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Evolving comparative advantage, sectoral linkages, and structural change

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ABSTRACT

Intermediate-input intensities vary systematically with economic development across countries. These cross-country differences in input–output linkages account for 74 % of the curvature in the hump shape in industry's share in value added across levels of income per capita. This is twice as much as can be accounted for by variation in the composition of final demand. Using a three-sector, open-economy model of structural change I find that this result is robust to general equilibrium effects.

1. Introduction

Recently, there has been a great deal of research on structural change using general equilibrium models aiming to explain three facts: (1) the decline in agriculture's share across levels of development, (2) the hump shape in industry's share, and (3) the rise in services' share. These papers have highlighted three key mechanisms that impact final demand. The first mechanism is income effects due to Ernst Engel, in which income elasticities of demand for each good differ from one another [e.g.,](Kongsamut et al., 2001; Laitner, 2000).

The second mechanism is the Baumol effect in which the elasticity of substitution between goods is less than one [e.g.,](Baumol, 1967; Ngai and Pissarides, 2007). A shock-induced fall in the relative price in one sector decreases that sector's share in final absorption.

The third mechanism is changes in comparative advantage in an open economy as in Uy et al. (2013). A positive, country-specific productivity shock in one sector increases the share of resources allocated to that sector to satisfy higher net exports

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due to improved comparative advantage. The fact that this mechanism works opposite to the Baumol effect is a reason to study structural change in an open economy (Matsuyama, 2009).

This paper explores a fourth mechanism: cross-country differences in sectoral linkages in production. Sectoral linkages refer to the extent that goods from various sectors are used as intermediate inputs in production in every sector. Unlike the previous mechanisms, sectoral linkages matter primarily for intermediate demand, and affect final demand only indirectly. In the paper, final demand refers to final absorption plus net exports, while final absorption refers to private and public consumption plus gross capital formation.

Very little research has targeted the role of cross-country differences in sectoral linkages in the context of structural change.[2] I document that sectoral linkages systematically vary with income per capita across countries. Two features stand out. First, rich countries utilize intermediates more intensively in agricultural production than poor countries do. Second, in all sectors, rich countries utilize services more intensively than poor countries do.

I incorporate country-specific sectoral linkages into a multi-country, open-economy, general equilibrium model of structural change. There are three sectors—agriculture, industry, and services—each with a continuum of tradable varieties. All varieties are aggregated into sector-specific composite goods that are consumed by households and used as intermediate inputs by firms. Production of each variety requires labor and composite goods from each sector. The intensity of each input in production differs across countries and across sectors. As in Eaton and Kortum (2002), the schedule for productivity across varieties, together with trade barriers, determines the pattern of specialization and trade. A representative household in each country supplies labor inelastically to domestic firms and consumes the composite goods, which are imperfect substitutes and have sector-specific income elasticities.

The model is calibrated to match exactly, for 41 countries, (i) input–output shares, (ii) sectoral value added, (iii) sectoral bilateral trade, and (iv) income per capita.

The model admits an input-output identity for each country in which the composition of value added is fully accounted for by input–output coefficients and the composition of final demand. The extent to which value added is sourced from each sector in order to produce a desired composition of final demand is determined solely by the sectoral linkages. Take as given a decline in agriculture's share in final demand and an increase in services' share. Cross-country heterogeneity in sectoral linkages imply a larger decline in agriculture's share in value added in poor countries than in rich countries, and a larger increase in services' share in value added in rich countries than in poor countries. The net effect yields a hump shape in industry's share in value added across income levels. Cross-country variation in input-output coefficients accounts for 74 % of the hump shape – twice as much as variation in the composition of final demand can account for.

In the model the composition of final demand itself depends endogenously on sectoral linkages, in addition to sector- and country-specific productivity levels and trade barriers. To isolate the importance of sectoral linkages, I evaluate the consequence of a counterfactual path for value-added productivity growth, where growth rates are equalized across countries. In line with the data, productivity grows the fastest in agriculture and the slowest in services.

Even with productivity growth rates equalized across countries, the relative price of services increases by more in rich countries than in poor countries, while the relative price of agriculture decreases by more in poor countries than in rich countries. The asymmetry is entirely due to differences in sectoral linkages and results in asymmetric responses in the composition of final absorption across countries through the Baumol and income effects. Differences in sectoral input-intensities also yield changes in comparative advantage. However, changes in the composition of net exports are quantitatively inconsequential relative to the changes in the composition of final absorption since the scope for changes in comparative advantage is restricted by imposing equal productivity growth across countries.

I carry out an analogous counterfactual exercise in an alternative model in which sectoral linkages are equalized across countries. In the alternative model, there are essentially no differences between rich and poor countries in the response of relative prices to exogenously evolving productivity. Any disparity between rich and poor countries in the response of the composition of final demand is entirely due to asymmetries in income effects.

The main results are robust to alternative treatments of aggregate trade imbalances, a range of values for sector-specific trade elasticities, and preference specifications.

This paper is not the first to incorporate sectoral linkages into a model of structural change. However, papers that have embedded sectoral linkages have done so either in the context of a two-country model with sectoral linkages held constant across countries (e.g., Uy et al., 2013), or in a single-country, closed-economy model (e.g., Herrendorf et al., 2013). Kehoe et al. (2018) employ a two-country, open-economy model with sectoral linkages in only one country. Other papers that have examined structural change across many countries have done so in models without sectoral linkages (e.g., Duarte and Restuccia, 2010 and Comin et al., 2018 in closed-economy settings, and Świecki (2017) in an open-economy setting).

[2] Crucini and Kahn (1996) provide the first quantitative, open-economy, GE model with input-output linkages in order to examine the impact of tariff wars on economic outcomes during the Great Depression. Caliendo and Parro (2015) incorporate country-specific sectoral linkages into a multi-country model to measure the gains from trade liberalization. Caliendo et al. (2017) examine how sectoral shocks that originate in individual U.S. states propagate throughout the entire United States, by emphasizing both the trade linkages between states as well as the sectoral linkages in production.

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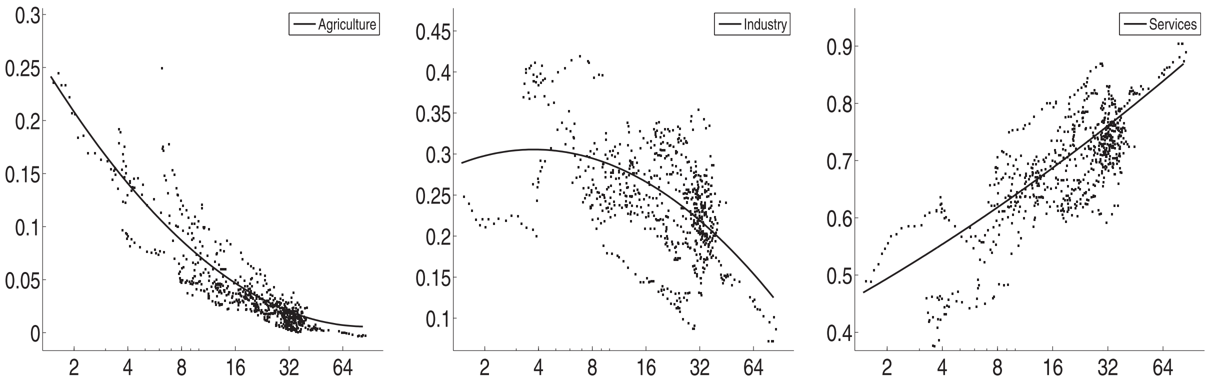

Fig. 1. Sectoral shares in value added. **Note:** The data are for a panel of 41 countries from 1995 to 2011. In each subfigure, the vertical axis represents each sector's share in aggregate value added, and the horizontal axis represents GDP per capita at PPP in thousands of 2005 U.S. dollars. The curves represent the best fit estimate using OLS of the relevant share against a second-degree polynomial in log-GDP per capita for the entire panel.

The existing literature emphasizes shock-induced changes in the composition of *final demand* as a source of generating structural change via either income effects, the Baumol effect, or comparative advantage.[3] However, the data suggest that changes in the composition of *intermediate demand* are also important. Using a partial equilibrium framework, Berlingieri (2014) shows that accounting for the intermediate use of "professional and business services" is important for explaining increased service-sector employment in the United States. This paper builds on Berlingieri (2014) by studying the importance of sectoral linkages for structural change across many countries using a general equilibrium model.

From a macro-development standpoint, understanding structural change is crucial for understanding aggregate outcomes (see Duarte and Restuccia, 2010; Gollin et al., 2014). McMillan and Rodrik (2011) argue that reallocations of resources across sectors have been growth reducing for some countries and growth enhancing for others, depending on whether resources shifted towards sectors with relatively lower or higher productivity.

From a measurement perspective, Duarte and Restuccia (2017) show the importance of incorporating sectoral linkages when inferring sectoral productivity from sectoral prices. Fadinger et al. (2017) argue that the combination of sectoral productivity and sectoral linkages, in turn, characterize aggregate productivity. They document that low-TFP sectors are highly connected to other sectors in rich countries but not in poor countries. As a result, sectoral linkages attenuate income differences. Boehm (2016) provides insight as to why sectoral linkages vary systematically with income. In particular, week enforcement, which is an important determinant of the extent of sector linkages, also implies higher distortions and lower aggregate productivity. Bartelme and Gorodnichenko (2015) identify sectoral-level distortions that account for the differences in sectoral linkages and argue that these distortions depress income in poor countries by roughly 10 percent.

Methodologically, this work relates closely to Cravino and Sotelo (2017). They note that tradable and nontradable sectors use skilled and unskilled workers with different intensities, and examine how the skill premium responds to trade-induced changes in the composition of output. This paper also complements the literature on global value-added chains by tracing out how growth in value-added productivity impacts prices, trade flows, and output (see Johnson, 2014; Johnson and Noguera, 2012).

2. Facts

The main source of data is the World Input–Output Database (see Timmer et al., 2015b, (WIOD)), which covers 41 countries and 34 industries (provided in the Appendix). I aggregate the industries up to three sectors—agriculture, industry, and services—using the "International Standard Industrial Classification of All Economic Activities, Rev.3" (ISIC). Agriculture corresponds to ISIC categories A (Agriculture, hunting and forestry) and B (Fishing). Industry corresponds to ISIC categories C (Mining and quarrying), D (Manufacturing), and E (Electricity, gas and water supply). Finally, services corresponds to the remainder of economic activity–ISIC categories F-Q. Data on GDP per capita at constant PPPs are from version 8.0 of the Penn World Table (see Feenstra et al., 2015, (PWT)).

Facts on structural change. Fig. 1 reiterates the key facts that the structural change literature aims to explain: (1) the decline in agriculture's share across levels of development, (2) the hump shape in industry's share, and (3) the rise in ser-

[3] Teignier (2018) shows that the combination of trade and income effects can speed up the decline in agriculture's share. Herrendorf et al. (2013) quantitatively decompose the relative importance of income and Baumol effects using CES preferences with Stone-Geary subsistence terms. Boppart (2014) and Comin et al. (2018) utilize flexible preferences that separate the income effect from the Baumol effect to examine structural change along a balanced growth path. Uy et al. (2013) show that the combination of the Baumol effect and comparative advantage helps explain the rise and flattening in industry's share in South Korea. Betts et al. (2017) argue that targeted trade policy in South Korea contributed to the rise in industry's share. Święcki (2017) decomposes the importance of the income effect, Baumol effect, and trade in accounting for structural change across multiple countries.

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Table 1
Input intensities for rich and poor countries.

Intermediate input shares		Output sector: Agriculture	Industry	Services
		poor (rich)	poor (rich)	poor (rich)
Input sector	Agriculture	0.32 (0.28)	0.10 (0.05)	0.03 (0.00)
	Industry	0.41 (0.35)	0.66 (0.60)	0.45 (0.19)
	Services	0.27 (0.37)	0.24 (0.35)	0.52 (0.80)
Value-added shares		0.67 (0.45)	0.35 (0.36)	0.57 (0.54)

Note: The terms "rich" and "poor" refer to the average of the 5 richest and 5 poorest countries, respectively, based on GDP per capita in 2011. Intermediate input shares are defined, for example, as expenditures on industrial inputs by the services sector as a share of total expenditures on all intermediate inputs by the service sector (input is industry, output is services). Value-added shares are defined as value added as a share of gross output in each sector.

vices' share. Each subfigure displays each sector's share in aggregate value added against GDP per capita across 41 countries from 1995 to 2011. Buera and Kaboski (2012) and Herrendorf et al. (2014) provide more thorough documentation of these facts across countries over a longer time period. The rest of this section documents new facts on how sectoral linkages vary across countries.

Facts on sectoral linkages. The following set of new facts documents how intensively intermediate goods from each sector are used by each sector, and how these intensities vary systematically across countries. First, I measure the share of value added in gross output for each sector. Second, I measure each sector's share in intermediate usage in every other sector (including its own). Table 1 reports each share for the average of the 5 richest and 5 poorest countries, respectively, based on GDP per capita, for 2011 only; estimates for 1995–2011 are similar and the time-series variation is negligible.[4]

Rich countries use intermediates more intensively than poor countries do in the production of agriculture, as reflected by a higher share of value added in gross output in poor countries. Within the intermediates used by agriculture, poor countries utilize agricultural inputs more intensively, including seeds and animal feed, while rich countries utilize service inputs more intensively (e.g., "Renting of M&E and Other Business Activities").

There is not a significant difference across countries in the share of intermediates in industrial goods production. However, within intermediate inputs used in industrial production, rich countries utilize services more intensively. This occurs in most subsectors of industry via "Renting of M&E and Other Business Activities", which includes professional business services. Poor countries utilize agricultural inputs more intensively than rich countries do, which includes processing and packaging of food and beverages.

There is not a significant difference across countries in the share of intermediates in services production. Within the intermediate inputs used in services production, agriculture accounts for a small share in all countries. Rich countries use services itself more intensively. Across most subsectors of services, the following inputs are used more intensively in rich countries than in poor countries: "Renting of M&E and Other Business Activities" and "Financial Intermediation". Poor countries utilize industrial inputs more intensively than rich countries do, such as fuels used in transportation services.

The key facts to take away are: (i) the share of value added in agricultural output tends to be higher in poor countries than in rich countries and (ii) rich countries utilize services more intensively than other intermediate inputs in the production of all goods, compared to poor countries, particularly in the production of services itself.

3. Model

I develop a three-sector, multi-country, Ricardian model of trade that builds on Uy et al. (2013) and Świecki (2017). There are I countries, indexed by $i = 1, \ldots, I$, each inhabited by a representative household, which is endowed with L_i units of labor. There are three sectors: agriculture, industry, and services, denoted by a, m, and s, respectively.

Technology. There is a unit interval of potentially tradable varieties in each sector indexed by $x_b \in [0, 1]$ for $b \in \{a, m, s\}$. Within each sector, all of the varieties are combined with constant elasticity in order to construct a sectoral composite good according to

$$Q_{bi} = \left[\int_0^1 q_{bi}(x_b)^{1-1/\eta} dx_b \right]^{\eta/(\eta-1)},$$

where η is the elasticity of substitution between varieties. The quantity of variety x_b used by country i, $q_{bi}(x_b)$, can be either imported or purchased domestically. The composite good, Q_{bi}, is used domestically either as an intermediate input or for final consumption.

[4] The 5 richest countries in the sample, starting with the richest, are: Luxembourg, United States, Australia, Netherlands, and Austria. The 5 poorest countries, starting with the poorest, are: India, Indonesia, Rest of World, China, and Brazil. The relationships are well approximated by a linear trend across income levels (i.e., there are no hump shapes), so the rich-versus-poor comparison provides sufficient information.

Each variety can be produced using labor and intermediate (composite) goods:

$$y_{bi}(x_b) = z_{bi}(x_b)\left(T_{bi}L_{bi}(x_b)\right)^{\nu_{bi}}\left(\prod_{n\in\{a,m,s\}} M_{bni}(x_b)^{\mu_{bni}}\right)^{1-\nu_{bi}}.$$

The term $M_{bni}(x_b)$, for $n,\ b\in\{a,\ m,\ s\}$, is the quantity of the composite good of type n used by country i as an input to produce variety x_b, and $L_{bi}(x_b)$ is the quantity of labor used.

The country-specific parameter $\nu_{bi}\in[0,\ 1]$ is the share of value added in total output in sector b, while $\mu_{bni}\in[0,\ 1]$ is the share of composite good n in total spending on intermediates by producers in sector b, with $\sum_n \mu_{bni} = 1$.

The term T_{bi} is the fundamental productivity that scales value-added for all varieties in sector b in country i. The term $z_{bi}(x_b)$ scales gross-output of variety x_b in sector b of country i. Following Eaton and Kortum (2002), gross-output productivities for each variety are drawn from independent Fréchet distributions with sector-specific shape parameters θ_b. The c.d.f. for idiosyncratic productivity draws in sector b in country i is $F_{bi}(z) = \exp(-z^{-\theta_b})$.

Preferences. The representative household has generalized, non-homothetic CES preferences defined over per-capita consumption, as in Comin et al. (2018):

$$\sum_{b\in\{a,m,s\}} \omega_b\left(\frac{C_i}{L_i}\right)^{\frac{\varepsilon_b-\sigma}{\sigma}}\left(\frac{C_{bi}}{L_i}\right)^{\frac{\sigma-1}{\sigma}} = 1,$$

where C_i denotes aggregate consumption (utility) in country i and C_{bi} denotes consumption of the sector b good in country i. The parameter $\omega_b\in(0,\ 1)$ determines the relative importance of the sector b good in aggregate consumption, with $\sum_b \omega_b = 1$. The term $\sigma > 0$ is the elasticity of substitution between the goods. The parameter ε_b governs the income elasticity of demand for the sector b good. Preference parameters are constant across countries.

Budget constraint. The representative household earns income by inelastically supplying labor domestically at the wage rate w_i. The budget constraint is

$$P_{ai}C_{ai} + P_{mi}C_{mi} + P_{si}C_{si} = w_iL_i - \zeta_i,$$

where P_{bi} is the price of the composite good in sector b. The representative household in country i transfers a net value of ζ_i to foreign countries. If $\zeta_i > 0$ then country i has a trade surplus; otherwise it has a deficit. I assume that net transfers in each country are a constant share of world GDP as in Costinot and Rodríguez-Clare (2014). This assumption maintains the static nature of the household's problem, yet still allows for aggregate trade imbalances. In the Appendix I consider an alternative specification in which trade imbalances are modeled as income proceeds from a global portfolio as in Caliendo et al. (2017).

Trade. International trade is subject to barriers. Country i must purchase $d_{bij}\geq 1$ units of any variety of sector b from country j in order for one unit to arrive; $d_{bij}-1$ units *melt* away in transit. As a normalization I assume that $d_{bii} = 1$ for all $(b,\ i)$.

Equilibrium. A competitive equilibrium satisfies the following conditions: (1) the representative household maximizes utility taking prices as given, (2) firms maximize profits taking prices as given, (3) each country purchases each variety from its least-cost supplier, and (4) markets clear. World GDP is the numéraire: $\sum_i w_iL_i = 1$. Equilibrium conditions are described in detail in the Appendix.

4. Calibration

The calibration is split into (i) common parameters and (ii) country-specific parameters. While time-series data are utilized to estimate the common parameters, country-specific parameters are calibrated for the year 2011 only. Data come from five sources: the GGDC 10-sector Database (see Timmer et al., 2015a), the EU KLEMS Database, the GGDC Productivity Level Database (see Inklaar and Timmer, 2014), PWT, and WIOD.[5]

4.1. Common parameters

Parameters that are common across countries are the preference parameters, ω_a, ω_m, ω_s, ε_a, ε_m, ε_s, and σ, the sector-specific shape parameters for the Fréchet distributions, θ_a, θ_m, and θ_s (trade elasticities from now on), and the elasticity of substitution between the individual varieties within the composite good, η. The parameter values are listed in Table 2.

Preference parameters. Preference parameters are estimated by exploiting both time series and cross sectional variation by constructing a panel of internationally comparable prices for 34 countries during the period 1995–2011, or whatever years that data are available for each country; data details are in the Appendix. Specifically, I minimize the squared distance

[5] The WIOD provides data on production, trade, intermediate expenditures, and final expenditures, all at basic prices. All values of intermediate and final expenditures in a sector reflect the amount receivable by the producer (in that sector) from the consumer after netting out taxes/subsidies and distribution margins. See Timmer et al. (2012) for further details on the construction of WIOD.

Table 2
Common parameters.

Relative weights in utility	$\omega_a = 0.01$	$\omega_m = 0.06$	$\omega_s = 0.93$
Income elasticities of demand	$\varepsilon_a = 0.19$	$\varepsilon_m = 1.00$	$\varepsilon_s = 1.19$
Price elasticity of demand	$\sigma = 0.40$		
Trade elasticities	$\theta_a = 4$	$\theta_m = 4$	$\theta_s = 4$

between the sectoral expenditures observed in WIOD and the sectoral expenditures implied by the first-order conditions using the panel of sectoral prices and aggregate consumption:

$$\min_{\substack{\omega_a,\omega_m,\omega_s,\\ \varepsilon_a,\varepsilon_s,\sigma}} \sum_t \sum_{b\in\{a,s\}} \sum_{i=1}^{I} \left[\left(\frac{\omega_b}{\omega_m}\right)^{\sigma} \left(\frac{P_{bit}}{P_{mit}}\right)^{1-\sigma} \left(\frac{C_{it}}{L_{it}}\right)^{\varepsilon_b - 1} - \left(\frac{E_{bit}}{E_{mit}}\right) \right]^2$$
$$\text{s.t. } \sigma, \omega_a, \omega_m, \omega_s \geq 0 \text{ and } \omega_a + \omega_m + \omega_s = 1.$$

The subscript t denotes the year. Consumption, C_{it}, is measured in a way that is internally consistent with the model as follows. GDP per capita (at PPP) in the model is defined as $y_i = w_i/P_{ci}$, which implies that $P_{ci}/w_i = 1/y_i$, by taking y_i directly from PWT. Next, note that $P_{ci}C_i = \sum_b E_{bi}$, which implies $C_i = \left(\frac{\sum_b E_{bi}}{w_i}\right)\left(\frac{w_i}{P_{ci}}\right)$, where the wage is computed as the aggregate value added per person: $w_i = (1/L_i)\sum_b \text{value added}_{bi}$.

As in Comin et al. (2018), income elasticities are estimated in relative terms (i.e., $\varepsilon_a - \varepsilon_m$ and $\varepsilon_s - \varepsilon_m$) so I set $\varepsilon_m = 1$ as the base. My estimate of $\varepsilon_a = 0.19$ is higher than the benchmark estimate in Comin et al. (2018) of 0.02, while my estimate of ε_s is very similar: 1.19 versus 1.17. My sample period is shorter so excludes really low-income observations present in Comin et al. (2018), accounting for my higher estimate of ε_a.

My estimate of the price elasticity, σ, is lower than that in both Comin et al. (2018) and Herrendorf et al. (2013). The latter paper uses time-series data for the United States only, and also uses CES preferences with Stone-Geary subsistence parameters, which do not separate income effects from substitution effects. I use exactly the same preferences as Comin et al. (2018) and the same data source for prices. However, their estimation uses data on employment shares in place of final expenditure shares. In my model employment shares equal value-added shares, however, value-added shares equal final expenditure shares only in a closed-economy model with no intermediate inputs. In the data, services' share in final expenditures rises slower with development than does services' share in employment; hence, using final expenditure data results in a lower estimated price elasticity.

Trade elasticities. Simonovska and Waugh (2014) estimate the trade elasticity for manufacturing to be 4. As such, I set $\theta_a = \theta_m = \theta_s = 4$. In Section 6, I estimate sector-specific trade elasticities and show that the results are robust. Finally, I set $\eta = 4$.[6]

4.2. Country-specific parameters

Some parameters are directly observable: factor shares—ν_{bi} and μ_{bni}, for $(n, b) \in \{a, m, s\}$—the labor endowment, L_i, and aggregate net exports, ζ_i. The remaining parameters are unobservable: fundamental productivity, T_{bi}, and the bilateral trade barriers, d_{bij}.

Factor shares. Factor shares come directly from country-specific input-output tables in WIOD: the share of value added in gross output in each sector, ν_{bi}, for $b \in \{a, m, s\}$, and the intermediate input shares in each sector, μ_{bni}, for $(n, b) \in \{a, m, s\}$.

Labor endowments and trade imbalances. The labor endowment is set equal to the size of the population from PWT. Aggregate net exports in country i is given by $\zeta_i = \sum_b \sum_j (X_{bji} - X_{bij})$, where X_{bij} is the gross trade flow (from WIOD) from country j to i in sector $b \in \{a, m, s\}$. Data are converted to model units so that world GDP equals 1.

Fundamental productivity and trade barriers. The fundamental productivities and the trade barriers are unobservable and are chosen so that the model matches the following for each country: the sectoral composition of value added, the sectoral bilateral trade shares, and GDP per capita. The calibration procedure builds on Święcki (2017), and the details are given in the Appendix.[7] In each sector, calibrated productivity varies positively with economic development, while cross-country productivity differences are larger in agriculture than in other sectors (see Gollin et al., 2014; Restuccia et al., 2008). Calibrated trade barriers are, on average, highest in services and lowest in industry, while all trade barriers decline with development as in Waugh (2010).

[6] The parameter η plays no quantitative role other than satisfying a technical condition: $1 + \frac{1}{\theta_b}(1-\eta) > 0$.

[7] The WIOD database provides bilateral trade data for each sector in final goods and intermediate goods separately. However, the production data is only segregated by industry and not by use. Therefore, it is not possible to calibrate production functions and trade barriers by use, but only by industry. As such, I use total trade flows at the sectoral level to construct bilateral trade shares in the data. This implies that the bilateral trade shares in the model are the same for final goods as they are for intermediate goods.

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In multi-sector open-economy models, researchers often rely on gravity-based approaches to estimate these parameters as in Levchenko and Zhang (2016). However, gravity-based estimates are not able to replicate both production and trade data simultaneously.

The approach used here, by design, allows the model to replicate the targets almost perfectly. The model matches sectoral net exports over GDP as well. The key to this result is the fact that the ratio of value added to gross output differs across countries. That is, GDP is a value-added concept, while bilateral trade shares are constructed using gross trade flows and gross output. Hence, simultaneously matching both of these requires being consistent with the ratio of value added to gross output in each sector and in each country. In addition, matching both the net export data and GDP data requires aggregate trade imbalances.[8]

5. Results

The model admits an input-output representation for each country that is useful for analyzing the channels through which sectoral linkages matter for structural change; see the Appendix for the full derivation. Let $N_{bi} = \sum_{j=1}^{I} \left(P_{bj}Q_{bj}\pi_{bji} - P_{bi}Q_{bi}\pi_{bij}\right)$ denote country i's net exports in sector b, let $E_{bi} = P_{bi}C_{bi}$ denote final absorption, and let $V_{bi} = w_i L_{bi}$ denote value added. Expressed in terms of shares in aggregate GDP, using lowercase letters,

$$\underbrace{\begin{bmatrix} v_{ai} \\ v_{mi} \\ v_{si} \end{bmatrix}}_{v_{it}} = \underbrace{\begin{bmatrix} \Omega_{aai} & \Omega_{ami} & \Omega_{asi} \\ \Omega_{mai} & \Omega_{mmi} & \Omega_{msi} \\ \Omega_{sai} & \Omega_{smi} & \Omega_{ssi} \end{bmatrix}}_{\Omega_{it}} \underbrace{\begin{bmatrix} e_{ai} + n_{ai} \\ e_{mi} + n_{mi} \\ e_{si} + n_{si} \end{bmatrix}}_{f_{it}}. \tag{1}$$

The *total requirements matrix*, Ω_i, uniquely governs the relationship between the composition of final demand and the composition of value added; it depends only on exogenous factor shares in country i. The coefficient Ω_{msi} is the total—direct plus indirect—share of industrial value-added embedded in country i's final demand for services: $\sum_{n\in\{a,m,s\}} \Omega_{nbi} = 1$, for all (b, i).

Eq. (1) provides a natural framework to do accounting. Specifically, cross-country variation in the composition of value added is fully accounted for by cross-country variation in sectoral linkages and cross-country variation in the composition of final demand.

5.1. Accounting exercise

First, consider removing cross-country variation in sectoral linkages. Define $\bar{\Omega}_t = \left(\frac{1}{I}\right)\sum_{i=1}^{I}\Omega_{it}$ as the "average" time-varying, total requirements matrix in year t. Then compute the implied shares in value added using $\bar{\Omega}_t$ in Eq. (1) together with the observed country-specific final demand shares, f_{it}. For both the data and the implied shares, I estimate a curve of industry's share against a second-degree polynomial in log-GDP per capita:

$$v_{mit} = \alpha + \beta_1 \ln(y_{it}) + \beta_2 \ln(y_{it})^2 + \epsilon_{it}. \tag{2}$$

The results for the implied industry value added shares are plotted, along with the baseline shares, in the left panel of Fig. 2. In the baseline, there is strong evidence of the hump shape. Clearly, the curve becomes substantially flatter using the imputed shares. Indeed, the estimated coefficient on the second-degree term, β_2 in Eq. (2), falls in absolute value by 74 %—from −0.0183 in the baseline to −0.0031—and is statistically different.

The implied shares of agriculture and services also differ substantially from the baseline. In the five poorest countries, agriculture's share in value added is, on average, only 6 percentage points higher than that in the five richest countries, compared to 13 percentage points in the baseline. The implied share of services for poor countries is only 13 percentage points lower than that of rich countries, compared to 22 percentage points in the baseline.

Second, consider a parallel exercise by removing cross-country variation in the composition of final demand. Define $\bar{f}_t = \left(\frac{1}{I}\right)\sum_{i=1}^{I} f_{it}$ as the cross-country average composition of final demand in each year t. Then use Eq. (1) to compute the implied shares in value added using $\bar{f}_t$ alongside the observed country-specific total requirements matrix, Ω_{it}. For the implied shares, I again estimate a curve using the implied shares in (2). The results for the implied industry value added shares are plotted, along with the baseline shares, in the right panel of Fig. 2. There is a slight reduction in the curvature in the hump shape. The estimated coefficient on the second-degree term (β_2 in Eq. (2)) falls in absolute value by 36 percent—from −0.0183 in the baseline to −0.0117—and is statistically different.

In sum, cross-country differences in both the composition of final demand and in sectoral linkages are important for accounting for systematic differences in agriculture's and services' share in value added. However, cross-country variation in sectoral linkages is roughly twice as important as variation in the composition of final demand in accounting for the hump

[8] The calibration replicates data on final absorption in each sector and every country. This is automatic since the model is calibrated to match the output values and the input-output coefficients.

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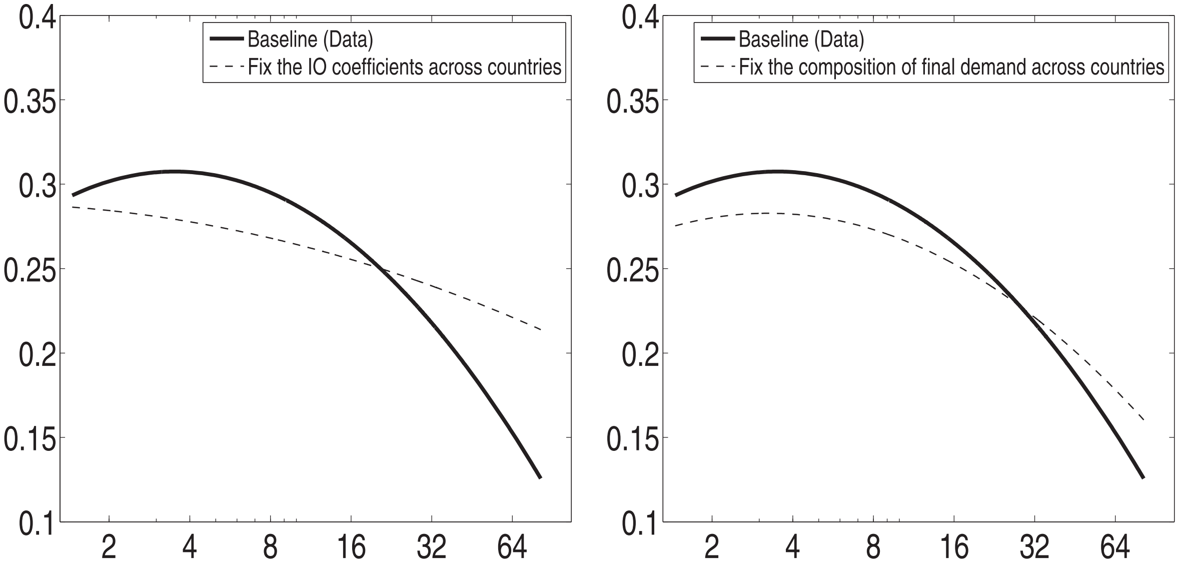

Fig. 2. Implied composition of value added across levels of development **Note:** In each subfigure, the vertical axis represents industry's share in value added, and the horizontal axis represents GDP per capita at PPP in thousands of 2005 U.S. dollars, across 41 countries from 1995 to 2011. Each panel displays the best-fit curves from regressing industry's share in value added against a second-degree polynomial in the log of GDP per capita. The left panel displays the implied share by holding the IO structure fixed across countries and feeding in the observed composition of final demand from 1995 through 2011. The right panel displays the implied share by holding the composition of final demand fixed across countries and feeding in the observed input-output coefficients.

shape in industry's share in value added. Next I consider a general equilibrium environment in which the composition of final demand depends on the sectoral linkages.

5.2. Counterfactual

In this counterfactual structural change occurs over time because of exogenously evolving fundamental productivity. Productivity grows at equal rates across countries so as to isolate the importance of differences in sectoral linkages in determining asymmetries in equilibrium outcomes across countries. Fundamental productivity growth is 3.11 percent per period in agriculture, 2.70 percent in industry, and 1.78 percent in services.[9] Table 3 reports the change in key endogenous variables after 10 periods, relative to the initial period.

Table 3 also reports results from an analogous counterfactual exercise in an alternative model in which sectoral linkages are equalized across countries. In the alternative model, ν_{bi} and μ_{bni} are set equal to the cross-country average in 2011. The fundamental productivities and trade barriers are re-calibrated to match the same targets as in the baseline model.[10] The alternative model is then hit with an exogenous evolution of productivity exactly as in the baseline specification.

The results expose how sectoral linkages impact the transmission from fundamental productivity growth to changes in the composition of final demand. I flesh out this channel in three steps: how changes in fundamental productivity impact (i) measured productivity, (ii) relative prices, and (iii) the composition of final demand. The channel connecting the composition of final demand to the composition of value added is the same as Section 5.1.

Impact on measured productivity. First consider the margin linking fundamental productivity, T_{bi} (which scales value added), to measured productivity, Z_{bi} (which scales gross output). Since $Z_{bi} \propto (T_{bi})^{\nu_{bi}}(\pi_{bii})^{-1/\theta_b}$, there are two components to consider. The first is the share of value added in gross output, ν_{bi}. The larger this share is, the greater will be the response of measured productivity to an increase in fundamental productivity.

The second component is the home trade share, π_{bii}, reflecting the degree of specialization as discussed in Finicelli et al. (2012). The response of this component to fundamental productivity growth in its own sector tends to be positive: higher fundamental productivity increases the share of goods that a country produces in that sector. In the case of fundamental productivity growth in other sectors, the impact on the home trade share is ambiguous, although it generally

[9] These growth rates are based on cross-country averages computed in the data. GGDC and EU KLEMS provide data on employment and value added at constant prices for 34 out of the 41 countries in my sample. For these countries I compute growth rates in fundamental productivity from 1995 to 2011 or whichever years are available. That is, real value-added productivity in sector b in country i at time t is $\frac{V_{bit}^{constant\,price}}{L_{bit}}$, which corresponds to $(Z_{bit})^{1/\nu_{bit}}$ in the model. I then correct for the home trade share to extract fundamental productivity as $T_{bit} = (Z_{bit}(\pi_{biit})^{1/\theta_b})^{1/\nu_{bi}}$.

[10] In the calibration of the alternative model, the model matches the targets perfectly. However, it is not able to reproduce the data on final absorption, since the IO linkages are counterfactual, by construction.

Table 3
Response to exogenous change in fundamental productivity.

Changes		Baseline			Same IO		
		Agr	Ind	Srv	Agr	Ind	Srv
Hm. trade share	Poor	0.08	0.14	0.03	0.01	0.07	0.02
$\Delta\ln(\pi_b)$ (pct)	Rich	−1.15	−0.33	−0.06	−0.08	0.00	−0.05
Meas. prod.	Poor	20.65	9.30	10.00	15.33	8.96	10.11
$\Delta\ln(Z_b)$ (pct)	Rich	14.06	9.71	9.47	15.35	8.98	10.13
Sectoral price	Poor	−28.66	−24.85	−19.71	−26.83	−23.83	−18.80
$\Delta\ln(P_b/w)$ (pct)	Rich	−26.48	−23.78	−18.48	−26.87	−23.87	−18.84
Dom. exp. shr.	Poor	−1.29	−0.90	2.20	−2.76	−0.18	2.94
Δe_b (ppts)	Rich	−0.19	−0.89	1.03	−0.07	−0.64	0.72
NX share	Poor	0.01	−0.03	0.01	0.04	−0.01	−0.03
Δn_b (ppts)	Rich	−0.04	0.01	0.08	−0.04	−0.07	0.10
VA share	Poor	−1.02	−0.37	1.38	−1.59	−0.24	1.83
$\Delta\nu_b$ (ppts)	Rich	−0.15	−0.49	0.64	−0.09	−0.37	0.46
Agg. cons.	Poor		19.20			22.46	
$\Delta\ln(C)$ (pct)	Rich		15.88			15.46	

Note: The table reports changes in key variables in response to equal changes in fundamental productivity, T_{bi}, across countries—agriculture increases by 35.83%, industry by 30.53%, and services by 19.30%—holding all other parameters at their baseline values. Results are for the average of the 5 richest and 5 poorest countries, respectively, in terms of GDP per capita in 2011. "Baseline" refers to the baseline model. "Same IO" refers to the alternative model in which every country has identical (cross-country average) sectoral linkages.

decreases. For instance, all else equal, higher fundamental productivity in industry increases the aggregate wage rate and makes services exports more expensive, thus reducing the home trade share in services.

In the baseline specification, measured agricultural productivity in poor countries increases by significantly more than in rich countries: 21 percent versus 14 percent. All of this asymmetry stems from the fact that the share of value added in agricultural output is higher in poor countries than in rich countries. The home trade share increases in poor countries and decreases in rich countries, which, all else equal, would reduce measured productivity in poor countries relative to rich countries.

There is far less asymmetry between rich and poor countries in the response of measured productivity in industry and in services, particularly since the share of value added in gross output in these two sectors does not systematically differ between rich and poor countries. The home trade shares are differentially impacted in rich versus poor countries, but the quantitative magnitude of these changes is small.

The quantitative importance of differences in sectoral linkages becomes more evident when examining the alternative specification. In the alternative model, there is essentially no difference between rich and poor countries in the response of measured productivity in any of the sectors. This is because the share of value added in gross output is equal across countries. The only margin for potentially differential effects is through asymmetric responses in home trade shares; the asymmetry in these responses is quantitatively negligible.

Impact on prices. Table 3 reports changes in relative prices, P_{bi}/w_i, so that the numbers are unit free and comparable across model specifications. In the baseline model, the price of agriculture falls by more in poor countries than in rich countries. This is because value-added productivity grows faster in agriculture than in other sectors, and agricultural production is more value-added intensive in poor countries than in rich countries.

Prices of both industry and services output decline by less in rich countries than in poor countries because rich countries use services more intensively as an input in both industry and services production. Productivity growth is slower in services than in the other sectors, increasing the price of services relative to the other sectors in all countries.

With sectoral linkages equal across countries, there are essentially no differences between rich and poor countries in how relative prices respond to exogenously evolving productivity.

Impact on the composition of final demand. Recall that final demand is comprised of final absorption and net exports. Beginning with final absorption, note that the preference structure parsimoniously separates the Baumol effect from the income effect:

$$\ln\left(\frac{P_{bi}C_{bi}}{P_{ni}C_{ni}}\right) = \sigma \ln\left(\frac{\omega_b}{\omega_n}\right) + (1-\sigma)\ln\left(\frac{P_{bi}}{P_{ni}}\right) + (\varepsilon_b - \varepsilon_n)\ln\left(\frac{C_i}{L_i}\right).$$

In the baseline specification, agriculture's share in final absorption declines in all countries for two reasons. One is because of the Baumol effect: the relative price of agriculture falls and $0 < \sigma < 1$. The second is the income effect: income (aggregate consumption) increases and $\varepsilon_a < \varepsilon_m < \varepsilon_s$. Both the Baumol effect and the income effect are larger in poor countries than in rich countries; hence, agriculture's share declines by more in poor countries than in rich countries. Services' share increases by more in poor countries than in rich countries. There is little difference across countries in the change in industry's share.

In the alternative specification, there are larger asymmetries between rich and poor countries in the response of the composition of final absorption, relative to that in the baseline model. However, in the alternative model, none of the asymmetries are explained by the Baumol effect since relative prices are impacted similarly in both sets of countries. All of the asymmetries stem from income effects, which are larger in poor countries than in rich countries. In particular, the differential between rich and poor countries in terms of the income effect is greater in the alternative model than in the baseline model.

The other component of final demand is net exports, which changes in line with comparative advantage. Poor countries gain comparative advantage in agriculture and lose comparative advantage in industry. Agricultural production is more value-added intensive in poor countries: given otherwise equal increases in value-added productivity, poor countries experience a larger decline in marginal costs of producing agriculture, and thus produce and export a larger share of agricultural varieties. As a result, agriculture's share in net exports increases in poor countries while it decreases in rich countries. Similarly, industry's share in net exports declines in poor countries while it increases in rich countries.

This result suggests that trade contributes negatively to the hump shape in industry's share in value added across income levels. While this appears at odds with the results in Uy et al. (2013), it is actually not. In their model manufacturing productivity grows faster in South Korea (the poor country) than in the rest of the world (mostly OECD), and also faster than in other sectors in Korea. This implies an increase in South Korea's comparative advantage in manufacturing, thus generating the increase in the hump. In their model manufacture's share tapers off as ongoing structural change swells the service sector.

Services' share in net exports increases by more in rich countries than in poor countries, but because of income effects and not comparative advantage. Since income increases by more in poor countries, there is a larger increase in demand for services consumption than in rich countries. This "increased demand" increases the poor countries' net imports of services.

In the alternative model, comparative advantage is not impacted significantly, but the composition of net exports is impacted by more than in the baseline model. This is, again, because of income effects, which in poor countries are greater in the alternative model than in the baseline model: rich countries export the "increased demand" for services by poor countries, and reduce exports for the "decreased demand" for agriculture in poor countries.

In both model specifications, the changes in the composition of net exports are quantitatively insignificant compared to the changes in the composition of final absorption.

5.3. Discussion

There are two main channels through which sectoral linkages matter for structural change. First, differences in sectoral linkages result in asymmetric responses in the composition of value added to otherwise identical changes in the composition of final demand. Take as given a decline in agriculture's share in final demand and a rise in services' share. Since agricultural production is more value-added intensive in poor countries than in rich countries, then all else equal, agriculture's share in value added declines by more in poor countries than in rich countries, thus shedding resources into industry and services. Since rich countries utilize service inputs more intensively than poor countries in production across all sectors, particularly in services itself, services' share in value added increases by more in rich countries than in poor countries. Resultantly, industry's share in value added in rich countries falls relative to poor countries, casting new light on the hump shape of industry's share.

Second, cross-country differences in sectoral linkages result in asymmetric responses of relative prices to otherwise identical changes in productivity. Below I derive a testable prediction to empirically examine the validity of this second channel.

Empirical evidence. The Appendix shows that the response of relative prices in country i to a change in measured productivity is given by

$$\frac{\partial \ln\left(\frac{P_{bi}}{w_i}\right)}{\partial \ln(Z_{ni})} = -\Gamma_{bni}, \tag{3}$$

holding all else equal. The key is that the term Γ_{bni} depends only on the exogenous factor intensities in country i. The "all else equal" qualifier involves some hand waving since, in general equilibrium, measured productivity, Z_{ni}, is itself endogenously determined.

To evaluate the empirical validity of Eq. (3), I examine time-series data on prices and productivity across a panel of countries. See the Appendix for details on the empirical counterparts to prices and measured productivity.

For each sector b and each country i, I estimate a time-series equation using OLS:

$$\Delta \ln\left(\frac{P_{bit}}{w_{it}}\right) = \kappa_{bi} + \sum_{n\in\{a,m,s\}} \beta_{bni}\Delta \ln(Z_{nit}) + \rho_{bi}\mathbf{X}_{it} + \epsilon_{bit}, \tag{4}$$

where κ_{bi} is an intercept term, Δ is the first time-difference operator, and subscript t denotes the year of the observation. The control vector $\mathbf{X}_{it}$ includes a year fixed effect, the growth rate of GDP per capita, and openness as measured by the ratio of trade to value added in each sector. I estimate Eq. (4) for 34 countries during the period 1995–2011, or whatever years are available for each country. I choose this sample so that it contains only countries and years that coincide with WIOD, since the coefficients, Γ_{bni}, come from WIOD.

Table 4
Robustness: Response to exogenous change in fundamental productivity.

		Baseline			Endog. trade imb.			Different θ_b			CES with Stone Geary		
Changes		Agr	Ind	Srv	Agr	Ind	Srv	Agr	Ind	Srv	Agr	Ind	Srv
Hm. trade share	Poor	0.08	0.14	0.03	0.07	0.12	0.03	0.14	0.13	0.01	0.07	0.12	0.02
$\Delta\ln(\pi_b)$ (pct)	Rich	−1.15	−0.33	−0.06	1.14	0.34	0.05	1.92	0.37	0.03	0.44	0.30	0.06
Meas. prod.	Poor	20.65	9.30	10.00	20.65	9.31	10.00	20.65	9.31	10.00	20.65	9.31	10.00
$\Delta\ln(Z_b)$ (pct)	Rich	14.06	9.71	9.47	14.06	9.71	9.47	13.99	9.69	9.46	13.88	9.70	9.47
Sectoral price	Poor	−28.66	−24.85	−19.71	−28.66	−24.86	−19.71	−28.67	−24.87	−19.72	−28.67	−24.85	−19.71
$\Delta\ln(P_b/w)$ (pct)	Rich	−26.48	−23.78	−18.48	−26.48	−23.78	−18.48	−26.38	−23.74	−18.46	−26.27	−23.76	−18.48
Dom. exp. shr.	Poor	−1.29	−0.90	2.20	−1.29	−0.89	2.23	−1.29	−0.90	2.20	−1.08	−0.26	1.36
Δe_b (ppts)	Rich	−0.19	−0.89	1.03	−0.19	−0.90	0.98	−0.19	−0.89	1.01	−0.06	−0.47	0.48
NX share	Poor	0.01	−0.03	0.01	0.01	0.06	0.00	0.05	0.06	0.00	0.03	0.05	0.01
Δn_b (ppts)	Rich	−0.04	0.01	0.08	0.04	0.01	0.13	0.05	0.03	0.14	0.04	0.01	0.10
VA share	Poor	−1.02	−0.37	1.38	−1.02	−0.38	1.39	−0.99	−0.38	1.37	−0.82	−0.08	0.90
$\Delta\nu_b$ (ppts)	Rich	−0.15	−0.49	0.64	−0.15	−0.49	0.64	−0.15	−0.51	0.66	−0.07	−0.26	0.33
Agg. cons.	Poor		19.20			19.24			19.22			22.48	
$\Delta\ln(C)$ (pct)	Rich		15.88			15.82			15.85			19.61	

Note: The table reports changes in key variables in response to equal changes in fundamental productivity, T_{bi}, across countries—agriculture increases by 35.83%, industry by 30.53%, and services by 19.30%—holding all other parameters at their baseline values. Results are for the average of the 5 richest and 5 poorest countries, respectively, in terms of GDP per capita in 2011. "Baseline" refers to the baseline model. "Endog. trade imbalances" refers to the alternative model in which trade imbalances are treated as income proceeds from a global portfolio as in Caliendo et al. (2017). "Different θ_b" refers to the alternative model in which the trade elasticities are sector specific. "CES with Stone Geary" refers to the alternative model with CES/Stone-Geary preferences as in Uy et al. (2013).

The theory predicts that $\hat{\beta}_{bni} \propto -\Gamma_{bni}$ for each country i. The cross-country correlation between $\hat{\beta}_{bni}$ and $-\Gamma_{bni}$ is positive in 8/9 sector pairs, the exception being for (s, a), which is not statistically different from zero. Moreover, in the model Γ_{sai} is close to zero for most countries since agriculture is not an important input in the production of services. The correlation is positive *and* statistically significant at the 95 percent level in 5/9 sector pairs: (a, a), (a, m), (m, m), (s, m), and (s, s). The most significant correlations pertain to the diagonal, which are also economically the largest in value, (a, a), (m, m), and (s, s).

6. Robustness

This section considers alternative modeling choices: (i) a different way to handle trade imbalances, (ii) sector-specific trade elasticities, and (iii) a different preference specification. All of the accounting results in Section 5.1 are unaffected. As such, I only focus on the channels through which sectoral linkages determine the composition of final demand in general equilibrium. I re-calibrate each model to match the same targets as the baseline and run the same counterfactual as in Section 5.2: fundamental productivity in each sector is increased equally across countries – by 35.83 percent in agriculture, 30.53 percent in industry, and 19.30 percent in services. For each alternative model, I present the main modeling changes and discuss the key results, which are summarized in Table 4. The Appendix provides further details about implementing each alternative specification and also includes a closed economy specification.

Alternative treatment of trade imbalances. In the baseline model trade imbalances are fixed with respect to world GDP as in Costinot and Rodríguez-Clare (2014). Here imbalances are modeled as income proceeds from a global portfolio as in Caliendo et al. (2017). Each country allocates an exogenous share of income, ρ_i, to a global portfolio that disperses a per-capita transfer, R, to each country. The budget constraint becomes

$$P_{ai}C_{ai} + P_{mi}C_{mi} + P_{si}C_{si} = w_iL_i + RL_i - \rho_i w_i L_i.$$

Net exports in country i is given by $\rho_i w_i L_i - RL_i$. The global portfolio must balance:

$$\sum_{i=1}^{I} RL_i = \sum_{i=1}^{I} \rho_i w_i L_i.$$

For the calibration I set ρ_i equal to country i's observed ratio of net exports to GDP, which implies that $R = 0$ in equilibrium, since net exports sum to zero globally.

As productivity counterfactually changes, ρ_i is unchanged and R adjusts endogenously. Relative to the baseline model, there are minor differences in the response of the composition of net exports: in the alternative model, industry's share in net exports declines by more in poor countries, while services' share in net exports increases by more in rich countries. However, the quantitative magnitude of this difference is small and the net effect on the composition of value added is almost identical.

Alternative trade elasticities. In the baseline model I set the values of trade elasticities for each sector to $\theta_a = \theta_m = \theta_s = 4$. However, given the importance of trade elasticities for evaluating how prices and trade flows respond to shocks, it is important to ask how robust the results are to allowing the trade elasticities to vary across sectors. I follow the methodology of Simonovska and Waugh (2014) and estimate trade elasticities for each sector.

My estimates yield $\hat{\theta}_a = 8.8$, $\hat{\theta}_m = 5.6$, and $\hat{\theta}_s = 6.2$. The estimate for industry is slightly higher than that of Simonovska and Waugh (2014). Caliendo and Parro (2015) propose another method for estimating trade elasticities. Their median elasticity across manufacturing subindustries is 5.3 and for agriculture is 8.1.

Gervais and Jensen (2013) bypass trade data and estimate elasticities for many disaggregate sectors. Their average service elasticity is greater than their manufacturing elasticity – an opposite ranking compared to my estimates. In their model, trade elasticities coincide with demand elasticities because of Armington-type preferences, while monopolistic competition implies that markups are the inverse of the elasticities. Empirically, the ratio of gross value added to gross operating surplus is higher in service sectors than in manufacturing, yielding a lower trade elasticity for services compared to manufacturing.

My estimation utilizes bilateral trade data and disaggregate country-level price data. Empirically, even though services bilateral trade shares tend to be small, they are actually large conditional on the magnitude of trade barriers and cross-country price differences in services. That is, small changes in trade costs or relative prices coincide with relatively greater bilateral trade shares, comparatively speaking with respect to manufacturing.

Since the trade elasticities are slightly different from the baseline model, the response of home trade shares, prices, and total income slightly differ somewhat. Nonetheless the implications for structural change are quantitatively similar to those in the baseline model.

Alternative preferences. A key channel in the model is how final absorption shares respond to relative prices, which hinges on preferences. The literature commonly uses CES with Stone Geary, (see Herrendorf et al., 2013; Uy et al., 2013). The key difference between my preference specification (generalized CES) and CES with Stone-Geary is that in the former, income elasticities are constant at all levels of income. In CES with Stone-Geary, income elasticities vanish at as income rises. Baumol effects are similar in the two specifications.

In this exercise I change the preference specification to CES with Stone-Geary:

$$C_i = \left(\omega_a (C_{ai} - L_i\bar{c}_a)^{1-1/\sigma} + \omega_m C_{mi}^{1-1/\sigma} + \omega_s (C_{si} + L_i\bar{c}_s)^{1-1/\sigma}\right)^{\frac{\sigma}{1-\sigma}}. \tag{5}$$

As in Uy et al. (2013) I further restrict $\bar{c}_s = 0$. I set the elasticity of substitution, $\sigma = 0.40$, as in the baseline, and also keep the weights—ω_a, ω_m and ω_s—unchanged. I set $\bar{c}_a = 0.078$ implying that the world subsistence consumption is 30% of total agricultural consumption. In Uy et al. (2013) this share is 60% (they include mining and quarrying in agriculture, I do not). The following results are also robust to other values of $\bar{c}_a$.

Relative to the baseline model, there is little difference in the response of relative prices. In fact, the preference structure has little influence on how relative prices respond to productivity growth. It is the difference in sectoral linkages that generates heterogeneity across countries in the response of relative prices to otherwise identical productivity growth. The two models produce only slightly different income effects.

7. Conclusion

Sectoral linkages systematically vary with economic development across countries and are important for understanding structural change through two channels. First, the mapping from changes in the composition of final demand (final absorption plus net exports) to changes in the composition of value added depends solely on the sectoral linkages. Cross-country differences in sectoral linkages account for 74 percent of the estimated curvature in the hump shape in industry's share in value added across levels of development.

Second, sectoral linkages govern the mapping from sectoral productivity growth into changes in relative prices. Agricultural production is more value-added intensive in poor countries than in rich countries, while services production utilizes service intermediate inputs more intensively in rich countries than in poor countries. Since productivity grows fastest in agriculture and slowest in services across most countries, declines in the relative price of agriculture are greater in poor countries, relative to rich countries, and increases in the relative price of services are greater in rich countries. These price effects amplify the decline in agriculture's share in final absorption in poor countries, relative to rich countries, thereby contributing to the hump shape in industry's share in value added.

Supplementary material

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.jmoneco.2018.08.003.

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