Structural Change and Global Trade Flow: Does an Emerging Giant Matter?

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Structural Change and Global Trade Flows: Does an Emerging Giant Matter? *

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Abstract

In this paper, we develop a novel trade-accounting framework that is based on a multi-country, multi-industry model of trade. The framework links observed changes in wages, sectoral employment shares, total labor force, and bilateral trade costs to changes in bilateral trade values at the sector level. In our application, we quantify the changes in trade patterns from 1995 to 2010 among 15 advanced and emerging market economies attributable to structural change in China, focusing on three manifestations of trade creation and destruction: China's replacement of manufactured final goods exports to advanced economies at the expense of other economies; an expansion of China's imports of manufactured final goods and commodities; and an expansion of China's imports of parts and components that are then processed and exported as manufactured final goods to the advanced economies. Our main findings are: (1) scale effects have more than compensated for the loss of competitiveness due to higher wages in China; (2) China's wage growth has been an economically more significant determinant of trade creation and destruction than its reallocation of labor across sectors, and (3) structural change in China has shifted other countries towards more commodity-intensive production.

JEL classification: F63; F12; F16;

Keywords: trade creation and diversion; scale effects; wage growth; reallocation of labor

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1 Introduction

Understanding the determinants of trade creation and trade diversion is essential for understanding the links between economic development and international trade.[1] While there are numerous potential determinants of trade creation and destruction, key fundamental mechanisms like backward and forward sectoral linkages allow one to directly link structural change and economic growth to changes in global trade patterns. The strength of these linkages in turn depends on cost competitiveness and scale effects (Fujita, Krugman, and Venables, 2001). In this paper, we present a novel theory-based trade-accounting framework that links, in a tractable way, a number of fundamental factors, including changes in wages, sectoral employment shares, total labor force, and bilateral trade costs to changes in bilateral trade values at the sector level.

To fix ideas, consider a change in the (log) value of trade between an origin-destination country pair (i, j) and an origin-destination sector pair (h, s) over two consecutive time periods $(t-1, t)$: $\Delta \ln Q^{hs}_{ij,t} \equiv \ln Q^{hs}_{ij,t} - \ln Q^{hs}_{ij,t-1}$. As we discuss below, this level of detail is necessary to think about a range of policy-relevant issues related to trade creation and destruction. Focusing now for brevity on changes in the wage rate $(\Delta \ln w_{\mathrm{c},t})$ and sectoral employment shares $(\Delta \ln l^{h}_{\mathrm{c},t})$ of a reference country c and their contribution to the bilateral trade flows of two regions i and j, our trade-accounting formula can be expressed as

$$\Delta \ln Q^{hs}_{ij,t}(\mathrm{c}) = \omega^{hs}_{ij,t}(\mathrm{c}) \Delta \ln w_{\mathrm{c},t} + \lambda^{hs}_{ij,t}(\mathrm{c}) \Delta \ln l^{h}_{\mathrm{c},t} + \text{remaining factors}^{hs}_{ij,t}.$$

This trade-accounting formula contains weights $\omega^{hs}_{ij}(\mathrm{c})$ and $\lambda^{hs}_{ij}(\mathrm{c})$ (which hinge on output elasticity parameters) that arise in a global production system integrated by trade, whereby bilateral trade between any two countries i and j can be influenced by structural changes taking place elsewhere. The "remaining factors" include changes in wages and sectoral employment shares in all countries participating in global trade, not just the origin and destination countries i and j. In this sense, the framework accounts for a rich array of factors and their interactions while maintaining a linear structure. An advantage of this formula is that all of the parameter values that ultimately determine the weights are immediately observable with the exception of the elasticity of substitution between intermediate inputs.

This trade-accounting framework is based on an extension of the multi-country, multi-industry trade model of Fujita et al. (2001, chp. 15). At the same time, its basic structure is consistent with a variety of modern approaches that lead to a gravity equation (Costinot and Rodríguez-Clare, 2014). Our analytical contributions are: (1) to derive a linear accounting formula, and (2) to advance the gravity equation to arrive at our theory-based weights by explicitly incorporating three critical effects: relative price effects (cost competitiveness) that are shaped by global considerations; sectoral and

[1] See Hirschman (1958), Grossman and Helpman (1992), and Findlay and O'Rourke (2007).

country-specific input-output linkages (factor and output composition); and sector and economy-wide scale effects. Our scale effects include both forward linkages, whereby producers prefer to locate closer to a "large" downstream market (local market effects), and backward linkages, whereby downstream industries tend to agglomerate in close proximity to economize on transportation costs incurred during the shipment of intermediate inputs (agglomeration effects). We apply this framework to account for the contribution of China in reshaping global trade patterns over the period 1995–2010.[2]

One dimension of our approach is worth highlighting at the outset. Any model of trade, including a model-driven accounting framework such as ours, must consider multiple feedback effects. For this reason, quantitative trade models that model the feedback effects between wages and the sectoral allocation of labor are highly nonlinear, are solved by numerical solution techniques, and require the calibration of total factor productivity levels for country-sector pairs. We do not model the impact of trade on wages given how much this depends on country-specific factors affecting their labor-markets.[3] Because we use observed changes in several fundamental factors, including wages, sectoral employment shares, the labor force, and transportation costs, and not their ultimate determinants, we do not conduct counterfactuals. The accounting framework we implement treats wage growth and the sectoral reallocation of labor as separate (not necessarily independently determined), proximate determinants of bilateral trade flows. Nevertheless, our framework captures the interactions among these fundamental factors to the extent that they affect relative prices that in turn change the volume of global trade for any given country-sector pair's output. In that sense, observed changes in all the fundamental factors accounted for in our linear framework fully incorporate and are thus consistent with endogenous changes in relative prices. At the same time, our accounting framework does not require us to take a stance on how changes in relative prices feed back into changes in wages and the reallocation of labour across countries and sectors.

In our application, we decompose changes in trade patterns among both advanced and emerging market economies (EMEs) into those due to changes in China's wage, sectoral allocation of labor, labor force, and access to international markets. Since 1978, the Chinese economy has undergone remarkable structural change characterized by the mass reallocation of labor across industries, and a significant increase in real wages and living standards. In tandem with this structural change, there has been (in the 1990s and 2000s) a deep integration of the Chinese economy into global trade with wide-ranging consequences for the trading patterns of other economies, as well as with important implications for trade and development policy. We thus illustrate the utility of our trade-accounting

[2] On the integration of China into the global economy, see Lardy (2002) and Prasad (2004). For a comprehensive account of China's economy over this period, see Naughton (2006).

[3] A model of wage determination would require additional assumptions to account for feedback effects linking trade back to wages and the sectoral allocation of labor; see, e.g., Fujita et al. (2001); Costinot and Rodríguez-Clare (2014); Caliendo, Dvorkin, and Parro (2019). One concrete justification for not pursuing this route here is that, over our study period, non-market forces—including the introduction of temporary worker programs, reforming of the household registration system *Hukou*, and restructuring of state employment, as well as demographic transition associated with one-child policy—were significant, if not the predominant, determinants of wages in China (Li et al., 2012; Meng, 2012).

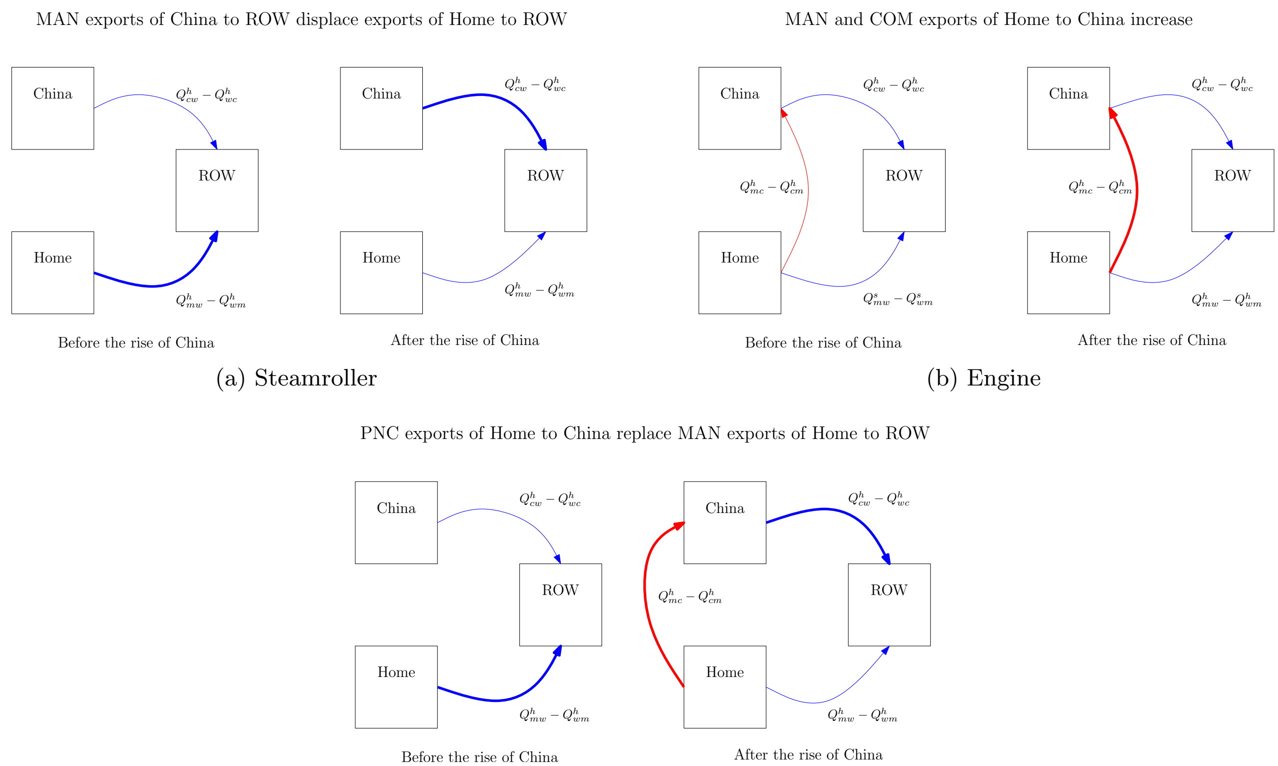
framework by assessing three potentially important consequences of structural change in China for changes in global trade patterns, encompassing both trade creation and destruction. First, China's replacement of manufactured final goods exports to advanced economies at the expense of other economies (the *steamroller* effect). Second, an expansion of China's imports of manufactured final goods and commodities (the *engine* effect). And third, an expansion of China's imports of parts and components that are then processed and exported as manufactured final goods to advanced economies (the *conduit* effect). (See figure 1 for a schematic representation of these effects.) To account for the contribution of structural change in China to these three effects, we focus on the two fundamental factors that are most closely associated with structural change: growth in wages (Kuznets, 1966), and the reallocation of labor across industries (Lewis, 1954).[4]

Consistent with the longer term focus of structural change, our analysis uses three non-overlapping five-year periods beginning in 1995 and ending in 2010 and we consider all changes in bilateral trade flows for 15 countries and 28 industries.[5] We use the most comprehensive input-output and trade-in-value-added data available, and account for all changes in industry-country dyad trade flows (176,400 cases). However, consistent with the thrust of the steamroller, engine, and conduit effects, we report the decomposition results by aggregating trade flows over major industries: manufactured final goods, parts and components, and commodities. We also report the contributions of wage growth and sectoral reallocation of labor across all the sectors in China to the observed changes in trade flows (in terms of the percentage points contributed, either positive or negative, by each factor to the growth rates of trade values).

According to the theoretical model underlying our formula, higher wages in China have dual consequences for bilateral trade flows as measured by the size and sign of the $\omega_{ij,t}^{hs}$ weights above: a loss of competitiveness due to higher unit costs, and a gain in competitiveness due to agglomeration effects. Our results indicate that, for most of the countries included in our study, scale effects have more than compensated for the loss of competitiveness due to higher wages. Our decomposition results also show that, although both wage growth and sectoral reallocation of labor in China contributed significantly to the observed changes in trade flows, wage growth was by far the biggest factor accounting for the steamroller, engine, and conduit effects.

[4] China's structural change as measured by the growth of its industrial wage and the reallocation of labor across industries has been remarkable. Within our study period from 1995 to 2010, China's share of labor in agriculture fell by 16 percentage points from 52% in 1995 to 36% in 2010, and its average manufacturing wage increased by 341% (supplementary material table S.3). We emphasize at the outset that China's structural change is an important but not necessarily the single most dominant cause of *overall* changes in trade patterns.

[5] The 28 industries adhere to the OECD's Inter-Country Input-Output (ICIO) Database classification used by the OECD in reporting its 2016 Trade in Value Added data (non-overlapping sub-groups only). The 15 countries broadly represent major advanced and emerging market economies involved in trade with China, and are restricted by the availability of data from multiple sources. The five-year periods correspond to distinct eras of structural change in China (supplementary material figure S.1). The distinction between aggregated sectors deemed to be producing manufactured final goods and parts and components has been the source of much original work on this topic (Haltmaier et al., 2007), and we find them to be effective organizing principles.



(a) Steamroller

(b) Engine

(c) Conduit

Figure 1: Steamroller, engine, and conduit effects: A schematic view

Notes: ROW stands for the rest of the world. Industries are grouped as producers of either commodities (COM), manufactured final goods (MAN), or manufactured intermediate inputs (PNC, parts and components), as the applicability of each effect depends on such industry characteristics. Exports of country i to country j sourced from industry h to industry s is represented by Q_{ij}^{hs}. The trade flows we illustrate are $Q_{ij}^{h} = \sum_s Q_{ij}^{hs}$.

Definition 1 (**Steamroller**)**.** China's replacement of manufactured final goods exports to advanced economies at the expense of other economies.

Definition 2 (**Engine**)**.** An expansion of China's imports of manufactured final goods and commodities.

Definition 3 (**Conduit**)**.** An expansion of China's imports of parts and components that are then processed and exported as manufactured final goods to the advanced economies.

These findings are consistent with scale effects that make the rise of China particularly relevant for the EMEs, as emphasized by Haltmaier et al. (2007) who coined the terms steamroller, engine, and conduit effects. For the entire period from 1995 to 2010 among the countries in our data, the combined effects of wage growth and sectoral reallocation of labor in China (structural change) have accounted for a 1.2 percentage point (pp) per year decline in the growth rate of manufactured final goods exports from EMEs to the United States (steamroller), a 9.8 pp per year increase in the growth rate of commodities exports from EMEs to China (engine), a 6.1 pp per year increase in the growth rate of manufactured final goods (engine), and a 6.2 pp per year increase in parts and components exports from EMEs to China (conduit).[6] We also consider the impact of the same mechanisms associated with wage growth in China on exports from China to the EMEs and find that structural change in China accounts for an 11.3 pp increase in the growth rate of manufactured final goods exports from China to EMEs (reverse engine), and a 10.6pp increase in the growth rate of parts and components exports from China to the EMEs (reverse conduit). When viewed from the standpoint of net engine and net conduit effects, then, structural change in China has induced significantly more robust growth of exports from China to the EMEs over our sample period. Although there is some variation across countries, in the majority of the cases, the contributions of structural change to each of these effects have increased over time.

The averages for each effect, however, mask considerable variation across countries even within a given period. For the full set of countries included in our study, we find that the steamroller effect was particularly significant for Indonesia, India, and Japan. We also find evidence that structural change in China has significantly boosted the commodity exports of Australia, Indonesia, Malaysia, Russia, United States, and Vietnam, and induced a group of countries, including Brazil, Indonesia, India, Mexico, and Turkey to export relatively more commodities than manufactured final goods to other countries. While Vietnam's exports of parts and components to China appear to be a major beneficiary of structural change in China, the evidence generally indicates that the emergence of China has led to a reallocation of parts and components trade across other economies. Overall, these individual country results point to the sometimes overlooked economic principle that stages of economic development matter for patterns of specialization and diversification.

Our conceptual framework is closely related to that of Vandenbussche, Garcia, and Simons (2019), who also develop a multi-region, multi-sector model of international trade with input-output linkages. Their main empirical focus, however, is on the economic consequences of Britain's exit from the European Union (Brexit), and their empirical strategy leaves aside trade-diversion effects that are incorporated in our trade accounting. Our application of trade accounting to trade creation and diversion is most closely related to that of Haltmaier et al. (2007). In grouping industries to align with

[6]Here and in the main text, the steamroller effect refers to the specific context of the impact of structural change in China on manufactured final goods exports to the United States from the rest of the countries included in our data.

those implied by the steamroller, engine, and conduit effects, we follow their empirical methodology as closely as possible. Changing patterns of global trade since the 1990s have been documented by Amiti and Freund (2008) and Riad et al. (2012), and here we contribute to that body of literature by developing a framework that decomposes these changes into trade diversion and creation.

There is also a large body of research on the effects of the rise of China on the EMEs and their trade patterns.[7] Our trade accounting is applicable to both EMEs and advanced economies, and accounts for interactions among all the economies included in our data. Recent work on the impact of global structural change also touches upon similar themes. For example, using a multi-country and two-sector model, Lewis et al. (2018) discuss the impact of structural change on measures of openness to trade, whereas here we focus on the impact of structural change in China on other economies. Moreover, our multilateral trade analysis makes use of all 28 industrial sectors, including services. By studying a range of trade creation and diversion effects that are of significance not only for advanced economies but also for EMEs, our work complements the body of literature that uniquely focuses on the impact of the rise of China on employment in the United States (Feenstra and Sasahara, 2018; Caliendo et al., 2019). There are also industry-based studies of trade creation and destruction that focus on a single destination country and find heterogeneous outcomes across origin countries, like the differential impact of the removal of U.S. textile and apparel quotas on rival exporters (Brambilla, Khandelwal, and Schott, 2010; Edwards and Sundaram, 2017). Finally, using a calibrated model, Bekkers, Koopman, and Rego (2019) make forecasts about the consequences of structural change in China on global trade relations, whereas we employ a theory-driven accounting framework and observed data.

The rest of the paper is organized as follows. Section 2 describes the model underlying the trade-accounting formula. Section 3 sets the stage for our application with a description of changes in global trade flows since the early 1990s. Section 4 provides the accounting of changes in global trade flows due to structural change in China from 1995 to 2010. Section 5 concludes. A data appendix and supplementary material complement the main text.

2 Trade accounting

In this section, we present the model of international trade underlying our decompositions and present the broad contours of the derivations that lead to our trade-accounting formula. We refer the reader to supplementary material section S.4 for detailed derivations.

[7] See, for instance, Eichengreen, Rhee, and Tong (2007), Devadason (2009), Park and Shin (2009), Hanson and Robertson (2010), and Lee, Park, and Shin (2017). For earlier work on similar themes, see Bradford and Branson (1987).

2.1 Preliminaries

There are $1, 2, \ldots, R$ regions that trade bilaterally that we index by subscripts. There are $1, \ldots, S$ producing sectors in each region that we index by subscripts. When we write q_{ij}^{hs}, we mean variable q originating from sector h in region i with destination sector s in region j. When there is no risk of confusion, we omit the time subscripts. To denote changes over time, we write $\Delta q_{ij,t}^{hs} := q_{ij,t}^{hs} - q_{ij,t-1}^{hs}$. There are (gross) iceberg transportation costs for cross-border trade, $\tau_{ij}^{hs} \geq 1$, with $\tau_{ij}^{hs} = 1$ for $i = j$. Employment in industrial sector s in region j is L_j^s with total employment $L_j = \sum_{s=1}^{S} L_j^s$, so that sectoral employment shares are $l_j^s \equiv L_j^s / L_j$.

2.2 Production

The framework we develop accounts for bilateral trade in value added between importing and exporting sectors. Production has a hierarchical structure starting with varieties and culminating in output in a given sector; see figure 2. Firms produce a unique variety of output in a particular sector. Production takes place using a Dixit-Stiglitz increasing-returns-to-scale technology with a composite input and a fixed cost of production. The composite input is a Cobb-Douglas combination of capital, labor, and a conglomerate intermediate input. The conglomerate input is a constant-elasticity-of-substitution (CES) function of the different varieties of firm output produced both domestically and abroad. The fixed and marginal cost increments of the composite input are identical in composition, and economic profits are zero, as in the standard Dixit-Stiglitz setup. Thus, the overall compositions of inputs and revenues follow the Cobb-Douglas form of constant input-expenditure shares that depend on output elasticity parameters. This production structure allows us to take full advantage of the national input-output tables (supplementary material table S.1). The firm's production decision is based on optimization with fixed costs, leading to a fixed firm-level output and monopolistic competition such that variety and scale matter. We first present the structure of the conglomerate intermediate input, then show the implications of the Dixit-Stiglitz technology for variety in a given sector, and finish by describing the emergent sectoral production function.

For each destination-origin pair of regions and sectors, the destination region provides a continuum of intermediate inputs that are aggregated according to

$$q_{ij}^{hs} = \left(\int_0^{n_i^h} m_{ij}^{hs}(\iota)^{\frac{\sigma-1}{\sigma}} \, d\iota \right)^{\frac{\sigma}{\sigma-1}}, \tag{1}$$

where q_{ij}^{hs} is the composite intermediate input sourced from region i sector h by region j sector s and a pair (i, i) would indicate home-sourced use of production in region i; $m_{ij}^{hs}(\iota)$ denotes the use of each variety originating from region i sector h in destination region j sector s; n_i^h is the number of varieties in the origin region i sector h; and $\sigma > 1$ is the elasticity of substitution across varieties in production.

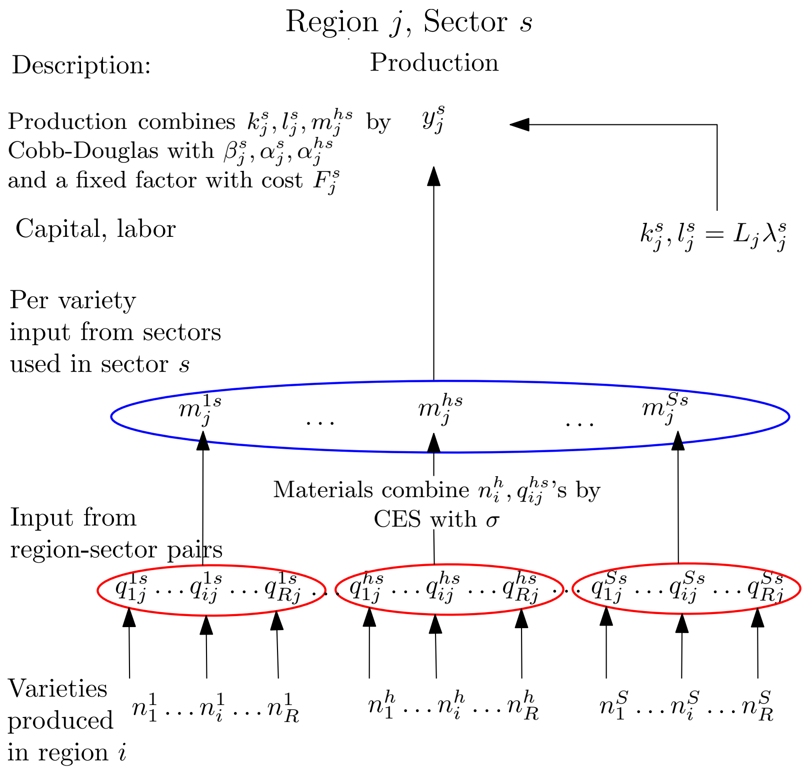


Figure 2: Production structure

In turn, intermediate inputs in sector s sourced from sector h from different regions of origin are combined into a locally-available conglomerate intermediate input purchased from industry h used in industry s region j according to

$$m_j^{hs} = \left(\sum_{i=1}^{R} (q_{ij}^{hs})^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}, \tag{2}$$

where q_{ij}^{hs} is the composite (of n_i^h varieties; equation (1)) intermediate input originating from region i sector h and used in region j sector s to produce the conglomerate intermediate input m_j^{hs}; $\sigma > 1$ is the elasticity of substitution across intermediate varieties in the production of each conglomerate intermediate input, which are composites of imports and domestic inputs.

Each conglomerate intermediate input enters into firm-level production whereby output is

$$y_j^s = \left(K_j^s\right)^{\beta_j^s} \left(L_j^s\right)^{\alpha_j^s} \left(m_j^{1s}\right)^{\alpha_j^{1s}} \dots \left(m_j^{Ss}\right)^{\alpha_j^{Ss}}, \tag{3}$$

where $1 > \beta_j^s > 0$ is the elasticity of output with respect to capital in sector s; $1 > \alpha_j^s > 0$ is the elasticity of output with respect to labor in sector s; $K_j^s > 0$ is capital stock; L_j^s is employment; m_j^{hs} is a conglomerate intermediate input (equation (2)); $\alpha_j^{hs} \geq 0$, for $h = 1, 2, \dots, S$, is the elasticity of output in industrial sector s with respect to the intermediate input from industry h; and where $\beta_j^s + \alpha_j^s < 1$ and $\beta_j^s + \alpha_j^s + \sum_{h=1}^{S} \alpha_j^{hs} = 1$.

This Dixit-Stiglitz style production function implies that the size of an economy is captured by the number of varieties that it produces. The latter in turn is inversely related to the relative cost of the goods produced in that sector and in a given economy, and directly related to the size of the labor force employed in a given sector

$$n_j^s = \frac{w_j L_j l_j^s}{p_j^{ms}}, \tag{4}$$

where given the Cobb-Douglas form of production (equation (3)), the firm-level unit cost function is

$$p_j^{ms} = \left(\frac{r}{\beta_j^s}\right)^{\beta_j^s} \left(\frac{w_j}{\alpha_j^s}\right)^{\alpha_j^s} \prod_{h=1}^{S} \left(\frac{G_j^{hs}}{\alpha_j^{hs}}\right)^{\alpha_j^{hs}}, \tag{5}$$

where G_j^{hs} denotes the producer price index (unit expenditure function) for the composite intermediate input sourced from sector h and for all regions. Firms also take the world interest rate r and the wage rate w_j as given. Fixed costs are such that optimal pricing by firms implies that $p_j^{ms} = p_j^s$.

2.3 Trade shares

We study global trade flows at the bilateral level between any two country-sector pairs (q_{ij}^{hs}), and use adding up constraints using region j input-expenditure shares to discipline the analysis. In order to derive these shares, we solve for a number of prices and input-expenditure functions, following the notation in Fujita et al. (2001) as closely as possible. We let a representative firm in each region maximize profits. Our derivations follow the order that the production structure was presented, starting with the lowest level input-expenditure function and ending with the price by sector.[8]

First, denote the c.i.f. price at the destination region and sector by the f.o.b. price at the origin region and sector multiplied for a unit transportation cost that is region-sector specific

$$p_{ij}^{hs} := p_i^h \tau_{ij}^{hs}.$$

Second, denote the expenditure on varieties of intermediate inputs by M_{ij}^{hs}, and the corresponding expenditure function by G_{ij}^{hs}. The cost minimization by the destination region and sector gives

$$G_{ij}^{hs} = (n_i^h)^{\frac{1}{1-\sigma}} p_{ij}^{hs}. \tag{6}$$

Next, let total expenditures on intermediate inputs by region j sector s procured from sector h be

$$M_j^{hs} := m_j^{hs} G_j^{hs} = \sum_{i=1}^{R} G_{ij}^{hs} q_{ij}^{hs}. \tag{7}$$

[8] Markups cover fixed costs as is standard in the monopolistically competitive models with increasing returns to scale.

Let x_{ij}^{hs} be the share of exports from region-sector pair (i, h) sourced by pair (j, s) in expenditures in region j. Cost minimization by each producer in sector s country j gives

$$x_{ij}^{hs} := \frac{Q_{ij}^{hs}}{M_j^{hs}} = n_i^h \left(\frac{p_i^h \tau_{ij}^{hs}}{G_j^{hs}}\right)^{1-\sigma} \tag{8}$$

$$= \frac{n_i^h \left(p_i^h \tau_{ij}^{hs}\right)^{1-\sigma}}{\sum_{k=1}^{R} n_k^h (p_k^h \tau_{kj}^{hs})^{1-\sigma}}.$$

The last expression is a form of the canonical micro-founded gravity equation (Costinot and Rodríguez-Clare, 2014). In our formulation of trade shares x_{ij}^{hs}, we use expenditures in region j as the denominator, as opposed to global trade in sector h.

2.4 Transportation costs

Information is only available on bilateral transportation costs for the originating sector, but not for the destination sector. Thus, we model transportation costs from region i to j and from sector h to s, as consisting of a period-dependent originating-sector, exporter, importer component, $\tau_{ij,t}^{h\cdot}$, a period-independent, originating-sector, destination-sector, exporter component, $\zeta_{i\cdot}^{hs}$, and a period-dependent origin-destination sector and region component, $\xi_{ij,t}^{hs}$

$$\ln \tau_{ij,t}^{hs} = \ln \tau_{ij,t}^{h\cdot} + \zeta_{i\cdot}^{hs} + \xi_{ij,t}^{hs}.$$

The change over time in transportation costs is

$$\Delta \ln \tau_{ij,t}^{hs} = \Delta \ln \tau_{ij,t}^{h\cdot} + \Delta \xi_{ij,t}^{hs}. \tag{9}$$

For future reference, we also define

$$u_{ij,t}^{hs} := -\left(\frac{1-\sigma}{\sigma}\right) \Delta \xi_{ij,t}^{hs}. \tag{10}$$

2.5 Changes in trade shares

Express the trade share equation (8) in logarithms and totally differentiate to obtain

$$\Delta \ln x_{ij,t}^{hs} = \Delta \ln n_{i,t}^h + (1-\sigma)\left(\Delta \ln(p_{i,t}^h \tau_{ij,t}^{hs}) - \Delta \ln G_{j,t}^{hs}\right). \tag{11}$$

Using equations (4) and (5) (after taking logs and totally differentiating) in the above expression gives

$$\Delta \ln x_{ij,t}^{hs} = \tilde{\Phi}_{ij,t}^h - \sigma u_{ij,t}^{hs} - \sigma \sum_{k=1}^{S} \alpha_i^{kh} \Delta \ln G_{i,t}^{kh} - (1-\sigma)\Delta \ln G_{j,t}^{hs}, \tag{12}$$

where the first term on the right-hand side collects directly observed variables, including those representing structural change ($\Delta \ln w_i$ and $\Delta \ln l_i^h$)

$$\tilde{\Phi}_{ij,t}^h := (1-\sigma\alpha_i^h)\Delta \ln w_{i,t} - \sigma\beta_i^h \Delta \ln r + \Delta \ln L_{i,t} + \Delta \ln l_{i,t}^h + (1-\sigma)\Delta \ln \tau_{ij,t}^{h\cdot}. \tag{13}$$

We solve equation (12) for changes in price indexes by summing over all origin regions, imposing the condition that changes in trade shares must add up to zero $\left(\sum_i \Delta x_{ij,t}^{hs} = 0\right)$, and using equation (5)

$$\Delta \ln G_{j,t}^{hs} = \left(\frac{1}{1-\sigma}\right) \sum_{i=1}^{R} x_{ij,t-1}^{hs} (\tilde{\Phi}_{ij,t}^{h} - \sigma u_{ij,t}^{hs}) - \left(\frac{\sigma}{1-\sigma}\right) \sum_{i=1}^{R} x_{ij,t-1}^{hs} \sum_{k=1}^{S} \alpha_i^{kh} \Delta \ln G_{i,t}^{kh}, \tag{14}$$

where all variables on the right-hand side are weighted by *lagged* trade shares. This expression contains all the information we need about the implications of changes in price indexes for trade shares that are fully consistent with and in part due to changes in the factors we consider in our model. Regardless of why, for instance, the structural factors change, the trade share and price equations and adding up constraints dictate that prices must change endogenously according to the above expression. Thus, our procedure directly accounts for changes in prices that are consistent with changes in our factors, and as such incorporates all endogenous price effects.

Equation (14) is linear in changes in price indexes, and can be solved analytically. It is easier to state the solution for the changes in trade shares using matrix notation. Here we omit time indexes. For origin–destination region pairs i and j, respectively, and in the destination sector s, collect the changes in trade shares in a column vector with S rows $\mathbf{Dx}_{ij}^s = \left[\Delta \ln x_{ij}^{1s}, \Delta \ln x_{ij}^{2s}, \cdots, \Delta \ln x_{ij}^{Ss}\right]$. Stack these into $R^2S \times 1$ column vectors $\mathbf{Dx}^s$. Let $\tilde{\Phi}_{ij} = \left[\tilde{\Phi}_{ij}^1, \tilde{\Phi}_{ij}^2, \cdots, \tilde{\Phi}_{ij}^S\right]'$ be a $S \times 1$ column vector. Stack these into a $R^2S \times 1$ column vector $\tilde{\mathbf{\Phi}}$. Let $\boldsymbol{\sigma}$ be a R^2S dimensional row vector. Next, let $\alpha_i^s = [\alpha_i^{1s} \quad \alpha_i^{2s} \ldots \alpha_i^{Ss}]$ be the elasticity (column) vector of sector s in region i, and $\mathbf{1}_{(S\times 1)}$ be an identity vector conformable with α_i^s, so that $\alpha_i^s \otimes \mathbf{1}$ is a square matrix. Let $\mathbf{S}_{(R^2S\times RS)}^s = diag\,[\alpha_1^s \otimes \mathbf{1} \quad \alpha_2^s \otimes \mathbf{1} \ldots \alpha_R^s \otimes \mathbf{1}]$ be a block-diagonal matrix. Let $\mathbf{Z}$ be a $R^2S \times RS$ matrix consisting of zeros except for columns from $1 + S(j-1)$ to $S \times j$, which contain R vertically concatenated copies of $diag[\tilde{\sigma} \quad \tilde{\sigma} \ldots \tilde{\sigma}]$, where $\tilde{\sigma} = (1-\sigma)/\sigma$. Let $\mathbf{J}$ be a $RS^2 \times RS^2$ matrix containing lagged trade share-weighted structural variables and elasticity coefficients (α_i^{hs} terms). Let, for each destination sector s, $\mathbf{x}_{t-1}^s$ be an $RS \times R^2S$ matrix consisting of lagged trade shares.

With this notation, for each episode from $t-1$ to t, the counterpart of equation (14) is

$$\mathbf{Dx}_t^s = \tilde{\mathbf{\Phi}}_t - \underbrace{\boldsymbol{\sigma}(\mathbf{S}_t^s + \mathbf{Z})\mathbf{J}_t\mathbf{x}_{t-1}^s}_{\text{indirect effects}} \tilde{\mathbf{\Phi}}_t + \mathbf{u}_t^s. \tag{15}$$

This fundamental expression includes all of the effects of our key structural variables on changes in trade shares. The first term on the right-hand side is the direct effect of changes in wages and labor allocations on the changes in trade shares in the absence of any relative price effects—a change in any of these variables in region i would have a direct impact on region i alone. The second term is the indirect price effect—feedback effects arising from changes in relative prices—of changes in wages and labor allocations on changes in trade shares. The last term (an $R^2S \times 1$ vector) contains the effects of changes in (not directly observable) transportation and trade costs (equation (10)) and other effects.

The direct effect of wages on export shares depends on $(1 - \sigma\alpha_i^h)$—the trade elasticity of income net of sector specific labor costs (see equation 13). The value of "1" in this term indicates that an increase in origin country wages has a proportional effect on the availability of intermediate inputs, which benefits exports. On the other hand, the $-\sigma\alpha_i^h$ term indicates that higher wages will have a countervailing negative effect on exports the higher the share of labor in the production of good "h" becomes. The net effect of higher wages on exports is therefore ambiguous, depending both on σ and α_i^h. The indirect effects are more involved, and are intermediated through changes in relative prices by altering costs and market sizes in *all* origin-destination region pairs.

While our framework accounts for the contributions of wage growth and sectoral reallocation of labor separately, we do not necessarily treat them as independent, and recognize that technological changes that have taken place over our study period are at least in part responsible for both changes in techniques in production and TFP growth. In our trade accounting framework, the period-specific elasticity terms reflect an important component of changes in the techniques of production. We also think that wage growth and the sectoral reallocation of labor may both be driven by changes in TFP, as in various theoretical models of structural change (see, e.g., Herrendorf, Rogerson, and Valentinyi, 2014). Our trade accounting framework, while consistent with a range of theoretical models with such features, does not impose uniform assumptions about the determination of wages that hold for all of the countries in the data.

2.6 Changes in trade flows

We are interested in accounting for changes in trade flows, which can happen either because of a change in market share or a change in the overall size of the market. We thus calculate changes in trade flows by using the definition of market share in equation (8)

$$\Delta \ln Q_{ij,t}^{hs} = \Delta \ln x_{ij,t}^{hs} + \Delta \ln M_{j,t}^{hs}, \tag{16}$$

where the first term on the right-hand side is the change in the export share of good h accounted for by all of the fundamental factors as obtained from equation (15), and the second term is the change in the absorption of good h from all sources in the destination market.[9] We apply this framework to account for the contribution of structural change in China to changes in trade flows between any two pairs of origin and destination countries (i, j).

We measure the contribution of China's structural change as the difference between actual $\Delta \ln Q_{ij,t}^{hs}$ and the $\Delta \ln Q_{ij,t}^{hs}(\text{CHN})$ that is obtained when either w_{CHN} or l_{CHN}^h are kept constant at the beginning-of-the-window values: 1995–2000, 2000–2005, and 2005–2010. For the elasticity parameters α_i^{hs}, following the notation in our derivations (supplementary material S.4), we used the end-of-period

[9] The theory-consistent changes in expenditures are $M_{j,t}^{hs} = \left(\alpha_j^{hs}/\alpha_j^s\right) w_{j,t} l_{j,t}^s L_{j,t}$, so that $\Delta \ln M$ is directly proportional to $\Delta \ln w$, $\Delta \ln l$, and $\Delta \ln L$. In our application, we use the end-of-period values of α_j^s, and α_i^{hs}.

(2000, 2005, 2010) values. The fact that third-party effects (here, due to structural change in China) are captured by our trade accounting allows us to single out the impact of any specific country on all other bilateral trade flows, such as our main focus on China, $\Delta \ln Q^{hs}_{ij,t}(\text{CHN})$. Furthermore, we report the contribution of the fundamental factors to trade in terms of their impact on the growth rate of trade flows. We present our findings using aggregate industrial groupings, by classifying each industry h into manufactured final goods (MAN), parts and components (PNC), or commodities (COM), using existing conventions. For example, we aggregate across sectors $h \in \{\text{MAN}\}$ using initial period trade values $Q^{hs}_{ij,t-1}$ as weights in calculating the growth rate of trade from region i to region j originating from sector h to all the destination sectors.

3 Changes in global trade flows: background

We apply our trade-accounting framework to quantify the contribution of structural change in China to the steamroller, engine, and conduit effects. Figure 3 illustrates these effects using *gross trade* flows among three major "regions": a group of Asian countries, China, and the United States.[10] There is an explosive growth in bilateral gross trade flows between any two of these regions from 1992 to 2013, with the most dramatic increases taking place between the Asia–China and China–USA pairs. Another striking feature of the data is the extent to which these regions conduct trade in PNC. Whereas much of the contemporary trade between the Asia–USA and China–USA pairs is in MAN, trade in PNC comprises a substantial fraction of the total trade between Asia and China, with exports of PNC from Asia to China comprising more than half of the total. Over this period, China had a growing trade surplus in MAN with the United States—seemingly at the expense of the rest of Asia (steamroller)—and a growing trade deficit with Asia both in commodities (not shown) and in MAN (engine). At the same time, there was explosive growth in PNC exports from Asia to China and MAN exports from China to the United States (conduit).

There are two concerns with gross trade data aggregated by region. First, an economically more meaningful measure in the context of trade creation and diversion is trade in *value-added*. Second, regional aggregates may mask considerable cross-country heterogeneity. We thus use trade-in-value-added (TiVA) data (OECD, 2017b), which allows us to measure value-added at the country and sector level.[11] In fact, within Asia there is considerable cross-country variation in the steamroller, engine, and conduit effects as measured by value-added trade flows. Consider, in particular, Indonesia, Malaysia, South Korea, and Vietnam that differ significantly in structure and income.[12] Figure 4a shows the growth rates of exports of MAN from these four countries plus China to the United States over each of

[10] The Asia region consists of seven economies, all of which are EMEs, except for South Korea.

[11] The TiVA data do not immediately map into the aggregated MAN and PNC product categories underlying figure 3.

[12] See supplementary material section S.1 for the details on the structure of these economies and for further discussion of the steamroller, engine, and conduit effects.

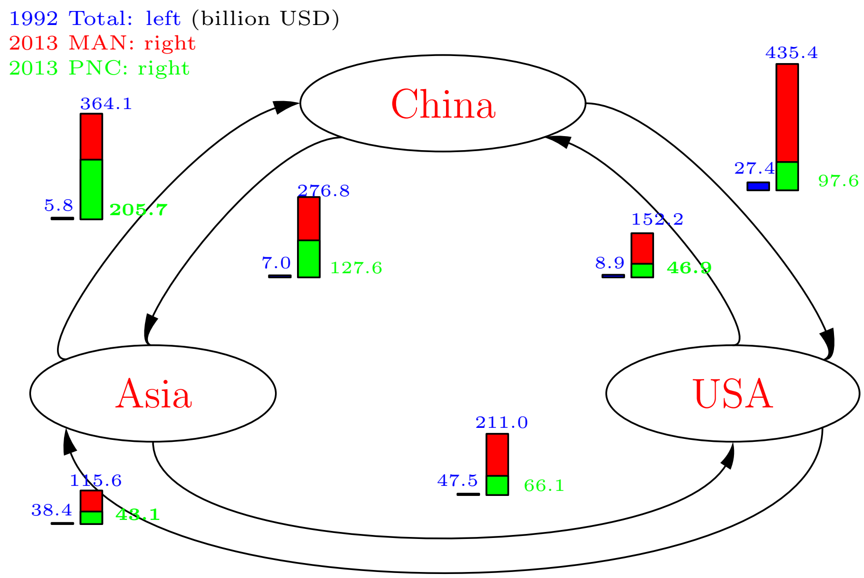


Figure 3: Regional trade flows, 1992 and 2013

Notes: Asia consists of India, Indonesia, Malaysia, Philippines, South Korea, Thailand, and Vietnam. All data are gross trade values. Total is non-service and non-commodity trade, which includes manufactured final goods (MAN) based on Standard Industrial Trade Classification, Revision 3 (SITC) codes $232 + 266 + 267 + 5 + 6 + 7 + 8 - 667 - 68$, and parts and components (PNC) based on Haltmaier et al. (2007). Comtrade data do not record service trade. See supplementary material section S.3 for details.
Source: Author's calculations from United Nations (2015) Comtrade database.

the five-year periods we consider. The increase in Vietnam's exports to the United States is remarkable, especially since 2000, although starting from a low base. China's export growth to the United States often exceeds that of its Asian competitors (except that of Vietnam), and by considerable margins in the 1995–2000 and 2005–2010 periods. The growth of MAN exports from Indonesia, South Korea and Malaysia are negative in the period from 1995 to 2000, but otherwise all other growth rates are positive. By contrast, the engine effect due to growing demand by China for commodities has been markedly positive for all the countries in the region, with Indonesia exhibiting large growth rates and Malaysia exhibiting an increasing rate of growth (figure 4b). Figure 4c shows the engine effect in the form of MAN exports to China, which can be contrasted with figure 4d, which shows the MAN exports from China (denoted as "reverse engine"). While the engine effect has been weak for South Korea, it has been strong for Indonesia and Vietnam. By comparison, the reverse engine effect has been uniformly strong for all four countries and has become more pronounced over time. On balance, Indonesia is the main beneficiary of the net engine effect, with the remaining three Asian countries exhibiting a net reverse engine effect. The conduit effect of exports of PNC from these four countries to China (figure 4e) and PNC exports from China to these same countries (figure 4f denoted as "reverse conduit") are similar in terms of general patterns to their engine effect counterparts, with Malaysia, South Korea, and Vietnam exhibiting particularly strong examples of net reverse conduit.[13]

Of course, these outcomes are not only heterogeneous across countries, but they are also indicative of heterogeneous consequences of the fundamental factors underlying them. Our trade-accounting framework allows us to disentangle, for example, domestic from global factors. In the next section, we will do so and quantify the contribution of structural change in China to steamroller, engine, and conduit effects for each of the countries included in our study.

4 Accounting for steamroller, engine, and conduit effects

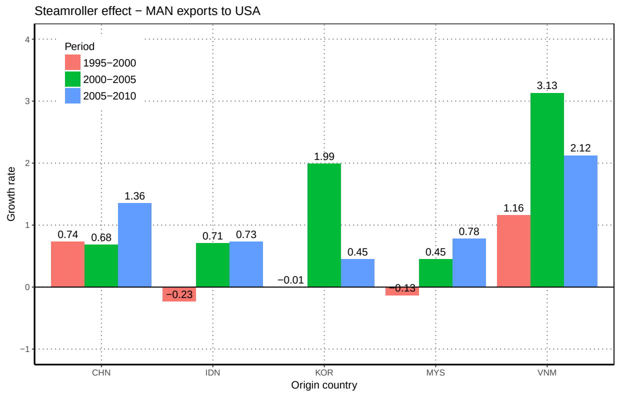
4.1 Data

To implement the trade-accounting formula (15), we use data on 15 countries over three five-year non-overlapping periods beginning in 1995 and ending in 2010. With the exception of a few country-specific cases, we rely on several harmonized OECD databases: (1) national input-output tables (IOT, OECD, 2017a) for production, wages, and technology terms; (2) Trade in Value Added data (TiVA, OECD, 2017b) for trade flows; (3) the Structural Analysis Database (STAN, OECD, 2017c) for employment shares; and (4) International Transport and Insurance Costs of Merchandise Trade data (ITIC, OECD, 2017d) for transportation costs. We reconcile these sources for 28 industries as described in Appendix A.

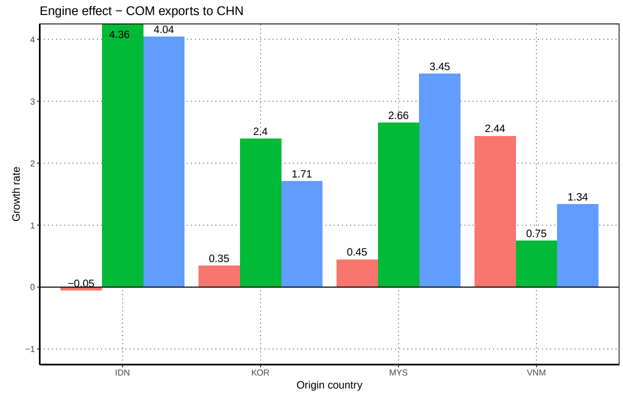
4.2 Structural change and trade flows

We now apply our trade-accounting framework developed in section 2 to account for the contribution of two specific fundamental factors to changes in trade shares asking: (1) how much does wage growth in China contribute, and (2) how much do changes in the allocation of labor across sectors in China contribute? We calculate their contributions independently, and isolate their impact from the contribution of changes in the other fundamental factors. For each factor, we report our results both in terms of regional averages and by country using four successive figures (table 1). In each case, we report the contributions of both China's wage growth and labor reallocation to changes in bilateral trade flows for each non-overlapping five-year period. For example, the first decomposition result in table 1 of -0.0390 means that China's wage growth subtracted 3.9 percentage points (pp) from the five-year growth rate in exports on manufactured final goods from the EMEs to the United States. Likewise, the result of 0.1964 means that China's wage growth contributed 19.64 pp to the five-year growth rate commodity exports from EMEs to China. (Similar interpretations hold for the decomposition results reported in the figures below.)

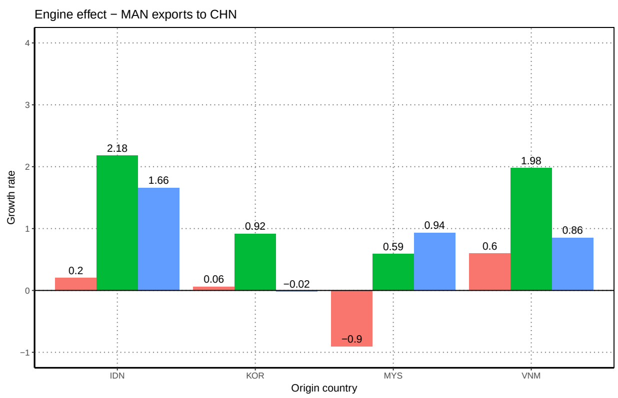
[13] Pairwise correlations of exports to China (p- values in parentheses, $df = 43$) for the entire sample of countries are as follows: MAN–COM = 0.21(0.028), MAN–PNC = 0.59(0.000), and COM–PNC = 0.26(0.200).



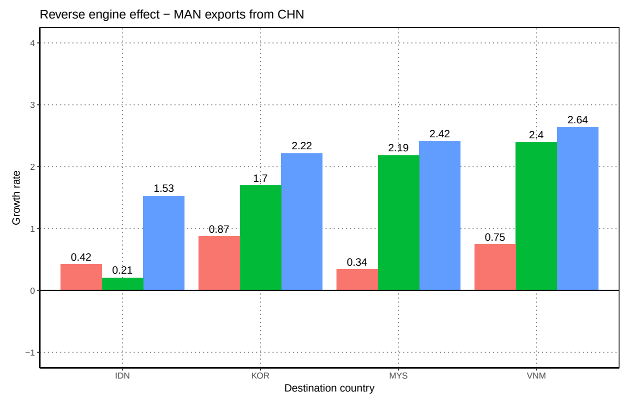
(a) Steamroller



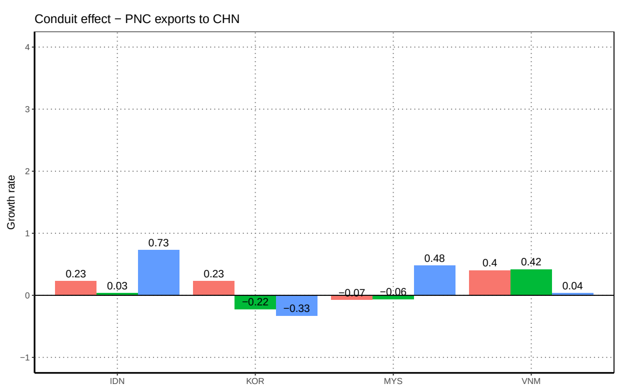
(b) Engine: commodities



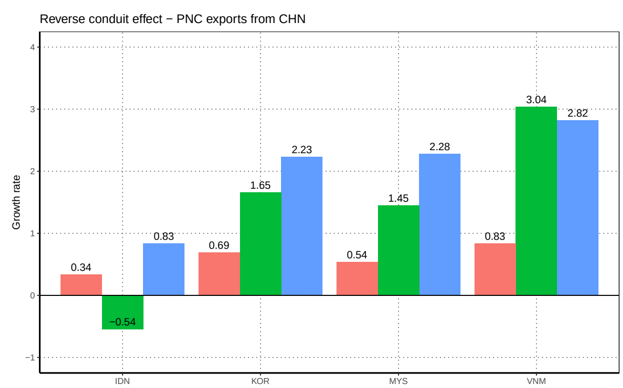
(c) Engine: final goods



(d) Reverse engine: final goods



(e) Conduit



(f) Reverse conduit

Figure 4: Changes in bilateral trade flows, 1995–2010

Notes: Author's calculations from OECD (2017b) Trade in Value Added database, covering the period from 1995 to 2010. For the lists of industries producing commodities (COM), manufactured final goods (MAN), and parts and components (PNC), see table A.2.

Table 1: China's wage growth and labor reallocation effects on trade flows: decomposition results

(five-year growth rates, $\sigma = 4$)

	Steamroller	Engine		Reverse Engine	Conduit	Reverse Conduit
Region, Period	MAN to USA	COM to CHN	MAN to CHN	MAN from CHN	PNC to CHN	PNC from CHN
			a) China's wage growth			
EMEs						
1995–2000	-0.0390	0.1964	0.0376	0.2701	0.0441	0.2890
2000–2005	-0.0112	0.3268	0.2664	0.1246	0.2665	0.1308
2005–2010	-0.0582	0.6611	0.3678	0.5994	0.3572	0.6192
Asia						
1995–2000	-0.0625	0.1796	0.0219	0.2830	0.0272	0.2962
2000–2005	-0.0196	0.3064	0.2449	0.1324	0.2444	0.1356
2005–2010	-0.0984	0.6590	0.3392	0.6306	0.3241	0.6365
Advanced economies						
1995–2000	-0.0209	0.2673	-0.0377	0.2626	-0.0458	0.2767
2000–2005	-0.0100	0.3168	0.2073	0.1174	0.2043	0.1263
2005–2010	-0.0455	0.5923	0.1137	0.5711	0.0823	0.6022
			b) China's labor reallocation			
EMEs						
1995–2000	-0.0114	-0.0554	0.0426	-0.0051	0.0169	-0.1120
2000–2005	-0.0140	0.0248	0.0580	0.1706	0.0473	0.1654
2005–2010	-0.0156	0.0258	-0.0376	0.1926	0.0131	0.1718
Asia						
1995–2000	-0.0210	-0.0476	0.0585	-0.0118	0.0332	-0.1154
2000–2005	-0.0310	0.0312	0.0867	0.1729	0.0676	0.1541
2005–2010	-0.0282	0.0169	0.0075	0.2020	0.0760	0.1688
Advanced economies						
1995–2000	0.0031	-0.1299	-0.0764	-0.0290	-0.0579	-0.1416
2000–2005	-0.0037	0.0730	-0.1747	0.1443	-0.1534	0.1667
2005–2010	-0.0123	0.1888	-0.1370	0.1801	-0.1232	0.1700

Notes: This table reports the contributions of China's wage growth (panel a) and sectoral reallocation of labor (panel b) to the growth rates of exports from the origin country groupings over each of the three five-year periods, where the destination region and industry of exports depend on the specific effect listed for each column. σ is the elasticity of substitution across varieties in production. See the main text and figure 1 for the description of steamroller, engine, conduit effects. Country groupings of bilateral trade partners of China (CHN) are emerging market economies (EMEs), Asian EMEs (Asia), and advanced economies (excluding the United States (USA) in the steamroller effect). See table A.1 for countries included in each region. Countries in each region are weighted by their beginning-of-period trade volumes. Table A.2 lists the industries producing commodities (COM), manufactured final goods (MAN), and parts and components (PNC). Aggregation across industries is by origin $h \in \{\text{COM}\}$, $h \in \{\text{MAN}\}$, or $h \in \{\text{PNC}\}$ based on actual trade $Q^{hs}_{ij,t-1}$ and the contribution of each factor to the growth rates of $\Delta \ln Q^{hs}_{ij,t}$ over a period from $t-1$ to t, from equation (16), where i is the origin country, j is the destination country, h is the origin industry, and s is the receiving industry. Actual growth rates for each country grouping and period are reported in supplementary material table S.5.

Steamroller. We start with evaluating China's steamroller effect on trade flows. We report growth of trade values accounted for by each structural factor after aggregating across industries with sectoral origin $h \in$ MAN, arrived at using actual trade $Q^{hs}_{ij,t-1}$ and growth rates from equation (15) as accounted for by either wage growth or labor reallocation in China. Table 1, column labelled "Steamroller", shows the cumulative contribution over the five-year period of China's wage growth (panel a) and sectoral labor reallocation (panel b) on exports of manufactured final goods (MAN) to the United States by region. Figure 5 does the same by country. The contribution of China's wage growth to the steamroller effect is on average twice the contribution of China's labor reallocation (p-value= 0.000 based on individual country results). For the entire group of EMEs, both China's wage growth and labor reallocation had a negative effect on MAN exports of EMEs to the United States in each period, with quantitatively larger impacts in both cases on Asia than on the rest of the EMEs. The steamroller effect due to China's wage growth on EMEs over the period 1995–2000 was −3.90 pp of growth in MAN exports to the United States, and it increased (in absolute value) to −5.82 pp in the period 2005–2010. By comparison, over the same period, the steamroller effect due to labor reallocation in China increased (in absolute value) from −1.14 pp to −1.56 pp.

However, there is considerable variation in the impact of structural change in China on the exports of MAN to the United States across countries in the same regional group. For instance, both wage growth and labor reallocation in China had markedly bigger negative impacts on Indonesia, India, and to some extent Japan. The decomposition results show that wage growth and labor reallocation within China had a positive contribution to China's own export growth to the United States, with one exception (1995–2000, labor reallocation). The combined influences of wage growth and labor reallocation are not as trade-reducing in Malaysia and South Korea as in Indonesia and not as trade-inducing in Vietnam as in Australia and Russia (although there is a small positive effect in the period 2005–2010 in Vietnam).

Consistent with our framework, these results can be interpreted by input-output relations. For both China's wage growth and labor reallocation, there are direct effects originating from the changes in the industrial wage and the sectoral reallocation of labor. The direct effect of wage growth in China is zero for all countries, except China: this is by design, as we are keeping the wage growth elsewhere constant, thereby controlling for remaining observed wage growth effects. For China, it depends on the sign and magnitude of the trade elasticity of income net of sector- and country-specific labor costs; the term $(1 - \sigma\alpha_i^h)$ in equation (13). Whenever this term is greater than zero, the home-market scale effect of higher wages outstrips any losses in competitiveness. The direct effect of labor reallocation is also zero for all countries, except China, in which case it has a unitary elasticity. The indirect effects of both wage growth and labor reallocation, however, will vary in complicated ways across countries depending on input-output structures and scale effects and their resulting influence on producer prices; as shown in equation (14). The cross-country variation emerging from the decompositions shown in

$\sigma = 4$

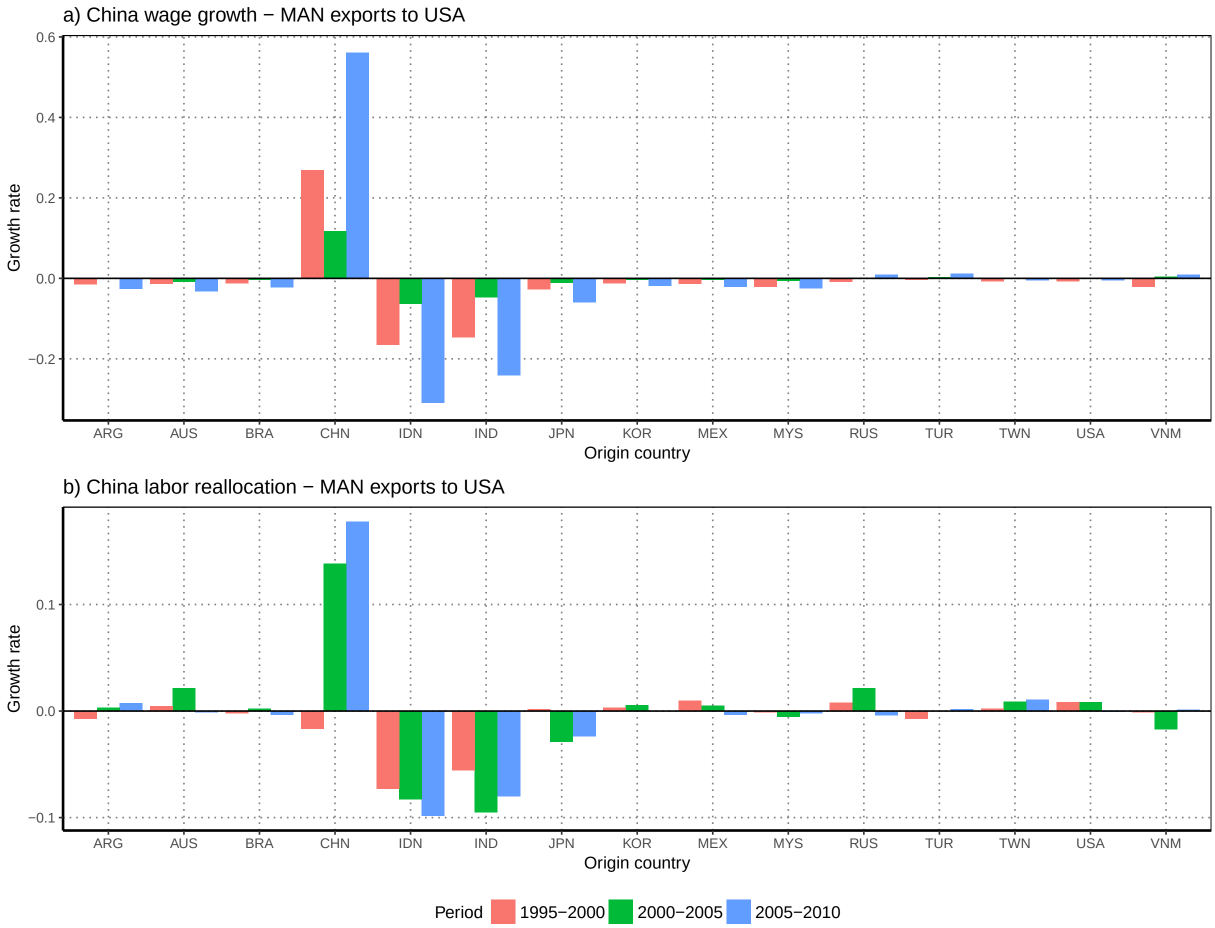


Figure 5: Decomposition of changes in manufactured final goods exports to the United States

Notes: This figure reports the contributions of China's wage growth (panel a) and sectoral reallocation of labor (panel b) to the growth rates of manufactured final goods (MAN) exports to the United States from origin countries over each of the three five-year periods. "Exports to USA from USA" means "domestic sales" by the U.S. producers. σ is the elasticity of substitution across varieties in production. Table A.2 lists the industries producing MAN. Aggregation across industries is by origin $h \in \{\text{MAN}\}$, based on actual trade $Q^{hs}_{ij,t-1}$ and the contribution of each factor to the growth rates of $\Delta \ln Q^{hs}_{ij,t}$ over a period from $t-1$ to t, from equation (16), where i is the origin country, j is the United States, h is a MAN industry, and s is any receiving industry. Vertical scales in panels a and b are different.

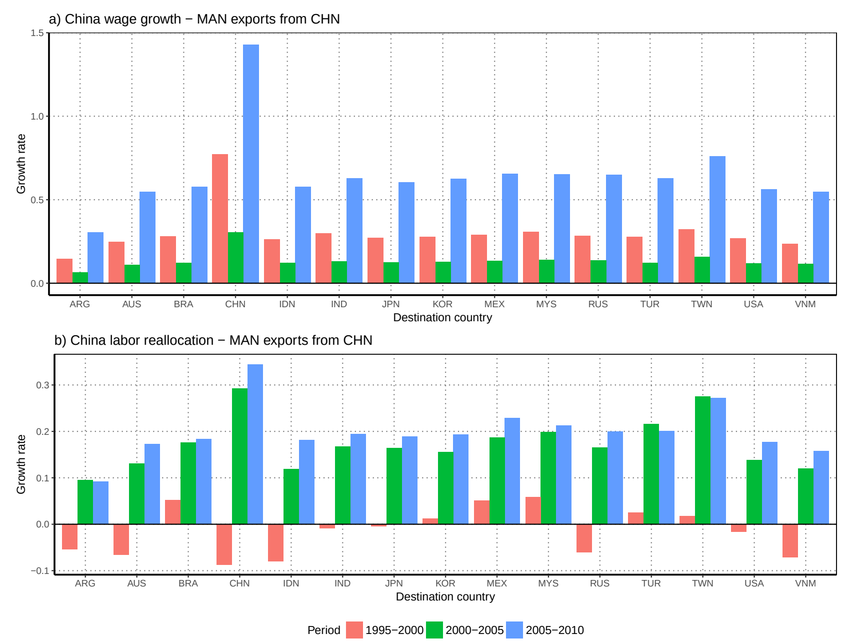
figure 5 is the result of cross-country differences in input-output structures that in turn reflect stages of development.

The relative strengths of China's wage growth and labor reallocation also depend on the phases of structural change that China's economy went through from 1995 to 2010. While mass reallocation of labor out of agriculture accelerated in each successive five-year period from 1995 to 2010, wage growth exploded in the period 2005–2010 when compared with earlier periods (table S.3). Quantitatively, however, for the EMEs as a whole, wage growth was a far larger contributor to the steamroller effect than labor reallocation in each of the three periods. At the same time, wage growth had a far larger impact in the periods 1995–2000 and 2005–2010 than in the period 2000–2005, and the contribution of labor reallocation to the steamroller effect has gradually increased over time (both patterns consistent with the within-category pattern of percentage changes across periods for wages and sectoral employment shares). These results demonstrate that while wage growth might be a good indicator of overall labor market "tightness" in an economy transitioning from one characterized by "surplus" labor, this process is strongly linked to the reallocation of labor across sectors. In fact, our decomposition results are consistent with the theory and simulation results of Fujita et al. (2001) where changes in the sectoral allocation of labor may have progressively more, and not necessarily less, impact on economic outcomes and bilateral trade over the course of economic development.

Overall, our decomposition results quantify and help us better understand the mechanisms underlying the steamroller effect in two ways. First, structural change has allowed China to gain market share in the United States without significantly reducing the value of MAN exports to the United States from the majority of the economies in our sample, with the notable exceptions of Indonesia, India, and Japan. Second, sectoral labor reallocation in China has benefited MAN exports to the United States from a number of countries such as Australia, Mexico, Russia, South Korea, and Taiwan, although the effects are economically small. At the country level, China's wage growth and labor reallocation do not always affect trade patterns in the same direction. As a result, their combined effects are often considerably smaller than the effects of the remaining factors (see supplementary material figure S.3).

$\sigma = 4$

(A) Exports to China



(B) Exports from China

Figure 6: Decomposition of changes in manufactured final goods exports to and from China

Notes: This figure reports the contributions of China's wage growth (row panels a) and sectoral reallocation of labor (row panels b) to the growth rates of manufactured final goods (MAN) exports to China from origin countries (vertical panel A) and exports from China (vertical panel B) over each of the three five-year periods. σ is the elasticity of substitution across varieties in production. "Exports to China from China" means "domestic sales" by the Chinese producers, and similarly for "exports from China to China." Table A.2 lists the industries producing MAN. Aggregation across industries is by origin $h \in \{\text{MAN}\}$, based on actual trade $Q^{hs}_{ij,t-1}$ and the contribution of each factor to the growth rates of $\Delta \ln Q^{hs}_{ij,t}$ over a period from $t-1$ to t, from equation (16), where i is the origin country, j is the destination country, h is a MAN industry, and s is any receiving industry. Vertical scales in panels A and B are different.

Engine by manufactured final goods. Table 1 shows the regional averages for the contributions of China's wage growth and labor reallocation to both engine (exports to China) and reverse engine (exports from China) effects in terms of manufactured final goods (MAN). Figure 6 does the same for each country in our sample. The decomposition of the engine effect for the EMEs indicates an overwhelmingly stronger contribution from China's wage growth, except in the period from 1995 to 2000. The decomposition of the reverse engine effect also shows a stronger contribution from wage growth than labor reallocation, except in the 2000–2005 period. At its peak, wage growth in China accounts for an average 38 pp increase in the growth rate of an EME's MAN exports to China (1995–2000), whereas labor reallocation accounts for about a 6 pp increase at its peak (2000–2005). For the reverse engine effect, the corresponding average growth rates due to China's wage growth and labor reallocation are 60 pp (2005–2010) and 20 pp (2000–2005), respectively.[14]

The decomposition results by country (figure 6A) show that whereas China's wage growth had a negative contribution to the exports of MAN from Argentina, Indonesia, Japan, and Russia to China in the period 1995–2000, it had a positive contribution in the latter periods. By contrast, while China's wage growth had a positive contribution to growth of exports of MAN from Mexico, the United States, and Vietnam to China in the period 1995–2000, it had a negative contribution in the period 2005–2010. These contrasting contributions suggest that the answer to whether competitiveness declines or improves (through scale effects) with higher wages critically depends on combined country–sector characteristics.

The individual country results for the contribution of China's labor reallocation to exports of MAN to China (figure 6A) exhibit considerably more heterogeneity over time compared to wage growth. For example, while labor reallocation across sectors in China had a particularly negative impact on the exports of MAN from the industrial countries to China, it boosted Vietnam's exports, and countries such as Mexico and Malaysia, which experienced higher MAN exports to China as a result of Chinese labor reallocation in 1995–2000, saw declining exports due to the ongoing reconfiguration of the Chinese economy over the last decade of our sample (2000–2010).

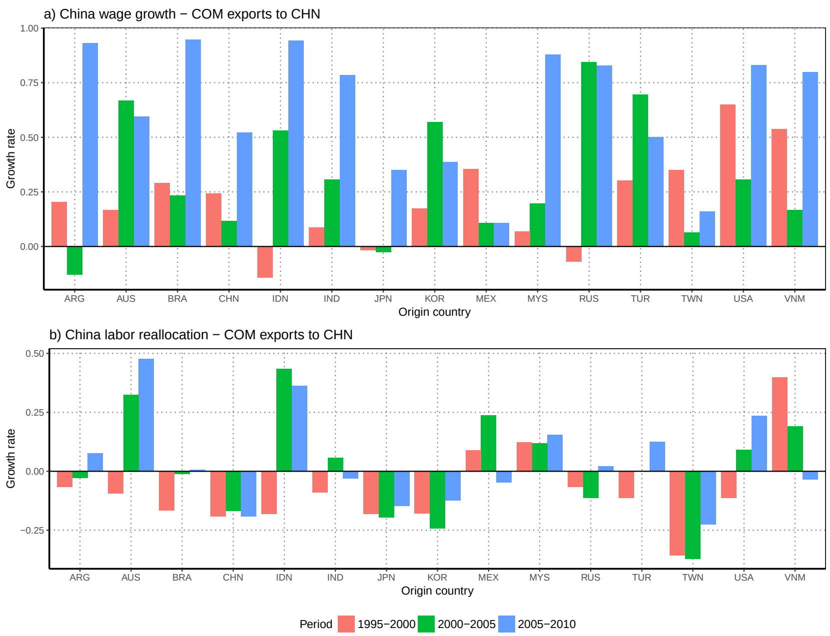
To evaluate the engine effect using *net* flows, figure 6B shows the changes in MAN exports from China to all the countries in our sample; the reverse engine effect. In our decomposition, China's wage growth and labor reallocation have considerably more uniform effects on the destination countries' imports of manufactured goods from China.[15] One important result is that China's wage growth has uniformly increased China's exports to all countries, which points to the merits of simultaneously accounting for each of the two opposing mechanisms: the scale effects associated with forward and

[14] The correlation between the contributions of China's wage growth and labor reallocation to the engine effect in MAN is negative but not statistically significant (p-value = 0.394). The correlation for the reverse engine is positive 0.76(p-value = 0.017).

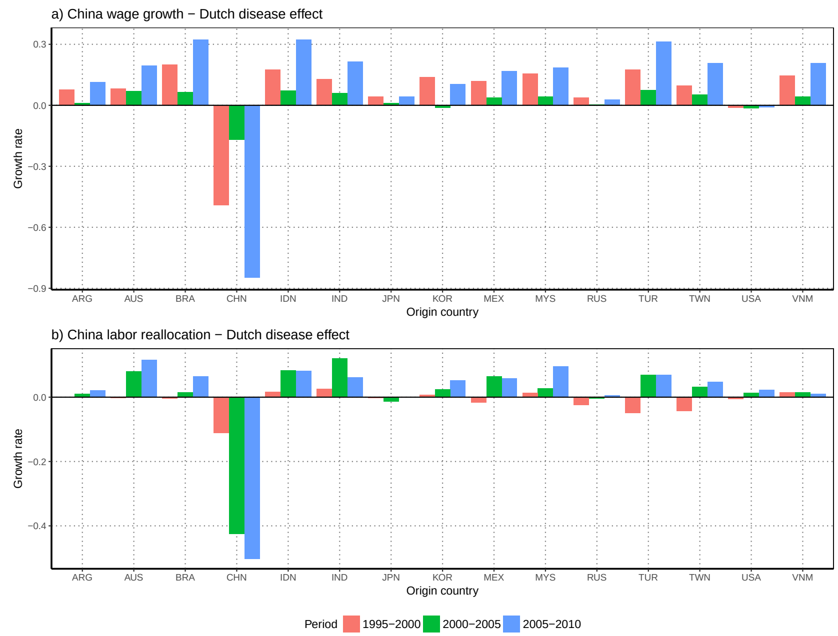
[15] The remaining structural effects in the case of reverse engine are more varied across countries; see supplementary material figure S.4.

backward linkages and the loss of cost competitiveness by China. Over our sample period, the evidence suggests that sectoral bilateral trade balances with China are most affected by forward and backward linkages, hence by scale effects. The labor reallocation effects are also uniformly positive, with the exception of the first period (1995–2000). A comparison of figures 6A and 6B indicates that structural change on balance served to increase both the growth of China's net exports of MAN and China's trade surpluses in MAN with other countries.

$\sigma = 4$



(A) Exports to China



(B) Commodity minus manufactured final goods exports to China

Figure 7: Decomposition of changes in commodity exports to China

Notes: This figure reports the contributions of China's wage growth (row panels a) and sectoral reallocation of labor (row panels b) to the growth rates of commodity (COM) exports to China from origin countries (vertical panel A) and commodity exports net of manufactured final goods exports to China (vertical panel B) over each of the three five-year periods. σ is the elasticity of substitution across varieties in production. "Exports to China from China" means "domestic sales" by the Chinese producers. Table A.2 lists the industries producing COM and MAN. Aggregation across industries is by origin $h \in \{\text{COM}\}$, or $h \in \{\text{MAN}\}$, based on actual trade $Q^{hs}_{ij,t-1}$ and the contribution of each factor to the growth rates of $\Delta \ln Q^{hs}_{ij,t}$ over a period from $t-1$ to t, from equation (16), where i is the origin country, j is China, h is a COM or MAN industry, and s is any receiving industry. Vertical scales in panels A and B are different.

Engine by commodities. Economic growth in China not only stimulated demand by Chinese consumers of manufactured final goods, but also enabled a global commodity boom. China's engine effect includes this increased global demand for commodities. To quantify the contribution of structural change in China to the commodity-driven engine effect, table 1 reports the growth of exports of commodities (COM) to China averaged across regions. Figure 7A shows the same by country. The results for wage growth are striking (table 1, panel A): income growth in China had an overwhelmingly positive impact on COM exports to China from all regions and over the entire sample period, culminating in a growth effect of 66 pp for EMEs in the period 2005–2010. The biggest beneficiaries of the commodity boom due to income growth in China include Australia, Indonesia, Malaysia, Russia, the United States, and Vietnam. Commodity exports to China from Japan, Korea, and Taiwan, with natural resource endowments relatively similar to that of China, were less affected (figure 7A).

At the same time, labor reallocation within China in the period 1995–2000 partially attenuated the growth of commodity exports from both EMEs and the advanced economies (table 1, panel B). Labor reallocation in China initially reduced its commodity imports in the first five years of our sample, but only slightly. This effect was reversed as China's sectoral reallocation of labor later in our study period increased its resource dependence from abroad. This could either be due to a reallocation of labor toward industries that use commodities more intensively or a reduction in the share of employment in industries that produce commodities (primarily agriculture). In any case, the labor reallocation effect on commodity exports to China is not negative for all countries; the commodity exports of Australia, Indonesia, Malaysia, and the United States grew due to labor reallocation in China (figure 7A).[16] Overall, viewed through the lens of a China-driven commodity boom, China's structural change has been unequivocally commodity trade-inducing for the rest of the world.

We also provide a net resource reallocation effect from the perspective of the exporting countries by comparing the changes in their MAN and COM exports to all destinations (figure 7B), driven by structural change in China. This allows us to assess whether China's structural change drove other countries towards more commodity-intensive production patterns. We measure this by

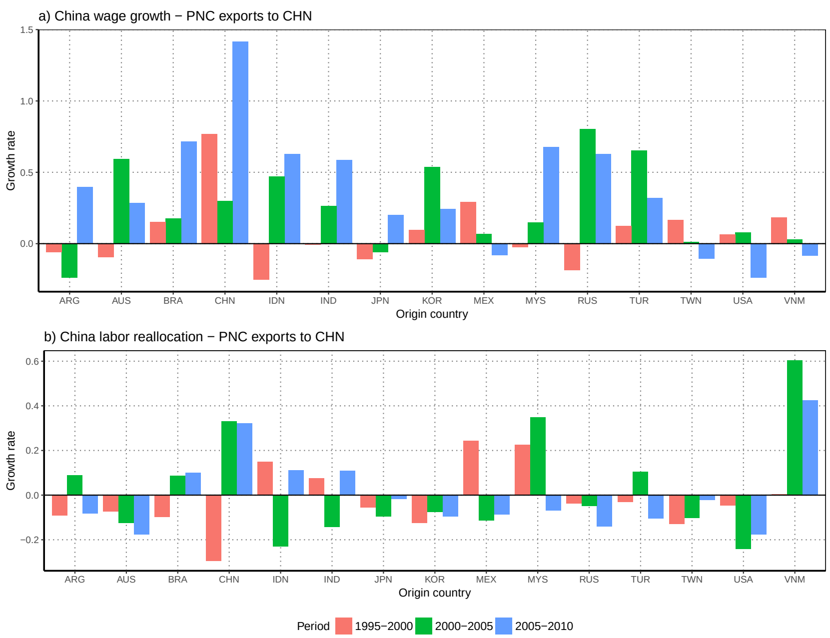
$$\mathrm{DDE} = \Delta \ln \tilde{Q}_j^{\mathrm{COM}} - \Delta \ln \tilde{Q}_j^{\mathrm{MAN}}, \tag{17}$$

where the subscript j references the home country, and the tilde indicates that we are considering the changes induced by either China's wage growth or labor allocation (as opposed to their combined effects). We subtract the growth rate of MAN sales from COM sales because only when positive growth in MAN production is less than growth in COM production would there be a China-driven shift towards commodity-intensive production in country j (reminiscent of the so-called "Dutch disease" effect, hence the acronym DDE).

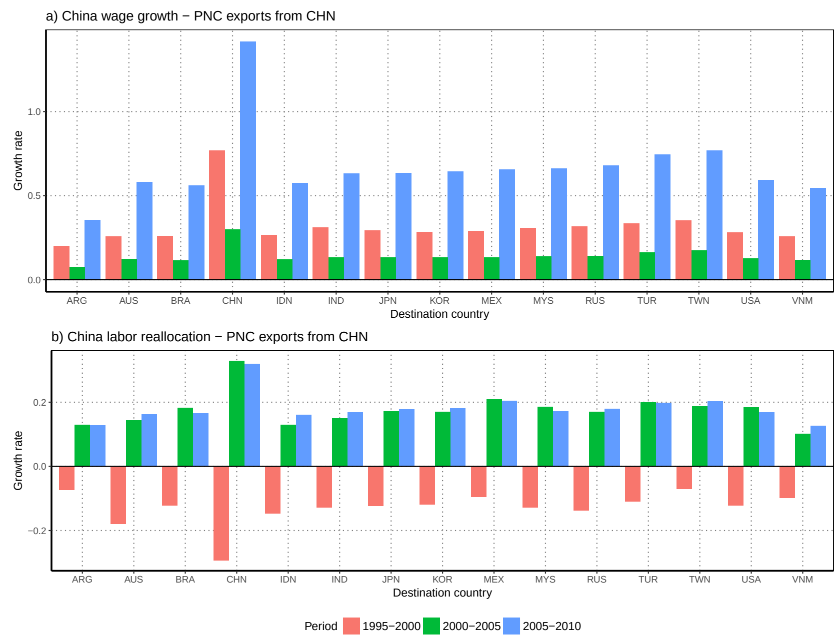
[16] The correlation between the contribution of China's wage growth and labor reallocation to the engine effect in COM is 0.6185 (0.0112).

Figure 7B shows the results based on equations (15) and (17). According to the results, China's wage growth (panel a) tended to push most of the economies in our sample towards commodity trade with China (Russia and the United States are notable exceptions). Brazil, Indonesia, and Turkey were those countries with the strongest commodities-biased shifts. On the other hand, China's labor reallocation (panel b) had a quantitatively smaller and more heterogeneous effect—though on balance there is still trade creation. The results show that, aside from China and a few exceptions in 1995–2000 related to labor reallocation, all countries moved towards a more commodity-intensive production structure as a result of structural change in China. It is worth pointing out the interesting complementarity between China's wage growth and labor reallocation in terms of their effects on trade. Labor reallocation tends to have a larger impact during the 2000–2005 period, and wage growth a larger impact during the 2005–2010 period. Both forces tend to have similar effects despite the fact that wages matter for export shares in more involved ways; see equation (13).

$\sigma = 4$



(A) Exports to China



(B) Exports from China

Figure 8: Changes in parts and components exports to and from China

Notes: This figure reports the contributions of China's wage growth (row panels a) and sectoral reallocation of labor (row panels b) to the growth rates of parts and components (PNC) exports to China from origin countries (vertical panel A) and exports from China (vertical panel B) over each of the three five-year periods. σ is the elasticity of substitution across varieties in production. "Exports to China from China" means "domestic sales" by the Chinese producers, and similarly for "exports from China to China." Table A.2 lists the industries producing PNC. Aggregation across industries is by origin $h \in \{\text{PNC}\}$ based on actual trade $Q^{hs}_{ij,t-1}$ and the contribution of each factor to the growth rates of $\Delta \ln Q^{hs}_{ij,t}$ over a period from $t-1$ to t, from equation (16), where i is the origin country, j is the destination country, h is a PNC, and s is any receiving industry. Vertical scales in panels A and B are different.

Conduit. The conduit effect can counterbalance the steamroller effect if wage growth and sectoral reallocation of labor in China increase the demand for imports of parts and components (PNC). Table 1 shows the regional averages for the growth of PNC exports to and PNC exports from China accounted for by China's wage growth and labor reallocation. Figure 7 does the same by country. There are considerable regional differences in terms of the strength and direction of the conduit effect and the contributions of China's wage growth and labor reallocation. While the growth of PNC exports from the EMEs to China accounted for by wage growth have been consistently positive and increasing over time, wage growth had a small or even negative (1995–2000) contribution to the growth of PNC exports from the advanced economies to China. The contribution of China's labor reallocation to PNC export growth to China is also sharply different between the EME's (positive over the entire sample) and advanced economies (negative). Figure 8A shows that, with the exceptions of Mexico and Vietnam, wage growth in China has boosted exports of PNC to China especially in the last decade of our sample (2000–2010). At the same time, China's labor reallocation has in general reduced PNC exports to China, with the exception of Vietnam in the period from 2000 to 2010.

Figure 8B shows the changes in PNC exports from China to destination countries in the sample. As in the case of MAN exports from China (figure 6B), the results are considerably more uniform across countries. While China's wage growth has stimulated China's exports of PNC across the three periods and for all the destination countries in our sample, labor reallocation had a positive contribution to the growth of PNC exports from China only from 2000 to 2010. Thus, China's structural change has stimulated China's exports of PNC primarily since the 2000s. Of course, economically it is the net conduit effect, the difference between China's PNC imports and exports, that matters for assessing the contribution of structural change in China to the conduit effect. A comparison of the relevant columns in table 1, and figures 8A and 8B suggests a a reverse conduit effect for the EMEs (except in the period 2000–2005) and the advanced economies. The evidence for a positive net conduit effect for Mexico and Taiwan is particularly weak, suggesting that these two economies might be losing market share in global PNC trade to other EMEs, including China.

4.3 Export shares

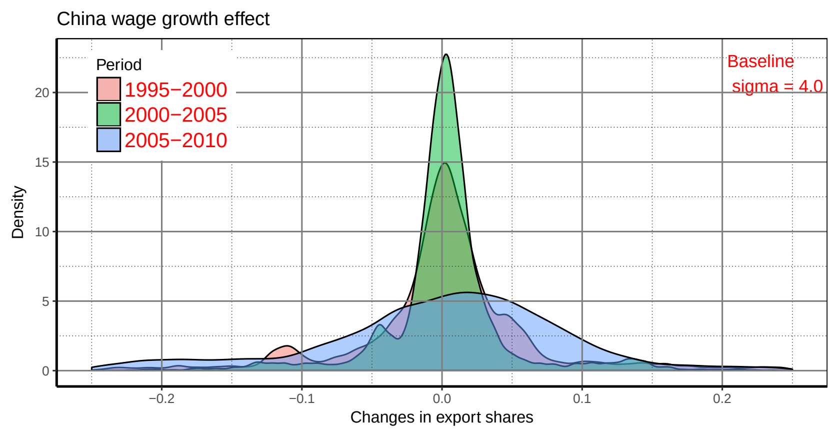
Nothing in our analytical framework hinges on specific industrial categories (COM, MAN, and PNC) as emphasized by the steamroller, engine, and conduit effects. Here, we present fundamental results relating structural change to changes in trade shares (equation 15), demonstrating the richness of the industry-country dyad trade shares implied by our analysis. We summarize these data in the form of densities. Figure 9a shows the changes in dyadic trade shares due to wage growth in China and figure 9b shows the same for labor reallocation in China. The distributions of impacts tend to center on zero but are distinct across time periods and structural components, indicating that wage growth and labor reallocation capture genuinely different determinants of bilateral trade. While changes in trade shares due to labor reallocation are tightly centered around zero for the 1995–2000 period, the same for wage growth are highly dispersed. Also, whereas the contributions of both wage growth and labor reallocation to changes in trade shares have become considerably more dispersed over time, this is markedly more pronounced in the case of wage growth. The density for wage growth in the 2005–2010 period is skewed to the right, suggesting that, on average, wage growth in China over this particular period has helped increase trade shares.[17]

4.4 Determinants of changes in trade flows

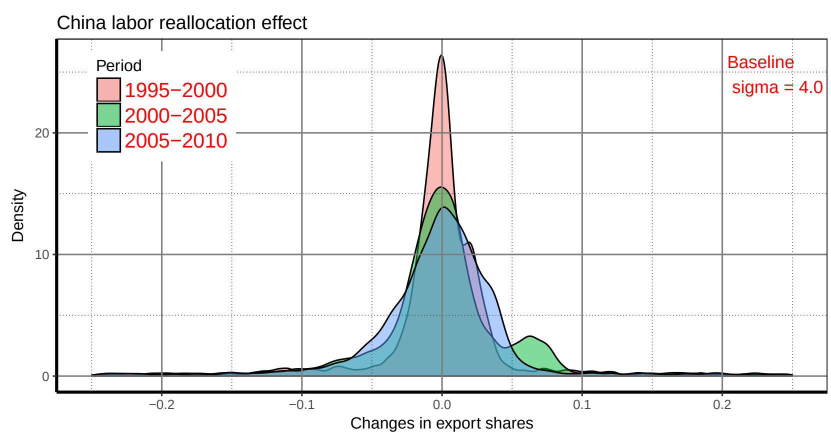
Although our underlying model is highly nonlinear, there is considerable scope to interpret our decomposition results, especially in accounting for the cross-country differences. Foremost, there are differences in changes in the impact of wages and reallocation of labor across industries, both interacting with input-output linkages. Some of these have already been pointed out in the context of a related model by Fujita et al. (2001, chp. 15), where countries have identical input-output linkages but differ in their initial wages and allocation of labor across industries. This can be thought of as giving some countries a head start in industrialization due to geography or historical–idiosyncratic accidents. Their simulation results show that, as global incomes rise (here equivalent to an increase in the industrial wage rate in China), depending on their initial conditions, countries can industrialize in stages and reallocate their labor across industries in complex ways with implications for trade patterns that resemble the steamroller, engine, and conduit hypotheses. This is caused by the varying strengths of forward and backward linkages as determined by local wages and input–output linkages (the α^{hs} terms in their theoretical model). To restate their argument, an initially higher wage rate in an early industrializer attracts industries that prefer proximity to a large market (a demand-driven forward linkage). In parallel, industrial agglomeration reduces the unit cost of intermediate inputs through lower transportation costs unleashing a virtuous circle (a supply-driven backward linkage). As wages increase, however, industries begin to find it cost-reducing to relocate to lower wage countries, bringing these low-wage countries into the fold of industrialization. The order in which certain industries relocate depends on the intensity with which they use local (or cheaply obtained) labor and intermediate inputs. In the spirit of the steamroller, engine, and conduit effects, then, industries that produce intermediate inputs would correspond to those which are more resilient to rising wages, and thus intermediate input producers are last to relocate to newly industrializing countries.

Thus, initial cross-country differences in the industrial wage and shares of labor across industries are in part responsible for differential responses to structural change in China. In our analysis, those differences in wages and distribution of labor across industries are captured by the lagged trade shares $x^{hs}_{ij,t-1}$. There is another explanation present in our model that is not accounted for in the simulation

[17] The density for the remaining structural effects—those that are not captured by China's wage growth and labor reallocation, are considerably more dispersed (as expected), and are reported in supplementary material figure S.2.



(a) Wage growth



(b) Labor reallocation

Figure 9: Distribution of changes in trade shares by period due to China's wage growth and labor reallocation

Notes: There are 15× 15× 28 observations based on origin-destination countries and origin sectors (averaged over destination sectors). Horizontal axes cropped at $(-.25, .25)$ beyond which the densities are negligible. σ is the elasticity of substitution across varieties in production.

results of Fujita et al. (2001), who use a universal input–output table with identical α^{hs} terms (in our notation) across economies. We use the national input–output tables in which the α_i^{hs} terms vary across countries.[18] These variations influence the magnitude and possibly the direction of these input–output linkages by interacting with differences in initial conditions.[19]

[18]We are not imposing, however, restrictions on where intermediate inputs are sourced, which would be the case if we were using World input-output tables.

[19]One could argue that, consistent with Fujita et al. (2001), the steamroller, engine, and conduit effects implicitly allow for differences across industries in α^{hs} terms, but not necessarily across countries. By allowing for both, our analysis enriches the set of explanations available for why individual countries might respond differently to structural change in China.

4.5 Sensitivity analysis

Sensitivity to the elasticity of substitution. To evaluate the sensitivity of the results to the elasticity of substitution between intermediate goods, σ—the only parameter that we do not estimate—we consider two complementary comparisons of the results with different values of σ. First, we compare the distributions of growth rates in export shares across alternative σ values. Second, we report whether using an alternative value of σ leads to a sign change in the decomposition results relative to those from the baseline value of 4. Our comparisons use alternative σ values of 2 (highly inelastic substitutability across varieties) and 8 (highly elastic substitutability) which span the range of commonly used values. Supplementary material tables S.7 and S.8 show the decomposition results by period, regional grouping, and all of the effects considered above. Below we summarize the sensitivity of country-specific results for steamroller, engine, and conduit effects to alternative values of σ.

In terms of the impact of China's wage growth and labor reallocation on exports to the United States or the steamroller effect (supplementary material figure S.5), a lower value of $\sigma = 2$ generates a different profile than is the case for values of 4 or 8 (which are very similar). This can be explained by equation (13): depending on the value of α_i^h, σ values below a certain threshold will lead to a shift in the sign of the term in front of wage growth, which governs the direct effect of wage growth on exports to the United States. Indirect effects also depend on σ, but with greater symmetry between different values of σ and without variation across regions and sectors. In the empirically more relevant comparison for our analysis of $\sigma = 4$ and 8, for both the wage growth and labor reallocation, the qualitative results are virtually identical.[20]

In terms of the net engine effect, measured as the difference between log changes in MAN exports to China and MAN imports from China (figure S.6), wage growth components for different σ values are similar. The contribution of China's labor reallocation to net engine effect for σ values of 4 and 8 generate almost identical profiles, whereas $\sigma = 2$ leads to a much flatter profile. Also, a comparison of the decomposition results for σ equals 4 and 8 suggest that the main findings are qualitatively the same.[21] Finally, in terms of the net conduit effect, measured as the difference between log changes in intermediate exports to China and intermediate imports from China (figure S.7), the profiles are similar to those of the net engine effect, both quantitatively and qualitatively.[22]

Elasticities of output. Our decomposition results, consistent with our notation, are based on the end-of-the-window period elasticities of output with respect to capital, labor, and conglomerate

[20]For China's wage growth, there is one sign change (Argentina) out of 15 countries in the 1995–2000 period, two changes (Russia and Turkey) in the 2000–2005 period, and three changes (Russia, Turkey and Vietnam) in the 2005–2010 period. For China's labor reallocation, there is one sign change (Vietnam) in the 1995–2000 period, no changes in the 2000–2005 period, and one change (Korea) in the 2005-2010 period.

[21]Overall, there are only three sign changes: two in the case of engine exports to China—India (wage growth), and Vietnam (labor reallocation), and one in the case of engine imports from China—Turkey (wage growth). All of these cases occure in the period 1995–2000.

[22]Changing σ from 4 to 8 leads to zero sign changes in the impact of either wage growth or labor reallocation on either conduit exports to or imports from China in any period.

intermediate inputs. We also checked whether the results are sensitive to the beginning-of-the-window period elasticities of output, and found that, while there are several quantitative differences between the two sets of decompositions, overall the results based on regional aggregates are qualitatively similar (supplementary material table S.9). In the case of China's wage growth (panel a), there are only four sign changes (out of 54 cases), and two of these occur for MAN exports to China by advanced economies. However, the decomposition shows that these effects account for an economically small percentage of observed changes in bilateral trade flows when we use the end-of-the-window period elasticities (with the exception of MAN exports to China by advanced economies in the period 2005–2010), and they remain small when we instead use the beginning-of-the-window period elasticities. In the case of China's sectoral reallocation of labor (panel b), there are 13 cases (again out of 54) with sign differences, and they are concentrated in Asia (MAN exports to China, and PNC exports to China), and in EMEs (PCN exports to China). Again, in almost all these instances, the decomposition shows that these effects account for an economically small percentage of observed changes in bilateral trade flows. More importantly, the sign differences based on regional aggregate effects are driven by within-region heterogeneity, with some of the opposing bilateral effects within a region becoming stronger or weaker, without a sign change in country-level effects, thereby reversing the sign of regional aggregate effects.[23] Overall, these findings are consistent with the direction of the bilateral effects reported above (figures 5–8).

Beyond these specific instances of quantitative differences, these findings raise important questions about the origins of these potentially significant variations in the elasticities of output, and their relation to changes in techniques of production in the global economy over the period we study. One particularly interesting question that future research might address is whether these variations were in response to changes in global trade flows or whether they themselves were a source of change in trade flows or altogether unrelated to changes in trade flows.

4.6 Changes in tariffs

So far, we have used our trade-accounting framework to interpret the consequences of China's structural change on global trade flows. Given that trade diversion and creation effects of changes in trade policies concerning China are of independent interest, in this section, we present an extension of our results by exploring the impact of changes in tariffs imposed on China's exports and imposed by

[23]Decomposition results based on bilateral trade flows show even fewer sign changes. There were no sign changes for MAN from China (reverse engine), PNC to China (conduit), and PNC from China (reverse conduit), COM to China (engine by commodities) in any of the three periods. In terms of MAN exports to China (engine), there were no sign changes for the effect of China's wage growth, and one sign change (Vietnam in the 1995–2000 period) for the effect of China's labor reallocation. In terms of MAN exports to USA (steamroller), there were 3 sign changes (Turkey 1995–2000, 2000–2005; Russia 2000–2005) for the effect of China's wage growth, and 4 sign changes (Turkey 2000–2005, 2005–2010; Australia, Malaysia 2005–2010) for the effect of China's labor reallocation. However, in all of these cases, the effects are all essentially zero, so the sign changes are not economically significant.

China on imports. We treat tariffs as trade frictions, and we augment our trade-accounting framework by modelling their influence on trade analogous to transport costs (see supplementary material section S.4). We use the World Integrated Trade Solution (WITS) database to obtain bilateral tariff rates for commodities (see Appendix A for details). We measure the contribution of China's tariffs to the growth rate of exports by the difference between actual $\Delta \ln Q^{hs}_{ij,t}$ and the $\Delta \ln Q^{hs}_{ij,t}(\text{CHN})$ that is obtained when tariffs on China's exports and China's tariffs on imports are kept constant over each of the window periods.

Table 2 reports the contribution of changes in China's tariffs to growth rates in bilateral trade through the steamroller, engine, and conduit effects. Focusing on the steamroller effect, we find that tariff policy had the biggest negative impact on other countries' manufactured goods exports to the United Stated within the 2000–2005 period, precisely when China became a member of the World Trade Organization (in 2001). For all EMEs, tariff policy effects decrease significantly in the 2005–2010 period. We also find that for the countries in our dataset, with the exception of engine effects on commodities trade over the periods 1995–2000 and 2000-2005, China's tariff policies were conducive to the growth of bilateral trade in the form of engine and conduit effects by China. Moreover, the strengths of reverse engine and reverse conduit effects were significantly more prominent than those for engine and conduit effects by China. Overall, given that we have not explored a fully-developed model of tariffs, let alone non-tariff barriers, our decomposition results are simply suggestive. Nevertheless, the results point in the direction that changes in tariff policies faced by China from 1995 to 2010 have significantly contributed to a net reverse conduit and engine effects from China toward the remaining countries included in our analysis.

5 Conclusion

We develop a data-driven accounting framework to decompose changes in bilateral trade flows into their structural determinants. In our application, we study the consequences of structural change in China for bilateral trade flows among China, a set of emerging market economies, and a set of industrial countries. The main empirical finding of our analysis is that, while both wage growth and sectoral reallocation of labor in China have been economically significant determinants of the observed changes in trade flows, wage growth was by far the biggest contributor of the two. In our framework, higher wages in China have dual consequences for its trade with the rest of the world: a loss of international competitiveness arising from higher unit costs, and a gain of competitiveness arising from local-market and scale effects. Our decomposition results point to non-negligible local-market effects.

Our application is focused strictly on the consequences of structural change in China on global trade patterns, and not on the causes of it. Given the non-market influences on China's product and factor

Table 2: Changes in China's tariffs and trade flows: decomposition results

(five-year growth rates, $\sigma = 4$)

	Steamroller	Engine		Reverse Engine	Conduit	Reverse Conduit
Region, Period	MAN to USA	COM to CHN	MAN to CHN	MAN from CHN	PNC to CHN	PNC from CHN
EMEs						
1995–2000	-0.0135	-0.1912	0.0461	0.1194	0.0434	0.0968
2000–2005	-0.0214	-0.1241	0.0259	0.2177	0.0378	0.1769
2005–2010	-0.0052	0.0793	0.0393	0.0378	0.0616	0.0608
Asia						
1995–2000	-0.0094	-0.2184	0.0252	0.1431	0.0269	0.0944
2000–2005	-0.0180	-0.1118	0.0277	0.2330	0.0510	0.1720
2005–2010	-0.0065	0.0892	0.0119	0.0119	0.0181	0.0568
Advanced economies						
1995–2000	-0.0013	-0.2094	0.0034	0.1519	0.0110	0.0888
2000–2005	0.0055	-0.3397	0.0069	0.1871	0.0528	0.1417
2005–2010	-0.0015	0.0347	-0.0042	-0.0147	-0.0036	0.0241

Notes: This table reports the contribution of changes in China's tariffs to the growth rates of exports from the origin country groupings over each of the three five-year periods, where the destination region and industry of exports depend on the specific effect listed for each column. σ is the elasticity of substitution between intermediate inputs in production. See the main text and figure 1 for the description of steamroller, engine, conduit effects. Country groupings of bilateral trade partners of China (CHN) are emerging market economies (EMEs), Asian EMEs (Asia), and advanced economies (excluding the United States (USA) in the steamroller effect). See table A.1 for countries included in each region. Countries in each region are weighted by their beginning-of-period trade volumes. Table A.2 lists the industries producing commodities (COM), manufactured final goods (MAN), and parts and components (PNC). Aggregation across industries is by origin $h \in \{\text{COM}\}$, $h \in \{\text{MAN}\}$, or $h \in \{\text{PNC}\}$ based on actual trade $Q^{hs}_{ij,t-1}$ and the contribution of each factor to the growth rates of $\Delta \ln Q^{hs}_{ij,t}$ over a period from $t-1$ to t, from equation (16), where i is the origin country, j is the destination country, h is the origin industry, and s is the receiving industry. Actual growth rates for each country grouping and period are reported in supplementary material table S.5.

markets, modelling China's structural transformation constitutes a separate research question. While we think that our framework is justified in the concrete context of China's structural change, future work could explore how to incorporate the interactions among changes in wages and the sectoral reallocation of labor. Modelling structural change could potentially address a range of additional dynamic issues related to international trade that have hitherto received relatively little attention in applied work. However, in our view, this approach faces significant empirical and technical challenges. Empirically, one would require estimates of country-sector level productivity levels to tie down wages and sectoral allocation of labour, and given data limitations, this is a challenge. Technically, even a model with few ultimate drivers of structural change, as in Dennis and İşcan (2009), would require solving a large-dimensional nonlinear system given the empirically-validated differences in sectoral factor intensity in production inherent to our model.

Appendix

A Data mapping

Table A.1 shows the 15 countries included in our study, and the availability of data from the data sources.

A.1 Industries

Table A.2 lists the 28 industries we use in the empirical analysis. This is the most detailed disaggregation that is available in the TiVA, IOT, and STAN databases. The categories that are shown in bold are the highest level aggregation in employment data available for either Malaysia, Taiwan, or Vietnam (see below). These consist of the following industries:

- C30T33 = C30T33X + C31 (Computer, Electronic and optical equipment; Electrical machinery and apparatus, nec)
- C34T35 = C34 + C35 (Motor vehicles, trailers and semi-trailers; Other transport equipment)
- C70T74 = C70 + C71 + C72 + C73T74 (Real estate activities; Renting of machinery and equipment; Computer and related activities; R&D and other business activities)
- C90T95 = C90T93 + C95 (Other community, social and personal services; Private households with employed persons)

Table A.1: Regions and data availability

Country	Country Code	TiVA 1995,2000, 2005, 2008–2015	IOT 1995–2011	STAN 1980–2015	ITIC 2011	Comtrade
Argentina	ARG	yes	yes	yes	yes	1988–2013
Australia	AUS	yes	yes	yes	yes	1988–2013
Brazil	BRA	yes	yes	yes	yes	1988–2013
China	CHN	yes	yes	yes	yes	1988–2013
India	IND	yes	yes	yes	yes	1988–2013
Indonesia	IDN	yes	yes	yes	yes	1989–2013
Japan	JPN	yes	yes	yes	yes	1973–2013
Korea	KOR	yes	yes	yes	yes	1988–2013
Malaysia	MYS	yes	yes	2001–2015	yes	1988–2013
Mexico	MEX	yes	yes	yes	yes	1988–2013
Russia	RUS	yes	yes	yes	yes	1992–2013
Taiwan	TWN	yes	yes	1980–2011	yes	no
Turkey	TUR	yes	yes	yes	yes	1988–2013
United States	USA	yes	yes	yes	yes	1988–2013
Vietnam	VNM	yes	yes	2000–2015	yes	1997–2013

Notes: Trade in Value Added (TiVA) are from OECD (2017b); Input–output tables (IOT) are from OECD (2017a); Structural Analysis (STAN) is from OECD (2017c); International Transport and Insurance Costs of Merchandise Trade (ITIC) are from OECD (2017d); Comtrade data are from United Nations (2015). Country codes are the current officially assigned ISO 3166-1 alpha-3 codes from World Atlas. Years available from national sources are also shown. For Taiwan, Malaysia, and Vietnam, see the text. Emerging market economies (EME) are ARG, BRA, IND, IDN, KOR, MYS, MEX, RUS, TWN, TUR, VNM; Asia includes IND, IDN, KOR, MYS, TWN, VNM; and advanced economies are AUS, JPN, USA.

Table A.2: List of industries

Codes					
OECD	MYS	TWN	VNM	Sector	Label
C01T05	1	1	5	COM	Agriculture, hunting, forestery and fishing
C10T14	2	2	8	COM	Mining and quarrying
C15T16	4–22	3		MAN	Food products, beverages and tobacco
C17T19	23–28	4		MAN	Textiles, textile products, leather and footwear
C20	29–31	5		MAN	Wood and products of wood and cork
C21T22	32–38	6		MAN	Pulp, paper, paper products, printing and publishing
C23	39–40	7		PNC	Coke, refined petroleum products and nuclear fuel
C24	41–49	8		PNC	Chemicals and chemical products
C25	50–59	9		PNC	Rubber and plastic products
C26	60–66	10		PNC	Other non-metallic mineral products
C27T28	67–76	11		PNC	Basic metals and fabricated metal products
C29	77–81	12		PNC	Machinery and equipment, nec
C30T33X				MAN	Computer, electronic and optical equipment
C31				PNC	Electrical machinery and apparatus, nec
C34T35	100–105	14		MAN	Transport equipment
C36T37	106–110	15		MAN	Manufacturing nec; recycling
C40T41	111–112	16	10,11	SRV	Electricity, gas and water supply
C45	113	17	13		Construction
C50T52	114	18-20	16	SRV	Wholesale and retail trade; repairs
C55	116	21	18	SRV	Hotels and restaurants
C60T63	115	22	20	SRV	Transport and storage
C64	117	23	21	SRV	Post and telecommunications
C65T67	118	24	22	SRV	Financial intermediation
C70T74	119–121	25,26	23–25	SRV	Real estate, renting and business activities
C75	122	27	26	SRV	Public admin., defence; compulsory social security
C80	123	28	28	SRV	Education
C85	124	29	29	SRV	Health and social work
C90T95	125–126	30,31	30–32	SRV	Other services

Notes: nec is "not elsewhere classified". Labels are from OECD (2017b) and Asia KLEMS (2016). Under Sector, "COM" indicates commodity, "MAN" indicates manufactured final goods, "PNC" is parts and components, and "SRV" is services. Manufactured goods (TOT) used in the text refers to the union of MAN and PNC. Our classifications are based on the closest industry correspondence with parts and components used in Haltmaier et al. (2007).
Source: OECD (2017b), Trade in Value Added (TiVA) database. For Taiwan, Asia KLEMS (2016). For Malaysia, see table A.4 industry definitions. For Vietnam, see table A.5.

A.2 Trade values

Table A.3 shows the mapping of the model variables to the data. Trade values are reported in current US dollars. Consistent with our model, we use the same price for intermediate and final goods originating from the same region and sector. From OECD (2017a), we obtain the total value of intermediate inputs sold by sector h to sector s in region j, M_j^{hs}; value of labor compensation W_j^s; and value added VA_j^s. From TiVA, we obtain VA_{ij}^{hs}, the value added of exports of intermediate inputs originating from region i sector h to destination region j sector s. The export shares are based on gross exports— $Q_{ij}^{hs} = p_i^h n_i^h q_{ij}^{hs}$ for intermediate goods and $p_i^h c_{ij}^h$ for final goods (with the understanding that origin and destination sectors are the same ($h = s$). Thus, from IOT we first compute the share of value added in sector h region i:

$$\nu_i^h = \frac{VA_i^h}{Q_i^h}.$$

Consistent with our production technology in equation (3), we then calculate

$$Q_{ij}^{hs} = \frac{VA_{ij}^{hs}}{\nu_i^h}$$

to construct the export shares x_{ij}^{hs}.[24]

A.3 Elasticity parameters

We use national IOT to calculate the elasticity parameters. In IOT, for a given column, row entries give the inputs used to produce the output of the sector given by that column. For a given row, column entries give the use by other sectors of the sector's output (table S.1). From these tables we extract the following entries. For intermediate demand, let M_i^{hs} represent the cell entry in row h and column s in region i. Intermediate input choices depend on prices faced by producers, including taxes net of subsidies. The IOT report an aggregate of taxes less subsidies on intermediate and final products purchased by each sector (T_i^s) as a separate row entry. We apportion these net taxes to origin sectors proportionately. Consistent with this accounting, our measure of total value of output by sector Q_i^s is the sum of the total intermediate and final expenditure at purchasers' prices and value added: $M_i^s + T_i^s + VA_i^s$. In IOT, value added is further decomposed into labor compensation and other value added. Wages are calculated based on manufacturing labor value added divided by manufacturing employment as reported in the OECD's Trade in Employment: Core Indicators from the OECD Input-Output Database. Supplementary material table S.2 illustrates the values we extract from a stylized IOT for a two-sector region.

[24]For export values reported (or censured) as zero in the data, we set x_{ij}^{hs} to an arbitrarily small value to prevent singularity.

Table A.3: Mapping model variables to data

Variable	Source	Model
Intermediate inputs,		
origin h, destination j and s	IOT	$M_j^{hs} = m_j^{hs} G_j^{hs}$
Composite intermediate input,		
destination j and s	IOT	$M_j^s = \sum_{h=1}^{S} M_j^{hs}$
Value added in intermediate inputs,		
origin i and h, destination j and s	TiVA	VA_{ij}^{hs}
Final domestic demand,		
destination j and s	TiVA	C_j^s
Labor compensation	IOT	$W_j^s = w_j L_j l_j^s$
Transportation cost,		
origin i and h, destination j	ITIC	$\tau_{ij}^{h\cdot}$
Employment by sector	STAN	$L_j l_j^s$
Wage rate	IOT, STAN	w_j
Rental rate of capital	WDI	r

Notes: IOT is OECD, National Input-Output Tables; TiVA is OECD, Trade in Value Added database which is based on inter-country input-output tables; ITIC is OECD, International Transport and Insurance Costs of Merchandise Trade database; STAN is a suite of databases from OECD (2017c), Structural Analysis; WDI is World Bank, World Development Indicators. Employment is number of persons engaged; Taiwan data is from Asia KLEMS (2016), and for Malaysia and Vietnam, from their national statistical offices.

We use gross output shares for the elasticity of output with respect to capital, labor and intermediate inputs:

$$\beta_i^s = \frac{VA_i^s - W_i^s}{Q_i^s}, \qquad \alpha_i^s = \frac{W_i^s}{Q_i^s}, \qquad \alpha_i^{hs} = \frac{M_i^{hs} + \omega_i^{hs} T_i^s}{Q_i^s},$$

where

$$\omega_i^{hs} = \frac{M_i^{hs}}{\sum_{k=1}^{S} M_i^{ks}}.$$

In the model, these parameters are time invariant. Thus, we use average values of these estimates over each of the episodes. In our baseline, we calibrate the elasticity of substitution between intermediate goods, $\sigma = 4.0$, based on the estimates reported in Simonovska and Waugh (2014) and Redding and Weinstein (2016, table 1).[25] We also present the sensitivity of the results to $\sigma = \{2.0, 8.0\}$. The results

[25] This baseline value and our parsimonious modelling of elasticities of substitution across goods is consistent with the conclusion of Feenstra, Luck, Obstfeld, and Russ (2014), who distinguish between the elasticity substitution between the home good and a composite foreign good (their "macro" elasticity), and across any two foreign goods ("micro" elasticity): "Our median estimates of the micro elasticity across individual industries are 3.24 and 4.12 for TSLS and 2-step GMM respectively, whereas the macro elasticities are significantly lower in up to one-half of the goods we analyze . . . The fact that the micro and macro elasticities are not significantly different from each other in the other half of cases offers some limited support for . . . models, which do not allow for any difference between them." In addition, based on firm-level estimates from five basic Chilean industries, Kasahara and Lapham (2013) find a large (in the range from 5 to 11) elasticity of substitution between intermediate inputs in production.

for $\sigma = 2$ are illustrative of the fact that the lowering of σ can amplify the results considerably. In the text, we focus on the comparison of the results for values of 2, 4 and 8, given that this is the range of values that are most commonly used in computable general equilibrium models of international trade. Another reason for the relevance of the values of σ equal to 4 and 8 is that we use five-year periods and, in their survey of the literature on substitution elasticities in international trade, McDaniel and Balistreri (2003) find that estimated long-run elasticities are higher than short-run elasticities.

A.4 Sectoral employment

Data, except for Malaysia, Taiwan, and Vietnam, are from STAN: Trade in Employment: Core Indicators and we use "World" as the partner country to extract the data from 1995 to 2011.

Malaysia. Data are from the Department of Statistics, Malaysia (accessed through Haver Analytics). For total employment (thousand persons), we use Haver code A548ELEQ, which starts in 1995. Data on employment by industry start in 2001. There are no disaggregate employment data within manufacturing until 2008. See table A.4 for the list of detailed industries for the period 2008–2016.

Taiwan. We use Asia KLEMS (2016), total number of persons engaged (EMP). See table A.2 for concordance between OECD and KLEMS codes (industry classifications are practically identical in the two datasets). Until 2001, employment in the Education industry is subsumed in other categories.

Vietnam. Data are from General Statistics Office of Vietnam (accessed through Haver Analytics). Data on employment by industry start in 2000, and there are only data for total manufacturing. Slightly more disaggregated data start in 2012. There are no data for 2010. See table A.5.

Disaggregation. When employment from STAN or our national sources are at a higher level of aggregation than available to us in IOT and TiVA, we use the highest level aggregation that is available in the limiting case, and apportion employment using value added shares from IOT. For instance, for Malaysia and Taiwan, we have employment data on industrial category C30T33; see table A.3 for category labels. IOT and TiVA both report more disaggregated C30T33X and C31 separately. We use the value added shares of these sectors to apportion the employment from C30T33 to these two sectors. Specifically, we first calculate

$$\theta_i^s = \frac{\mathrm{VA}_i^s}{\sum_{s=1}^{S} \mathrm{VA}_i^s}.$$

Next, we set

$$\mathrm{EMP}_i^{\mathrm{C30T33X}} = \mathrm{EMP}_i^{\mathrm{C30T33}} \frac{\theta_i^{\mathrm{C30T33X}}}{\theta_i^{\mathrm{C30T33X}} + \theta_i^{\mathrm{C31}}}$$

Missing years. Employment data from the national sources of Malaysia and Vietnam do not go as far back as 1995. In these cases, we use the value added shares to backcast the missing years. In particular, using the last year of observation on the share of employment in any industry as the benchmark, by going back in time, we add or subtract the year-over-year changes in the share of value added realized by this industry, with the constraint that the sum of all changes in the share of employment by sector add up to zero.

A.5 Factor prices

Wage rate. We compute the country-specific wage rate as labor compensation divided by total employment in total manufactures (C15T37). Labor compensation is calculated from a ready-made file on the share of labor compensation in value added, available from the Structural Analysis (STAN) Databases, (under Input Output Database, Input-Output Tables 2015, Export: Related files, and `OECD_IO2015_Valu.zip`). For Taiwan, we use labor compensation (LAB) and the number of persons engaged (EMP) in total manufactures from Asia KLEMS (2016) converted into US dollars using the average exchange rate from Republic of China (Taiwan), National Statistics (2017).

Rental rate of capital. We assume a constant depreciation rate, and measure the changes in the world real interest rate by using the real interest rate for the United States published by the World Bank (2017), World Development Indicators, calculated as the lending interest rate adjusted for inflation as measured by the GDP deflator.

A.6 Transportation costs and tariffs

We use International Transport and Insurance Costs of Merchandise Trade (ITIC) data from the OECD (2017d) to calculate transportation costs, τ_{ij}^{h}. Tariff data (section 4.6) are from the World Integrated Trade Solution (WITS) database housed at the World Bank which aggregates data from the UN Comtrade and UNCTAD Trade Analysis Information System (TRAINS) databases. We use data on effectively applied tariff rates, which are available for all countries for the years 2000, 2005, and 2010. Data for 1995 are only available for Argentina, Brazil, Indonesia, Japan, Korea, Mexico, Turkey, and the United States. Using the nearest year to 1995 for which data are available, we consequently use 1996 tariff data as the starting point for Australia, China, India, Malaysia, Russia, and Taiwan. We use 1994 tariff data for Vietnam. Weighted average effectively applied tariff rates are given for SITC Revision 3 data, which corresponds to our sectoral groupings. In several cases, we used import weights to further aggregate tariff data.

Table A.4: Malaysia, 2008–2016: List of industries

Code	Label (Haver codes in parentheses)
1	Agriculture, forestry and fishing (N548ETA)
2	Mining and quarrying (N548ETN)
3	Manufacturing (N548ETM)
4	Canning of fish, crustaceans and mollusks/processing, curing and preserving of fish, crustacean and mollusks (N548EEFF)
5	Pineapple canning/jams, marmalades and table jellies (N548EFVC)
6	Coconut oil (N548EFL5)
7	Crude and refined vegetable oil/compound cooking fats (N548EMFL)
8	Condensed, powdered and evaporated milk (N548EMFD)
9	Rice milling (N548EFGR)
10	Flour milling (N548EMFS)
11	Prepared animal feeds (N548EMFA)
12	Biscuits and cookies (N548EFK2)
13	Bread, cakes and other bakery products (N548EFK3)
14	Sugar (N548EFCS)
15	Cocoa products (N548EFCA)
16	Chocolate and chocolate products/sugar confectionaries (N548EFCC)
17	Sauces and condiments (N548EFRU)
18	Snack products (N548EFRC)
19	Other food products nec (N548EFHO)
20	Soft drinks (N548EFBN)
21	Production of natural mineral waters and other bottled (N548EFNW)
22	Tobacco products (N548EMFO)
23	Preparation and spinning of textile fibers/weaving of textiles (N548EXTN)
24	Dyeing, bleaching, printing and finishing of yarns and fabrics (N548EXDF)
25	Knitted and crocheted fabrics (N548EXTD)
26	Clothing (N548EMTW)
27	Tanning and dressing of leather; luggage, handbags and the like, saddlery and harness/harness (N548EML1)
28	Rubber footwear (N548EMLF)
29	Veneer sheets and plywood (N548EMWH)
30	Particle board and fiberboard (N548EMWD)
31	Builders' carpentry (N548EMOW)
32	Pulp, paper and paperboard (N548EMBZ)
33	Corrugated paper and paperboard and of containers of paper and paperboard (N548EBDC)
34	Envelopes and letter-card (N548EBAK)
35	Household and personal hygiene paper (N548EBDO)
36	Gummed or adhesive paper in strips or rolls and labels and wall paper (N548EM1W)
37	Printing (N548EBUR)
38	Service activities related to printing (N548EBRS)
39	Refined petroleum products (N548EMDR)
40	Liquefied or compressed inorganic industrial or medical gases (N548ECYI)
41	Basic organic chemicals/inorganic compounds (N548ECYH)
42	Fertilizers/associated nitrogen products (N548EMCF)

Continued on next page

Table A.4 (*Continued*)

Code	Label (Haver codes in parentheses)
43	Plastics in primary forms (N548EMCR)
44	Pesticides and other agrochemical products (N548EMCT)
45	Paints, varnishes and similar coatings ink and mastics (N548EMCV)
46	Printing ink (N548EMNK)
47	Medicinal active substances to be used for their pharmacological properties in the medicaments (N548EMHM)
48	Soap and detergents, cleaning and polishing preparations/perfumes and toilet preparations (N548EMCC)
49	Photographic plates, films, sensitized paper and other sensitized unexposed materials/other chemical products NEC (N548EMCN)
50	Rubber tires for vehicles (N548EMRT)
51	Interchangeable tire treads and retreading rubber tires (N548EMRE)
52	Other products of natural or synthetic rubber, unvulcanized, vulcanized or hardened/rubber remilling; Latex Processing (N548EMRP)
53	Rubber gloves (N548EMRG)
54	Other rubber products nec (N548EMRX)
55	Semi-manufactures of plastic products/finished plastic products (N548ERLX)
56	Builders' plastics ware (N548ERLK)
57	Plastic articles for the packing of goods (N548ERLF)
58	Plastic tableware, kitchenware and toilet articles (N548ERLI)
59	Diverse plastic products nec (N548ERLO)
60	Flat glass, including wired, colored or tinted flat glass/other glass products nec (N548EMG)
61	Other porcelain and ceramic products (N548EMN1)
62	Refractory mortars and concretes; Non-refractory ceramic (N548EMN3)
63	Hydraulic cement (N548EMNE)
64	Ready-mix and dry-mix concrete and mortars (N548E4MI)
65	Precast concrete, cement or artificial stone articles for use in construction/prefabricated structural components for building or civil engineering of cement, concrete or artificial stone/other articles of concrete, cement and plaster NEC (N548E4MX)
66	Other non-metallic mineral products nec (N548EMNX)
67	Production of pig iron and spiegeleisen in pigs, blocks or other primary forms/production of bars and rods of stainless steel or other alloy steel/seamless tubes, by hot rolling, hot extrusion or hot drawing, or by cold drawing or cold rolling/other basic iron and steel products NEC (N548EMI)
68	Production of aluminum from alumina/other basic precious and other non-ferrous metals nec (N548EMAN)
69	Metal doors, windows and their frames, shutters and gates/other structural metal products (N548EFXZ)
70	Tanks, reservoirs and containers of metal (N548EFXM)
71	Forging, pressing, stamping and roll-forming of metal: powder metallurgy (N548EFXG)
72	Treatment and coating of metals; machining (N548EMU6)
73	Tins and cans for food products, collapsible tubes and boxes (N548EFXN)
74	Metal cable, plaited bands and similar articles/bolts, screws, nuts and similar threaded products (N548EFXW)
75	Metal household articles (N548EFXB)
76	Any other fabricated metal products nec (N548EFXX)
77	Fluid power equipment/other pumps, compressors, taps and valves (N548EMXU)
78	Air-conditioning machines, including for motor vehicles (N548EMHA)
79	Power-driven hard tools with self-contained electric or non-electric motor or pneumatic drives/metal-forming machinery and machine tools (N548EMX4)

Continued on next page

Table A.4 (*Continued*)

Code	Label (Haver codes in parentheses)
80	Other special-purpose machinery nec (N548EMX9)
81	Domestic appliances (N548EMXD)
82	Computers/peripheral equipment (N548EMEU)
83	Electric motors, generators and transformers (N548EMKG)
84	Electricity distribution and control apparatus (N548EMKD)
85	Fiber optic cables (N548EMKT)
86	Other electronic and electric wires and cables (N548EMKW)
87	Batteries and accumulators (N548EMKA)
88	Electric lighting equipment (N548EMKL)
89	Miscellaneous electrical equipment other than motors, generators and transformers, batteries and accumulators, wires and wiring devices lighting equipment or domestics appliances (N548EMKH)
90	Miscellaneous electrical equipment other than motors, generators and transformers, batteries and accumulators, wires and wiring devices, lighting equipment or domestic appliances/manufacture electronic integrated circuits micro assemblies (N548EMES)
91	Other components for electronic applications/printed circuit boards/display components (N548EETQ)
92	Other components for electronic applications (N548EETO)
93	Communication equipment (N548EMEN)
94	Consumer electronics (N548EMZV)
95	Irradiation, electro medical and electrotherapeutic equipment (N548EMED)
96	Measuring, testing, navigating and control equipment (N548EEMM)
97	Optical instruments and equipment (N548EEOO)
98	Photographic equipment (N548EEOC)
99	Watches and clocks and parts (N548EEMW)
100	Passenger cars/commercial vehicles (N548EMSW)
101	Bodies (coachwork) for motor vehicles, trailers and semi-trailers (N548EMSD)
102	Parts and accessories for motor vehicles (N548EMSZ)
103	Building of ships and floating structures/repair and maintenance of transport equipment except motorcycles and bicycles (N548EMSS)
104	Motorcycles (N548EMSC)
105	Bicycles and invalid carriages (N548EMSB)
106	Wooden and cane furniture (N548EMWO)
107	Jewelry and related articles (N548EMOJ)
108	Sports goods (N548EMOS)
109	Games and toys (N548EMOG)
110	Stationery (N548EOOS)
111	Electricity, gas, steam and air conditioning supply (N548ETVU)
112	Water supply; sewerage, waste management and remediation activities (N548ETWS)
113	Construction (N548ETK)
114	Wholesale and retail trade; repair of motor vehicles and motorcycles (N548ET2T)
115	Transportation and storage (N548ETS)
116	Accommodation and food service activities (N548ETO)
117	Information and communication (N548ETCN)
118	Financial and insurance activities (N548ETFT)
119	Real estate activities (N548ETRE)
120	Professional, scientific and technical activities (N548ETPS)
121	Administrative and support service activities (N548ETAS)

Continued on next page

Table A.4 (*Continued*)

Code	Label (Haver codes in parentheses)
122	Public administration and defense; compulsory social security (N548ETG)
123	Education (N548ETE)
124	Human health and social work activities (N548ETH)
125	Arts, entertainment and recreation (N548ETCS)
126	Other service activities (N548ETOS)

Table A.5: Vietnam: List of industries

Code	Label (Haver codes in parentheses)
3	Agriculture, forestry, 2000-2009 (A582ETA)
4	Fishing, 2000-2009 (A582ETAC)
5	Agriculture, forestry and fishery sector, 2012-2015 (N582ETA)
6	Industry, 2000-2009 (A582ETIC)
7	Industry and construction sector, 2012-2015 (N582ETI2)
8	Mining and quarrying, 2012-2015 (N582ETN)
9	Manufacturing, 2012-2015 (N582ETM0)
10	Production and distribution of electricity, gas, steam and hot water and air conditioners, 2012-2015 (N582ETVU)
11	Distribution of water, management and processing activities of sewage and waste, 2012-2015 (N582ETWS)
12	Construction, 2000-2009 (A582ETK)
13	Construction, 2012-2015 (N582ETK)
14	Services sector, 2012-2015 (N582ETV)
15	Trade, 2000-2009 (A582ETR)
16	Wholesale and retail trade, repair of cars, motorcycles and other motor vehicles, 2012-2015 (N582ET2T)
17	Hotels, restaurant, 2000-2009 (A582ETHR)
18	Hotels and restaurants, 2012-2015 (N582ETO)
19	Transport, storage and communications, 2000-2009 (A582ETSC)
20	Transport and storage, 2012-2015 (N582ETS)
21	Information and communication, 2012-2015 (N582ETCN)
22	Financial intermediation, banking and insurance, 2012-2015 (N582ETFI)
23	Real estate activities, 2012-2015 (N582ET68)
24	Technological, scientific and specialized activities, 2012-2015 (N582ET6Z)
25	Administrative activities and supporting services, 2012-2015 (N582ETAS)
26	Activities of communist party, social-political organizations, governmental management, 2012-2015 (N582ET84)
27	Culture, health, education, 2000-2009 (A582ETEH)
28	Training and education, 2012-2015 (N582ETE)
29	Health and social work, 2012-2015 (N582ETH)
30	Recreational cultural and sporting activities, 2012-2015 (N582ETCS)
31	Other services, 2000-2009 (A582ETOS)
32	Other service activities, 2012-2015 (N582ETOS)

Notes: The data are from 2000 to 2015, and are more disaggregated from 2012 to 2015, as indicated by the periods next to each label.

S Supplementary Material

S.1 Indonesia, Malaysia, South Korea, and Vietnam

From 1995 to 2010, the GDP per capita in South Korea increased by 79%, whereas in Malaysia it increased by a factor of two, in Indonesia by a factor of three, and in Vietnam by a factor of 4.75 (all measured in current US dollars). Despite these variations in growth rates, in 2010, the richest country among the four, South Korea had a per capita income of $22,087 in current US dollars. In the same year, Malaysia's GDP per capita was 41% that of South Korea, Indonesia's was 14%, and Vietnam's was 6% (supplementary material table S.4). In terms of non-service value-added exports from OECD (2017b), in 2010, 81% of exports of Indonesia to China were in commodities (mining, foodstuffs, and wood). By contrast, 59% of South Korea's exports to China were in electronics and machinery, and electronics alone represented 27% of Malaysia's exports to China, whereas it accounted for only 7% of Vietnam's exports to China. Mining exports from both Malaysia and Vietnam to China in 2010 represented 24% and 45%, respectively, of their total non-service value-added exports.

For the four Asian economies as a whole, MAN value-added exports have on average grown faster than PNC exports to China (average growth rates of 75% and 15% over five-year periods), MAN imports from China have grown more than MAN exports to China (147% versus 75%), and PNC imports from China have grown more than PNC exports to China (135% versus 15%). At the same time, the average growth rate of commodity exports to China exceed those of commodity exports from China to these four Asian economies (198% versus 88%). Indonesia's net exports of commodities to China were balanced by net negative engine and conduit effects (especially over the last two periods). For Malaysia, the net conduit and engine effects dissipated over time, and even gave way to a steamroller effect. For South Korea all three were present, but on net the magnitudes were relatively weak. Vietnam shows engine and conduit effects that were boosted by a rising trade surplus with the United States—possibly becoming an export platform for China-made PNC, consistent with the reverse conduit effect.

S.2 Supplementary tables and figures

Table S.1: OECD national input-output tables: symmetric sector-by-sector at basic prices

	Intermediate demand (to:)			Final expenditure			Output (bp)
(from:)	C1	...	C34	Domestic demand	Cross-border exports	Direct purchases	
DOM C1 ... DOM C34						Expenditure by non-residents	
IMP C1 (bp) ... IMP C34 (bp)	Imports of intermediate products			Imports of final products	Re-imports and re-exports	Direct purchases by residents	
Taxes less subsidies on intermediate/final products							
Total int./final expenditure (pu)							
Value added (bp) Labor compensation Other value added							
Output (bp)							

Notes: Imports are valued at basic prices of the country of origin. According to the OECD, this is done by allocating domestic and international distribution in imports in c.i.f. purchasers' prices to transport, trade and insurance sectors of origin and destination countries.
"bp"' indicates basic prices.
"pu" indicates purchasers' prices.

Table S.2: OECD national input-output table entries used in the analysis

		Input bought from row by column: Sector 1	Input bought from row by column: Sector 2	Final domestic demand
	$r \downarrow \diagdown c \rightarrow$	1	2	
Output sold to column by row	1	M_i^{11}	M_i^{12}	C_i^1
	2	M_i^{21}	M_i^{22}	C_i^2
Taxes less subsidies on intermediate and final products		T_i^1	T_i^2	
Total intermediate and final expenditure at purchasers' prices		M_i^1	M_i^2	
Value added		VA_i^1	VA_i^2	
Compensation of labor		W_i^1	W_i^2	
Output		Q_i^1	Q_i^2	

Note: See supplementary material figure S.1 for a stylized national-input table.

Table S.3: Structural change in China, 1995–2010

Year	Industrial wage	Share of employment in agriculture	Total employment
1995	0.927	52.2	680,376.1
2000	1.523	50.0	720,530.4
2005	1.815	44.5	745,738.8
2010	4.088	36.4	760,422.4

Notes: Share of employment in agriculture is in percent. Total employment is in thousands of persons. Industrial wage is per hour in current US dollars.
Source: Authors' calculations based on OECD (2017c).

Table S.4: GDP per capita in Indonesia, Malaysia, South Korea, and Vietnam, 1995–2010

	GDP per capita			Relative to 1995			Relative to South Korea		
Country	1995	2000	2010	1995	2000	2010	1995	2000	2010
Indonesia	1,026.3	780.1	3,113.5	1.00	0.76	3.03	0.08	0.07	0.14
Malaysia	328.0	4,045.2	9,071.4	1.00	0.93	2.10	0.35	0.34	0.41
South Korea	2,333.0	11,947.6	22,087.0	1.00	0.97	1.79	1.00	1.00	1.00
Vietnam	75.8	388.3	1,310.4	1.00	1.41	4.75	0.02	0.03	0.06

Note: GDP per capita is measured in current US dollars.
Source: World Bank (2017).

Table S.5: Changes in trade flows by steamroller, engine, and conduit effects

	Steamroller	Engine		Reverse Engine	Conduit	Reverse Conduit
Region Period	MAN to USA	COM to CHN	MAN to CHN	MAN from CHN	PNC to CHN	PNC from CHN
EMEs						
1995–2000	0.2112	0.6124	0.1748	0.7120	0.2586	0.5740
2000–2005	1.3430	1.9290	1.1437	1.6676	0.1266	1.5329
2005–2010	0.8885	2.1404	0.6255	2.1242	0.1467	1.9564
Asia						
1995–2000	0.1802	0.6033	0.0630	0.6926	0.1911	0.6291
2000–2005	1.3719	2.0743	1.1587	1.8457	-0.3070	1.5857
2005–2010	0.8665	2.1350	0.6430	2.2871	-0.1081	2.0504
Advanced economies						
1995–2000	-0.4890	0.4391	-0.0348	0.7525	0.0102	0.4460
2000–2005	0.4031	1.5424	0.8120	1.3741	0.0510	1.3704
2005–2010	-0.1199	1.7393	0.0483	1.8126	-0.4026	1.7548

Notes: See the main text and figure 1 for the description of steamroller, engine, conduit effects. Country groupings of bilateral trade partners of China (CHN) are emerging market economies (EMEs), Asian EMEs (Asia), and advanced economies (excluding the United States (USA) in the steamroller effect). See table A.1 for countries included in each region. Countries in each region are weighted by their beginning-of-period trade volumes. Table A.2 lists the industries producing commodities (COM), manufactured final goods (MAN), and parts and components (PNC). Aggregation across industries is by origin $h \in \{\text{COM}\}$, $h \in \{\text{MAN}\}$, or $h \in \{\text{PNC}\}$, averaged across countries of growth rates of value-added exports $\Delta \ln Q^{hs}_{ij,t}$ over a period from $t-1$ to t, where i is the origin country, j is the destination country, h is the origin industry, and s is any destination industry.
Source: OECD (2017b).

Table S.6: China's wage growth and labor reallocation effects on trade flows: annualized growth rates

($\sigma = 4$)

	Steamroller	Engine		Reverse Engine	Conduit	Reverse Conduit
Region Period	MAN to USA	COM to CHN	MAN to CHN	MAN from CHN	PNC to CHN	PNC from CHN
			a) China's wage growth			
EMEs	-0.0090	0.0987	0.0560	0.0828	0.0556	0.0866
Asia	-0.0150	0.0954	0.0505	0.0872	0.0496	0.0890
Advanced economies	-0.0064	0.0980	0.0236	0.0793	0.0201	0.0838
			b) China's labor reallocation			
EMEs	-0.0034	-0.0004	0.0052	0.0298	0.0064	0.0188
Asia	-0.0067	0.0000	0.0127	0.0303	0.0147	0.0173
Advanced economies	-0.0011	0.0110	-0.0323	0.0246	-0.0279	0.0163

Notes: This table reports the contributions of China's wage growth (panel a) and sectoral reallocation of labor (panel b) to the annualized growth rates of exports from the origin country groupings over the period 1995–2010, where the destination region and industry of exports depend on the specific effect listed for each column. σ is the elasticity of substitution between intermediate inputs in production. See the main text and figure 1 for the description of steamroller, engine, conduit effects. Country groupings of bilateral trade partners of China (CHN) are emerging market economies (EMEs), Asian EMEs (Asia), and advanced economies (excluding the United States (USA) in the steamroller effect). See table A.1 for countries included in each region. Countries in each region are weighted by their beginning-of-period trade volumes. Table A.2 lists the industries producing commodities (COM), manufactured final goods (MAN), and parts and components (PNC). Aggregation across industries is by origin $h \in \{\text{COM}\}$, $h \in \{\text{MAN}\}$, or $h \in \{\text{PNC}\}$ based on actual trade $Q^{hs}_{ij,t-1}$ and the contribution of each factor to the growth rates of $\Delta \ln Q^{hs}_{ij,t}$ over a period from $t-1$ to t, from equation (16), where i is the origin country, j is the destination country, h is the origin industry, and s is the receiving industry.

Table S.7: China wage growth and labor reallocation effects on trade flows: decomposition results for $\sigma = 2$

	Steamroller	Engine		Reverse Engine	Conduit	Reverse Conduit
Period	MAN to USA	COM to CHN	MAN to CHN	MAN from CHN	PNC to CHN	PNC from CHN
			a) China's wage growth ($\sigma = 2$)			
EMEs						
1995-2000	1.8773	3.2891	7.4297	5.2305	2.7059	1.1765
2000-2005	-0.1533	0.0436	-0.1052	0.1071	0.0504	0.2342
2005-2010	0.9735	-0.4248	-2.7581	2.5836	2.1444	-0.5152
Asia						
1995-2000	0.9452	2.7972	7.2724	5.5953	2.8547	1.1076
2000-2005	-0.1640	0.0315	-0.1064	0.0676	0.0431	0.2121
2005-2010	0.8356	-0.7112	-2.9079	1.5235	1.8139	-0.5641
Advanced economies						
1995-2000	1.9937	3.6804	7.6653	3.7129	1.4961	1.3131
2000-2005	-0.0474	-0.0884	-0.2777	0.0927	0.0113	0.2070
2005-2010	1.8803	-1.9302	-4.0412	1.5721	0.5370	-0.8582
			b) China's labor reallocation ($\sigma = 2$)			
EMEs						
1995-2000	0.1557	0.4730	0.9158	0.4662	0.2922	0.0905
2000-2005	-0.2760	-0.1056	-0.3419	0.1739	0.1110	-0.2090
2005-2010	0.5006	-0.1439	-1.0879	1.0636	0.9805	-0.2551
Asia						
1995-2000	0.0406	0.4317	0.9362	0.5058	0.3153	0.0891
2000-2005	-0.3120	-0.0977	-0.3004	0.0987	0.1251	-0.1773
2005-2010	0.4591	-0.2224	-1.0748	0.6333	0.8693	-0.2919
Advanced economies						
1995-2000	0.2266	0.3901	0.8769	0.2546	0.0859	0.0562
2000-2005	-0.0137	-0.4211	-0.6329	0.1893	-0.0125	-0.0337
2005-2010	0.8187	-0.7675	-1.5891	0.6699	0.2358	-0.1070

Notes: This table reports the contributions of China's wage growth (panel a) and sectoral reallocation of labor (panel b) to the growth rates of exports from the origin country groupings over each of the three five-year periods, where the destination region and industry of exports depend on the specific effect listed for each column. σ is the elasticity of substitution between intermediate inputs in production. It is used to evaluate the sensitivity of the results in table 1 to a lower elasticity of substitution between intermediate inputs $\sigma = 2$. See the main text and figure 1 for the description of steamroller, engine, conduit effects. Country groupings of bilateral trade partners of China (CHN) are emerging market economies (EMEs), Asian EMEs (Asia), and advanced economies (excluding the United States (USA) in the steamroller effect). See table A.1 for countries included in each region. Countries in each region are weighted by their beginning-of-period trade volumes. Table A.2 lists the industries producing commodities (COM), manufactured final goods (MAN), and parts and components (PNC). Aggregation across industries is by origin $h \in \{\text{COM}\}$, $h \in \{\text{MAN}\}$, or $h \in \{\text{PNC}\}$ based on actual trade $Q^{hs}_{ij,t-1}$ and the contribution of each factor to the growth rates of $\Delta \ln Q^{hs}_{ij,t}$ over a period from $t-1$ to t, from equation (16), where i is the origin country, j is the destination country, h is the origin industry, and s is the receiving industry.

Table S.8: China wage growth and labor reallocation effects on trade flows: decomposition results for $\sigma = 8$

	Steamroller	Engine		Reverse Engine	Conduit	Reverse Conduit
Period	MAN to USA	COM to CHN	MAN to CHN	MAN from CHN	PNC to CHN	PNC from CHN
			a) China's wage growth ($\sigma = 8$)			
EMEs						
1995-2000	-0.0283	0.0416	0.0324	0.0764	0.0519	0.3016
2000-2005	-0.0131	0.2633	0.2627	0.0740	0.0644	0.3570
2005-2010	-0.0598	0.3573	0.3449	0.3953	0.3554	0.8069
Asia						
1995-2000	-0.0420	0.0275	0.0172	0.0876	0.0622	0.2834
2000-2005	-0.0189	0.2430	0.2422	0.0785	0.0717	0.3344
2005-2010	-0.0881	0.3336	0.3195	0.4102	0.3865	0.8393
Advanced economies						
1995-2000	-0.0255	-0.0279	-0.0673	0.0564	0.0570	0.5604
2000-2005	-0.0121	0.2079	0.1970	0.0723	0.0666	0.3987
2005-2010	-0.0503	0.1158	0.0622	0.3910	0.3618	0.9269
			b) China's labor reallocation ($\sigma = 8$)			
EMEs						
1995-2000	-0.0108	0.0407	0.0160	-0.1148	-0.0073	-0.0581
2000-2005	-0.0142	0.0546	0.0459	0.1615	0.1650	0.0189
2005-2010	-0.0159	-0.0397	0.0119	0.1684	0.1887	0.0114
Asia						
1995-2000	-0.0198	0.0572	0.0326	-0.1183	-0.0146	-0.0502
2000-2005	-0.0292	0.0857	0.0683	0.1502	0.1653	0.0245
2005-2010	-0.0279	0.0062	0.0767	0.1650	0.1967	0.0016
Advanced economies						
1995-2000	0.0022	-0.0774	-0.0582	-0.1438	-0.0296	-0.1339
2000-2005	-0.0048	-0.1804	-0.1565	0.1623	0.1429	0.0613
2005-2010	-0.0105	-0.1399	-0.1250	0.1675	0.1786	0.1682

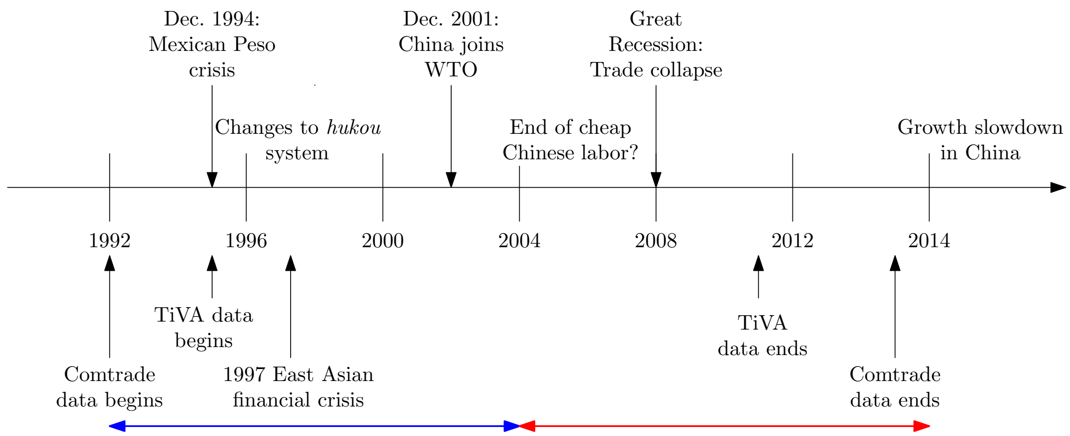
Notes: This table reports the contributions of China's wage growth (panel a) and sectoral reallocation of labor (panel b) to the growth rates of exports from the origin country groupings over each of the three five-year periods, where the destination region and industry of exports depend on the specific effect listed for each column. σ is the elasticity of substitution between intermediate inputs in production. It is used to evaluate the sensitivity of the results in table 1 to a higher elasticity of substitution between intermediate inputs $\sigma = 8$. See the main text and figure 1 for the description of steamroller, engine, conduit effects. Country groupings of bilateral trade partners of China (CHN) are emerging market economies (EMEs), Asian EMEs (Asia), and advanced economies (excluding the United States (USA) in the steamroller effect). See table A.1 for countries included in each region. Countries in each region are weighted by their beginning-of-period trade volumes. Table A.2 lists the industries producing commodities (COM), manufactured final goods (MAN), and parts and components (PNC). Aggregation across industries is by origin $h \in \{\text{COM}\}$, $h \in \{\text{MAN}\}$, or $h \in \{\text{PNC}\}$ based on actual trade $Q^{hs}_{ij,t-1}$ and the contribution of each factor to the growth rates of $\Delta \ln Q^{hs}_{ij,t}$ over a period from $t-1$ to t, from equation (16), where i is the origin country, j is the destination country, h is the origin industry, and s is the receiving industry.

Table S.9: China's wage growth and labor reallocation effects on trade flows: decomposition results with beginning-of-the-window period elasticities

(five-year growth rates, $\sigma = 4$)

	Steamroller	Engine		Reverse Engine	Conduit	Reverse Conduit
Region, Period	MAN to USA	COM to CHN	MAN to CHN	MAN from CHN	PNC to CHN	PNC from CHN
a) China's wage growth						
EMEs						
1995–2000	-0.0223	0.1084	0.0648	0.2751	0.0618	0.2816
2000–2005	-0.0084	0.3706	0.3239	0.1060	0.3717	0.1088
2005–2010	-0.0477	0.8409	0.2772	0.6095	0.3047	0.6212
Asia						
1995–2000	-0.0219	0.0876	-0.0124	0.2795	-0.0190	0.2794
2000–2005	-0.0092	0.2513	0.1380	0.1040	0.1326	0.1082
2005–2010	-0.0538	0.8432	0.2315	0.5992	0.2283	0.6148
Advanced economies						
1995–2000	-0.0075	0.3349	0.0034	0.2773	-0.0561	0.2715
2000–2005	-0.0031	0.5155	0.0069	0.0969	0.0057	0.1010
2005–2010	-0.0019	0.6457	-0.0042	0.5525	0.0817	0.5788
b) China's labor reallocation						
EMEs						
1995–2000	-0.0016	-0.0464	-0.0244	0.0085	-0.0708	-0.1073
2000–2005	-0.0033	0.0790	0.0182	0.1823	-0.0560	0.1723
2005–2010	-0.0112	0.0997	-0.0895	0.2047	-0.0437	0.1791
Asia						
1995–2000	-0.0018	-0.0444	-0.0483	-0.0016	-0.0662	-0.1155
2000–2005	-0.0066	0.1240	-0.0397	0.1725	-0.0785	0.1684
2005–2010	-0.0136	0.1447	-0.0675	0.1990	-0.0272	0.1766
Advanced economies						
1995–2000	0.0080	-0.1112	-0.0747	-0.0158	-0.0525	-0.1243
2000–2005	0.0082	0.2355	-0.1731	0.1454	-0.1368	0.1783
2005–2010	0.0002	0.4091	-0.0985	0.1815	-0.0678	0.1712

Notes: This table reports the contribution of changes in China's wage growth (panel a) and sectoral reallocation of labor (panel b) to the growth rates of exports from the origin country groupings over each of the three five-year periods, where the destination region and industry of exports depend on the specific effect listed for each column. Parameters calculated from national IOTs are the elasticity of output with respect to capital, labor, and intermediate inputs ($\beta_i^s, \alpha_i^s, \alpha_i^{hs}$). The decomposition results reported in this table use the beginning-of-the-window period values (like $\alpha_{i,t-1}^{hs}$), whereas the results reported in the main text use their end-of-the-window period values (like $\alpha_{i,t}^{hs}$). σ is the elasticity of substitution between intermediate inputs in production. See the main text and figure 1 for the description of steamroller, engine, conduit effects. Country groupings of bilateral trade partners of China (CHN) are emerging market economies (EMEs), Asian EMEs (Asia), and advanced economies (excluding the United States (USA) in the steamroller effect). See table A.1 for countries included in each region. Countries in each region are weighted by their beginning-of-period trade volumes. Table A.2 lists the industries producing commodities (COM), manufactured final goods (MAN), and parts and components (PNC). Aggregation across industries is by origin $h \in \{\text{COM}\}$, $h \in \{\text{MAN}\}$, or $h \in \{\text{PNC}\}$ based on actual trade $Q_{ij,t-1}^{hs}$ and the contribution of each factor to the growth rates of $\Delta \ln Q_{ij,t}^{hs}$ over a period from $t-1$ to t, from equation (16), where i is the origin country, j is the destination country, h is the origin industry, and s is the receiving industry. Actual growth rates for each country grouping and period are reported in supplementary material table S.5.



Variable (as a % of total)	1992–2003	2004–2013
Share of global GDP:	3.03	7.89
Share of global MAN exports:	7.34	17.06
Share of global PNC exports:	3.76	13.12

Figure S.1: Key events and data on China's economic transformation

Sources: International trade data are from United Nations (2015) Comtrade database. GDP data are from World Bank (2017). Export flows from a source region to a destination region use the import data of the destination. MAN refers to finished manufactured goods based on Standard Industrial Trade Classification, Revision 3 (SITC) codes $232 + 266 + 267 + 5 + 6 + 7 + 8 - 667 - 68$. Parts and components (PNC) are classified as in Haltmaier et al. (2007). The first phase of China's structural transformation represented a prototypical surplus labor economy. Despite the presence of restrictions on internal migration—although weakening after 1996) (Chan and Zhang, 1999; Fang, 2003), there was large scale transitory migration (Hertel and Zhai, 2006), and release of workers from state owned enterprises—mostly from 1997 to 2000 (Appleton et al., 2002; Knight and Yueh, 2004; Dekle and Vandenbroucke, 2012). In the second phase since 2004, cheap labor sourced from the rural labor reservoir has been rapidly exhausted (Li et al., 2012).

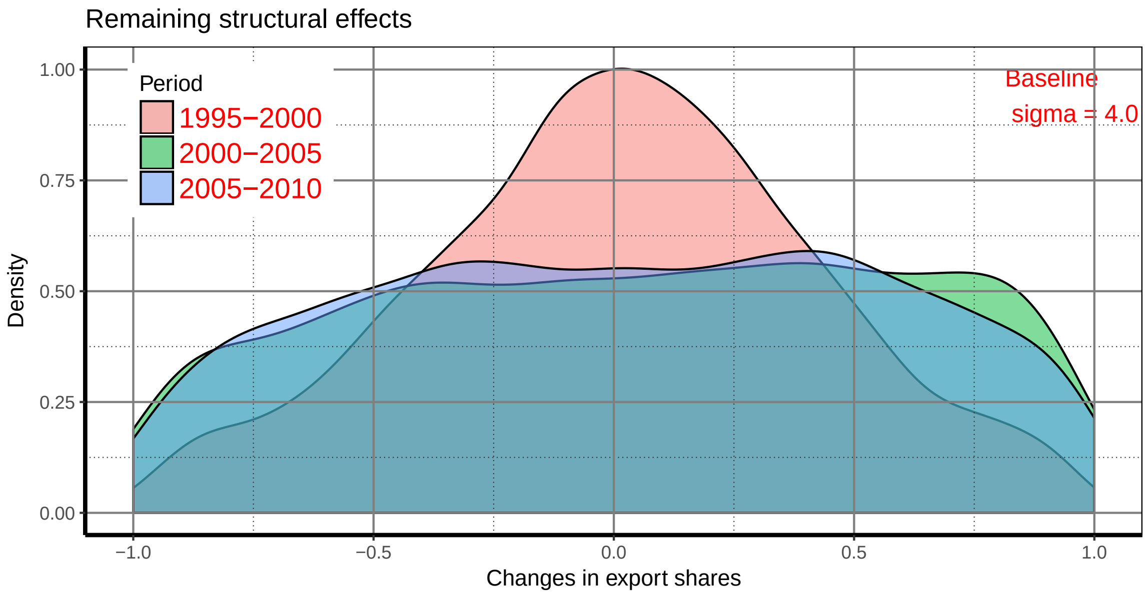
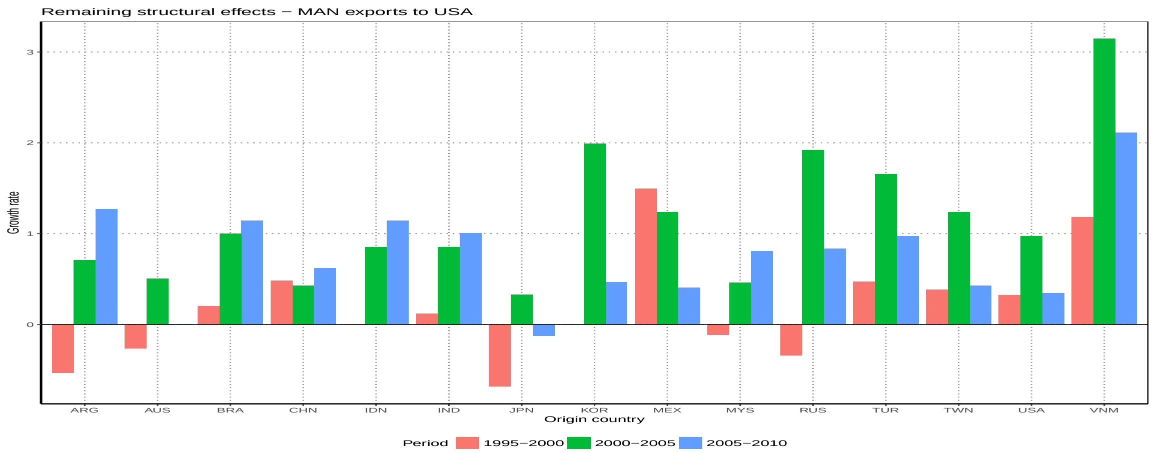
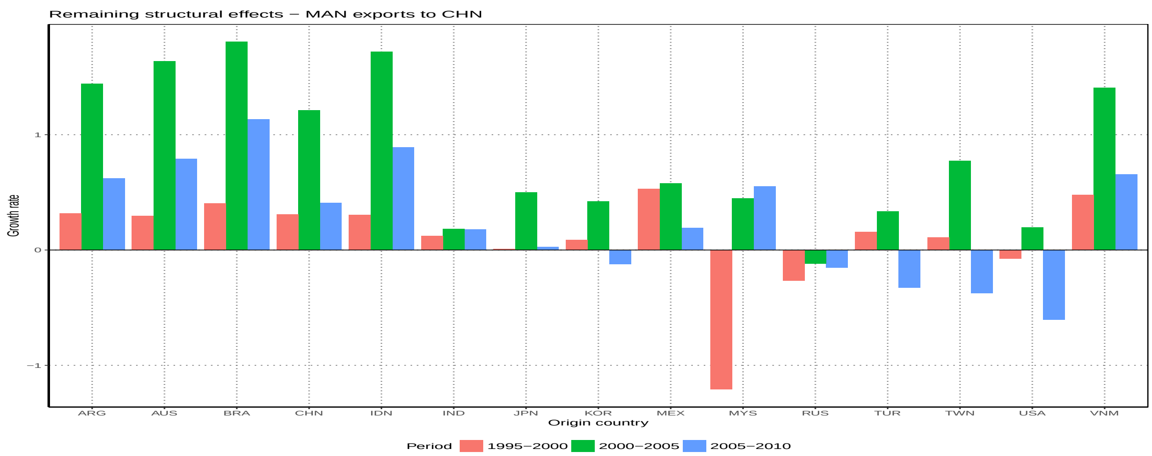


Figure S.2: Distribution of changes in trade values by period as accounted by structural factors excluding China's wage growth and sectoral labor reallocation

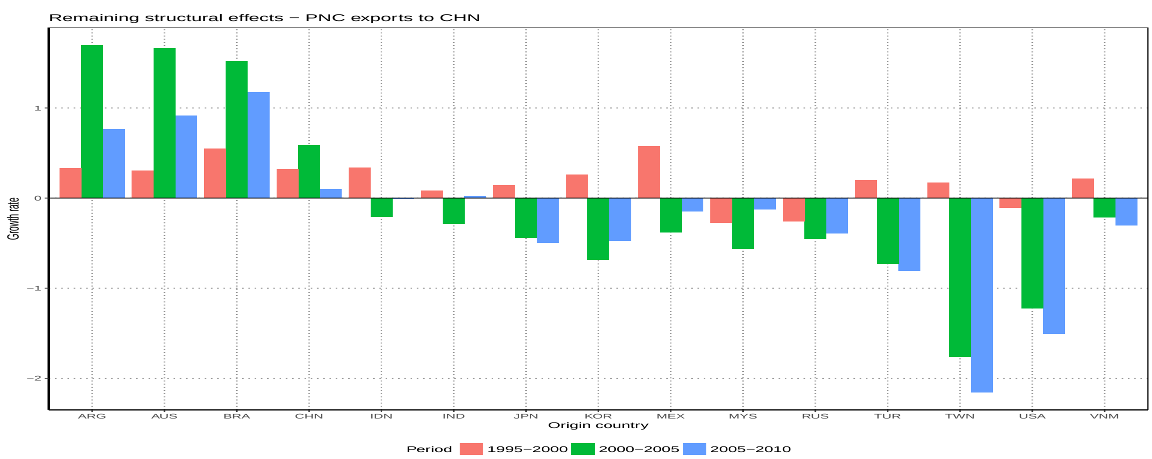
Notes: This figure plots the density of changes in export shares for 15 (origin country) $\times$ 28 (origin industries) over each of the three five-year periods accounted by the world interest rate, labor force in China, transportation costs, and other trade costs ("remaining structural effects"). σ is the elasticity of substitution between intermediate inputs in production.



(a) Steamroller



(b) Engine

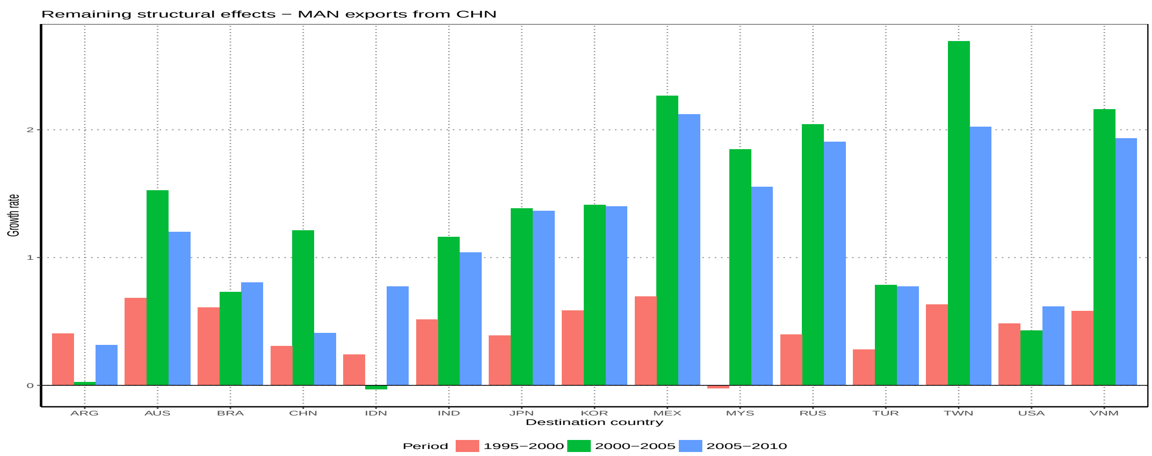


(c) Conduit

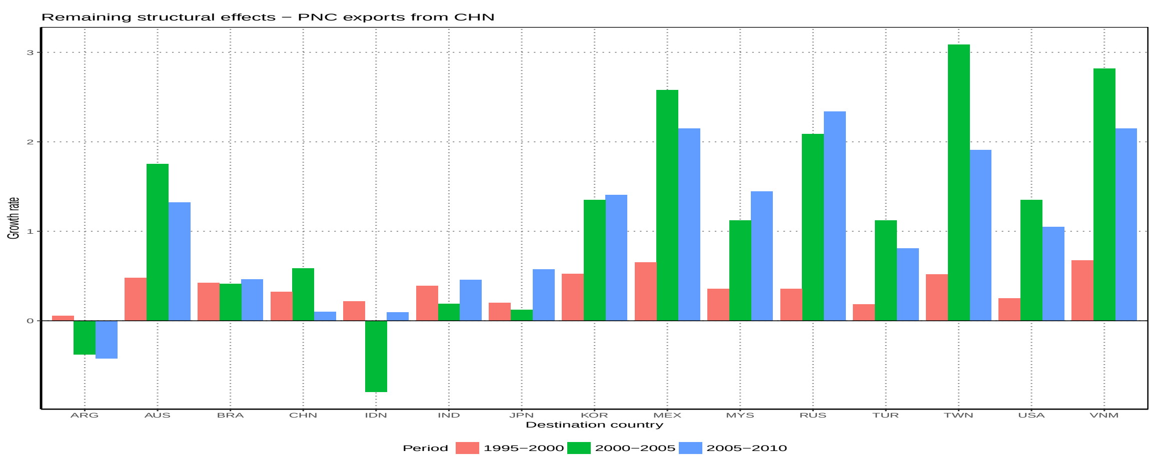
Figure S.3: Remaining structural effects: steamroller, engine by MAN, and conduit

Notes to figure S.3 continue on the next page.

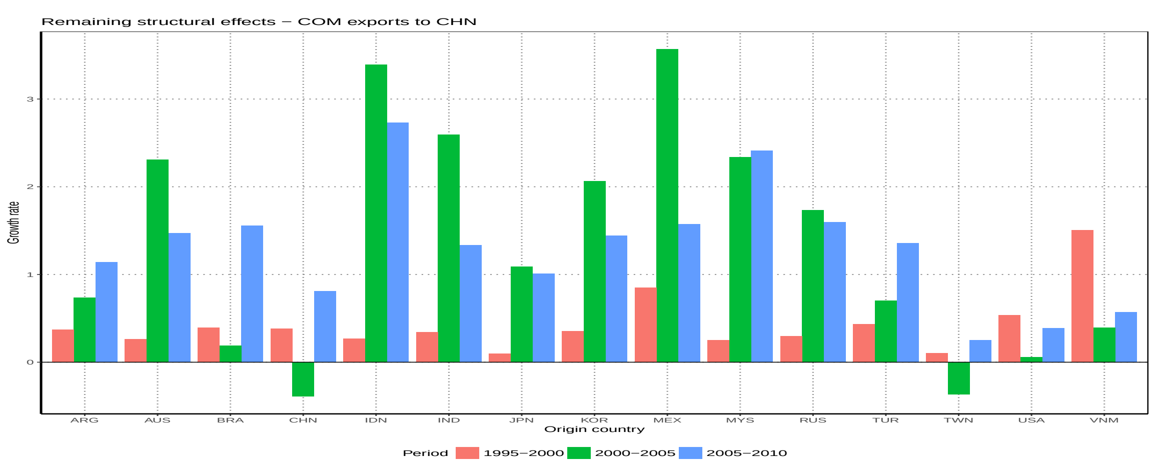
Notes to figure S.3: This figure reports the contributions of changes over each of the three five-year periods in the world interest rate, labor force in China, transportation costs, and other trade costs ("remaining structural effects") to the growth rates of manufactured final goods (MAN) exports to the United States from origin countries (panel a) MAN exports to China (panel b), and parts and components (PNC) exports to China (panel c). "Exports to USA from USA" means "domestic sales" by the U.S. producers. σ is the elasticity of substitution between intermediate inputs in production. Table A.2 lists the industries producing MAN and PNC. Aggregation across industries is by origin $h \in \{\text{MAN}\}$, based on actual trade $Q_{ij,t-1}^{hs}$ and the contribution of remaining structural factors to the growth rates of $\Delta \ln Q_{ij,t}^{hs}$ over a period from $t-1$ to t, from equation (16), where i is the origin country, j is the United States (panel a) or China (panels b and c), h is MAN industry (panels a and b) or PNC industry (panel c), and s is any receiving industry. Vertical scales in panels a—c are different.



(a) Reverse engine



(b) Reverse conduit

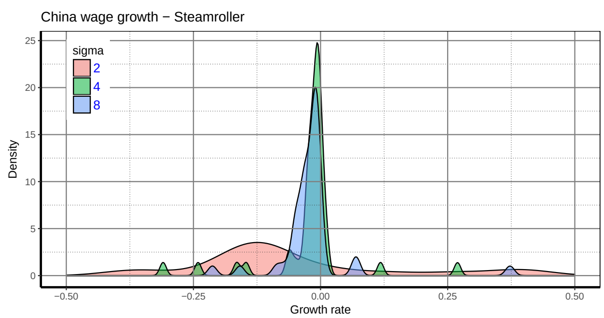


(c) Commodity boom

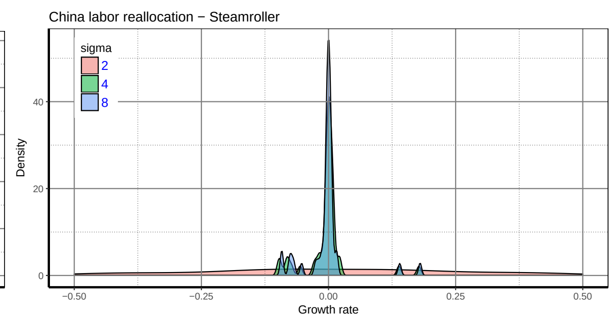
Figure S.4: Remaining structural effects: reverse engine, reverse conduit, and engine by COM

Notes to figure S.4 continue on the next page.

Notes to figure S.4: This figure reports the contributions of changes over each of the three five-year periods in the world interest rate, labor force in China, transportation costs, and other trade costs ("remaining structural effects") to the growth rates of manufactured final goods (MAN) exports to China (CHN) from origin countries (panel a) parts and components (PNC) exports from China (panel b), and commodity (COM) exports to China (panel c). σ is the elasticity of substitution between intermediate inputs in production. "Exports to CHN from CHN" means "domestic sales" by the Chinese producers. Table A.2 lists the industries producing MAN, PNC, and COM. Aggregation across industries is by origin $h \in \{\text{MAN}\}$, based on actual trade $Q^{hs}_{ij,t-1}$ and the contribution of remaining structural factors to the growth rates of $\Delta \ln Q^{hs}_{ij,t}$ over a period from $t-1$ to t, from equation (16), where i is China, j is the destination country (panels a and b) or i is the origin country and j is China (panel c), h is a MAN (panel a), PNC (panel b), or COM (panel c), and s is any receiving industry. Vertical scales in panels a—c are different.



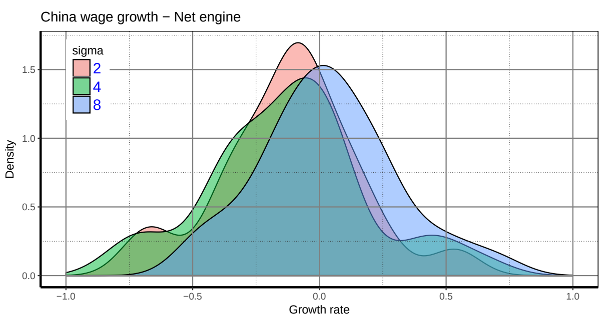
(a) Wage growth effect



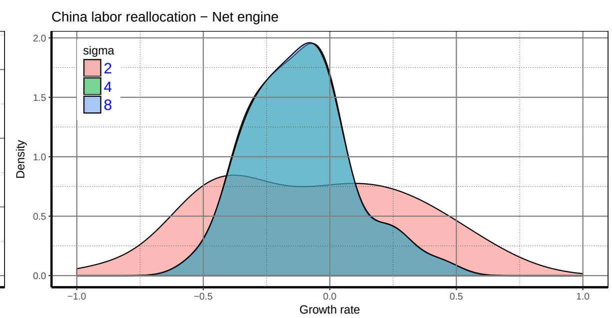
(b) Labor reallocation effect

Figure S.5: Steamroller effect: sensitivity of results to σ value

Notes: The density plots in this figure illustrate the sensitivity to different values of the elasticity of substitution between intermediate inputs in production (σ) of changes in manufacturing export shares to the United States (steamroller effect) by each country in our dataset and over three five-year periods accounted by wage growth (panel a) and sectoral reallocation of labor (panel b) both in China. There are 15 (origin country) $\times$ 3 (periods) observations underlying each density. Horizontal axes cropped at $(-.5, .5)$ beyond which the densities are negligible.



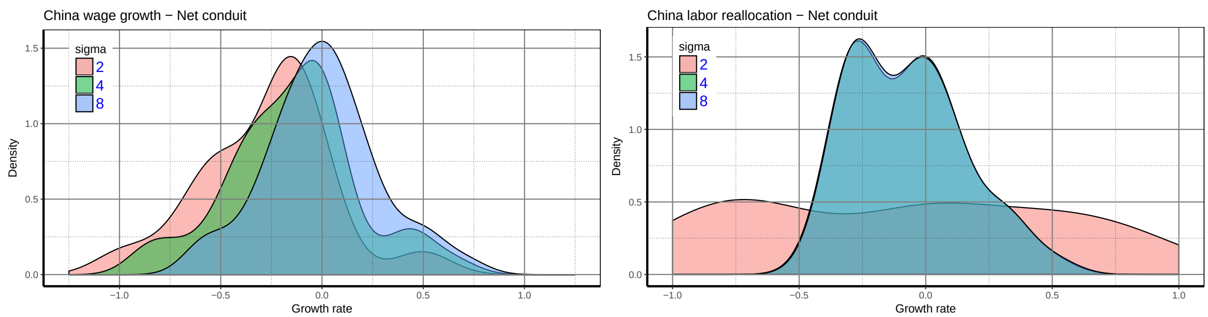
(a) Wage growth effect



(b) Labor reallocation effect

Figure S.6: Engine by MAN effect: sensitivity of results to σ value

Notes: The density plots in this figure illustrate the sensitivity to different values of the elasticity of substitution between intermediate inputs in production (σ) of changes in manufacturing export shares to China minus manufacturing exports from China (net engine effect) by each country in our dataset and over three five-year periods accounted by wage growth (panel a) and sectoral reallocation of labor (panel b) both in China. There are 15 (origin country) $\times$ 3 (periods) observations underlying each density. Horizontal axes cropped at $(-1.0, 1.0)$ beyond which the densities are negligible.

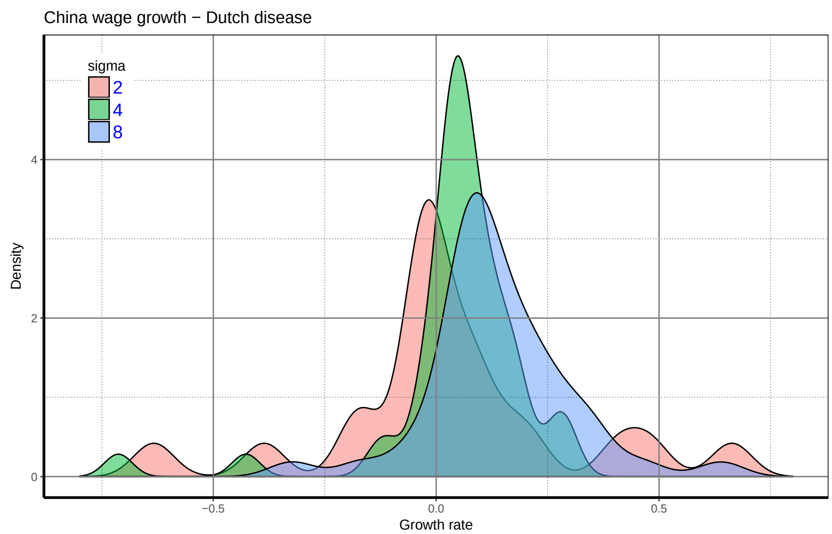


(a) Wage growth effect

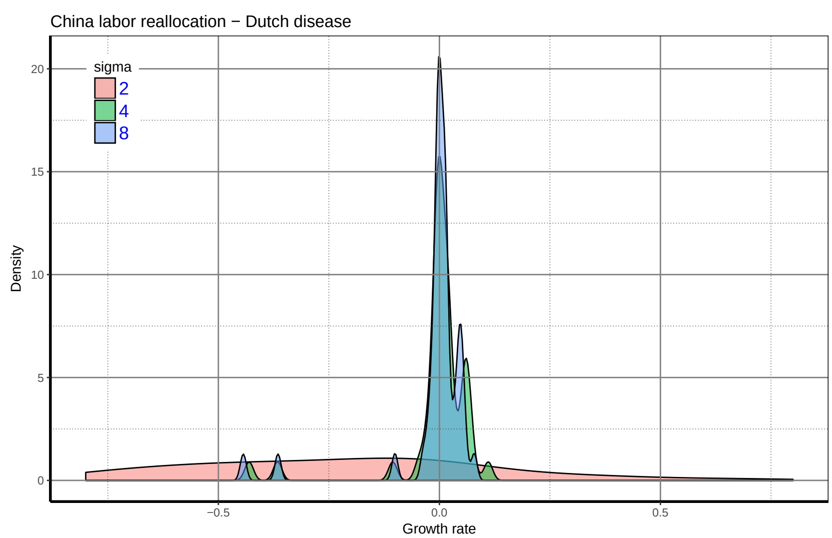
(b) Labor reallocation effect

Figure S.7: Conduit effect: sensitivity of results to σ value

Notes: The density plots in this figure illustrate the sensitivity to different values of the elasticity of substitution between intermediate inputs in production (σ) of changes in parts and components export shares to China minus parts and components exports from China (net conduit effect) by each country in our dataset and over three five-year periods accounted by wage growth (panel a) and sectoral reallocation of labor (panel b) both in China. There are 15 (origin country) $\times$ 3 (periods) observations underlying each density. Horizontal axes cropped at $(-1.25, 1.25)$ beyond which the densities are negligible.



(a) Wage growth effect



(b) Labor reallocation effect

Figure S.8: Dutch disease effect: sensitivity of results to σ value

Notes: The density plots in this figure illustrate the sensitivity to different values of the elasticity of substitution between intermediate inputs in production (σ) of changes in commodity export shares to China (Dutch disease effect) by each country in our dataset and over three five-year periods accounted by wage growth (panel a) and sectoral reallocation of labor (panel b) both in China. There are 15 (origin country) $\times$ 3 (periods) observations underlying each density. Horizontal axes cropped at $(-.8, .8)$ beyond which the densities are negligible.

S.3 Comtrade data

S.3.1 Industry definitions in Comtrade data

Data are in U.S. dollars. To categorize internationally traded goods, we use Standard Industrial Trade Classification, Revision 3 (SITC3), and define manufacturing by using the following SITC3 codes (with their descriptions given in parentheses).

$$
\begin{aligned}
\text{MAN} &= 232 && \text{(Synthetic rubber)}\\
&+ 266 && \text{(Synthetic fibres suitable for spinning)}\\
&+ 267 && \text{(Other man-made fibres)}\\
&+ 5 && \text{(Chemicals and related products)}\\
&+ 6 && \text{(Manufactured goods classified chiefly by material)}\\
&+ 7 && \text{(Machinery and transport equipment)}\\
&+ 8 && \text{(Miscellaneous manufactured articles)}\\
&- 667 && \text{(Pearls and precious or semiprecious stones)}\\
&- 68 && \text{(Non-ferrous metals).}
\end{aligned}
$$

We construct intermediate inputs "parts and components" based on Haltmaier et al. (2007, pp. 73–75). They construct their series using SITC Revision 3, so we use the SITC3 codes that most closely correspond to the categories they list. For the purposes of illustration, we note that the products included in their list range from plastics in non-primary form (58) to optical lenses (8843).

Finally, we construct "commodities" by the following SITC3 codes.

$$
\begin{aligned}
\text{COM} &= 0 && \text{(Food and live animals)}\\
&+ 1 && \text{(Beverages and tobacco)}\\
&+ 2 && \text{(Crude materials, inedible, except fuels)}\\
&+ 3 && \text{(Mineral fuels, lubricants and related materials)}\\
&+ 4 && \text{(Animal and vegetable oils, fats and waxes)}\\
&+ 68 && \text{(Non-ferrous metals).}
\end{aligned}
$$

Our total (gross) trade value is the sum of manufacturing and commodities.

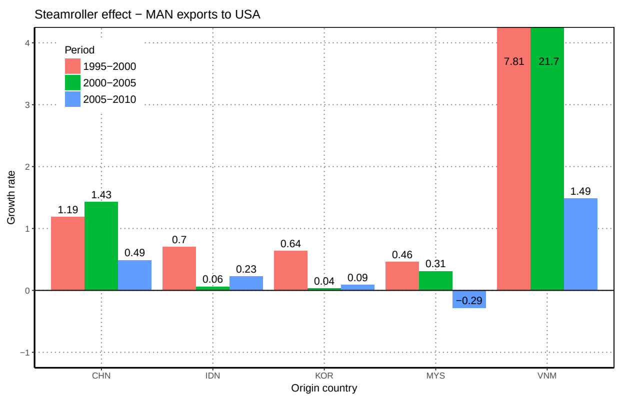
S.3.2 Steamroller, engine, and conduit effects in Comtrade data

Figure S.9a shows the growth rates of exports of MAN from these four countries plus China to the United States over each of the five year periods we consider calculated using the Comtrade database. Vietnam's exports to the United States, especially in the first two periods, exhibit phenomenal growth, though starting from a low base. China's export growth exceeds that of its Asian competitors in each of these periods and by large margins in the 2000–2005, and 2005–2010 periods. While the growth of MAN exports from South Korea and Indonesia are negligible in these periods, only Malaysia over the period 2005–2010 exhibits negative growth in exports of MAN. By contrast, the engine effect in the form of growing demand by China for commodities has been remarkably uniform across all the countries in the region, with Malaysia exhibiting an increasing rate of growth (figure S.9b). Figure S.9c shows the engine effect in the form on MAN exports to China, which can be contrasted with figure S.9d, which shows the MAN exports from China (reverse engine). While the engine effect has weakened over time, except for Vietnam, the reverse engine effect has become stronger except for Malaysia. On balance, Malaysia and Vietnam are the main beneficiaries of the net engine effect, whereas in the case of Indonesia, there is a shifting pattern over time from the engine to the reverse engine effect. The conduit effect of exports of PNC from these four countries to China (figure S.9e) and PNC exports from China to these same countries (figure S.9f, reverse conduit) are similar in terms of general patterns to their engine effect counterparts.[26]

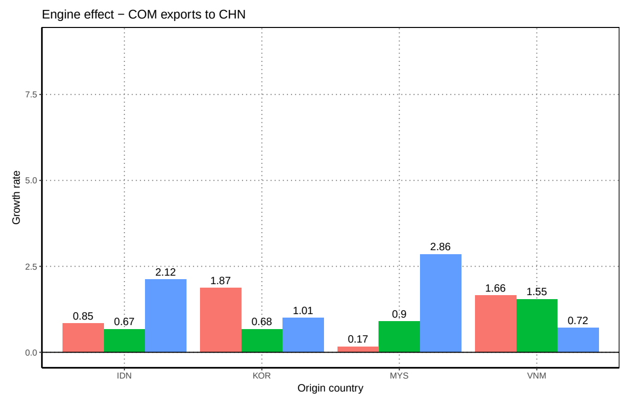
Overall, MAN exports have on average grown faster than PNC exports to China (average growth rates of 336% and 285% over five year periods), MAN imports from China have grown less than MAN exports to China (199% versus 336%), and PNC imports from China have growth less than PNC exports to China (235% versus 285%).[27] Indonesia's net exports of commodities to China were balanced by net negative engine and conduit effects (especially over the last two periods). For Malaysia, the net conduit and engine effects dissipated over time, and even gave way to a steamroller effect. For South Korea all three were present, but on net the strengths were relatively weak. Vietnam shows engine and conduit effects that were boosted by a rising trade surplus with the United States—possibly becoming a low-wage export platform for China-made PNC. The heterogeneous outcomes of changes in trade flows documented here are indicative of the intermediating connections between China's structural change, on one hand, and structural factors and specialization in the rest of the world, on the other.

[26] Pairwise correlations ($p-$ values in parentheses, $N = 24$) are as follows: MAN–COM = 0.001(0.996), MAN–PNC = 0.795(0.000), and COM–PNC = 0.281(0.183). These correlations include China's commodity exports to these four countries.

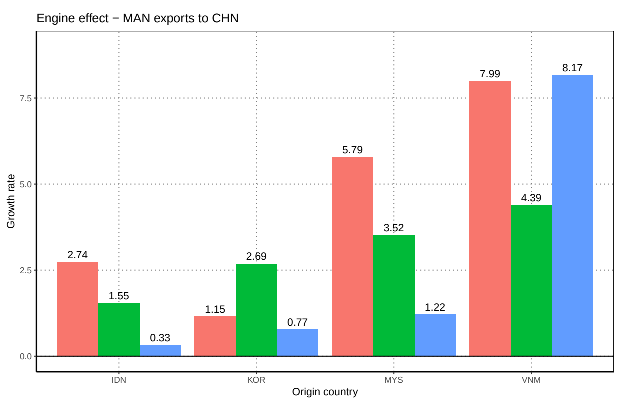
[27] These growth rates are highly influenced by those of Vietnam. While not reported here, the average growth rate of commodity exports to China exceed those of commodity exports of China to these four Asian economies (126% versus 49%).



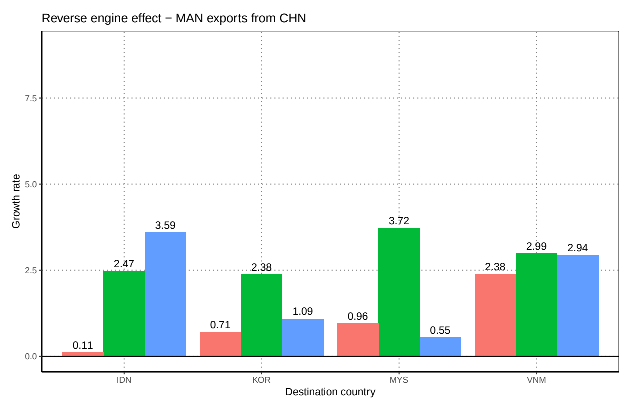
(a) Steamroller



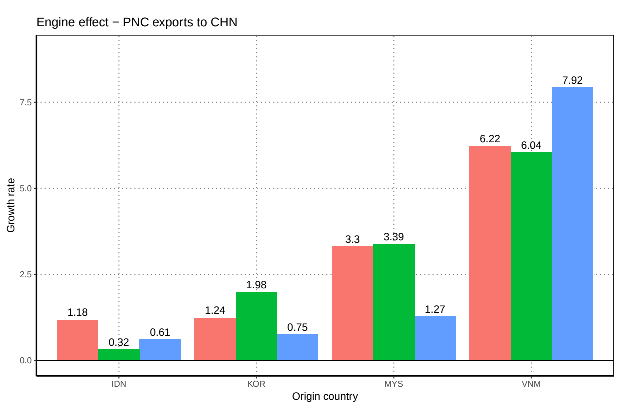
(b) Engine: commodities



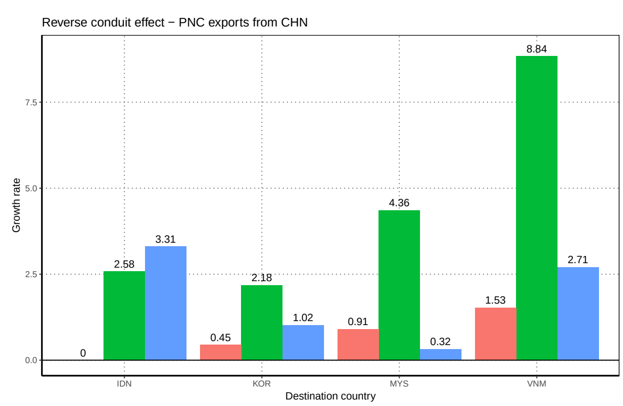
(c) Engine: final goods



(d) Reverse engine: final goods



(e) Conduit



(f) Reverse conduit

Figure S.9: Changes in bilateral gross trade values, 1995–2010

Notes: Author's calculations from United Nations (2015) Comtrade database. Manufactured final goods (MAN) are based on Standard Industrial Trade Classification, Revision 3 (SITC) codes $232 + 266 + 267 + 5 + 6 + 7 + 8 - 667 - 68$, and parts and components (PNC) are based on Haltmaier et al. (2007). Commodities (COM) include SITC 0 through 4 plus 68. Data for Vietnam starts in 1997.

S.4 Derivations

S.4.1 Preliminaries

There are $1, 2, \ldots, R$ regions that trade bilaterally. There are $1, \ldots, S$ sectors that produce goods in each region. Our conventions are as follows. When we write q_{ij}^{hs}, we mean quantity q originating from sector h in region i with destination sector s in region j. There are (gross) iceberg transportation costs for cross-border trade, $\tau_{ij}^{hs} \geq 1$. Total employment in region j is L_j, and employment in industrial sector s in region j is l_j^s. Total employment in industry is $l_j = \sum_{s=1}^{S} l_j^s$.

We use the following set of assumptions.

Assumption 1. The elasticity of substitution $\sigma > 1$ in production across distinct composite intermediate inputs procured from sector h by sector s and across varieties in the production of intermediate goods are identical both across sectors and regions.

Assumption 2. All varieties in a origin-destination, region-sector have the same price, $p_{ij}^{hs}(\iota) = p_{ij}^{hs}$.

Assumption 3. Fixed costs of production is an increasing function of the share of capital in value added.

S.4.2 Production

There are region- and sector-specific fixed costs of production, $F_i^h > 0$. Once a firm is active, there are three "stages" to production. The most basic element of production is varieties of a differentiated intermediate input sourced from different sectors in each region. For each pair of destination-origin region and sector, there is a continuum of varieties used as intermediate inputs

$$q_{ij}^{hs} = \left(\int_0^{n_i^h} m_{ij}^{hs}(\iota)^{\frac{\sigma-1}{\sigma}} d\iota \right)^{\frac{\sigma}{\sigma-1}}, \tag{S.1}$$

where q_{ij}^{hs} is the composite intermediate input sourced from region i sector h by region j sector s; $m_{ij}^{hs}(\iota)$ denotes the use of each variety originating from region i sector h in destination region j sector s; n_i^h is the number of varieties in the origin region i sector h; and $\sigma > 1$ is the elasticity of substitution across varieties in production.

Next, each producer sources these varieties (intermediate inputs) from each region and sector, and combines them to produce a composite intermediate input. Each composite intermediate input in region j sector s sourced from sector h is produced by the production function

$$m_j^{hs} = \left(\sum_{i=1}^{R} (q_{ij}^{hs})^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}, \tag{S.2}$$

q_{ij}^{hs} is the intermediate input of each variety originating from region i sector h and used in region j sector s to produce a composite intermediate input m_j^{hs}; $\sigma > 1$ is the elasticity of substitution across intermediate varieties in the production of each composite intermediate input. Thus, intermediate inputs are composites of imports and domestic inputs.

Finally, output in region j sector s is produced by the production function

$$y_j^s = \underbrace{\left(K_j^s\right)^{\beta_j^s}\left(L_j^s\right)^{\alpha_j^s}}_{\text{value added}}\ \underbrace{\left(m_j^{1s}\right)^{\alpha_j^{1s}}\dots\left(m_j^{Ss}\right)^{\alpha_j^{Ss}}}_{\text{intermediate inputs}}, \tag{S.3}$$

where $\beta_j^s > 0$ is the elasticity of output with respect to capital stock in sector s; $\alpha_j^s > 0$ is the elasticity of output with respect to labor in sector s; $K_j^s > 0$ is capital stock; L_j^s is employment; m_j^{hs} is a composite intermediate input purchased from industry h used in industry s region j; $\alpha_j^{hs} \geq 0$, for $h = 1, 2, \dots, S$, is the elasticity of output in industrial sector s with respect to the intermediate input from industry h, where $\beta_j^s + \alpha_j^s + \sum_{h=1}^S \alpha_j^{hs} = 1$. The first two terms on the right-hand side of equation (S.3) represent the direct value added function $f(K^s, L^s)$, while the last term represents intermediate inputs.

S.4.3 Derivation of trade shares

The model involves a number of prices and input-expenditure functions, and we derive them in the order we presented the production structure, starting with the lowest level expenditure function and ending with the price by industry. Denote the c.i.f. price at the destination region and sector by the f.o.b. price at the origin region and sector multiplied by a unit transportation cost that is region-sector specific

$$p_{ij}^{hs} := p_i^h \tau_{ij}^{hs}.$$

We will determine p_i^h endogenously, but for now treat it as given.

First, denote the expenditure on varieties of intermediate inputs by M_{ij}^{hs}, and the corresponding expenditure function by G_{ij}^{hs}. The cost minimization by the destination region and sector implies:

$$\min M_{ij}^{hs} = \int_0^{n_i^h} p_{ij}^{hs}(\iota) m_{ij}^{hs}(\iota) d\iota \tag{S.4}$$

$$\text{s.t. } q_{ij}^{hs} = \left(\int_0^{n_i^h} m_{ij}^{hs}(\iota)^{\frac{\sigma-1}{\sigma}} d\iota\right)^{\frac{\sigma}{\sigma-1}}$$

$$m_{ij}^{hs}(\iota) \geq 0. \tag{S.5}$$

Let λ be the Lagrange multiplier associated with the constraint set. The first-order condition to this cost minimization problem yields

$$p_{ij}^{hs}(\iota) - \lambda\left(\frac{\sigma}{\sigma-1}\right)\left(\int_0^{n_i^h} m_{ij}^{hs}(\iota)^{\frac{\sigma-1}{\sigma}} d\iota\right)^{\frac{\sigma}{\sigma-1}-1} m_{ij}^{hs}(\iota)^{\frac{\sigma-1}{\sigma}-1}\left(\frac{\sigma-1}{\sigma}\right) = 0,$$

Combining first-order conditions yields equality of marginal rates of substitution to the ratio of prices

$$\left(\frac{m_{ij}^{hs}(\iota)}{m_{ij}^{hs}(\kappa)}\right)^{1/\sigma} = \frac{p_{ij}^{hs}(\iota)}{p_{ij}^{hs}(\kappa)}, \tag{S.6}$$

for any two varieties ι, κ. Re-arranging terms gives

$$m_{ij}^{hs}(\kappa) = m_{ij}^{hs}(\iota)\left(\frac{p_{ij}^{hs}(\iota)}{p_{ij}^{hs}(\kappa)}\right)^{\sigma}.$$

Substituting into the production function (S.2) gives

$$\begin{aligned} q_{ij}^{hs} &= \left(\int_0^{n_i^h} m_{ij}^{hs}(\kappa)^{\frac{\sigma-1}{\sigma}}\left(\frac{p_{ij}^{hs}(\kappa)}{p_{ij}^{hs}(\iota)}\right)^{\sigma-1} d\iota\right)^{\frac{\sigma}{\sigma-1}} \\ &= m_{ij}^{hs}(\kappa)p_{ij}^{hs}(\kappa)^{\sigma}\left(\int_0^{n_i^h} p_{ij}^{hs}(\iota)^{1-\sigma}d\iota\right)^{\frac{\sigma}{\sigma-1}}. \end{aligned}$$

Thus we have

$$m_{ij}^{hs}(\kappa) = \frac{q_{ij}^{hs}}{p_{ij}^{hs}(\kappa)^{\sigma}}\left(\int_0^{n_i^h} p_{ij}^{hs}(\iota)^{1-\sigma}d\iota\right)^{\frac{\sigma}{1-\sigma}}.$$

Multiplying both sides by price $p_{ij}^{hs}(\kappa)$ and integrating over all varieties gives

$$\begin{aligned} \int_0^{n_i^h} p_{ij}^{hs}(\kappa)m_{ij}^{hs}(\kappa)d\kappa &= q_{ij}^{hs}\left(\int_0^{n_i^h} p_{ij}^{hs}(\iota)^{1-\sigma}d\iota\right)^{\frac{\sigma}{1-\sigma}}\int_0^{n_i^h} p_{ij}^{hs}(\kappa)^{1-\sigma}d\kappa \\ &= q_{ij}^{hs}\left(\int_0^{n_i^h} p_{ij}^{hs}(\iota)^{1-\sigma}d\iota\right)^{\frac{1}{1-\sigma}}. \end{aligned}$$

Thus the expenditure function for input varieties is simply (for $q_{ij}^{hs} = 1$)

$$G_{ij}^{hs} := \left(\int_0^{n_i^h} p_{ij}^{hs}(\iota)^{1-\sigma}d\iota\right)^{\frac{1}{1-\sigma}}. \tag{S.7}$$

Finally, we assume that all varieties are available at the same price (Assumption 2), so that

$$G_{ij}^{hs} = (n_i^h)^{\frac{1}{1-\sigma}}p_{ij}^{hs}. \tag{S.8}$$

Next, denote by G_j^{hs} the price index (unit expenditure function) for the composite intermediate input sourced from sector h and for all regions. Let total expenditures on intermediate inputs by region j sector s procured from sector h be

$$M_j^{hs} := m_j^{hs}G_j^{hs} = \sum_{i=1}^{R} G_{ij}^{hs}q_{ij}^{hs}. \tag{S.9}$$

Each producer in sector s country j solves the following minimization problem

$$\min \sum_{i=1}^{R} G_{ij}^{hs} q_{ij}^{hs} \tag{S.10}$$

$$\text{s.t. } m_j^{hs} = \left(\sum_{i=1}^{R} (q_{ij}^{hs})^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}},$$

$$q_{ij}^{hs} \geq 0.$$

Let λ denote the Lagrange multiplier associated with the constraint. The first-order necessary conditions to the cost minimization problem, for all $i = 1, 2, \ldots, R$ are

$$G_{ij}^{hs} - \lambda \left(\frac{\sigma}{\sigma - 1} \right) \left(\sum_{i=1}^{R} (q_{ij}^{hs})^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1} - 1} (q_{ij}^{hs})^{\frac{\sigma-1}{\sigma} - 1} \left(\frac{\sigma - 1}{\sigma} \right) = 0.$$

These conditions yield equality of marginal rates of substitution to the ratio of prices

$$q_{kj}^{hs} = q_{ij}^{hs} \left(\frac{G_{ij}^{hs}}{G_{kj}^{hs}} \right)^{\sigma},$$

for intermediate input sourced from sector h and any two regions $i \neq k$. Substituting into equation (S.9) gives

$$\begin{aligned} m_j^{hs} G_j^{hs} &= \sum_{k=1}^{R} G_{kj}^{hs} q_{kj}^{hs} \\ &= \sum_{k=1}^{R} G_{kj}^{hs} q_{ij}^{hs} \left(\frac{G_{ij}^{hs}}{G_{kj}^{hs}} \right)^{\sigma} \\ &= q_{ij}^{hs} (G_{ij}^{hs})^{\sigma} \sum_{k=1}^{R} (G_{kj}^{hs})^{1-\sigma}. \end{aligned}$$

Solving for input variety q_{ij}^{hs}, for $i = 1, 2, \ldots, R$ gives

$$q_{ij}^{hs} = \frac{m_j^{hs} G_j^{hs} (G_{ij}^{hs})^{-\sigma}}{\sum_{k=1}^{R} (G_{kj}^{hs})^{1-\sigma}}. \tag{S.11}$$

Now substitute these into equation (S.2) and set $m_j^{hs} = 1$

$$1 = \left(\sum_{i=1}^{R} \left(\frac{G_j^{hs} (G_{ij}^{hs})^{-\sigma}}{\sum_{k=1}^{R} (G_{kj}^{hs})^{1-\sigma}} \right)^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}.$$

Solving for the expenditure function G_j^{hs}, using equation (S.8), gives

$$
\begin{aligned}
\sum_{k=1}^{R}(G_{kj}^{hs})^{1-\sigma} &= G_j^{hs}\left(\sum_{i=1}^{R}\left((G_{ij}^{hs})^{-\sigma}\right)^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}} \\
\left(\sum_{k=1}^{R}(G_{kj}^{hs})^{1-\sigma}\right)^{\frac{\sigma-1}{\sigma}} &= \left(G_j^{hs}\right)^{\frac{\sigma-1}{\sigma}}\sum_{i=1}^{R}\left((G_{ij}^{hs})^{-\sigma}\right)^{\frac{\sigma-1}{\sigma}} \\
\left(\sum_{k=1}^{R}(G_{kj}^{hs})^{1-\sigma}\right)^{\frac{\sigma-1}{\sigma}} &= \left(G_j^{hs}\right)^{\frac{\sigma-1}{\sigma}}\sum_{i=1}^{R}(G_{ij}^{hs})^{1-\sigma} \\
\left(G_j^{hs}\right)^{\frac{\sigma-1}{\sigma}} &= \left(\sum_{k=1}^{R}\left((n_k^h)^{\frac{1}{1-\sigma}}p_{kj}^{hs}\right)^{1-\sigma}\right)^{-\frac{1}{\sigma}} \\
G_j^{hs} &= \left(\sum_{k=1}^{R}n_k^h(p_{kj}^{hs})^{1-\sigma}\right)^{\frac{1}{1-\sigma}}.
\end{aligned} \tag{S.12}
$$

Now use equations (S.8), (S.9), and (S.12) in equation (S.11), to obtain

$$
\begin{aligned}
q_{ij}^{hs} &= \frac{m_j^{hs}G_j^{hs}(G_{ij}^{hs})^{-\sigma}}{\sum_{k=1}^{R}(G_{kj}^{hs})^{1-\sigma}} \\
&= \frac{M_j^{hs}(G_{ij}^{hs})^{-\sigma}}{\sum_{k=1}^{R}(G_{kj}^{hs})^{1-\sigma}} \\
&= \frac{M_j^{hs}(G_{ij}^{hs})^{-\sigma}}{\sum_{k=1}^{R}\left((n_k^h)^{\frac{1}{1-\sigma}}p_{kj}^{hs}\right)^{1-\sigma}} \\
&= \frac{M_j^{hs}(G_{ij}^{hs})^{-\sigma}}{(G_j^{hs})^{1-\sigma}}.
\end{aligned}
$$

Multiplying both sides by G_{ij}^{hs} gives Q_{ij}^{hs}, defined as the expenditures by region j sector s on intermediate inputs from region i sector h ("exports" from region i to j)

$$
Q_{ij}^{hs} := G_{ij}^{hs}q_{ij}^{hs} = \left(\frac{G_{ij}^{hs}}{G_j^{hs}}\right)^{1-\sigma}M_j^{hs}. \tag{S.13}
$$

Substituting equation (S.8) into the expression above gives

$$
\begin{aligned}
Q_{ij}^{hs} &= \left(\frac{(n_i^h)^{\frac{1}{1-\sigma}}p_{ij}^{hs}}{G_j^{hs}}\right)^{1-\sigma}M_j^{hs} \\
&= n_i^h\left(\frac{p_i^h\tau_{ij}^{hs}}{G_j^{hs}}\right)^{1-\sigma}M_j^{hs}.
\end{aligned} \tag{S.14}
$$

We end this section by determining prices charged by each industry.

S.4.4 Derivation of the gravity equation

Define $x_{ij}^{hs} = Q_{ij}^{hs}/M_j^{hs}$ as the share of exports from region-sector pair (i, h) sourced by pair (s, j) in expenditures in region j; thus, for any j and origin–destination sector pair (h, s), we have $\sum_i x_{ij}^{hs} = 1$. We now derive an expression of this share. Use equation (S.14), divide both sides by M_j^{hs}, and use equation (S.12):

$$
\begin{aligned}
x_{ij}^{hs} := \frac{Q_{ij}^{hs}}{M_j^{hs}} &= n_i^h \left(\frac{p_i^h \tau_{ij}^{hs}}{G_j^{hs}}\right)^{1-\sigma} \\
&= \frac{n_i^h \left(p_i^h \tau_{ij}^{hs}\right)^{1-\sigma}}{\sum_{k=1}^{R} n_k^h (p_k^h \tau_{kj}^{hs})^{1-\sigma}}.
\end{aligned}
\tag{S.15}
$$

The last expression is the canonical micro-founded gravity equation (Costinot and Rodríguez-Clare, 2014).

S.4.5 Derivation of output by industry

Total output of each variety in sector s depends on a fixed and marginal cost of production:

$$F_j^s + cq_j^s,$$

where F_j^s is the fixed cost of production; c is the marginal cost of production, and q_j^s is output sold by any variety producer in sector s country j. The profits of the monopolistic firm are

$$p_j^s q_j^s - p_j^{ms}\left(F_j^s + cq_j^s\right).$$

where p_j^{ms} is the price of the composite (capital, labor, and materials) input in sector s. Cost minimization subject to the production function (S.3) and price indices G_j^{hs} gives the prices charged by firms in sector s region j

$$p_j^{ms} = \left(\frac{r}{\beta_j^s}\right)^{\beta_j^s} \left(\frac{w_j}{\alpha_j^s}\right)^{\alpha_j^s} \prod_{h=1}^{S} \left(\frac{G_j^{hs}}{\alpha_j^{hs}}\right)^{\alpha_j^{hs}}. \tag{S.16}$$

The first-order condition to the profit maximization problem by the monopolist is

$$
\begin{aligned}
0 &= p_j^s + q_j^s \frac{\partial p_j^s}{\partial q_j^s} - cp_j^{ms} \\
&= p_j^s + p_j^s \left(\frac{\partial p_j^s}{\partial q_j^s} \frac{q_j^s}{p_j^s}\right) - cp_j^{ms} \\
&= p_j^s \left(1 - \frac{1}{\sigma}\right) - cp_j^{ms},
\end{aligned}
$$

where the last line follows from the fact that the price elasticity of demand is $-\sigma$ and the term in parentheses in the second line is one over this elasticity. (We use the same elasticity of substitution in consumption and in production between intermediate inputs for parsimony.) This condition can be solved for the monopoly price

$$p_j^s\left(\frac{\sigma-1}{\sigma}\right)=cp_j^{ms}.$$

Choose units such that $c=(\sigma-1)/\sigma$, which gives $p_j^s=p_j^{ms}$. Next, use this final expression to determine maximized profits:

$$\begin{aligned}
p_j^s q_j^s - p_j^s\left(F_j^s + cq_j^s\right) &= \underbrace{\left(\frac{\sigma}{\sigma-1}\right)c}_{=1}\, p_j^s q_j^s - p_j^s\left(F_j^s + cq_j^s\right) \\
&= p_j^s\left(\frac{cq_j^{s*}}{\sigma-1} - F_j^s\right).
\end{aligned}$$

Now, impose the zero profit condition, use the term for the marginal cost and solve for the optimal output by each firm in sector s in region j

$$q_j^s=\frac{F_j^s(\sigma-1)}{c}=F_j^s\sigma.$$

Next, consistent with Assumption 3, we set fixed costs equal to $F_j^s=(\sigma\alpha_j^s)^{-1}$, so that

$$q_j^s=\frac{1}{\alpha_j^s}. \tag{S.17}$$

As is standard in this class of models, specialization depends on the inverse of the share of labor in production, α_j^s.

S.4.6 The number of varieties

In the model, the number of varieties are linked to the size of the economy measured by the wage bill in region j sector s. First, each sector equates the marginal value product of labor to the wage rate

$$\begin{aligned}
w_j &= p_j^s\frac{\partial n_j^s q_j^s}{\partial L_j^s} \\
&= p_j^s\alpha_j^s n_j^s\frac{q_j^s}{L_j^s}.
\end{aligned}$$

Next, multiply both sides to obtain the share of labor employed in sector s

$$w_jL_jl_j^s=p_j^s\alpha_j^s n_j^s\frac{q_j^s}{L_j^s}L_jl_j^s,$$

where employment shares by industry are denoted by $l_j^s=L_j^s/L_j$.

Now, use equation (S.17), to obtain

$$w_jL_jl_j^s=n_j^sp_j^s.$$

Finally, substitute equation (S.16) into the above expression and solve for the number of varieties

$$n_j^s=\frac{w_jL_jl_j^s}{(r/\beta_j^s)^{\beta_j^s}(w_j/\alpha_j^s)^{\alpha_j^s}\prod_{h=1}^{S}(G_j^{hs}/\alpha_j^{hs})^{\alpha_j^{hs}}}. \tag{S.18}$$

S.4.7 Derivation of changes in trade shares

First, take logs and totally differentiate the price equation (S.16) for any origin region i to get[28]

$$d\ln p_i^s = \beta_i^s d\ln r + \alpha_i^s d\ln w_i + \sum_{h=1}^{S} \alpha_i^{hs} d\ln G_i^{hs}. \tag{S.19}$$

Also, solve for the number of varieties in equation (S.18), after taking logs and differentiation

$$d\ln n_i^s = (1-\alpha_i^s) d\ln w_i - \beta_i^s d\ln r + d\ln L_i + d\ln l_i^s - \sum_{h=1}^{S} \alpha_i^{hs} d\ln G_i^{hs}. \tag{S.20}$$

Next, totally differentiate the export share equation (S.15)

$$d\ln x_{ij}^{hs} = d\ln n_i^h + (1-\sigma)\left(d\ln(\tau_{ij}^{hs}) + d\ln(p_i^h) - d\ln G_j^{hs}\right). \tag{S.21}$$

Finally, substituting equations (S.19) and (S.20) into equation (S.21) gives

$$\begin{aligned} d\ln x_{ij}^{hs} &= (1-\alpha_i^h) d\ln w_i - \beta_i^h d\ln r + d\ln L_i + d\ln l_i^h - \sum_{k=1}^{S} \alpha_i^{ks} d\ln G_j^{ks} \\ &\quad + (1-\sigma)\left(d\ln(\tau_{ij}^{hs}) + \beta_i^h d\ln r + \alpha_i^h d\ln w_i + \sum_{k=1}^{S} \alpha_i^{ks} d\ln G_i^{ks} - d\ln G_j^{hs}\right) \\ &= \Phi_{ij}^{hs} - \sigma \sum_{k=1}^{S} \alpha_i^{ks} d\ln G_i^{ks} - (1-\sigma) d\ln G_j^{hs}, \end{aligned} \tag{S.22}$$

where Φ_{ij}^{hs} collects the observables with the exception of τ_{ij}^{hs}, and is given by

$$\Phi_{ij}^{hs} = (1-\sigma\alpha_i^h) d\ln w_i - \sigma\beta_i^h d\ln r + d\ln L_i + d\ln l_i^h + (1-\sigma) d\ln \tau_{ij}^{hs}. \tag{S.23}$$

The first term on the right-hand side is the impact of a change in the wage rate in country i, say China, on all the destination regions $j = 1, 2, \ldots, R$, including China. A change in the wage rate influences export shares through a cost and a market size channel. The magnitude of the cost channel depends on the elasticity of output with respect to labour α_i^h multiplied by the trade elasticity $1-\sigma$, and the market size channel depends on $1-\alpha_i^h$.

S.4.8 Transportation costs

With an eye to the empirical analysis, we model transportation costs from region i to j and from sector h to s as consisting of a period dependent originating-sector, exporter, importer component, $\tau_{ij,t}^{h.}$, a period independent originating-sector, destination-sector, exporter component, $\zeta_{i.}^{hs}$, and period dependent origin-destination sector and region component, $\xi_{ij,t}^{hs}$

$$\ln \tau_{ij,t}^{hs} = \ln \tau_{ij,t}^{h.} + \zeta_{i.}^{hs} + \xi_{ij,t}^{hs}.$$

[28] In our derivations, we treat the elasticity of output with respect to each input $(\alpha_i^s, \beta_i^s, \alpha_{ij}^{hs})$ as time invariant.

We thus express a change over time in transportation costs as[29]

$$\Delta \ln \tau_{ij,t}^{hs} = \Delta \ln \tau_{ij,t}^{h\cdot} + \Delta \xi_{ij,t}^{hs}. \tag{S.24}$$

Furthermore, using equation (S.23), we have

$$\Phi_{ij,t}^{hs} = \tilde{\Phi}_{ij,t}^{h} - \sigma u_{ij,t}^{hs}, \tag{S.25}$$

where we allowed for period-dependent share parameters, and defined

$$u_{ij,t}^{hs} := -\left(\frac{1-\sigma}{\sigma}\right) \Delta \xi_{ij,t}^{hs},$$

$$\tilde{\Phi}_{ij,t}^{h} := (1 - \sigma \alpha_{i,t}^{h}) \Delta \ln w_{i,t} - \sigma \beta_i^h \Delta \ln r + \Delta \ln L_{i,t} + \Delta \ln l_{i,t}^{h} + (1-\sigma) \Delta \ln \tau_{ij,t}^{h\cdot},$$

and the last term collects the variables we observe.

S.4.9 Changes in Price Indices

We now demonstrate how our procedure incorporates endogenous price changes due to changes in our factors. We do this in two instructive steps. The first step is intermediate with the added benefit of expressing the changes in trade shares as a linear regression model, where changes in price indexes are coefficients to be estimated, and the error terms are the dyadic trade costs. Our accounting formula does not use any of these estimates. However, this step provides us with a summary statistic ($\overline{R}^2$) to gauge the overall statistical fit of the model.

Step 1. Rearrange equation (S.22) for sector s, use equation (S.25) and define

$$\tilde{\Phi}_{ij,t}^{h} - \Delta \ln x_{ij,t}^{hs} = \sigma \left(\sum_{k=1}^{S} \alpha_{i,t}^{ks} \Delta \ln G_{i,t}^{ks} + \frac{1-\sigma}{\sigma} \Delta \ln G_{j,t}^{hs} \right) + \sigma u_{ij,t}^{hs}. \tag{S.26}$$

Now, let $a_{ij,t}^{hs} = (\tilde{\Phi}_{ij,t}^{h} - \Delta \ln x_{ij,t}^{hs})/\sigma$, $B_{j,t}^{hs} = \Delta \ln G_{j,t}^{hs}$, and $\tilde{\sigma} = (1-\sigma)/\sigma$, so that

$$a_{ij,t}^{hs} = \sum_{k=1}^{S} \alpha_{i,t}^{ks} B_{i,t}^{ks} + \tilde{\sigma} B_{j,t}^{hs} + u_{ij,t}^{hs}.$$

In a more compact form and omitting time indices, let $\alpha_i^s = [\alpha_i^{1s} \quad \alpha_i^{2s} \ldots \alpha_i^{Ss}]$ be the input coefficient (column) vector of sector s in region i, and $\mathbf{1}_{(S\times 1)}$ be an identity vector conformable with α_i^s, so that $\alpha_i^s \otimes \mathbf{1}$ is a square matrix. Let $\mathbf{S}^s = diag\,[\alpha_1^s \otimes \mathbf{1} \quad \alpha_2^s \otimes \mathbf{1} \ldots \alpha_R^s \otimes \mathbf{1}]$ be a block-diagonal matrix. Let A_j^s be a $RS \times 1$ column vector containing the a_{ij}^{hs} terms, for all $h = 1, 2, \ldots, S$, and $i = 1, 2, \ldots, R$ (similarly for u_j^s); β^s be a $RS \times 1$ column vector containing the changes in relative prices B_i^{hs}, for all $h = 1, 2, \ldots, S$, and $\mathbf{Z}_j$ be a $RS \times RS$ matrix consisting of zeros except for columns from $1 + S(j-1)$ to

[29] Unless otherwise stated, to denote changes over time in a variable x, we write $\Delta x_t = x_t - x_{t-1}$.

$S \times j$, which contain R vertically concatenated copies of $diag[\tilde{\sigma} \quad \tilde{\sigma} \ldots \tilde{\sigma}]$. Thus, for each $s = 1, 2, \ldots, S$, and $j = 1, 2, \ldots, R$, we have

$$A^s_{j,t(RS\times 1)} = \left(\mathbf{S}^s_{j,t(RS\times RS)} + \mathbf{Z}_{j,(RS\times RS)}\right)\beta^s_{t(RS\times 1)} + u^s_{j,t(RS\times 1)}.$$

There are S such regression equations. Stack them as

$$A^s_t = (\mathbf{S}^s_t + \mathbf{Z})\beta^s_t + u^s_t,$$

where a typical matrix block of $A^s_{t(R^2S\times 1)}$ is $A^s_{j,t}$, and similarly for $\mathbf{S}^s_{t(R^2S\times RS)}$, $\mathbf{Z}_{(R^2S\times RS)}$ and $u^s_{t(R^2S\times 1)}$. For $R = 15$ regions, $S = 28$ sectors, and 4 episodes with 3 growth episodes Δt, we have

$$R \times R \times S \times S \times \Delta t = 529,200$$

distinct observations on bilateral trade.

Step 2. Express the export share equation (S.15) in logarithms

$$\ln x^{hs}_{ij} = \ln n^h_i + (1-\sigma)\left(\ln(p^h_i \tau^{hs}_{ij}) - \ln G^{hs}_j\right).$$

Totally differentiate both sides

$$d\ln x^{hs}_{ij} = \frac{dx^{hs}_{ij}}{x^{hs}_{ij}} = d\ln n^h_i + (1-\sigma)\left(d\ln(p^h_i \tau^{hs}_{ij}) - d\ln G^{hs}_j\right).$$

Rearrange terms

$$dx^{hs}_{ij} = x^{hs}_{ij}\left(d\ln n^h_i + (1-\sigma)\left(d\ln(p^h_i \tau^{hs}_{ij}) - d\ln G^{hs}_j\right)\right).$$

(Adding up constraints) Now sum across all $i \in R$

$$\begin{aligned}
\sum_i dx^{hs}_{ij} &= \sum_i x^{hs}_{ij}(1-\sigma)\left(d\ln(p^h_i \tau^{hs}_{ij}) - d\ln G^{hs}_j\right) + \sum_i x^{hs}_{ij} d\ln n^h_i \\
&= (1-\sigma)\left(\sum_i x^{hs}_{ij} d\ln(p^h_i \tau^{hs}_{ij}) - \sum_i x^{hs}_{ij} d\ln G^{hs}_j\right) + \sum_i x^{hs}_{ij} d\ln n^h_i \\
&= (1-\sigma)\left(\sum_i x^{hs}_{ij} d\ln(p^h_i \tau^{hs}_{ij}) - d\ln G^{hs}_j \sum_i x^{hs}_{ij}\right) + \sum_i x^{hs}_{ij} d\ln n^h_i \\
&= (1-\sigma)\left(\sum_i x^{hs}_{ij} d\ln(p^h_i \tau^{hs}_{ij}) - d\ln G^{hs}_j\right) + \sum_i x^{hs}_{ij} d\ln n^h_i,
\end{aligned}$$

where the last term follows from the fact that expenditure shares add up to one: $\sum_i x^{hs}_{ij} = 1$. Also, changes in expenditure shares must add up to zero, so that $\sum_i dx^{hs}_{ij} = 0$, so that

$$d\ln G^{hs}_j = \sum_i x^{hs}_{ij} d\ln(p^h_i \tau^{hs}_{ij}) + (1-\sigma)^{-1} \sum_i x^{hs}_{ij} d\ln n^h_i. \tag{S.27}$$

Finally, using the expression for transportation costs in equation (S.27) gives

$$\Delta \ln G_{j,t}^{hs} = \sum_{i=1}^{R} x_{ij,t-1}^{hs} \left(\Delta \ln p_{i,t}^{h} + \Delta \ln \tau_{ij,t}^{h\cdot} + \Delta \hat{\xi}_{ij,t}^{hs} \right) + (1-\sigma)^{-1} \sum_{i} x_{ij,t-1}^{hs} \Delta \ln n_{i,t}^{h},$$

where $\Delta \hat{\xi}_{ij,t}^{hs} = (\sigma/(\sigma-1))\, u_{ij,t}^{hs}$, with $u_{ij,t}^{hs}$ as defined in Step 1 above.

Next consolidate terms

$$\Delta \ln G_{j,t}^{hs} = \sum_{i=1}^{R} x_{ij,t-1}^{hs} \left(\Delta \ln p_{i,t}^{h} + (1-\sigma)^{-1} \Delta \ln n_{i,t}^{h} + \Delta \ln \tau_{ij,t}^{h\cdot} + \Delta \hat{\xi}_{ij,t}^{hs} \right), \tag{S.28}$$

where using equations (S.19) and (S.20),

$$\begin{aligned}
&\Delta \ln p_{i,t}^{h} + (1-\sigma)^{-1} \Delta \ln n_{i,t}^{h} \\
&\quad = \beta_i^h \Delta \ln r_t + \alpha_i^h \Delta \ln w_{i,t} + \sum_{k=1}^{S} \alpha_{i,t}^{kh} \Delta \ln G_{i,t}^{kh} \\
&\qquad + (1-\sigma)^{-1} \left((1-\alpha_i^h) \Delta \ln w_{i,t} - \sigma \beta_i^h d \ln r + \Delta \ln L_{i,t} + \Delta \ln l_{i,t}^{h} - \sum_{k=1}^{S} \alpha_i^{kh} \Delta \ln G_{i,t}^{kh} \right) \\
&\quad = \left(\frac{\sigma}{\sigma-1} \right) \beta_i^h \Delta \ln r_t + \left(\frac{1-\sigma\alpha_i^h}{1-\sigma} \right) \Delta \ln w_{i,t} - \left(\frac{\sigma}{1-\sigma} \right) \sum_{k=1}^{S} \alpha_{i,t}^{kh} \Delta \ln G_{i,t}^{kh} \\
&\qquad + (1-\sigma)^{-1} \left(\Delta \ln L_{i,t} + \Delta \ln l_{i,t}^{h} \right).
\end{aligned}$$

Now substitute these terms into equation (S.28)

$$
\begin{aligned}
\Delta \ln G^{hs}_{j,t} &= \sum_{i=1}^{R} x^{hs}_{ij,t-1} \left(\left(\frac{\sigma}{\sigma-1} \right) \beta^h_i \Delta \ln r_t + \left(\frac{1-\sigma\alpha^h_i}{1-\sigma} \right) \Delta \ln w_{i,t} - \left(\frac{\sigma}{1-\sigma} \right) \sum_{k=1}^{S} \alpha^{kh}_{i,t} \Delta \ln G^{kh}_{i,t} \right. \\
&\quad \left. + (1-\sigma)^{-1} \left(\Delta \ln L_{i,t} + \Delta \ln l^h_{i,t} \right) + \Delta \ln \tau^{h\cdot}_{ij,t} + \Delta \hat{\xi}^{hs}_{ij,t} \right) \\
&= \left(\frac{1}{1-\sigma} \right) \sum_{i=1}^{R} x^{hs}_{ij,t-1} \Bigg(\left(1-\sigma\alpha^h_i \right) \Delta \ln w_{i,t} - \sigma \beta^h_i \Delta \ln r_t + \Delta \ln L_{i,t} + \Delta \ln l^h_{i,t} \\
&\quad + (1-\sigma) \Delta \ln \tau^{h\cdot}_{ij,t} + (1-\sigma) \Delta \hat{\xi}^{hs}_{ij,t} - \sigma \sum_{k=1}^{S} \alpha^{kh}_{i,t} \Delta \ln G^{kh}_{i,t} \Bigg) \\
&= \left(\frac{1}{1-\sigma} \right) \sum_{i=1}^{R} x^{hs}_{ij,t-1} \left(\tilde{\Phi}^h_{ij,t} + (1-\sigma) \Delta \hat{\xi}^{hs}_{ij,t} - \sigma \sum_{k=1}^{S} \alpha^{kh}_{i,t} \Delta \ln G^{kh}_{i,t} \right) \\
&= \left(\frac{1}{1-\sigma} \right) \sum_{i=1}^{R} x^{hs}_{ij,t-1} \left(\tilde{\Phi}^h_{ij,t} + (1-\sigma) \Delta \hat{\xi}^{hs}_{ij,t} \right) - \left(\frac{\sigma}{1-\sigma} \right) \sum_{i=1}^{R} x^{hs}_{ij,t-1} \sum_{k=1}^{S} \alpha^{kh}_{i,t} \Delta \ln G^{kh}_{i,t} \\
&= \left(\frac{1}{1-\sigma} \right) \sum_{i=1}^{R} x^{hs}_{ij,t-1} \underbrace{\left(\tilde{\Phi}^h_{ij,t} - \sigma u^{hs}_{ij,t} \right)}_{\Phi^{hs}_{ij,t}} - \left(\frac{\sigma}{1-\sigma} \right) \sum_{i=1}^{R} x^{hs}_{ij,t-1} \sum_{k=1}^{S} \alpha^{kh}_{i,t} \Delta \ln G^{kh}_{i,t} \\
&= \underbrace{\left(\frac{1}{1-\sigma} \right) \sum_{i=1}^{R} x^{hs}_{ij,t-1} \Phi^{hs}_{ij,t}}_{\text{structural variables}} - \underbrace{\left(\frac{\sigma}{1-\sigma} \right) \sum_{i=1}^{R} x^{hs}_{ij,t-1} \sum_{k=1}^{S} \alpha^{kh}_{i,t} \Delta \ln G^{kh}_{i,t}}_{\text{trade-share weighted elasticities}} .
\end{aligned}
$$

Notice that "structural" variables are also lagged trade-share weighted.

Next we use matrix algebra to solve for the growth rates of price indices, which are given by

$$
\underbrace{\left[(1-\sigma)\mathbf{I} + \sigma \mathbf{H} \right]^{-1}}_{\mathbf{J}} \mathbf{y},
$$

where $\mathbf{I}$ is an $RS^2 \times RS^2$ identity matrix, $\mathbf{H}$ is an $RS^2 \times RS^2$ matrix of lagged trade-share weighted elasticities, and $\mathbf{y}$ is an $RS^2 \times 1$ column vector of lagged trade-share weighted structural variables, such that the $RS^2 \times RS^2$ matrix $\mathbf{J}$ only depends on lagged export shares (predetermined variables) and elasticity coefficients; it does not involve the current values of the wage rate, employment shares, economic size, and transportation costs.

S.4.10 Changes in export shares

For origin–destination region pairs i and j, respectively, and in the destination sector s, define a column vector with S rows of actual changes in export shares

$$
\mathbf{Dx}^s_{ij} = \left[\Delta \ln x^{1s}_{ij}, \Delta \ln x^{2s}_{ij}, \vdots, \Delta \ln x^{Ss}_{ij} \right]' .
$$

Stack these into a $R^2 S \times 1$ column vector $\mathbf{Dx}^s$

Using equation (S.26) and calculations in Step 2, we write

$$\begin{aligned}\mathbf{D}\mathbf{x}_t^s &= \tilde{\boldsymbol{\Phi}}_t - \sigma(\mathbf{S}_t^s + \mathbf{Z})\beta_t^s - \sigma u_t^s \\ &= \tilde{\boldsymbol{\Phi}}_t - \sigma(\mathbf{S}_t^s + \mathbf{Z})\mathbf{J}\mathbf{y} - \sigma u_t^s + \hat{u}_t^s,\end{aligned} \tag{S.29}$$

where $\hat{u}_t^s$ is the adjustment needed to ensure that we account for other effects that include unobserved changes in trade and transportation costs. We implement our decomposition by writing the growth rates of sectoral trade shares in equation (S.29) as

$$\begin{aligned}\mathbf{D}\mathbf{x}_t^s = {} & \tilde{\boldsymbol{\Phi}}_t^s && \text{(direct effect)} \\ & - \sigma(\mathbf{S}_t^s + \mathbf{Z})\mathbf{J}\mathbf{x}^s\tilde{\boldsymbol{\Phi}}_t^s && \text{(indirect price effect)} \\ & + \tilde{u}_t^s. && \text{(other effects)}\end{aligned}$$

S.4.11 Changes in tariffs

To introduce tariffs into our trade-accounting framework in section 4.6, we approximate the tariff on output of industry h originating in country i, being imported into country j, and processed by industry s, by using the iceberg cost approach identical to that of transport costs, giving us a modified price equation

$$p_{ij}^{hs} = p_i^h \tau_{ij}^{hs} \times \text{tariff}_{ij}^h, \tag{S.30}$$

where τ and "tariff" are both greater than or equal to 1. This formulation closely approximates

$$p_{ij}^{hs} = p_{i^h}\left(1 + \text{ad valorem transport cost} + \text{ad valorem tariff}\right),$$

for "small" ad valorem transport costs and tariffs, preserving our linear decomposition with an extended set of structural variables

$$\begin{aligned}\tilde{\Phi}_{ij,t}^h := {} & (1-\sigma\alpha_i^h)\Delta\ln w_{i,t} - \sigma\beta_i^h\Delta\ln r + \Delta\ln L_{i,t} + \Delta\ln l_{i,t}^h + (1-\sigma)\Delta\ln\tau_{ij,t}^h \\ & + (1-\sigma)\Delta\ln\text{tariff}_{ij,t}^h,\end{aligned}$$

where the last term accounts for changes in the tariff rate. The remainder of our decomposition proceeds as before.

S.4.12 Matrices

In this section, we explicitly state our matrices.

$\mathbf{S}_j^s$ is the matrix of elasticities of output with respect to conglomerate intermediate inputs in region $j = 1, 2, \ldots, R$ and industry $s = 1, 2, \ldots, S$,

$$\mathbf{S}^s_{j(RS\times RS)} = \begin{bmatrix} \alpha_1^{1s} & \cdots & \alpha_1^{Ss} & 0 & \cdots & 0 & \cdots & 0 & \cdots & 0 \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots & \ddots & \vdots & \ddots & \vdots \\ \alpha_1^{1s} & \cdots & \alpha_1^{Ss} & 0 & \cdots & 0 & \cdots & 0 & \cdots & 0 \\ 0 & \cdots & 0 & \alpha_2^{1s} & \cdots & \alpha_2^{Ss} & \cdots & 0 & \cdots & 0 \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots & \ddots & \vdots & \ddots & \vdots \\ 0 & \cdots & 0 & \alpha_2^{1s} & \cdots & \alpha_2^{Ss} & \cdots & 0 & \cdots & 0 \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots & \ddots & \vdots & \ddots & \vdots \\ 0 & \cdots & 0 & 0 & \cdots & 0 & \cdots & \alpha_R^{1s} & \cdots & \alpha_R^{Ss} \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots & \ddots & \vdots & \ddots & \vdots \\ 0 & \cdots & 0 & 0 & \cdots & 0 & \cdots & \alpha_R^{1s} & \cdots & \alpha_R^{Ss} \end{bmatrix}.$$

$\mathbf{Z}_{(R^2S\times RS)}$ contains the elasticity of substitution between intermediate inputs in production, with for $j = 1$

$$\mathbf{Z}_{1(RS\times RS)} = \begin{bmatrix} \tilde{\sigma} & \cdots & 0 & 0 & \cdots & 0 & \cdots & 0 & \cdots & 0 \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots & \ddots & \vdots & \ddots & \vdots \\ 0 & \cdots & \tilde{\sigma} & 0 & \cdots & 0 & \cdots & 0 & \cdots & 0 \\ \tilde{\sigma} & \cdots & 0 & 0 & \cdots & 0 & \cdots & 0 & \cdots & 0 \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots & \ddots & \vdots & \ddots & \vdots \\ 0 & \cdots & \tilde{\sigma} & 0 & \cdots & 0 & \cdots & 0 & \cdots & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ \tilde{\sigma} & \cdots & 0 & 0 & \cdots & 0 & \cdots & 0 & \cdots & 0 \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots & \ddots & \vdots & \ddots & \vdots \\ \underbrace{0 \quad \cdots \quad \tilde{\sigma}}_{j=1} & & & \underbrace{0 \quad \cdots \quad 0}_{j=2} & & & \cdots & \underbrace{0 \quad \cdots \quad 0}_{j=R} & & \end{bmatrix},$$

where $\tilde{\sigma} := (1 - \sigma)/\sigma$.

$\mathbf{H}$ is a matrix of lagged export shares weighted by global elasticity parameters

$$\mathbf{H}_{(RS^2\times RS^2)} = \begin{bmatrix} \mathbf{H}^1 \\ \mathbf{H}^2 \\ \vdots \\ \mathbf{H}^S \end{bmatrix}.$$

with for $s = 1, 2, \ldots, S$

$$\mathbf{H}^s_{(RS \times RS^2)} = \begin{bmatrix} h_1^{1s} & 0 & \cdots & 0 \\ 0 & h_1^{2s} & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & h_1^{Ss} \\ h_2^{1s} & 0 & \cdots & 0 \\ 0 & h_2^{2s} & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & h_2^{Ss} \\ \vdots & \vdots & \ddots & \vdots \\ h_R^{1s} & 0 & \cdots & 0 \\ 0 & h_R^{2s} & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & h_R^{Ss} \end{bmatrix}$$

where $h_j^{h,s}$ is a row vector of RS columns such that for $h_{j=1}^{h=1,s}$ and $s = 1, 2, \ldots, S$

$$h_j^{h=1,s} = \Big[\; x_{i=1,j,t-1}^{h=1,s}\alpha_{i=1,t}^{1,h=1} \quad x_{1j,t-1}^{1s}\alpha_{1,t}^{21} \quad \cdots \quad x_{1j,t-1}^{1s}\alpha_{1,t}^{S1} \quad x_{2j,t-1}^{1s}\alpha_{2,t}^{11} \quad \cdots \quad x_{Rj,t-1}^{1s}\alpha_{R,t}^{11} \quad x_{Rj,t-1}^{1s}\alpha_{R,t}^{21} \quad \cdots \quad x_{Rj,t-1}^{1s}\alpha_{R,t}^{S1} \; \Big].$$

$\mathbf{y}$ is a column vector of lagged trade-weighted structural variables

$$\mathbf{y}_{(RS^2 \times 1)} = \begin{bmatrix} \mathbf{x}^1(\tilde{\mathbf{\Phi}} - \sigma\mathbf{u}^1) \\ \mathbf{x}^2(\tilde{\mathbf{\Phi}} - \sigma\mathbf{u}^2) \\ \vdots \\ \mathbf{x}^S(\tilde{\mathbf{\Phi}} - \sigma\mathbf{u}^S) \end{bmatrix},$$

where (i) $\mathbf{x}^s_{ij}$ contains lagged trade shares for sector s

$$\mathbf{x}^s_{ij,t-1(S \times S)} = \begin{bmatrix} x_{ij,t-1}^{1s} & 0 & \cdots & 0 \\ 0 & x_{ij,t-1}^{2s} & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & x_{ij,t-1}^{Ss} \end{bmatrix},$$

such that, for each s

$$\mathbf{x}^s_{(RS \times R^2S)} =$$
$$\begin{bmatrix} \mathbf{x}^s_{11,t-1} & \mathbf{x}^s_{21,t-1} & \cdots & \mathbf{x}^s_{R1,t-1} & 0 & 0 & \cdots & 0 & \cdots & 0 & 0 & \cdots & 0 \\ 0 & 0 & \cdots & 0 & \mathbf{x}^s_{12,t-1} & \mathbf{x}^s_{22,t-1} & \cdots & \mathbf{x}^s_{R2,t-1} & \cdots & 0 & 0 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots & \vdots & \vdots & \ddots & \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & 0 & 0 & 0 & \cdots & 0 & \cdots & \mathbf{x}^s_{1R,t-1} & \mathbf{x}^s_{2R,t-1} & \cdots & \mathbf{x}^s_{RR,t-1} \end{bmatrix}.$$

(ii) $\tilde{\mathbf{\Phi}}$ contains structural variables

$$\tilde{\mathbf{\Phi}}_{(R^2S\times 1)} = \begin{bmatrix} \tilde{\Phi}_{11,t} \\ \tilde{\Phi}_{21,t} \\ \vdots \\ \tilde{\Phi}_{R1,t} \\ \tilde{\Phi}_{12,t} \\ \tilde{\Phi}_{22,t} \\ \vdots \\ \tilde{\Phi}_{R2,t} \\ \vdots \\ \tilde{\Phi}_{1R,t} \\ \tilde{\Phi}_{2R,t} \\ \vdots \\ \tilde{\Phi}_{RR,t} \end{bmatrix},$$

with

$$\tilde{\Phi}_{ij(S\times 1)} = \begin{bmatrix} \tilde{\Phi}^1_{ij,t} \\ \tilde{\Phi}^2_{ij,t} \\ \vdots \\ \tilde{\Phi}^S_{ij,t} \end{bmatrix},$$

and (iii) $\mathbf{u}^s_{(R^2S\times 1)}$ contains the remaining factors unaccounted for by the model.

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