find that the correlation between the trade specialization and borrowing mechanisms in these partial specifications and the data are close to zero. In other words, both shock series fail the test of relevance for the key mechanisms of their operation. I innovate on these standard methods of calibration in two respects. First, I use Pseudo-Poisson Maximum Likelihood to estimate sectoral productivity. Second, I back out the impatience shocks assuming that international borrowing is subject to frictions. These new shock series give rise to simulations that show high correlation with the data. Thus, this is also the first paper to critically assess the quality of estimated shock series, and to conduct analysis using a plausible set of estimates.

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 studied the effects of the so-called 'China shock', typically leveraging cross-regional heterogeneity in exposure to competition from China to identify impact (see Autor, Dorn, and Hanson (2016) for an overview). In comparison, I estimate the impact in general equilibrium. This gives rise to country-level estimates of China-driven deindustrialization. In turn, within-country cross-regional studies miss the country-level impact by construction.[2] Second, the structural framework sidesteps the identification challenges commonly associated with the 'China shock' research design. Finally, my analysis covers a wide range of countries in a consistent setting. Thus, not only are the cross-country impacts directly comparable, they also take into account the rich interactions across the economies, including the effects of competition from China in third-party markets. My analysis of structural change in South Korea, in turn, is aimed at studying how its engagement in global markets led to export-driven industrialization. This topic has been studied extensively, with particular focus on the effect of industrial policies in promoting the expansion of heavy industries (see Lane (2022) for an overview). This paper takes a complementary approach. First, I use a structural model to estimate country-level evolution of sectoral productivities and trade costs. Then, I turn to a general equilibrium framework to study the role of trade in driving South Korea's industrialization, taking care to control for concurrent secular drivers of structural change.

The organization of this paper is as follows. In Section 2, I present the model. In section 3, I develop a decomposition of changes in sectoral value added shares into contributions of mechanisms and fundamental shocks. In Section 4, I present the dataset and discuss the calibration of the model. In Section 5, I apply the decompositions to manufacturing share time series and discuss the drivers of structural transformation in my sample, whereas in 6 I focus on case studies of China and South Korea. Finally, Section 7 concludes.

2. This is sometimes referred to as 'missing intercept problem': cross-regional studies identify the difference between affected and unaffected regions, but are silent on the general equilibrium effects common to both.

2 Model

In this section, I present the model that I will use to interpret structural transformation as observed in the data, and define its equilibrium. 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 discount factor shifters, 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 discount factor shifter, 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 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:

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

where B_{it} is this period's payment associated with bond holdings of the previous period, and $\mu_{t+1}B_{it+1}$ is the sale or purchase 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).

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.1).

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

$$\Pi_{jik} = \left(\frac{c_{ik} \tau_{jik}}{A_{ik} P_{jk}} \right)^{-\theta_k}, \quad \text{where } P_{ik} = \left[\sum_l \left(\frac{c_{lk} \tau_{ilk}}{A_{lk}} \right)^{-\theta_k} \right]^{-\frac{1}{\theta_k}} \tag{16}$$

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

$$c_{ik} = w_{ik}^{\omega_{ikl}} \left(\sum_s \omega_{iks} P_{iks}^{1-\sigma_s} \right)^{\frac{1-\omega_{ikl}}{1-\sigma_s}}, \tag{17}$$

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:

$$\beta_{ikl} = \frac{w_i l_{ik}(z)}{p_{ik}(z) y_{ik}(z)} = \omega_{ikl}, \tag{18}$$

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

$$\beta_{ikn} = \frac{P_{in} m_{ikn}(z)}{p_{ik}(z) y_{ik}(z)} = \begin{cases} (1-\omega_{ikl}) \dfrac{\omega_{ikP} P_{iP}^{1-\sigma_s}}{\sum_s \omega_{iks} P_{iks}^{1-\sigma_s}}, & \text{if } n = 1 \\ (1-\omega_{ikl}) \dfrac{\omega_{ikM} P_{ikM}^{1-\sigma_s}}{\sum_s \omega_{iks} P_{iks}^{1-\sigma_s}} \dfrac{\omega_{ikm} P_{im}^{1-\sigma_m}}{\sum_m \omega_{ikm} P_{im}^{1-\sigma_m}}, & \text{if } 1 < n < K \\ (1-\omega_{ikl}) \dfrac{\omega_{ikS} P_{iS}^{1-\sigma_s}}{\sum_s \omega_{iks} P_{iks}^{1-\sigma_s}}, & \text{if } n = K. \end{cases} \tag{19}$$

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

$$\alpha_{in} = \frac{P_{in} C_{in}}{E_i} = \begin{cases} \Omega_{iP} \left(\dfrac{P_{iP}}{E_i} \right)^{1-\sigma_s} C_i^{(1-\sigma_s)\epsilon_P}, & \text{if } n = 1 \\ \Omega_{iM} \left(\dfrac{P_{iM}}{E_i} \right)^{1-\sigma_s} C_i^{(1-\sigma_s)\epsilon_M} \dfrac{\Omega_{im} P_{im}^{1-\sigma_m}}{\sum_m \Omega_{im} P_{im}^{1-\sigma_m}}, & \text{if } 1 < n < K \\ \Omega_{iS} \left(\dfrac{P_{iS}}{E_i} \right)^{1-\sigma_s} C_i^{(1-\sigma_s)\epsilon_S}, & \text{if } n = K, \end{cases} \tag{20}$$

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:

$$\rho\frac{\phi_{it}}{\phi_{it-1}} = \mu_t \frac{1+bd_{it}}{1+bd_{it-1}} \frac{E_{it}\epsilon_{it}}{E_{it-1}\epsilon_{it-1}}, \quad \text{where} \quad d_{it} = \frac{E_{it}-w_i}{w_i} \text{ and } \epsilon_{it} = \sum_s \alpha_{ist}\epsilon_s. \tag{21}$$

Sectoral bundle market clearing in i, k satisfies

$$X_{ik} = \alpha_{ik}L_iE_i + \sum_{n\in K}\beta_{ink}\int_0^1 p_{in}(z)y_{in}(z) = \alpha_{ik}L_iE_i + \sum_{n\in K}\beta_{ink}Y_{in}, \tag{22}$$

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:

$$Y_{ik} = \sum_j \Pi_{jik}X_{jk}. \tag{23}$$

Labour market clears

$$wL_i = \sum_{k\in K}\int_0^1 wl_{ik}(z)dz = \sum_{k\in K}\beta_{ikl}Y_{ik}. \tag{24}$$

Finally, bond market clearing together with normalization require

$$\sum_i L_{it}E_{it} = \sum_i L_{it}w_{it} = 1. \tag{25}$$

3 Drivers of Structural Change

In this section, I explore the main factors driving structural transformation in my model. I do so by manipulating the equilibrium conditions derived in Section 2. First, in Section 3.1, I break down the changes in sectoral value added shares into the contributions of changes in trade shares, sectoral expenditure shares, and international borrowing. Next, in Section 3.2, I link changes in sectoral shares to the operation of different types of exogenous shocks.

For ease of exposition, I begin my discussion by assuming away the use of intermediate inputs and population growth. I then discuss how these factors alter analysis in Section 3.2. The results in Section 5 feature both.

3.1 Mechanisms of Structural Change

First, consider the sectoral demand and market clearing conditions (22), (23):

$$Y_{ik} = \sum_j \Pi_{jik} \alpha_{jk} L_j E_j.$$

Let $D_i = E_i/w_i = d_i + 1$ stand for aggregate deficits: $D_i > 1$ for economies that borrow, whereas $D_i < 1$ for economies that lend. The market clearing condition can be rewritten as

$$Y_{ik} = \sum_j \Pi_{jik} \alpha_{jk} D_j w_j L_j = \sum_j \Pi_{jik} \alpha_{jk} D_j \sum_k Y_{jk},$$

where the last equality relies on the observation that, in a model with no intermediate inputs, country's labour income is simply the sum of its sales.

Consider the total derivative of sectoral sales with respect to the full set of changes in trade shares, sectoral expenditure shares and aggregate deficits. It is convenient to work with changes with respect to level, so let $\tilde{x}$ denote an infinitesimal change in variable x divided by its level: $\tilde{x} = dx/x$. Then, change in sectoral sales satisfies

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

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.2 I show that the full set of equations for all countries and sectors can be used to solve for changes in sectoral sales as a function of changes in trade shares, expenditure shares, and aggregate deficits, such that

$$\tilde{Y}_{ik} = \tilde{Y}_{ik}(\tilde{\Pi}) + \tilde{Y}_{ik}(\tilde{\alpha}) + \tilde{Y}_{ik}(\tilde{D}),$$

where $\tilde{x}(\tilde{\Psi}) = \sum_{\psi \in \Psi} \frac{dx}{d\psi}\frac{\psi}{x}$ denotes the sum of elasticities of x with respect to variables in Ψ.

Finally, as value-added share changes reflect relative shifts in sector sales, these too can be decomposed into the operation of different margins:

$$\tilde{va}_{ik} = \underbrace{\tilde{Y}_{ik}(\tilde{\Pi}) - \sum_n va_{in}\tilde{Y}_{in}(\tilde{\Pi})}_{\text{Ricardian}} + \underbrace{\tilde{Y}_{ik}(\tilde{\alpha}) - \sum_n va_{in}\tilde{Y}_{in}(\tilde{\alpha})}_{\text{Secular}} + \underbrace{\tilde{Y}_{ik}(\tilde{D}) - \sum_n va_{in}\tilde{Y}_{in}(\tilde{D})}_{\text{Borrowing}}. \quad [1^*]$$

I discuss each term in turn.

Ricardian term can be broken down into the direct and indirect effects,

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

The former, 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* if this effect is stronger than that in other sectors. Thus, its operation reflects specialization subject to Ricardian comparative advantage. The indirect effect, in turn, accounts for changes in countries' incomes due to changes in trade shares, $\tilde{Y}_i(\tilde{\Pi}) = \sum_n va_{in}\tilde{Y}_{in}(\tilde{\Pi})$, which affect sectoral shares depending on the sector's exposure to a given market compared to the economy average, $\overline{\phi_{ji}} = \sum_n va_{in}\phi_{jin}$. Sectors that are above average exposed to an economy that grew – expand.

Secular term combines the direct and indirect effects of changes in final expenditure shares:

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

The direct effect is positive if either domestic or foreign households switch their expenditures towards sector k. Note that changes in the sectoral composition of economies driven by long-term trends in relative prices and incomes are commonly referred to as 'secular' – giving rise to the title of this term. The indirect effect operates as before, this time reflecting changes in incomes that arise due to shifts in spending patterns.

Finally, the borrowing term captures the direct and indirect effects of changes in countries' international borrowing:

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

Suppose home increases its borrowing, so that $\tilde{D}_i > 0$, and let k be non-tradable. Then, market exposure to oneself, ϕ_{iik}, is equal to one – larger than the market exposure to oneself of an average sector in the economy $\overline{\phi_{ii}}$. Thus, the direct effect of borrowing is positive for non-tradables. The reverse holds true for the sectors with high export to sales ratios – the direct effect of borrowing is negative. In other words, 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, note that the total effect boils down to the difference between the deficit and income changes.

3.2 Fundamental Drivers of Structural Change

Each of trade shares, sectoral expenditure shares and aggregate deficits are endogenous. In this section I discuss how they respond to exogenous drivers in the model. All derivations are presented in Appendix A.3.

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

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

where

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

Combining the two, i's trade share of sector k goods 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.

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

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

where aggregate consumption responds to expenditures and prices,

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

and where $\epsilon_i = \sum_s \alpha_{is} \epsilon_s$ is the average income elasticity in economy i. Price changes satisfy

$$\tilde{P}_i = \sum_s \alpha_{is} \tilde{P}_{is}, \quad \tilde{P}_{iM} = \sum_m \frac{\alpha_{im}}{\sum_m \alpha_{im}} \tilde{P}_{im}.$$

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.

Households choose their level of expenditure subject to their intertemporal optimization. In Appendix A.3 I show that if countries' net borrowing is small relative to their income, such that $D_{it} \approx 1$, then

$$\tilde{E}_{it} \approx \frac{\tilde{\phi}_{it} - \tilde{\phi}_t}{1+b} + \frac{b\tilde{w}_{it}}{1+b} + \frac{\tilde{e}_{it} - \tilde{e}_t}{1+b}, \tag{26}$$

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, $\tilde{E}_{it} = \tilde{w}_{it}$, and agents spend exactly what they earn. If, instead, international borrowing is frictionless ($b = 0$), then the key determinant of shifts in expenditure are impatience shocks. In this world, agents smooth consumption, such that absent the shocks to impatience, expenditures do not respond to (expected) shocks.[5] The exception are shocks that shift expenditure shares and through that, average expenditure elasticity. A higher average expenditure elasticity today increases contemporaneous returns to expenditure, and thus encourages borrowing. For a given wage change, aggregate deficit change simply reflects changes in expenditure:

$$\tilde{D}_i = \tilde{E}_i - \tilde{w}_i.$$

Finally, the wage change solves

$$\tilde{w}_i = \sum_k va_{ik} \tilde{Y}_{ik} \left(\tilde{A}, \tilde{\tau}, \tilde{\phi}, \tilde{\Omega}, \tilde{w} \right).$$

This exercise highlights the fact that changes in sectoral productivity, for example, affect sectoral value-added shares through all three mechanisms. Directly, by changing costs of production and relative prices, therefore changing patterns of specialization and expenditure shares. However, changes in productivity also have indirect effects, operating through changes in incomes, which matter for each of three mechanisms.

This observation gives rise to the second decomposition, where changes in sectoral value-added shares can be attributed to contributions of different types of shocks regardless of their mechanism of operation:

$$\tilde{va}_{ik} = \tilde{va}_{ik}(\tilde{A}) + \tilde{va}_{ik}(\tilde{\tau}) + \tilde{va}_{ik}(\tilde{\phi}) + \tilde{va}_{ik}(\tilde{\Omega}), \tag{2*}$$

5. Note that the invariance of expenditures with respect to global shocks obtains due to the normalization of nominal global GDP to one in each period. Real expenditures respond to such shocks to reflect the movements in global real output.

and which can be applied to individual components of decomposition [1*]:

$$\tilde{va}_{ik}^{X} = \tilde{va}_{ik}^{X}(\tilde{A}) + \tilde{va}_{ik}^{X}(\tilde{\tau}) + \tilde{va}_{ik}^{X}(\tilde{\phi}) + \tilde{va}_{ik}^{X}(\tilde{\Omega}) \text{ for } X \in \{R, S, B\}.$$

Finally, note that since each of the terms captures elasticities with respect to a set of shocks, these can be disaggregated further into contributions of individual country and sector shocks:

$$\tilde{va}_{ik} = \sum_{j,k} \tilde{va}_{ik}(\tilde{A}_{jk}) + \sum_{j,l,k} \tilde{va}_{ik}(\tilde{\tau}_{jlk}) + \sum_{j} \tilde{va}_{ik}(\tilde{\phi}_{j}) + \sum_{j,k} \tilde{va}_{ik}(\tilde{\Omega}_{jk}).$$

3.3 Attributing the Drivers of Structural Change

The many-to-many relationship between shocks and mechanisms is summarized in Figure 1.

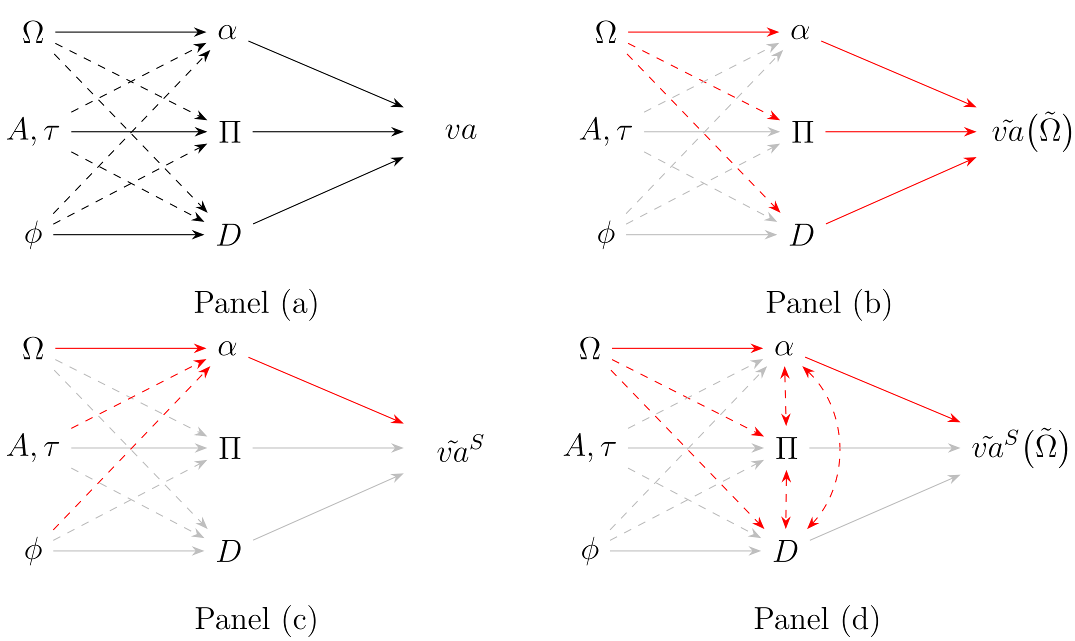

Figure 1: Mapping the Shocks to Mechanisms

Panel (a) reiterates that value added shares are a function of four types of fundamental shocks, each of which operates through all three mechanisms, either directly (solid arrows), or indirectly (dashed arrows). Panel (b) depicts the effect of a given shock type on sectoral shares. Here, for example, the preference shifters affect expenditure shares directly, but also have indirect effects on trade shares and borrowing. In order to measure the effect of this type of shock on sectoral shares, the appropriate measure is the total derivative with respect to shocks in $\Omega - \tilde{va}(\tilde{\Omega})$. Panel (c), conversely, presents the operation of one mechanism – 'Secular'. It is brought into motion, directly, by preference shifters, and indirectly by all other shocks. In order to retrieve the total effect of all shocks operating through this one mechanism, the appropriate measure is dva^S. Finally, Panel (d) shows that the effect of one given shock series operating through one mechanism can be obtained by solving for the total derivative of the relevant accounting decomposition term, with respect to the given shock series. Note the red dashed arrows crossing the mechanisms in Panel (d): preference shifters will induce changes in trade shares and borrowing. However, these effects will only be captured inasmuch as they feed back into changes in expenditure shares.

Figure 1 can be used to disentangle the effects that commonly used counterfactual exercises pick up. First, it is common to study the effect of 'trade' by simulating an open economy with only trade costs evolving, and forcing all other shock series to stay constant (Cravino and Sotelo 2019; Świecki 2017). Figure 1 clarifies that this exercise misses the effect of other shocks, most prominently changes in productivity, in driving specialization, and omits completely the borrowing channel. Such measures of the role of trade will likely underestimate its role. It is likewise common to study the effect of 'sector-biased technological change', i.e. asymmetric evolution of sectoral productivities, by switching this force off, and letting all other shock series evolve. Sposi, Yi, and Zhang (2021) interpret the results of this exercise as measuring 'trade specialization'. In fact, as Panels (b) and (c) in Figure 1 show, this exercise also includes the operation of a different channel – borrowing, and excludes the component of trade specialization that is driven by asymmetric changes in productivity. Świecki (2017) runs an analogous simulation, but instead compares the resulting counterfactuals with observed changes in sectoral shares. The difference is interpreted as the role of price and income effects. However, as Panel (b) shows, this measure is contaminated by the effects of productivity on trade specialization. Finally, it is common to run counterfactual simulations in autarky. The difference with the data is interpreted as the role of trade. This is largely accurate, but this method has two limitations: first, it cannot distinguish between the role of specialization and borrowing, and it does not permit the analysis of contribution of open economy forces over time, which would require economies to be partially open in the benchmark scenario. This analysis is unfit to address a range of policy relevant questions, such as changes in sectoral composition in response of changes in foreign competition (e.g. 'China shock'), or role of changing comparative advantage in episodes of export-led industrialization (e.g. that of South Korea).

To sum up, accounting decomposition is the appropriate measure to use when considering the role of different channels in driving structural change. Using simulations with subsets of shocks 'on' both results in conflation of operation of different mechanisms, and misses the role of other shocks in the operation of the mechanism in question. Simulations with subsets of shocks 'on', in turn, are helpful to distinguish between fundamental forces at play, but need to be combined with the accounting decompositions in order to interpret these as operating through particular channels.

The role of intermediate inputs and population. Up until now, I have abstracted from the input-output structure of production and assumed away population growth. However, both can be accommodated with minimal alterations.

First, since firms produce with CES technology, the demand for sectoral intermediate inputs varies over time. This constitutes yet another moving part driving sectoral sales. In the decomposition by mechanisms, I treat changes in intermediate input shares as contributing to the secular term. Population growth has no effect on decomposition [1*]. In Appendix A.2, I derive the decomposition by mechanism for general input-output structure, which takes the following form:

$$\tilde{va}_{ik} = \tilde{va}_{ik}^{R}(\tilde{\Pi}) + \tilde{va}_{ik}^{S}(\tilde{\alpha}, \tilde{\beta}) + \tilde{va}_{ik}^{B}(\tilde{D}).$$

Decomposition [2*] now has further exogenous shocks: to intermediate input and labour weights in the production function ω_{ikl} and ω_{ikn}, as well as to population sizes L_i. The contribution of these different shocks, as before, can be computed using a total derivative:

$$\tilde{va}_{ik} = \tilde{va}_{ik}(\tilde{A}) + \tilde{va}_{ik}(\tilde{\tau}) + \tilde{va}_{ik}(\tilde{\phi}) + \tilde{va}_{ik}(\tilde{\Omega}) + \tilde{va}_{ik}(\tilde{\omega}) + \tilde{va}_{ik}(\tilde{L}).$$

4 Calibration

In this section, I first describe the data sources that I use. In Section 4.2, I discuss the construction of model-consistent time series from the data. I describe the choice of time-invariant parameter values in Section 4.3, and, in Section 4.4, use the equilibrium conditions of the model to back out the exogenous shocks. I discuss the implementation of decompositions 1* and 2* in Section 4.5, and finally, talk about the model fit in Section 4.6.

4.1 Data Description

I use Groningen Growth and Development Centre World Input Output Database (WIOD) as a source of data on annual sector level bilateral trade flows, final consumption and intermediate inputs use.[6] In particular, the dataset features sector level 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}. Furthermore, I obtain the data on country-level population and sectoral price deflators from the Socio-Economic Accounts, which accompany WIOD. In order to extend the sample length, I merge the Long Run (1965-2000) and 2013 Release (1995-2011) versions 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.[7] 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. This gives rise to $K = 13$. The list of countries and sectors can be found in Appendix B.1.

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

7. 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.

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.

4.2 Solving for Paths of Endogenous Variables

Eaton and Kortum (2002) model can be solved using the base year values of endogenous variables and the changes in the values of exogenous shocks, where change is from the level of the previous period: $\hat{x} = x_{t+1}/x_t$. The model presented in Section 2 retains this property. Annual values for all endogenous variables can be derived using data on final and intermediate expenditures, along with population time series data, as follows:

$$X_{ijk} = X_{ijk}^{FC} + \sum_n X_{ijnk}^{II}, \quad Y_{ik} = \sum_j X_{jik}, \quad \Pi_{ijk} = \frac{X_{ijk}}{\sum_l X_{ilk}},$$

$$\beta_{ikn} = \frac{\sum_j X_{ijkn}^{II}}{Y_{ik}}, \quad \beta_{ikl} = 1 - \sum_n \beta_{ikn}, \quad E_i = \sum_{j,k} X_{ijk}^{FC}/L_i, \quad \alpha_{ik} = \frac{\sum_j X_{ijk}^{FC}}{L_i E_i}.$$

I present the hat-algebra formulation of the model in Appendix A.4.

4.3 Time-Invariant Parameter Values

There are seven time-invariant objects in the model: $\{\epsilon_P, \epsilon_M, \epsilon_S, \sigma_s, \sigma_m, \theta, b\}$.[8] 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

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

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 from the hat-algebra formulation of the model to estimate b that minimizes the distance between the expenditure changes under no impatience shocks and that in the data. The procedure yields $b = 7.5$ (see Appendix B.2 for details).

4.4 Calibration of the Shocks Series

There are six types of exogenous shocks in the model: $\hat{A}, \hat{\tau}, \hat{\phi}, \hat{\Omega}, \hat{\omega}, \hat{L}$. The model presented in Section 2 retains the key property of Eaton and Kortum (2002) setup: appropriately calibrated, the model generates paths of endogenous variables that match those in the data. $\hat{L}$ can be solved for directly from the data, by computing the ratios of country populations in consecutive years. The rest of the shock series can be obtained by inverting the equilibrium conditions of the model. I do so in two steps.

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

$$\hat{\Pi}_{jikt} = \left(\frac{\hat{c}_{ikt} \hat{\tau}_{jikt}}{\hat{A}_{ikt} \hat{P}_{jkt}} \right)^{-\theta_k}, \tag{27}$$

where, as before, $\hat{x} = x_{t+1}/x_t$. However, trade shares alone are insufficient to uniquely identify the changes in trade costs and productivities. There are two alternative ways forward.

Previous literature has used price deflators from the data to back out the trade cost and productivity shocks from equation (27). However, this method poses a risk of a measurement error, stemming from the imperfect match between the price series in the model, and what is measured in the data. In particular, in the model, price indices reflect differences in costs of production. However, in the real world, countries' produce also differs in quality.[9] The price indices in the data reflect both. Inasmuch as quality differences are systematic across countries, using price deflators will tend to assign lower productivity to higher quality producers. In turn, mismeasurement of productivity shocks results in mismeasurement of trade cost shocks: if productivity series are underestimated, equation (27) will result in artificially low outward trade costs in order to match the observed trade flows. Note that while using quality-adjusted price series is sufficient to address this problem, this type of data is not available for the multi-country, long-run sample I work with. Nonetheless, I estimate trade cost and productivity shock series using the price deflators from the data. I will present the comparison between these series and my preferred estimates in Section 4.6.

Instead of relying on price deflators, 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. Suppose the bilateral trade cost changes can be represented as a product of the symmetric trade cost decline and an idiosyncratic term: $\hat{\tau}_{jikt} = \hat{\mathtt{τ}}_{jikt}\hat{\upsilon}_{jikt}$. Then, equation (27) can be rewritten as a product of exporter fixed effect $e_{ikt} = (\hat{c}_{ikt}/\hat{A}_{ikt})^{-\theta_k}$, importer fixed effect $m_{jkt} = \hat{P}^{\theta_k}_{jkt}$, symmetric trade cost decline $\hat{\mathtt{τ}}^{-\theta_k}_{jikt}$ and an error term $\varepsilon_{jikt} = \hat{\upsilon}^{-\theta_k}_{jikt}$, such that

$$\hat{\Pi}_{jikt} = m_{jkt}e_{ikt}\hat{\mathtt{τ}}^{-\theta_k}_{jikt}\varepsilon_{jikt}. \tag{28}$$

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

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

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 adding the missing $I \times K$ restrictions by requiring that estimated asymmetric components of trade shocks have, on average, zero impact on trade shares.[10]

9. See Eaton and Fieler (2019) for a detailed discussion.

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

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$^{\text{th}}$ percentile of trade share changes is 1.19. As the conditional variance of these observations is likely orders of magnitude higher than their conditional mean, unweighted PPML is likely to be extremely inefficient.[11] Since it is difficult to predict such transitions based on observables, and it is plausible that changes in trade for low-volume country pairs are mostly noise, I exclude observations with trade share changes above a certain threshold, effectively assigning them zero weight in the estimation. All other observations carry equal weight. In my baseline specification, I use the 95$^{\text{th}}$ percentile of the dependent variable for a given sector and year as the cutoff. However, results remain virtually unchanged if 90$^{\text{th}}$ or 97.5$^{\text{th}}$ percentile cutoff are used instead.

Once the model is estimated, I use the importer fixed effect to back out 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 Appendix B.4. I find that trade costs have declined over the period, by 37% on average.

trade costs.

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

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 $\hat{\Omega}$, discount factor 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 Implementation

I now discuss the implementation of the decompositions [1*] and [2*]. Decomposition [1*] is immediate to compute using the formula derived in Appendix A.2,

$$\Delta va_{im} = \Delta va^R_{im} + \Delta va^S_{im} + \Delta va^B_{im}, \quad \text{where} \quad \Delta x_t = \Delta x_{t+1} - \Delta x_t, \tag{1}$$

plugging in the relevant level variables as measured in the beginning of each year, and replacing variables in changes by year-on-year percentage change in the data. I multiply both sides of the decomposition by the beginning of the year value added shares to obtain changes measured in percentage points. In order to obtain the decomposition at longer time horizons I add up the results in [1] computed at a yearly frequency across years. To measure change in aggregate manufacturing share, I sum across the subsectors of manufacturing.

To obtain an empirical counterpart to decomposition [2*], I simulate the model, year by year, with one type of shocks active at a time. Note that the shocks estimated in Section 4.4 map immediately to the changes-from-level transformation of exogenous variables used to derive [2*]. Thus, in any one year, the resultant change in sectoral shares corresponds to the individual components of decomposition [2*]:

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

As before, I re-scale the results to obtain changes in percentage points, and add up across the subsectors of manufacturing when studying changes in the aggregate manufacturing shares.

Finally, note that decompositions [1] and [2] give rise to first order approximations to changes in sectoral shares in the data. In both cases, the imprecision arises from the absence of interaction terms. These can be ignored in decompositions [1*] and [2*], as the changes considered are infinitesimal. However, the empirical counterparts, measured as year-on-year changes, are not, leading to non-zero second- and higher-order terms. Incorporating interaction terms in [1] yields an exact match with the data. Similarly, simulations with only a subset of shocks 'on' fail to account for interactions between shocks, resulting in discrepancies between the left-hand side of [2] and the data. Simulation with all shocks active restores the exact match. In practice, yearly changes are small enough to ensure a close fit between the left-hand side of [1] and [2] and the data (with correlations of 0.997 and 1 respectively). Thus, from now on, I treat the decompositions as applying to the data.

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.[12] 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

12. 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.

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.

4.6 Model Fit

In this section I discuss the properties of the shock series estimated in Section 4.4. Note that by construction, the model subject to baseline calibration matches the data exactly. Thus, the fit of the fully parameterized model cannot be used to assess the quality of shock estimates. However, a model simulated with a subset of shocks operating at a time is not restricted to match the data. Thus, I use the ability of such partial model specifications to predict patterns in the data as a signal of the informativeness of a given shock series. I study the ability of shock series to match the changes in sectoral shares, as well as the individual components of decomposition 1. The idea is that changes in trade costs, for example, should predict changes in trade specialization much better than changes in borrowing. Thus, a close fit with the former will provide a more reliable signal of the quality of the respective shock series. Results can be seen in Table 1.

Each shock series has a correlation of between 0.24 and 0.55 with the changes in sectoral shares in the data. Exception is population shocks, which have no predictive power. However, the correlations between the simulated series and the component of the decomposition that the underlying shock affects directly is higher. For example, the correlations between the Ricardian term in the data and that in the 'only productivity' and 'only trade costs' simulations are 0.44 and 0.56 respectively. The borrowing components in the 'impatience only' counterfactual have a correlation of 0.69 with that in the data, whereas the preference and production shifters result in the correlation of 0.24 and 0.55 with the secular component in the data. In other words, the estimated shock series pass the test of relevance.

This exercise also provides a framework for comparison with alternative shock specifications. For example, I find that productivity shocks estimated using the price deflators result in a poorer fit for each of the terms of the decomposition. Crucially, the correlation with the Ricardian term decreases to mere 0.08. Trade cost shocks from this specification have a somewhat better fit to the data, but still show a worse fit than that of the PPML estimates. In short, the shock series estimated in this manner, and productivities in particular, have essentially no bearing on the specialization patterns as observed in the data. This is a problem when studying the relationship between trade and structural change.

Finally, this exercise is also helpful for highlighting the role of international borrowing frictions introduced in the model. Earlier literature has estimated the model with frictionless capital flows. The fit of such calibration with all shocks in operations is always exact. However, in the counterfactual scenarios where only impatience shocks are 'on', the two specifications yield markedly different results. I re-estimate the model setting $b = 0$, and compute the fit of the simulation with impatience shocks alone. The correlation of this simulation with the borrowing term is 0.14. Again, the shock series that is supposed to be the key engine of the borrowing mechanism has negligible effect on its operation. The reason for the deterioration of the fit is that free capital flows specification predicts that fast-growing economies should be borrowing aggressively. In the data, they rarely do. In order to reconcile the model and the data, this specification infers extreme patience on behalf of these economies, 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. As a result, the shock series reconciling the lack of borrowing on the part of the fast growing economies are much less extreme.

	τ	A	ϕ	L	Ω	ω	τ^P	A^P	ϕ^{fc}
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 ($b = 0$).

5 Results

In this section, I use the decompositions developed in Section 3 to study structural transformation in my sample. In Section 5.1 I study the contribution of mechanisms and shocks to changes in aggregate manufacturing share. In Section 5.2, I discuss the drivers of cross-country heterogeneity in patterns of industrialization. In both, I emphasize how 'naive' mapping between shocks and mechanisms can lead to mismeasurement and misattribution. Finally, in Section 5.3 I discuss the structural change within manufacturing.

5.1 Drivers of Aggregate Manufacturing Share

Figure 2 below presents the decomposition [1], applied to the aggregate manufacturing shares between years 1965 and 2011.

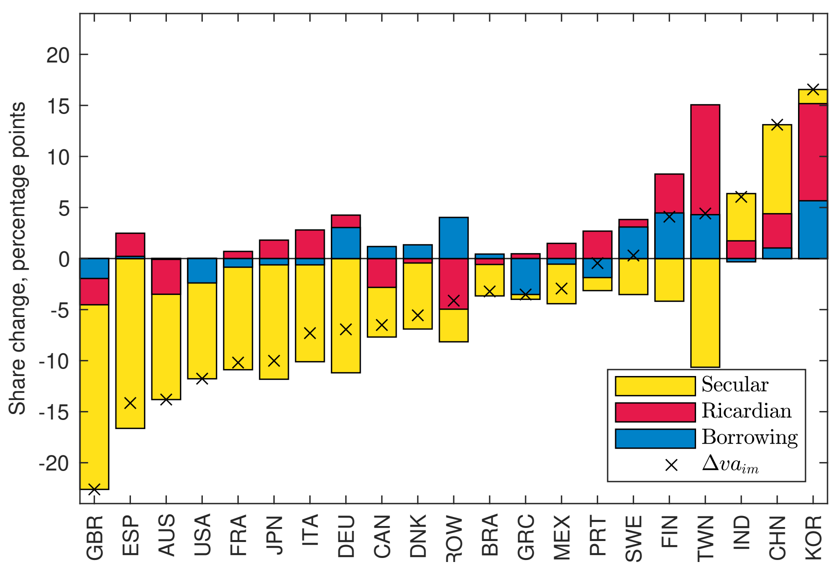

Figure 2: Mechanisms of Changes in Manufacturing Value Added Shares

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 total change in manufacturing shares as follows:

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

Over the period, the secular component accounts for 60% of the total aggregate change in manufacturing shares. In turn, Ricardian and borrowing terms contribute 23% and 17%, respectively. Two observations are in order. First, note that these effects are sizeable: while it is common to model structural change in a closed economy, these results shows that such analyses miss almost half of the picture. Second, this is the appropriate measurement of the roles of trade specialization and borrowing. As I argue in Section 3.3, what identifies a mechanism is not the fundamental shocks that drive it, but the margins of adjustment on behalf of the agents. These are captured precisely by the decomposition [1].

Next, I turn to the fundamental shocks behind the mechanisms of structural change discussed in the previous segment. I begin by applying the decomposition [2] to changes in aggregate manufacturing shares over the period. Results can be seen in Figure 3.

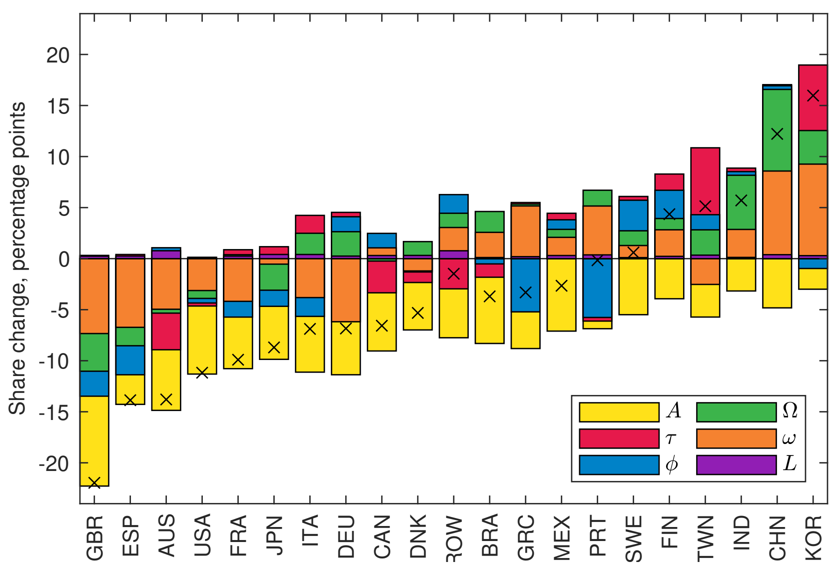

Figure 3: Fundamental Drivers of Manufacturing Value Added Shares

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

Computing the relative contribution as before, I find that the most important driver are productivity shocks, accounting for approximately 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 repeat the exercise, but this time study the contribution of different shock series to the operation of individual channels. The results can be seen in Table 2 (also see Figure C.1 in Appendix C.1). In line with analysis in Section 3, I find that productivity shocks are the primary determinant of the operation of the secular component. However, they are also the secondary driver of specialization and of borrowing. Trade costs contribute mainly to specialization, but also affect the secular and borrowing terms. Impatience shocks primarily drive borrowing, but are also the third most important driver of specialization. Finally, preference and production function shifters are primarily affecting the secular channel, whereas population growth plays a minor role in specialization.

	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.

Discussion in Section 3.3, as well as the results in the Table 2 emphasize that the mapping between shocks and mechanisms is not one-to-one. Instead, there are rich spillover effects operating through the forces of general equilibrium. Ignoring these effects can lead to mismeasurement and misattribution. To make this argument more concrete, I conduct three 'naive' estimations which have precedent in the literature.

First, if I misidentify the contribution of trade specialization with the role of trade costs alone, I find that it is responsible for 11% of observed change in manufacturing shares. Measured appropriately, the contribution doubles to 23%. If, instead, I mistakenly add impatience shocks together with trade costs to measure trade specialization, I recover the correct magnitude at 23%, but through wrong calculation. Additionally, country-level results would be incorrect. Finally, if I misidentify the contribution of price and income effects as the joint effect of changes in productivity, as well as of preference and production shifters, I find that they are responsible for 74% of the observed change. Appropriately measured, their contribution is lower – at 60% – the difference being due to the misattribution of the effects of productivity as they operate through other channels. To sum up, 'naive' mapping between shocks and channels results in inaccurate estimates of their relative importance, as well as in a misleading picture of the causes of (de)-industrialization across economies.

5.2 Cross-Country Heterogeneity

Figure 2 also highlights that the Ricardian and borrowing terms are important in explaining the heterogeneous patterns of structural change across economies. A priori, one might expect similar patterns of structural transformation for 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 on the same end of global capital flows. To study the drivers of cross-country heterogeneity in patterns of industrialization, I split my sample into two equally sized groups on the basis of their GDP per capita in 1965. Next, 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]:

$$\Delta va_{im} - \overline{\Delta va_m} = \Delta va^R_{im} - \overline{\Delta va^R_m} + \Delta va^S_{im} - \overline{\Delta va^S_m} + \Delta va^B_{im} - \overline{\Delta va^B_m},$$

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

	Lower Income	Higher Income
Secular	56	46
Ricardian	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 expenditure shares, although still a primary contributor, have a lesser impact on deviations from a common trend than on overall changes in manufacturing shares. Approximately half of the dynamics can now be ascribed to trade specialization and international borrowing. In the lower-income group, changes in trade competitiveness drove the divergence in manufacturing shares. This is evident in Figure 2: Taiwan and South Korea, two economies with the highest industrialization rates during this period, experienced 11 and 10 percentage point increases in their manufacturing shares due to this factor. These remarkable transformations occurred during a time of deindustrialization for most economies, highlighting the power of open economy forces in reshaping economies. Among the higher income group, instead, losses associated with changes in trade competitiveness contributed to two of the most rapid deindustrialization experiences in the sample – those of the United Kingdom and Australia – leading to a 3pp decline in their manufacturing shares, respectively.

The effect of borrowing on cross-country heterogeneity can also be read off Figure 2. Note that this factor is the sole reason high-income, surplus economies like Sweden and Finland register increases in manufacturing shares during this period, contrary to standard model predictions. Similarly, Germany's ability to maintain a relatively high manufacturing share, despite its high income and strongly negative expenditure shares contribution, can be credited, in part, to its lender status. In contrast, the United States and the United Kingdom, both running aggregate deficits throughout the period, experienced a decline in manufacturing shares due to this force, shrinking by two percentage points each.

In sum, both trade specialization and borrowing are quantitatively important in explaining cross-country heterogeneity in industrialization experiences – jointly responsible for a half of observed variation – and are key for rationalizing some of the outliers in my sample.

Sposi, Yi, and Zhang (2021) make a related point, arguing that cross-country heterogeneity in manufacturing shares increased over time – a pattern they dub 'industry polarization'. Authors document the increase in unconditional and conditional variance of the logarithm of manufacturing shares over time, and argue that this was driven by trade specialization. I revisit this claim using the methodology developed in this paper. In particular, I break down the log-variance of manufacturing shares into contributions of individual channels using the accounting decomposition. Results can be seen in Figure 4.

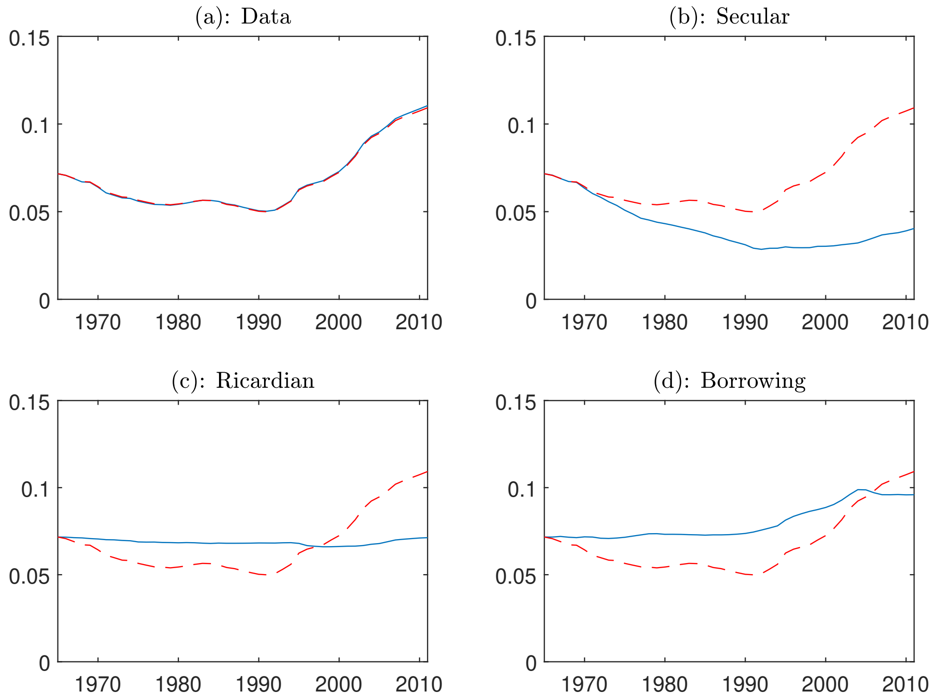

Figure 4: Industry Polarization by Mechanism

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 data by construction.

I find that borrowing can explain 62% of the increase in industry polarization. Remarkably, trade specialization explains a negative 1%. Note that this is in no contradiction to the results in this section: trade specialization matters for heterogeneity, but not more so today than previously. However, international borrowing did increase between 1965 and 2011, driving industry polarization. Why then was this pattern ascribed to trade specialization? In Appendix C.2, I replicate the exercise in Sposi, Yi, and Zhang (2021), forcing sectoral productivity growth to be symmetric, and letting the other shock series follow the baseline. This specification yields an increase in polarization in line with the data. However, the same exercise with international borrowing shut down results in a *decrease* in industry polarization over time. In other words, impatience shocks are included in the simulation, but the authors do not test for their individual effect, and instead interpret the results as implying a role for trade specialization. Using the correct measurement for the mechanisms avoids this pitfall.

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.

First, I map the manufacturing shares to a log-GDP per capita polynomial. However, instead of treating manufacturing as homogeneous, I break it up into two sub-sectors: low-technology manufacturing (LT) and high-technology manufacturing (HT). Results can be seen in Figure 5. First, note that the aggregate inherits the hump shape from the low-technology manufacturing: high-tech manufacturing share essentially flattens out as income grows. Moreover, income is only a weak predictor of high-technology manufacturing shares, with the R-squared of the quadratic relationship of just 0.06. The corresponding figure for the low-technology manufacturing is 0.33, a five-fold increase. Second, observe that both low- and high-technology manufacturing final expenditure shares exhibit a hump-shaped pattern in income (albeit, again, income has little explanatory power for HT expenditure shares). Thus, it looks as though while households eventually switch out of high-technology manufacturing expenditure, this need not happen in terms of production. What, then, determines the size of the high-technology manufacturing sector?

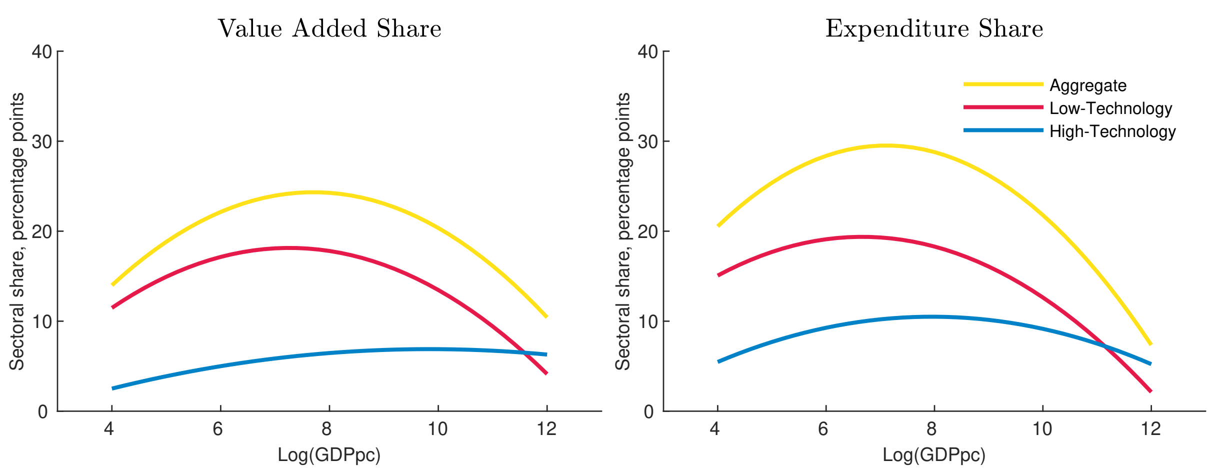

Figure 5: Structural Change within Manufacturing

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

To address this question, I repeat the decomposition exercise for the two subsectors. Results can be seen in Figure 6 (see also Figure C.2 in Appendix C.1 for industry-level results).

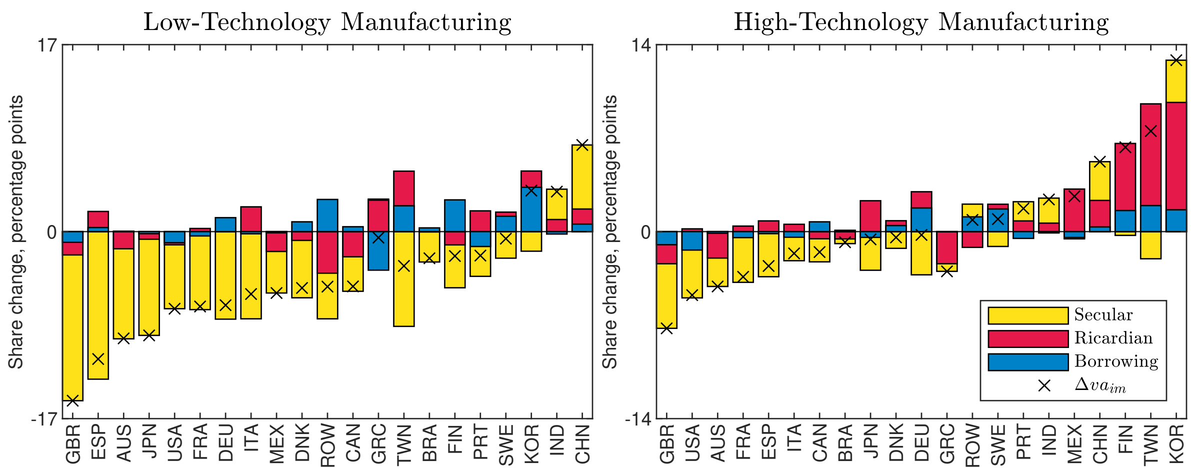

Figure 6: Mechanisms of Structural Change across Sectors

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 – explaining 68% of the observed change and, in virtually all cases, causing deindustrialization. The role of the open economy forces, on the other hand, has been relatively limited. High-technology manufacturing, in turn, exhibits a completely different pattern. Secular forces are no longer the most important component; instead, their role is comparable to that of trade specialization (explaining 42% and 41% respectively). Furthermore, whereas LT manufacturing shares seemed to follow a global trend, HT manufacturing shares, instead, diverged. As such, a small subset of countries increasingly specialized in HT manufacturing production – most notably South Korea, Taiwan and Finland, but also China, Mexico, Japan and Germany. Other economies either lost specialization, or saw little change over time.

To sum up, I find that trade is important beyond the aggregate manufacturing. In particular, I find that low- and high-technology subsectors within manufacturing behave very differently. The latter, in particular, exhibits no hump-shaped pattern as income grows, and instead is, to a large extent, shaped by trade specialization.

6 Case Studies

In Section 5 I studied the role of trade in driving aggregate manufacturing, cross-country heterogeneity in industrialization experiences and structural change within manufacturing. However, in all cases, I studied the effects of exposure to global factors. In this section, I take a more granular approach, and bring my methodology to study the role of individual economies. In particular, I revisit two popular narratives that link trade and structural change: China-driven deindustrialization and export-led industrialization in South Korea.

6.1 The rise of China

Between 2000 and 2011, China's economy tripled in size, jumping the ranks 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 Section 4.5 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 7.

First, note that China did, in fact, cause a contraction in manufacturing shares around the world, costing an average economy 0.36 percentage points of its manufacturing share between years 2000 and 2011. This accounted for 18% of the change in manufacturing shares over the period. Note that in year 2000, Chinese economy constituted mere 3.5% of the global GDP. Thus, given its size, the effect is indeed sizeable.

Next, I turn to dissecting the aggregate 'China effect' by shocks and channels. Figure 8 shows that for aggregate manufacturing, Ricardian forces were 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 current account

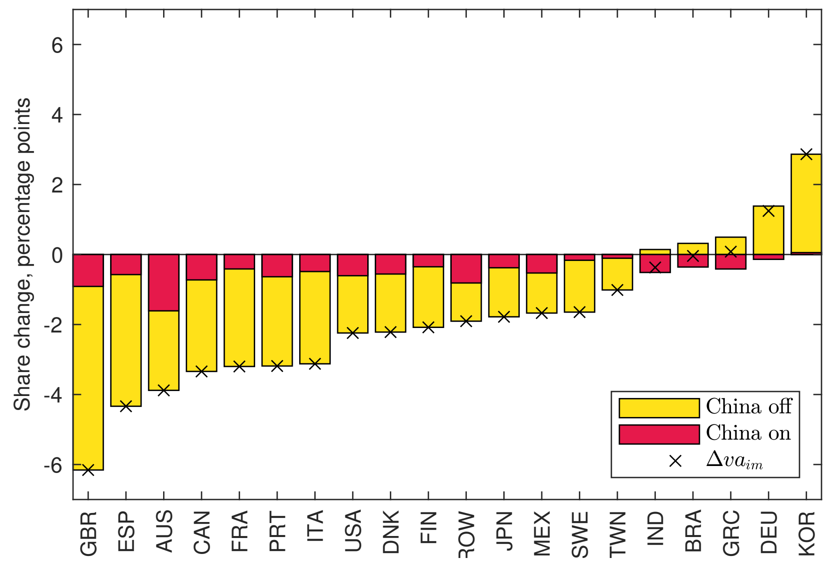

Figure 7: China-driven De-industrialization

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.

surpluses over the 2000-2011 period, which pushed the rest of the world towards borrowing.[13] Higher borrowing in the 'China on' counterfactual meant that economies were spending more on domestic non-tradables, and made up for increases in demand for tradables by imports from China. Breaking up the operation of channels into contributing shocks lends further insights. For example, Panel (c) shows that the Ricardian 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 per se.

Next, I turn to analysis at the level of individual subsectors. First, as before, I break

13. Note that in the data, many economies ran surpluses. However, the effect of China's surpluses was to cause either further deficits, or lower surpluses, elsewhere in the world. The 'China on' scenario isolates this net effect. Another way to think about it is that China's surpluses have put downward pressure on the global interest rates, making borrowing more attractive.

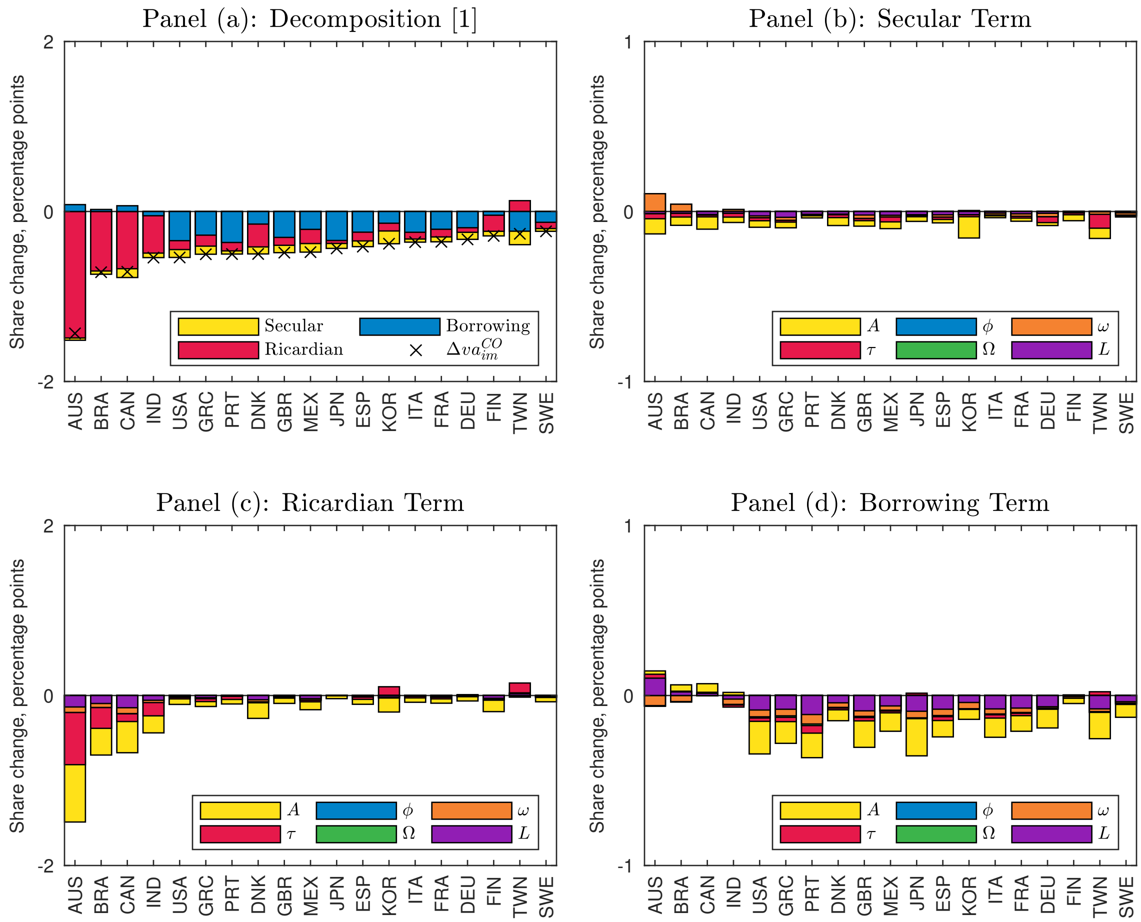

Figure 8: China-driven De-industrialization by Shock

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.

down manufacturing into low-technology and high-technology subsectors and repeat the exercise. Results can be seen in Figure **??**. I find that China has caused a decline in both low-technology and high-technology manufacturing shares in most economies. However, surprisingly, the effects in the HT manufacturing were larger – at 33% of the observed change (compared to 17% for the LT manufacturing). Industry-level analysis in C.4 in Appendix C.3, further tracks down much of the HT effect to a single two-digit sector, that of electrical equipment, where China was responsible for 47% of the observed dynamics. In Figure 10, I zoom into this industry by breaking down the effect of China by mechanisms and shocks.

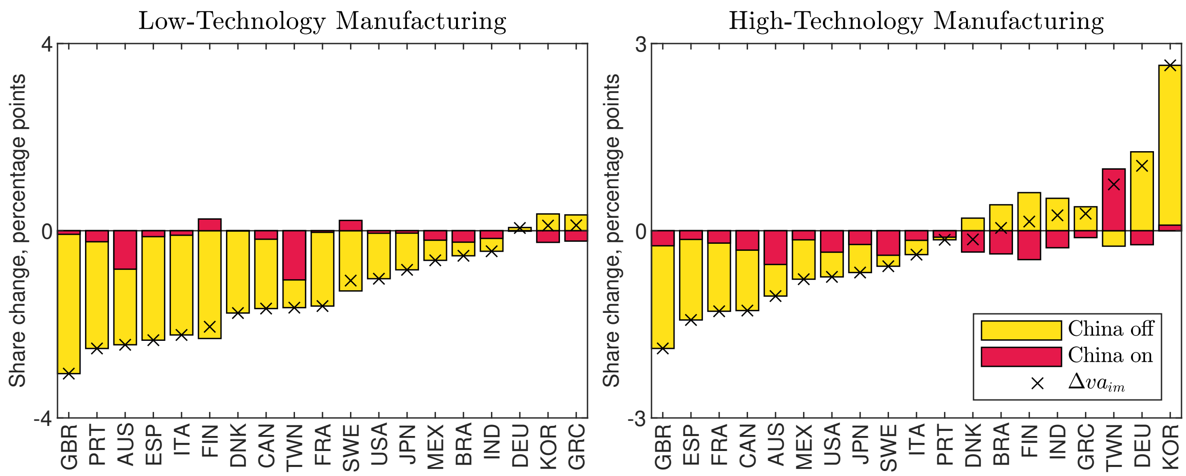

Figure 9: China-driven De-industrialization within Manufacturing

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.

First, I find that China-induced decline in electrical equipment shares was mostly due to the Ricardian forces. For two of China's closest trading partners – South Korea and Taiwan – the decline in secular demand for electronics in China had an additional negative effect. Turning to the Ricardian channel, I find two distinct patterns. First, it was mainly driven by 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, Germany, and Denmark – suffered the biggest declines. Second, 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.

In short, I find that between 2000 and 2011, China has caused a contraction in manufacturing shares across the world. However, these findings can be substantially refined. As such, I find that much of this effect can be traced to the operation of Ricardian and borrowing channels. Moreover, I find that high-technology subsectors were relatively more affected – first and foremost the electrical equipment industry, where declining trade costs and continued improvement of Chinese productivity put a squeeze on economies worldwide.

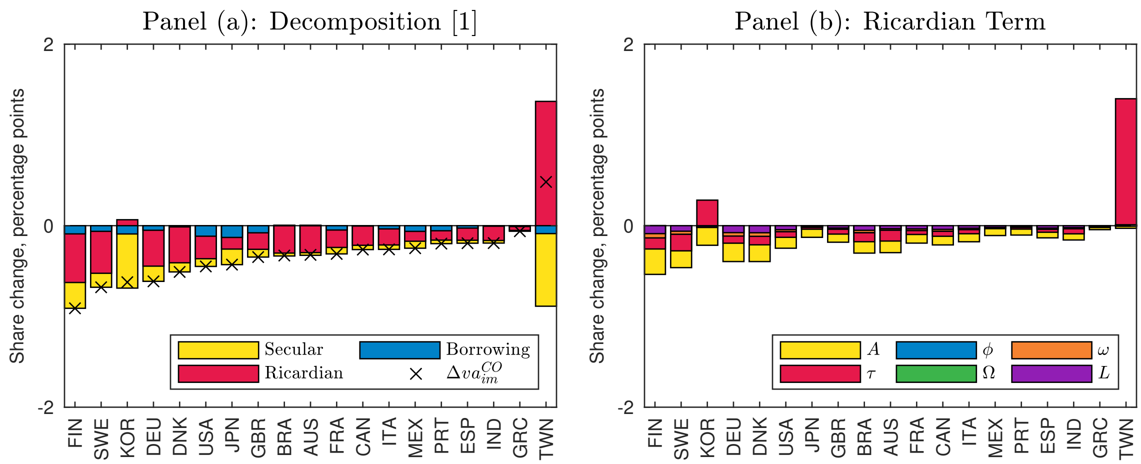

Figure 10: China-driven De-industrialization in Electrical Equipment

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.

In this segment, 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. With the implementation of export-oriented industrial policies, South Korea emerged as a key player in various sectors, such as automobiles, electronics, and shipbuilding. In this segment I ask: what was the contribution of trade to this dramatic transformation?

I begin by outlining the industrialization of South Korea. Between 1965 and 2011, South Korea saw its manufacturing share double, from 17 to 33 percentage points. Figure 11 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 Ricardian, secular, and borrowing terms. The figure reveals that the increase in manufacturing share resulted from a mix of trade specialization, secular turn towards manufacturing expenditure, and the expansionary impact of aggregate trade surpluses. However, among these three, trade specialization played the key role, explaining 57% of the observed increase.

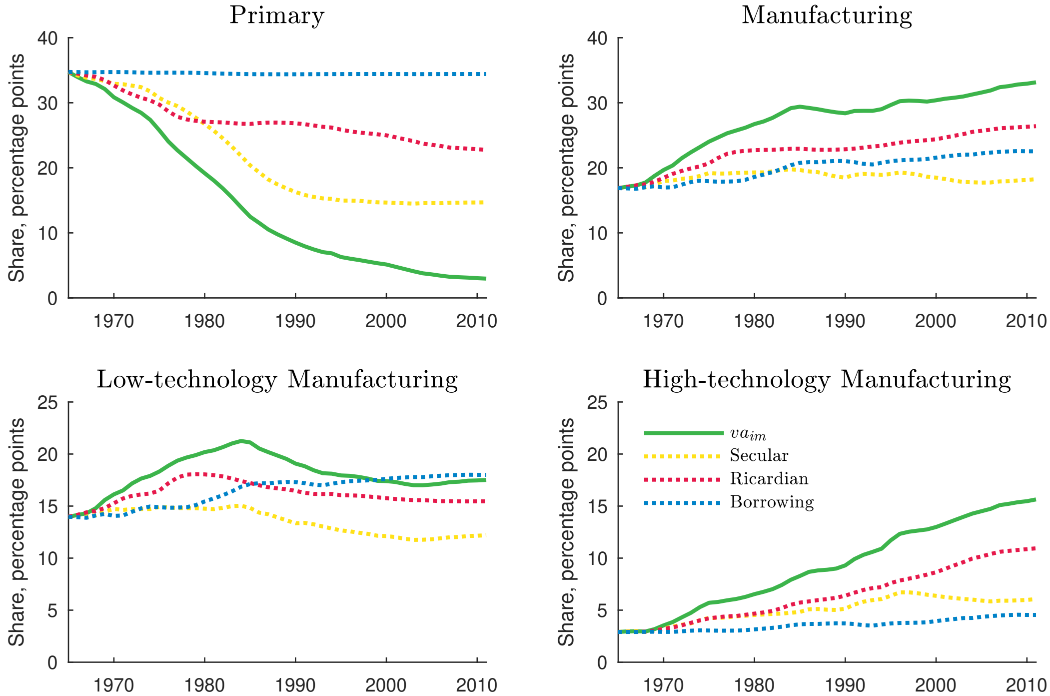

Figure 11: Industrialization in South Korea

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 $X \in \{S, R, B\}$.

Decomposition by subsectors, in turn, makes it clear that the aggregate trend conceals two distinct patterns. 1965 to mid-80s saw an expansion in the low-technology manufacturing, driven primarily by the Ricardian term. This pattern reversed from mid-80s onward. Further disaggregation by industry, presented in Figure C.5 in Appendix C.3, links most of this dynamic to the textiles and metals. In contrast, high-technology manufacturing, electronics and transportation in particular, expanded throughout. Turing to Panel (a) of Figure 11 gives important context: specialization in manufacturing was made possible by a massive contraction in the share of the primary sector, which made up 35 percentage points of the economy's value added in 1965 and has virtually vanished by 2011.

To shed light on these processes, I repeat the exercise in the previous segment, but now 'freeze' and, shock by shock, 'unfreeze' South Korea, while the rest of the world evolves according to the baseline calibration. The results can be seen in Figure 12, which replicates

Figure 11, but trade specialization term is now further broken down by contributing shocks. The results further complicate the sub-sectoral analysis in the previous segment. First, falling costs of trade 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 in South Korea in the beginning of the period: South Korea was already a net importer of agricultural goods in 1965. A decline in trade costs permitted it to move resources away from the relatively unproductive agriculture, and into the relatively more productive LT manufacturing, mainly textiles. 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, HT manufacturing grew by drawing on the resources from the LT manufacturing.

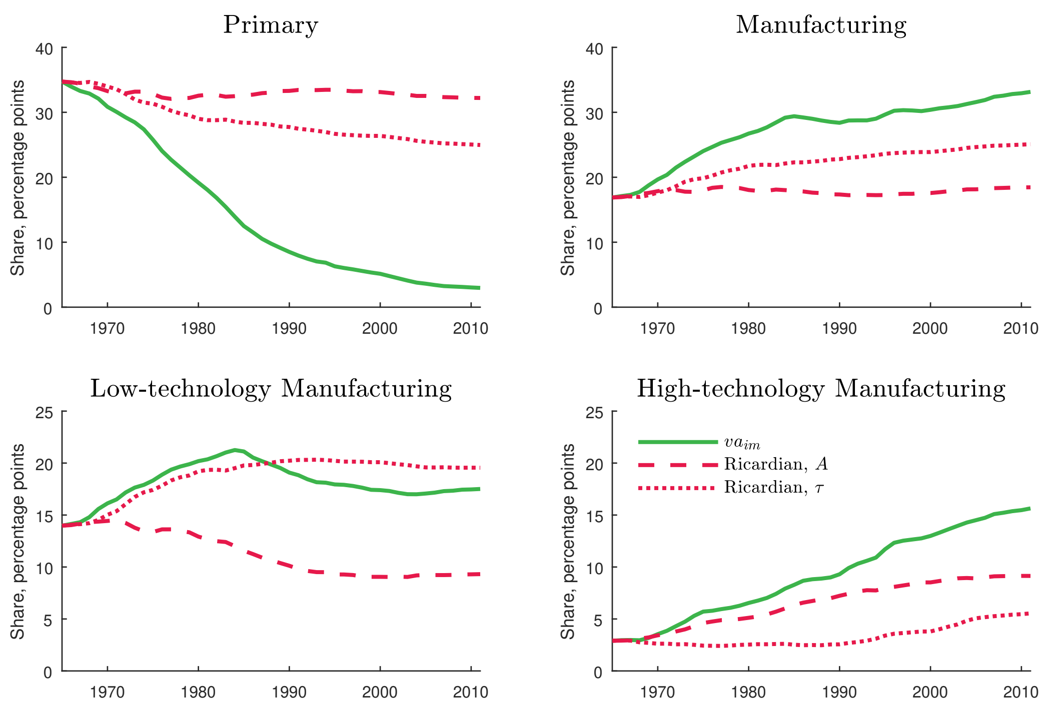

Figure 12: Industrialization in South Korea, by Shock Series

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.

To sum up, I find that industrialization in South Korea cannot be understood without taking into account trade specialization, the distinct roles played by changes in trade costs and productivities, and internal dynamics within the aggregate manufacturing.

7 Conclusion

In this paper, I have argued that openness to international trade is important for understanding structural change over the long run in a large sample of economies. By employing structural decompositions, the analysis showed that changes in trade competitiveness 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.

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A Mathematical Appendix

A.1 Derivations of the Equilibrium Conditions

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 (16).

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:

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

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

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

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

The unit cost of production (17) obtains by combining these first order conditions with intermediate input cost function and production function defined in (1)–(3). The input expenditure shares (18) and (19) 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:

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

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

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

where λ_i is the Lagrange multiplier on the budget constraint. Final consumption expenditure shares in (20) 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.

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

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

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 (21).

A.2 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

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

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,

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

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.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

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

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 (16):

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

[ii] Changes in production costs can be derived from (17):

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

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 (18):

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

[iv] Changes in intermediate input shares can be derived from (19):

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

[v] Changes in the final expenditure shares can be derived from condition (20):

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

where $\hat{C}_i$ satisfies:

$$\sum_s \alpha_{is}\hat{\Omega}_{is}\Big(\frac{\hat{P}_{is}}{\hat{E}_i}\Big)^{1-\sigma_s} \hat{C}_i^{(1-\sigma_s)\epsilon_s} = 1.$$

[vi] Changes in household expenditure can be derived from (21):

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

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 (22):

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

[viii] $\hat{Y}_{ik}$ satisfies the sectoral market clearing condition (23):

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

[ix] Wages change as to clear the labor market (24):

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

[x] Finally, μ_{t+1} satisfies (25):

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

B Calibration Appendix

B.1 Dataset Description

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.

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

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.

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:

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

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.

C Results Appendix

C.1 Additional Figures for Section 5

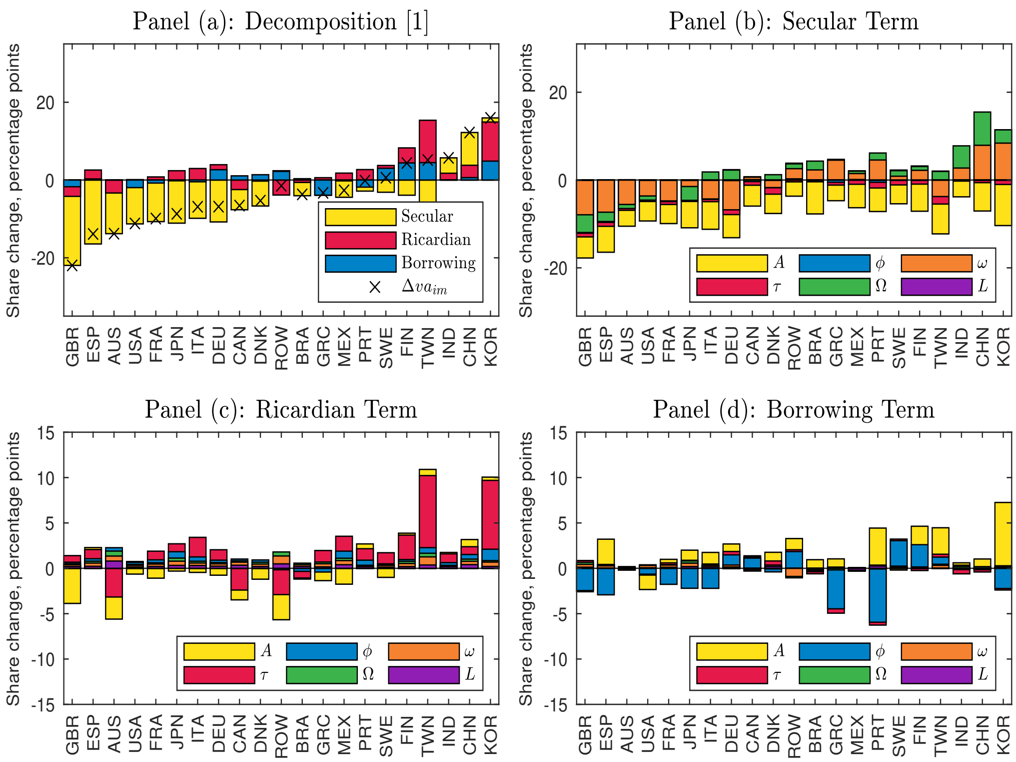

Figure C.1: Mechanisms of Manufacturing Value Added Shares by Shock

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).

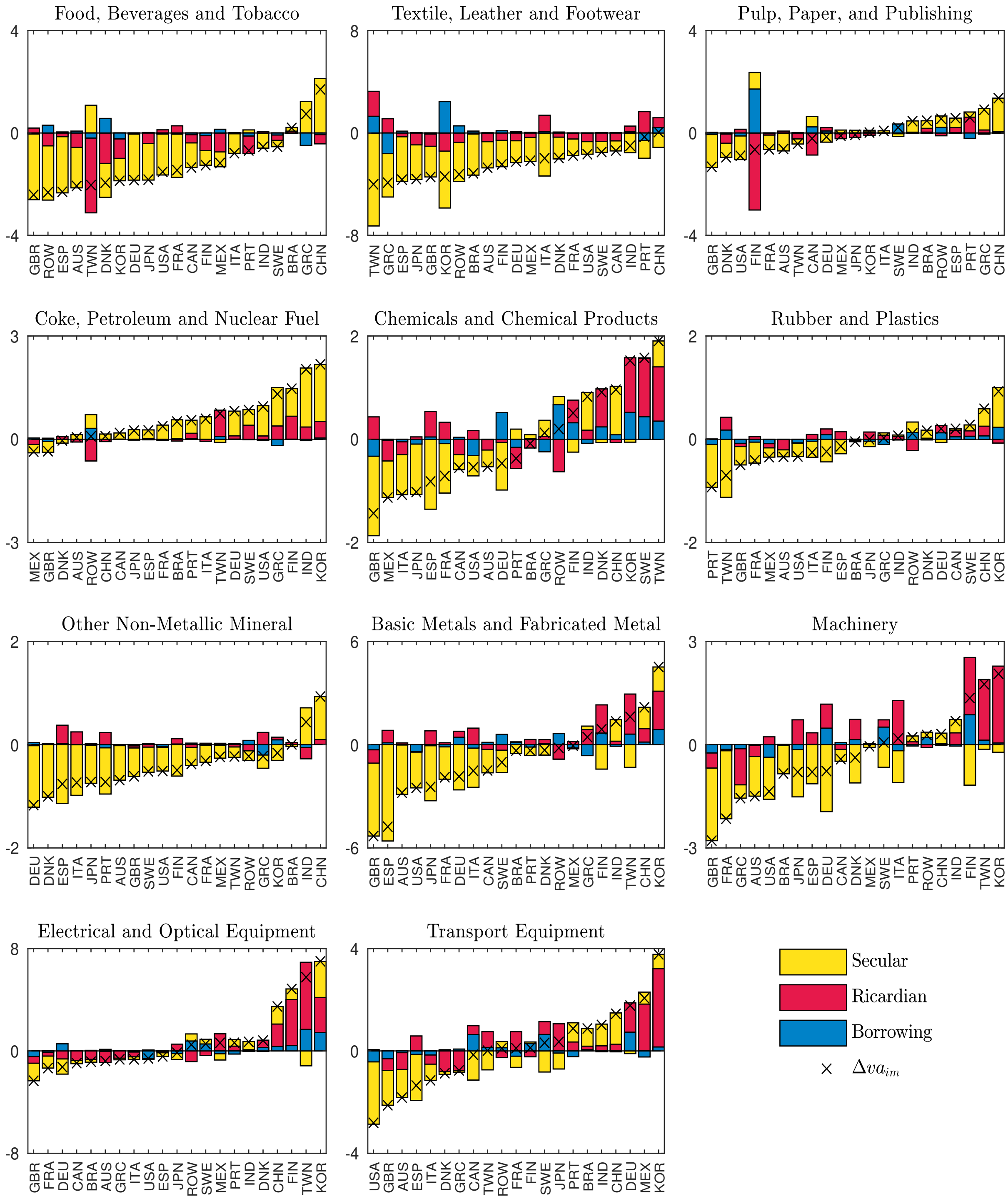

Figure C.2: Mechanisms of Structural Change within Manufacturing

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 Drivers of Industry Polarization

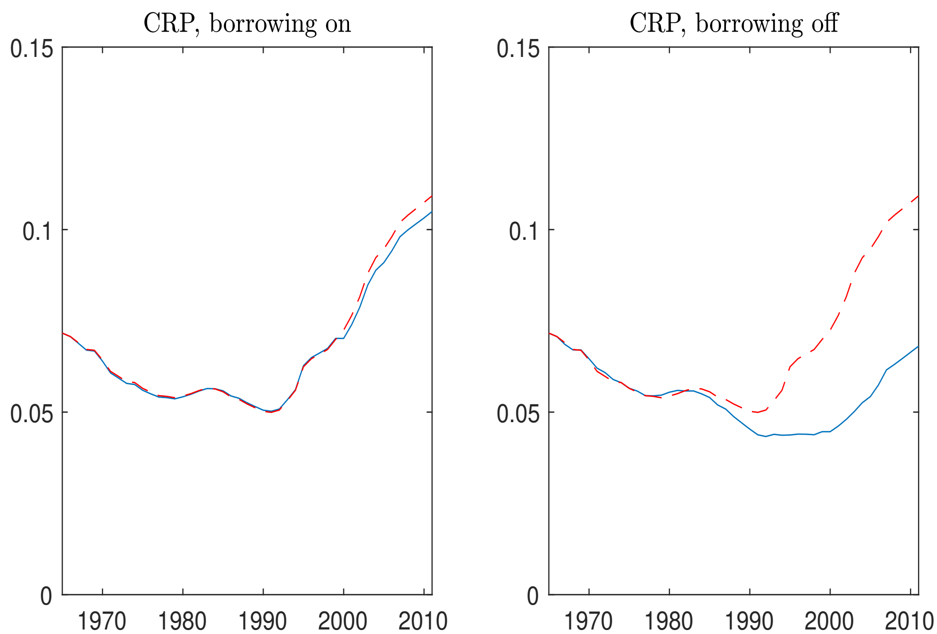

Figure C.3: Industry Polarization by Mechanism

Note: Red dashed line in both panels represents the unconditional variance of the logarithm of manufacturing value added shares in my sample in a given year. The blue line in Panel (a) represents the variance of the logarithm of manufacturing shares in the simulation where all shocks are calibrated as in the baseline, except for productivity, which is set at the average sectoral productivity in a given country in a given year (CRP stands for constant relative productivity as in Sposi, Yi, and Zhang (2021)). The blue line in Panel (b) represents the variance of the logarithm of manufacturing shares in a simulation with the same shock series, but with borrowing channel shut off by forcing expenditure growth to equal wage growth in each country and period.

C.3 Additional Figures for Section 6

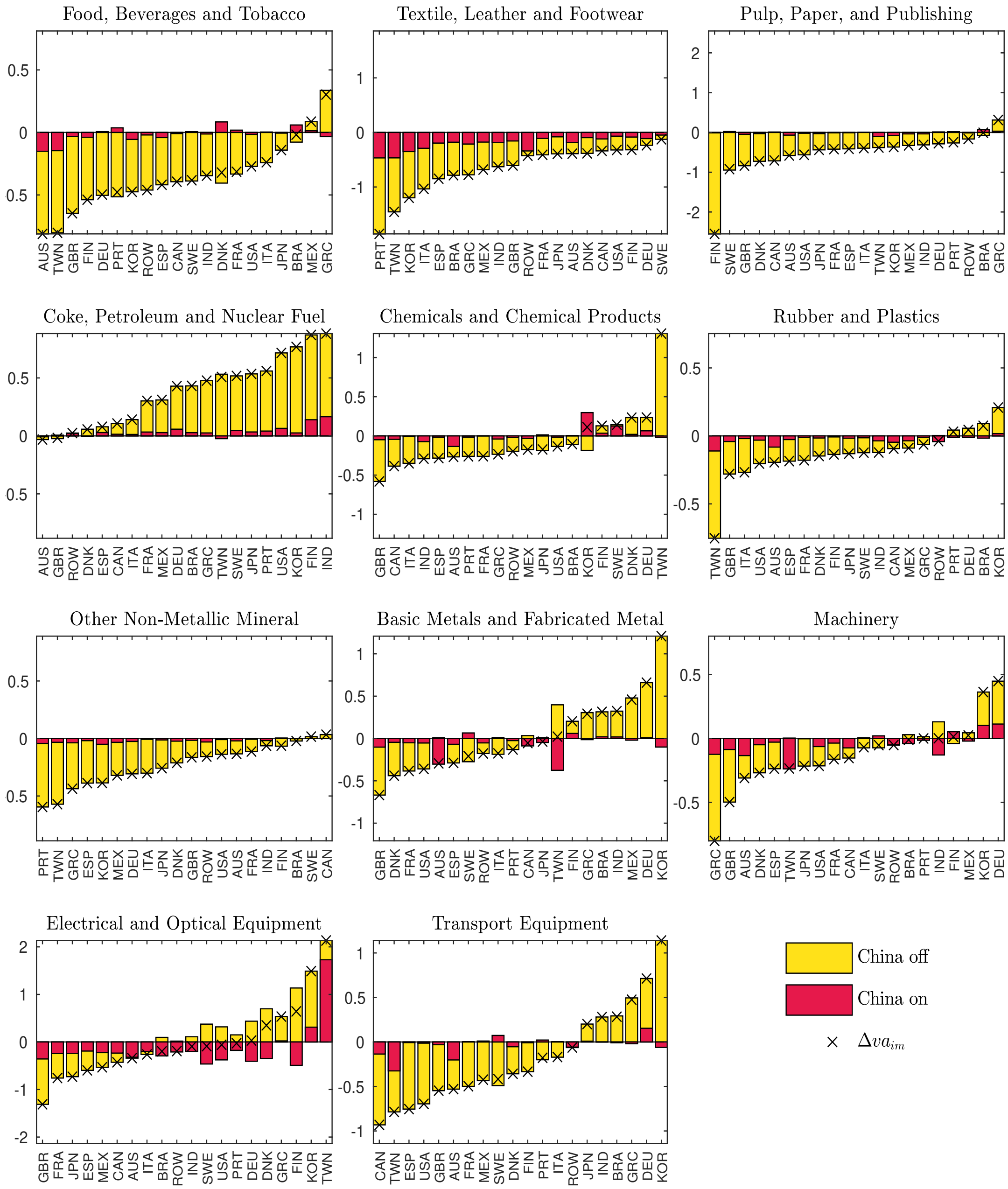

Figure C.4: China-driven De-industrialization by Industry

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.

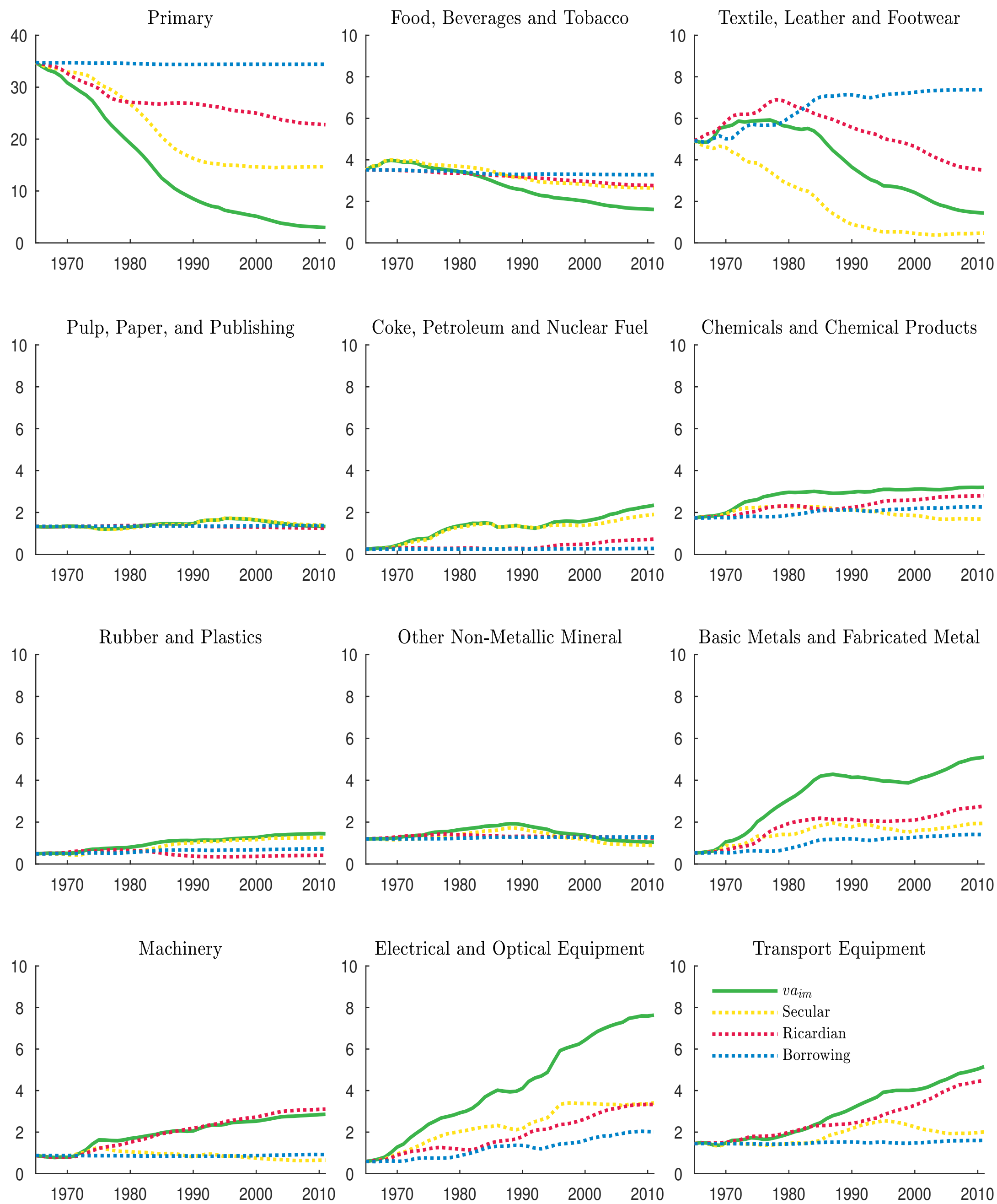

Figure C.5: Industrialization in South Korea, by Industry

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.