Globalization, Structural Change and International Comovement*

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Abstract

We study the roles of globalization and structural change in the evolution of international GDP comovement over the period 1978-2007. In this period, trade integration between advanced economies increased rapidly while average GDP correlations remained stable. Structural change – reallocation of economic activity towards services – is important in resolving this apparent puzzle. Business cycle shocks in the service sector are less internationally correlated than in manufacturing, and thus structural change lowers GDP comovement by increasing the GDP share of less correlated sectors. Globalization – reductions in trade costs – exerts two opposing effects on international comovement. While greater trade linkages increase international transmission of shocks, globalization also induces structural change towards services. We quantify these effects in a multi-country, multi-sector model of international production and trade. The two opposing effects of globalization on comovement largely cancel each other out, limiting the net contribution of globalization to increasing international comovement.

Keywords: globalization, structural change, international comovement

JEL Codes: F41, F44, F62, L16

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1. Introduction

The decades between the end of World War II and the 2008 Great Trade Collapse are the golden age of trade globalization. The left panel of Figure 1 plots the evolution of the trade to GDP ratio from 1970 to 2007 for the group of wealthy OECD countries. As documented in numerous studies, international trade grew much faster than GDP over this period.

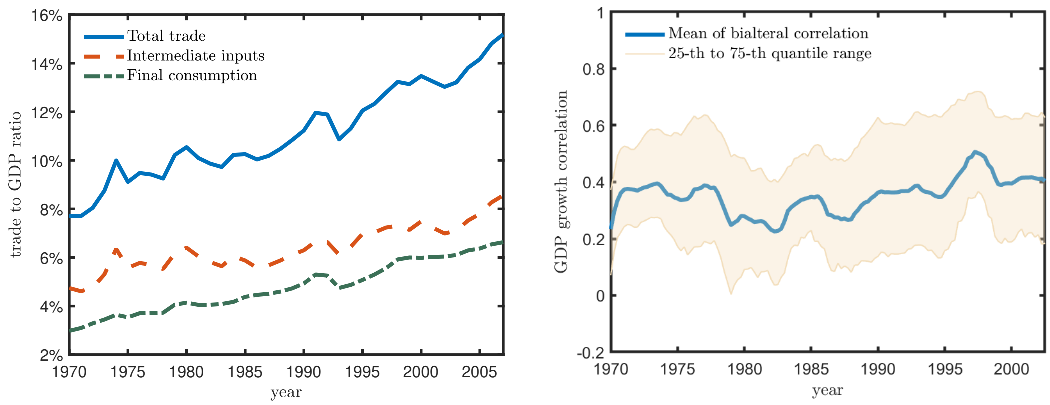
Abundant empirical evidence shows that trade linkages transmit business cycle shocks across countries. It is thus a natural conjecture that these decades of ever closer trade integration should have seen an increase in the international business cycle comovement. The right panel of Figure 1 plots the average 10-year rolling GDP growth correlations in the same sample of countries. Surprisingly, there is no strong upward trend in GDP comovement in the data over these 4 decades: the average correlations in the 2000s are essentially the same as in the 1970s. Indeed, both the short-run variability in the rolling correlations and the cross-sectional dispersion are larger than long-run changes.[1] Transmission of shocks through increasingly important trade and production networks does not appear to have translated into noticeably greater GDP synchronization.

This paper resolves this apparent puzzle, along the way providing a broad narrative of the evolution of GDP comovement from the 1970s to the Great Trade Collapse. We study two forces that acted on international comovement over this period: structural change and globalization. Structural change for the advanced economies is the secular rise in the share of services in value added and employment, and the corresponding fall in the share of manufacturing. Globalization refers to changes in trade costs and tastes that lead to greater import shares. Structural change and globalization matter for comovement because, as we show below, business cycle shocks to services in this period are less correlated internationally than business cycle shocks to manufacturing.[2] A reallocation of economic activity towards services in effect increases the GDP share of the sector that is less correlated internationally, in the process reducing business cycle

[1]Appendix Figure C1 displays (i) the rolling correlation for the G7 countries, showing that if anything there is a modest downward trend in GDP correlation in these major industrial economies; and (ii) the correlation patterns under various detrending methods. The absence of an increase in international comovement over this period is also evidenced by more sophisticated approaches that fit factor models to international macro data. Kose, Otrok, and Whiteman (2008) show that the importance of the common factor in the G7 business cycle did not increase between the 1970s and the mid-2000s. Aruoba et al. (2011) show that the average bilateral correlation of country factors remained stable in the 1970s, 80s, 90s and 2000s before 2008.

[2]The pattern that shocks in manufacturing are more correlated than services holds for the Solow residuals as well as the composite shocks that perfectly replicate the value added data. It is also evident in the simple correlations in value added growth in these sectors. This pattern has not received much attention in the literature. A partial exception is Johnson (2014), who documents that estimated correlations of shocks to manufacturing can match sectoral output comovement in the data, but estimated correlations of shocks to services sectors cannot, suggesting that shocks to services might be less correlated than shocks to manufacturing.

Figure 1: Trends in trade/GDP and GDP comovement, OECD



Trade integration | Bilateral GDP correlations

Notes: The left panel displays the total trade between pairs of OECD countries as a fraction of OECD GDP. The right panel displays the average bilateral rolling quarterly (year-on-year) GDP growth correlations. The year denotes the midpoint of the 10 year rolling window. The shaded bands display the interquartile range. The sample contains countries that were members of the OECD since the beginning of the 1970s.

comovement.

Structural change thus acts to push down cross-country GDP correlations, all else equal. Globalization has two opposing effects. The first is the obvious one prominent in much of the literature: a higher share of international trade in gross output. This produces stronger cross-border transmission of shocks and *ceteris paribus* increases comovement. The second one is less well-known: globalization itself contributes to structural change. A relative fall in manufacturing trade costs lowers the relative price of manufacturing to services, and raises expenditure shares on services when manufacturing and services are complements (Cravino and Sotelo, 2019). As it shifts economic activity towards the less correlated service sector, globalization lowers international comovement all else equal. Thus, globalization actually has an ambiguous effect on international comovement.

We quantify the contribution of these forces to the evolution of international GDP comovement from 1978 to 2007 using a tractable multi-country, multi-sector framework of production and international trade.[3] Our model extends Huo, Levchenko, and Pandalai-Nayar (2023) and

[3]This period of growing trade and stable comovement is the best laboratory to study the effects we highlight. As we now know, world trade to GDP peaked in 2007, while the Global Financial Crisis followed by the European Debt Crisis and the COVID-19 pandemic ushered in an era of large correlated disturbances to both international trade and GDP. While the forces we study find their clearest manifestation in the golden era of globalization, both the basic ideas and the machinery developed here are applicable more generally. Appendix Figure C6 extends the analysis to the most recent available year, 2015.

Bonadio et al. (2021) to a more flexible formulation of labor supply, that nests both traditional business cycle and trade frameworks. The model is adapted to studying business cycle questions, and can fit the data on both trade linkages and international comovement. We use data on the long-run evolution of the world input-output matrix from Johnson and Noguera (2017) and the World Input Output Database, and real output data from EU KLEMS (O'Mahony and Timmer, 2009).

In order to compute and decompose business cycle comovement in our model world economy, we must subject it to some shocks. We present the full set of results with 2 shocks (i) the traditional Solow residual; and (ii) a composite supply shock that rationalizes the observed real value added growth in every country and every sector given the observed structure of production and trade. By construction, therefore, when the composite supply shocks are fed back into the model, it reproduces actual real GDP growth of all countries, and thus can be used as a starting point for decompositions of observed GDP correlations.

Conceptually, countries can experience positive GDP comovement because shocks originating in one country transmit to the other via trade and production linkages; or because shocks in the two countries are correlated. We state a decomposition of the GDP correlation between any two countries into additive components that capture cross-border shock transmission and shock correlation. We implement this decomposition using the observed structure of the world economy in each year between 1978 and 2007. Tracking these components over time illuminates the evolving nature of international comovement. Not surprisingly, the component of GDP correlations due to the international transmission of shocks rose in relative importance over this period. This confirms much of the conventional wisdom about the role of international trade in the transmission of shocks. However, the component capturing the correlation of shocks fell by some 50% at the same time, because the rise in the service share of GDP reallocates economic activity towards the less internationally correlated part of the economy.

As argued by Cravino and Sotelo (2019), globalization can itself be a driver of the rise in the service share. To isolate globalization from other drivers of structural change (such as demand shifts and trend sectoral productivity growth differentials), we then present several counterfactuals designed to separate the impacts of these forces. To implement these counterfactuals, we need to infer the long-run changes in trade costs, tastes, and productivities that drove long-run changes in sectoral shares and international trade openness. We therefore long-difference the model and invert it to obtain the changes in trade costs and preferences in all sectors that rationalize the evolution of sectoral expenditure shares and international trade shares between the 1978 and 2007 world economies. We then start with the 1978 world economy, and feed in one driver of structural change at a time to examine its impact on comovement.

Our first counterfactual focuses on the role of globalization. We compare comovement in the 1978 world economy to a counterfactual economy that started out with the 1978 structure and experienced only the 1978-2007 reductions in international trade costs. Globalization by itself does not necessarily increase international GDP comovement, as the effect of globalization on structural change highlighted above limits the increase in GDP correlations. The components of the overall correlation also change: globalization increases both the absolute and relative importance of shock transmission in overall correlation. On the flip side, the component due to correlated shocks falls, counteracting the impact of greater international transmission. To further illustrate this point, we also present an alternative "globalization-only" counterfactual in which trade costs fall by the same amount but sectoral expenditure shares are held fixed at their 1978 levels. This scenario leads to a clear increase in comovement, as greater cross-border shock transmission is not offset by globalization-driven structural change. Comovement in the globalization scenario without structural change is some 20-30% higher than comovement in the scenario in which globalization also leads to structural change.

The next counterfactual evaluates the role of other drivers of structural change: productivity and preferences. Comovement falls 5-15% when long-run productivity and long-run preference shifters are applied to the 1978 economy. This is expected, since the conventional forces of structural change lead the economy to reallocate expenditure towards the less correlated services.[4]

Related Literature. We contribute to the research program studying international comovement using both theory (see, among many others, Backus, Kehoe, and Kydland, 1992; Heathcote and Perri, 2002; Huo, Levchenko, and Pandalai-Nayar, 2023) and empirics (e.g. Imbs, 1999; Kose, Otrok, and Whiteman, 2003; Ambler, Cardia, and Zimmermann, 2004). There is relatively little work documenting how international comovement has changed over the past decades (the few recent contributions include Kose, Otrok, and Whiteman, 2008; Aruoba et al., 2011; Imbs and Pauwels, 2019; Ko, 2020; Miyamoto and Nguyen, 2024). This paper quantifies how the forces of globalization and structural change interacted to generate the observed evolution of comovement during a period of rapid trade integration. In our quantification, the main international shock

[4]Our preference shifters are a reduced-form way of capturing the role of demand non-homotheticities in structural change (e.g. Kongsamut, Rebelo, and Xie, 2001; Boppart, 2014; Comin, Lashkari, and Mestieri, 2021), among other forces. We do not take a stand on the non-globalization induced sources of structural change in this paper, but instead match changes in sector shares in value added in the data, given the contemporaneous changes in trade costs.

transmission mechanism is through trade in final goods and inputs, following, among others, Burstein, Kurz, and Tesar (2008), Johnson (2014), and our previous work. This paper highlights how the heterogeneity between the goods and service sectors in the cross-border trade intensity and shock correlations conditions the evolution of comovement over time.

A large body of work attempts to understand and quantify the structural transformation process (see Herrendorf, Rogerson, and Valentinyi, 2014, for a recent survey). While the literature has proposed a variety of drivers of structural change, the most relevant for this paper is the idea that large sectors – such as goods and services – are complements (Baumol, 1967; Ngai and Pissarides, 2007). We draw on the literature on structural change in open economies (see, among many others, Matsuyama, 2009; Uy, Yi, and Zhang, 2013; Swiecki, 2017; Sposi, 2019; Sposi, Yi, and Zhang, 2021; Alviarez et al., 2022; Alessandria, Johnson, and Yi, 2023). Most closely related are Cravino and Sotelo (2019) and Lewis et al. (2022). The latter points out that the rise in the relatively non-tradeable services through the process of structural transformation lowers the trade to GDP ratio, all else equal. The former shows that the reduction in trade costs itself can shift economic activity towards the non-tradeable sectors. We explore and quantify the role of these mechanisms in international business cycle comovement.

This paper is also related to the literature that studies business cycles in the context of structural change in the closed economy (e.g. Da-Rocha and Restuccia, 2006; Carvalho and Gabaix, 2013; Moro, 2015; Storesletten, Zhao, and Zilibotti, 2019; Yao and Zhu, 2021). This literature has focused on business cycle volatility, or the cyclical properties of employment changes induced by labor reallocation between sectors. Our study instead explores the role of structural change for international business cycle synchronization and relates it to the strength of trade linkages across countries.

The rest of the paper is organized as follows. Section 2 outlines our theoretical and quantitative framework. Section 3 describes the calibration and illustrates the basic patterns in the data. Section 4 presents the baseline results of the GDP comovement decomposition, and discusses comovement in the counterfactual scenarios. Section 5 concludes.

2. Theoretical Framework

Our theoretical framework extends the model developed in Huo, Levchenko, and Pandalai-Nayar (2023) and Bonadio et al. (2021) to a more flexible labor supply formulation that nests both standard trade and business cycle frameworks.

Preliminaries. Let there be N countries indexed by n, m, and ℓ, J sectors indexed by j, i, and k, and time indexed by t. In our baseline quantitative implementation, $J = 4$: services, manufacturing, agriculture, and non-manufacturing industries. Each country n is populated by households that consume the final good available in country n and supply labor to firms.

Households. There is a continuum of households indexed by ω, that maximize

$$\max_{\mathcal{F}_{nt}(\omega), H_{nt}(\omega)} \left(\mathcal{F}_{nt}(\omega) - \chi_n \frac{H_{nt}(\omega)^{1+1/\psi}}{1+1/\psi} \right) \tag{1}$$

subject to

$$P_{nt}\mathcal{F}_{nt} = W_{nt}(\omega) H_{nt}(\omega)$$

in each period t, where $\mathcal{F}_{nt}(\omega)$ is consumption of final goods, P_{nt} is its price index, and $H_{nt}(\omega)$ is the supply of hours worked, receiving a wage $W_{nt}(\omega)$. Each household can supply labor to any sector j with household-specific productivity $b_{nj}(\omega)$. If household ω decides to work in sector j, it supplies $b_{nj}(\omega)H_{nt}(\omega)$ effective units of labor and collects the labor income of $W_{nt}(\omega)H_{nt}(\omega) = W_{njt} b_{nj}(\omega) H_{nt}(\omega)$, where W_{njt} is the equilibrium price of one efficiency unit of labor in that country-sector. The household idiosyncratic labor productivity in sector j is distributed $b_{nj}(\omega) \sim$ Fréchet(ξ_{nj}, μ), with dispersion parameter μ and central tendency parameter ξ_{nj} that can potentially vary by country and sector:

$$\Pr\left(b_{nj}(\omega) < b\right) = \exp\left(-\xi_{nj} b^{-\mu}\right).$$

Agent ω working in sector j gets utility

$$\frac{W_{njt} b_{nj}(\omega)}{P_{nt}} H_{nt}(\omega) - \chi_n \frac{H_{nt}(\omega)^{1+1/\psi}}{1+1/\psi},$$

and thus the utility-maximizing supply of hours worked to sector j is:

$$H_{nt}(\omega) = \left(\frac{1}{\chi_n} \frac{W_{njt} b_{nj}(\omega)}{P_{nt}} \right)^{\psi},$$

and the indirect utility conditional on working in sector j is given by:

$$\frac{1}{\psi+1} \left(\frac{1}{\chi_n}\right)^{\psi} \left(\frac{W_{njt} b_{nj}(\omega)}{P_{nt}} \right)^{1+\psi}.$$

Household ω chooses to work in sector j if doing so yields the highest indirect utility, specifically, if $W_{njt}b_{nj}(\omega) > W_{nit}b_{ni}(\omega)\ \forall i \neq j$. Standard steps lead to the following share of households that supply labor to j:

$$\pi_{njt}^{H} = \frac{\xi_{nj}\left(W_{njt}\right)^{\mu}}{\sum_i \xi_{ni}\left(W_{nit}\right)^{\mu}}.$$

The total effective labor supply to sector j is equal to the probability that a household works in that sector times the effective units it supplies conditional on working there:

$$H_{njt} = \pi_{njt}^{H}\int_{\omega\in j} H_{nt}(\omega)\, b_{nj}(\omega)\, d\omega.$$

With some manipulation, it can be written as:

$$H_{njt} = \xi_{nj}\left(\frac{1}{\chi_n}\frac{W_{nt}}{P_{nt}}\right)^{\psi}\left(\frac{W_{njt}}{W_{nt}}\right)^{\mu-1}, \tag{2}$$

up to a normalization and under the regularity condition that $\mu > \psi + 1$, where $W_{nt} \equiv \left(\sum_i \xi_{ni}W_{nit}^{\mu}\right)^{\frac{1}{\mu}}$ is an economywide wage index. Up to a normalization constant, aggregate labor supply is:

$$H_{nt} = \left(\frac{W_{nt}}{P_{nt}\chi_n}\right)^{\psi}. \tag{3}$$

Our specification nests a variety of labor supply frameworks in macro and trade. The formulation of the disutility of the within-period labor supply extends the Greenwood, Hercowitz, and Huffman (1988, GHH) preferences. Indeed, the aggregate labor supply (3) coincides with the textbook GHH formulation in which only one type of labor is supplied to the market. GHH preferences mute the wealth effects on the labor supply, making the labor supply decision simply isoelastic in the real wage. The aggregate labor supply elasticity is given by ψ. A $\psi = 0$ implies a fixed aggregate labor supply as in most canonical trade models. In macro, it is normally assumed that the labor supply is flexible, $\psi > 0$. Below the aggregate level, labor is differentiated by sector as in the textbook "Roy-Fréchet" framework (e.g. Lagakos and Waugh, 2013; Hsieh et al., 2019; Galle, Rodríguez-Clare, and Yi, 2023). The labor supply elasticity to a given sector conditional on a fixed aggregate labor supply is $\mu - 1$ (eq. 2). Canonical trade and macro models with perfectly mobile labor across sectors correspond to $\mu \to \infty$. The lower is the value of μ, the less labor mobility there is across sectors.

Final consumption $\mathcal{F}_{nt}$ is a CES aggregate of sectoral consumption bundles:

$$\mathcal{F}_{nt} = \left[\sum_j \zeta_{nj}^{\frac{1}{\rho}} \mathcal{F}_{njt}^{\frac{\rho-1}{\rho}}\right]^{\frac{\rho}{\rho-1}}, \qquad P_{nt} = \left[\sum_j \zeta_{nj} \left(P_{njt}^f\right)^{1-\rho}\right]^{\frac{1}{1-\rho}},$$

where $\mathcal{F}_{njt}$ is the quantity consumed of sector j, P_{njt}^f is its price, and P_{nt} is the consumption price index.

Trade is subject to iceberg costs τ_{mnj}^f to ship good j from country m to country n, adopting the convention that the first subscript denotes source, and the second destination. Sector j bundle is an Armington aggregate of goods coming from different countries:

$$\mathcal{F}_{njt} = \left[\sum_m \mu_{mnj}^{\frac{1}{\gamma}} \mathcal{F}_{mnjt}^{\frac{\gamma-1}{\gamma}}\right]^{\frac{\gamma}{\gamma-1}}, \qquad P_{njt}^f = \left[\sum_m \mu_{mnj} (\tau_{mnj}^f P_{mjt})^{1-\gamma}\right]^{\frac{1}{1-\gamma}},$$

where $\mathcal{F}_{mnjt}$ is the final consumption by country n of sector j goods imported from country m, and γ controls the substitution elasticity between different origin-sector goods within a category. The P_{mjt}'s are the prices of sector j country m's product "at the factory gate" in the origin country. No arbitrage in shipping implies that the price faced by the consumer in n is P_{mjt} times the iceberg cost τ_{mnj}^f.

The share of sector j composite in total final expenditure π_{njt}^f, and the share of the good from country m in total sector j final expenditure π_{mnjt}^f are given by

$$\pi_{njt}^f = \frac{\zeta_{nj}\left(P_{njt}^f\right)^{1-\rho}}{\sum_k \zeta_{nk}\left(P_{nkt}^f\right)^{1-\rho}} \qquad \pi_{mnjt}^f = \frac{\mu_{mnj}\left(\tau_{mnj}^f P_{mjt}\right)^{1-\gamma}}{\sum_\ell \mu_{\ell nj}\left(\tau_{\ell nj}^f P_{\ell jt}\right)^{1-\gamma}}.$$

Firms. A representative firm in sector j in country n operates a CRS production function

$$Y_{njt} = Z_{njt} H_{njt}^{\eta_j} X_{njt}^{1-\eta_j}, \tag{4}$$

where the total factor productivity is denoted by Z_{njt}, and the intermediate input usage X_{njt} is an aggregate of sectoral inputs:

$$X_{njt} \equiv \left(\sum_i \vartheta_{i,nj}^{\frac{1}{\varepsilon}} X_{i,njt}^{\frac{\varepsilon-1}{\varepsilon}}\right)^{\frac{\varepsilon}{\varepsilon-1}}.$$

Because it is the only primary factor of production, H_{njt} should be interpreted as "equipped labor" encompassing all primary factor services (Alvarez and Lucas, 2007). The total use of sector i inputs in sector j in country n is an Armington aggregate across different source countries:

$$X_{i,njt} \equiv \left(\sum_m \mu_{mi,nj}^{\frac{1}{\nu}} X_{mi,njt}^{\frac{\nu-1}{\nu}} \right)^{\frac{\nu}{\nu-1}} \qquad P_{i,njt}^X = \left(\sum_m \mu_{mi,nj} \left(\tau_{mi,nj}^x P_{mit} \right)^{1-\nu} \right)^{\frac{1}{1-\nu}},$$

where $X_{mi,njt}$ is the usage of inputs coming from sector i in country m in production of sector j in country n, $\mu_{mi,nj}$ is a taste shifter, and $P_{i,njt}^X$ is the price index of sector i inputs in production of sector j in country n. We allow the iceberg trade cost for intermediate inputs $\tau_{mi,nj}^x$ to generically differ from the iceberg trade cost for final goods τ_{mni}^f.

Let $\pi_{i,njt}^x$ be the share of sector i in total intermediate expenditure by (n,j), and $\pi_{mi,njt}^x$ be the share of intermediates from country m in total intermediate spending on sector i by (n,j):

$$\pi_{i,njt}^x = \frac{\vartheta_{i,nj} \left(P_{i,njt}^X \right)^{1-\varepsilon}}{\sum_k \vartheta_{k,nj} \left(P_{k,njt}^X \right)^{1-\varepsilon}} \qquad \pi_{mi,njt}^x = \frac{\mu_{mi,nj} \left(\tau_{mi,nj}^x P_{mit} \right)^{1-\nu}}{\sum_\ell \mu_{\ell i,nj} \left(\tau_{\ell i,nj}^x P_{\ell it} \right)^{1-\nu}}.$$

To summarize, both final use and intermediate input bundles have two nests, governed by different elasticities. The upper nest combines broad sectors, such as manufacturing and services. Following the tradition in the structural change literature going back to Baumol (1967), the upper nest sectors are complements: $\rho < 1$, $\varepsilon < 1$. The lower nest is an Armington aggregate of items coming from different source countries. Following the tradition in both the international macro and trade literatures, the varieties in the lower nest are substitutes: $\gamma \geq 1$, $\nu \geq 1$.

Cost minimization implies that payments to primary factors and intermediate inputs are:

$$W_{njt} H_{njt} = \eta_j P_{njt} Y_{njt} \tag{5}$$

$$P_{mi,njt} X_{mi,njt} = \pi_{i,nj}^x \pi_{mi,njt}^x \left(1 - \eta_j\right) P_{njt} Y_{njt}. \tag{6}$$

Equilibrium. An equilibrium in this economy is a set of goods and factor prices $\{P_{njt}, W_{njt}\}$, factor allocations $\{H_{njt}\}$, and goods allocations $\{Y_{njt}\}$, $\{\mathcal{F}_{mnjt}, X_{mi,njt}\}$ for all countries and sectors such that (i) households maximize utility; (ii) firms maximize profits; and (iii) all markets clear.

The following sectoral market clearing condition holds for each country n sector j:

$$P_{njt}Y_{njt} = \sum_m P_{mt}\mathcal{F}_{mt}\pi^f_{mjt}\pi^f_{nmjt} + \sum_m \sum_i (1-\eta_i)P_{mit}Y_{mit}\pi^x_{j,mit}\pi^x_{nj,mit}. \tag{7}$$

Meanwhile, trade balance implies that each country's final expenditure equals the sum of value added across domestic sectors:[5]

$$P_{mt}\mathcal{F}_{mt} = \sum_i \eta_i P_{mit}Y_{mit}. \tag{8}$$

Real GDP. We follow the national accounting conventions and define real GDP as value added evaluated at base prices b:

$$G_{nt} = \sum_{j=1}^{J} \left(P_{nj,b}Y_{njt} - P^X_{nj,b}X_{njt}\right), \tag{9}$$

where $P_{nj,b}$ is the gross output base price, and $P^X_{nj,b}$ is the base price of inputs in that sector-country. The log real GDP change in any country n is to first order given by

$$\ln G_{nt} = \sum_{j=1}^{J} \frac{P_{nj}Y_{nj}}{G_n} \ln Z_{njt} \; + \; \sum_{j=1}^{J} \eta_j \frac{P_{nj}Y_{nj}}{G_n} \ln H_{njt}, \tag{10}$$

where the items without t-subscripts denote the steady state/pre-shock values, and "ln" denotes the log-deviation from the steady state/pre-shock equilibrium. The first term in equation (10) captures the impact of exogenous domestic shocks on GDP. Note that there is no direct dependence of country n's GDP on foreign shocks. The second term in (10) captures the endogenous changes in hours. Solving the model for the real GDP change means finding the responses of the hours in each country and sector to the worldwide vector of shocks. This expression highlights the need for within-period elastic labor supply in our model. Frameworks of structural change commonly feature inelastic labor supply, a reasonable assumption in the long run. However, in business cycle models fixed aggregate labor supply would imply that foreign shocks have no effect on domestic measured GDP – there is no transmission. This is clearly contrary to abundant empirical evidence suggesting that transmission of shocks is an important phenomenon at business cycle frequencies.

[5] We assume no deficits in our baseline, however we can incorporate exogenous trade imbalances in a manner similar to Dekle, Eaton, and Kortum (2008).

Analytical solution. Similar to Huo, Levchenko, and Pandalai-Nayar (2023), this model can be solved analytically to first order. Let the vector $\ln \mathbf{H}_t$ of length NJ collect the worldwide sectoral hours log changes. The response of $\ln \mathbf{H}_t$ to the global vector of supply shocks $\ln \mathbf{Z}_t$ is to a first order approximation given by

$$\ln \mathbf{H}_t = \mathbf{\Lambda}^{\boldsymbol{H}} \ln \mathbf{Z}_t, \tag{11}$$

where $\mathbf{\Lambda}^{\boldsymbol{H}}$ is an influence matrix. It encodes the general equilibrium response of sectoral hours in a country to shocks in any sector-country, taking into account the full model structure and all direct and indirect links between the countries and sectors. Equation (11) underscores that the labor input in every country and sector depends on the entire vector of $\ln Z_{njt}$ worldwide. The closed-form expression for $\mathbf{\Lambda}^{\boldsymbol{H}}$ is provided in Appendix B (eq. B.6). While in general analytical solutions for $\mathbf{\Lambda}^{\boldsymbol{H}}$ are hard to obtain, in our framework the elements of $\mathbf{\Lambda}^{\boldsymbol{H}}$ are (i) the shares of value added in production η_j, the expenditure shares π^f_{mjt}, π^f_{nmjt}, $\pi^x_{j,mit}$, and $\pi^x_{nj,mit}$ for all n, m, i, j and (ii) model elasticities. Thus, the model is easily parameterized and yields itself to quantification. Note that $\mathbf{\Lambda}^{\boldsymbol{H}}$ is built directly from the observable final and intermediate domestic and international expenditure shares. Thus, there is no need to specify further deep parameters of the model, such as steady state/pre-shock levels of productivity, taste shifters, and trade costs.

The closed-form solution for $\mathbf{\Lambda}^{\boldsymbol{H}}$ in equation (B.6) resembles the typical solution of a network model, that writes the equilibrium change in output as a product of the Leontief inverse and the vector of shocks. Our expression also features a vector of shocks, and an inverse of a matrix that is, in general, more complicated due to the multi-country structure of our model combined with elastic factor supply and non-unitary elasticities of substitution.

Evolution of international comovement. To illustrate how we will use the model above to understand the long-run evolution of international comovement, we next present some simple accounting decompositions. The linear representation of the GDP change in country n as a function of the global vector of shocks (10)-(11) implies that to first order, the log deviation of real GDP of country n from steady state can be written as:

$$\ln G_{nt} = \sum_m \sum_i s_{mni} \ln Z_{mit}, \tag{12}$$

where s_{mni} are the elements of the global influence matrix, that give the elasticity of the GDP of country n with respect to shocks in sector i, country m, characterized by (10)-(11). The GDP change in country n can be written as an inner product of the vector of all the shocks in the world and the elasticities of country n's GDP to both domestic and foreign shocks.

To highlight the sources of international GDP comovement, write real GDP growth as

$$\ln G_{nt} = \underbrace{\sum_j s_{nnj} \ln Z_{njt}}_{\mathcal{D}_n} + \underbrace{\sum_{n' \neq n} \sum_j s_{n'nj} \ln Z_{n'jt}}_{\mathcal{T}_n}. \tag{13}$$

This equation simply breaks out the double sum in (12) into the component due to country n's domestic shocks ($\mathcal{D}_n$), and the component due to its trading partners' shocks $\mathcal{T}_n$.

Then, the GDP correlation between country n and country m is:

$$\varrho_{nm} = \underbrace{\frac{\text{Cov}(\mathcal{D}_n, \mathcal{D}_m)}{\sigma_n \sigma_m}}_{\text{Shock Correlation}} + \underbrace{\frac{\text{Cov}(\mathcal{D}_n, \mathcal{T}_m) + \text{Cov}(\mathcal{T}_n, \mathcal{D}_m) + \text{Cov}(\mathcal{T}_n, \mathcal{T}_m)}{\sigma_n \sigma_m}}_{\text{Transmission}}, \tag{14}$$

where σ_n is the standard deviation of GDP growth of country n.

This expression separates the sources of international comovement. The key component of the Shock Correlation term can be written as:

$$\text{Cov}(\mathcal{D}_n, \mathcal{D}_m) = \sum_j \sum_i s_{nnj} s_{mmi} \text{Cov}(\ln Z_{nj}, \ln Z_{mi}). \tag{15}$$

It captures the fact that economies might be correlated even in the absence of transmission if the underlying shocks themselves are correlated, especially in sectors influential in both economies.

The second term captures international transmission of shocks. It arises when country m is sensitive to country n's shocks and vice versa, and when both countries n and m are sensitive to third-country shocks. The Transmission term would be zero in the absence of international trade in the model environment above. Taking one of the terms of the Transmission component:

$$\begin{aligned} \text{Cov}(\mathcal{D}_n, \mathcal{T}_m) &= \sum_j \sum_{n' \neq m} \sum_i s_{nnj} s_{n'mi} \text{Cov}(\ln Z_{nj}, \ln Z_{n'i}) \\ &= \sum_{n' \neq m} \boldsymbol{s}'_{nn} \boldsymbol{\Sigma}_{n'n} \boldsymbol{s}_{n'm}, \end{aligned} \tag{16}$$

where $\boldsymbol{\Sigma_{n'n}}$ is the $J \times J$ covariance matrix of shocks between countries n' and n, and $\boldsymbol{s}_{n'm}$ is the $J \times 1$ influence vector collecting the impact of shocks in n' on GDP in m. Thus, one source of comovement is that under trade, both country n and country m will be affected by shocks in n'. For instance, the element of the summation (16) for $n' = n$ captures the sensitivity of both countries n and m to shocks in country n: $s'_{nn}\mathbf{\Sigma}_n \boldsymbol{s}_{nm}$. This term is nonzero when shocks to country n, that affect n's GDP by construction, also propagate to country m through trade and production linkages.

The developments in the world economy brought about by globalization and structural change will manifest themselves in as changes in s_{mni} over time. This paper provides an account of how the long-run evolution of the influence terms s_{mni} interacted with the differences across sectors in shock correlations $\text{Cov}(\ln Z_{nj}, \ln Z_{n'i})$ to shape the long-run changes in international comovement. Structural change can be thought of as a trend increase in the domestic influence s_{nni} for i =services. The impact of globalization is more subtle. On the one hand, by lowering trade costs and therefore increasing foreign expenditure shares, it increases the foreign influence terms s_{mni}, $m \neq n$. On the other, if the substitution elasticities between services and manufacturing ρ and ε are below unity, reductions in trade costs lower the relative price of manufacturing to services, and thus increase the influence of services.

These forces interact with the correlations of shocks. Suppose, as we document below, service sector shocks are less correlated than manufacturing sector shocks. Then, the reallocation towards services lowers the Shock Correlation component $\text{Cov}(\mathcal{D}_n, \mathcal{D}_m)$, pushing down GDP correlations. At the same time, a globalization-induced rise in the foreign influence terms s_{mni}, $m \neq n$ raises the Transmission components of the total correlation. The net effect is ambiguous, but we can use the machinery developed in this paper to separate and quantify these effects.

3. Data, Calibration, and Basic Facts

The baseline analysis employs 21 countries listed in Appendix Table A1 and a composite Rest of the World, 4 sectors ("Agriculture", "Non-Manufacturing Industries", "Manufactures" and "Services"), and covers the period from 1978 to 2007. We use data from two main sources: (i) the annual world input-output data compiled by Johnson and Noguera (2017); (ii) the 2009 EU-KLEMS release (O'Mahony and Timmer, 2009) for the majority of the countries, as well as national statistical offices for some countries. Appendix A discusses the data in further detail.

Table 1 summarizes the parameters we use. We set the substitution elasticities between goods and service bundles in final consumption (ρ) and intermediate use (ε) to 0.2, following estimates in the literature that show those to be in this range (Herrendorf, Rogerson, and

Table 1: Parameter values

Param.	Value	Source	Related to
ρ	0.2	Herrendorf, Rogerson, and Valentinyi (2013)	final cross-sector substitution elasticity
ε	0.2	Cravino and Sotelo (2019)	intermediate cross-sector subst. elasticity
γ	1	Boehm, Levchenko, and Pandalai-Nayar (2023)	trade elasticity in final consumption
ν	1	Boehm, Levchenko, and Pandalai-Nayar (2023)	trade elasticity in intermediate inputs
ψ	1	Chetty et al. (2011)	Frisch elasticity of labor supply
μ	1.5	Galle, Rodríguez-Clare, and Yi (2023)	Sectoral labor supply elasticity
η_j		Johnson and Noguera (2017)	value added share in gross output
π^f_{njt} , $\pi^x_{i,njt}$		Johnson and Noguera (2017)	final and intermediate sectoral use
π^f_{mnjt}, $\pi^x_{mi,njt}$		Johnson and Noguera (2017)	final and intermediate trade shares

Notes: This table summarizes the parameters and data targets used in the baseline quantitative model and their sources. Appendix C shows results under alternative parameters.

Valentinyi, 2013; Cravino and Sotelo, 2019).[6] For the Armington elasticities of substitution between domestic and foreign goods in the final (γ) and intermediate (ν) bundles, we use the short-run estimates from Boehm, Levchenko, and Pandalai-Nayar (2023). Similar estimated values were obtained by Huo, Levchenko, and Pandalai-Nayar (2023) using a different dataset. The only remaining structural parameters are the Frisch labor supply elasticity, which we set to 1 following Chetty et al. (2011), and the parameter μ which governs the sectoral labor supply elasticity. We set μ to 1.5 following Galle, Rodríguez-Clare, and Yi (2023). Production function parameters and final/input shares are taken directly from the data.

Shocks. To study international GDP comovement in the model, we must subject it to some business cycle shocks. At a formal level, the only business cycle shocks in this economy are TFP shocks Z_{njt} in every country and sector. We present the full results under two sets of shocks: (i) Solow residuals and (ii) composite supply.

The Solow residual is traditionally equated with TFP. It is standard to compute it as:

$$\ln S_{njt} = \ln Y_{njt} - \eta_j d \ln H_{njt} - (1 - \eta_j) \ln X_{njt}.$$

As argued above, our H_{njt} variable should be thought of as "equipped labor" encompassing all primary factors. Thus we proxy for it by $\ln H_{njt} = \alpha_j \ln K_{njt} + (1 - \alpha_j) \ln L_{njt}$, where K_{njt} is capital, L_{njt} is the labor input taken from the data, and α_j is the capital share in value added.

[6] Herrendorf, Rogerson, and Valentinyi (2013) emphasize that the elasticity estimates are sensitive to whether consumption is specified in terms of gross output or value added. Cravino and Sotelo (2019) estimate the substitution elasticity in gross output terms, consistent with the setup in this paper.

The advantage of the Solow residual is that it is relatively model-free, easy to interpret, and has been the main shock considered by the international business cycle literature. As we will see below, all the main messages of the paper hold when the Solow residual is the only shock driving the business cycle. Its disadvantage is that when fed into the model, it does not reproduce value added growth, and by extension actual GDP correlations in the data. Thus, we cannot use the Solow residual to, say, decompose the observed GDP correlations.

Thus, as an alternative, we recover composite supply shocks Z_{njt} in such a way as to match the actual value added growth in every country-sector (and therefore the actual GDP growth in every country), as in Huo, Levchenko, and Pandalai-Nayar (2023). Let the vector $\ln \mathbf{V}_t$ of length NJ denote sectoral value added in log deviations from steady state. Similar to GDP, sectoral value added can also be expressed as changes in productivity and primary inputs:

$$\ln \mathbf{V}_t = \boldsymbol{\eta}^{-1} \ln \mathbf{Z}_t + \ln \mathbf{H}_t.$$

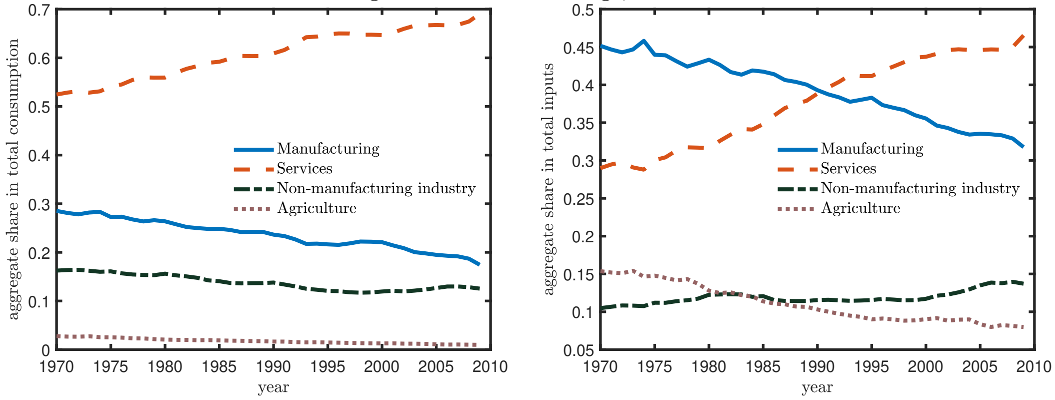
We have data on the $NJ \times 1$ vector of log changes in real value added $\ln \mathbf{V}_t$ in each year, which allows us to recover the shocks:

$$\ln \mathbf{Z}_t = \left(\boldsymbol{\eta}^{-1} + \boldsymbol{\Lambda}^{\boldsymbol{H}} \right)^{-1} \ln \mathbf{V}_t. \tag{17}$$

In other words, the structure of the model world economy and the observed/measured objects are used to infer a global vector of supply shocks $\ln \mathbf{Z}_t$ that rationalizes the observed growth rates in real value added in each country-sector. Note that the interdependence between country-sectors through input linkages implies that the entire global vector $\ln \mathbf{Z}_t$ must be solved for jointly, which requires all the inputs into the model solution and calibration, such as the expenditure shares and structural elasticities.

The composite supply shock matches the observed GDP by construction. Its disadvantage is that it is more difficult to interpret structurally. This shock is agnostic on the deeper sources of fluctuations, for instance on whether the business cycle is driven primarily by technology or non-technology ("demand") shocks. To see this more clearly, one could consider a model with both technology and non-technology shocks. Technology shocks could be proxied by the Solow residual S_{njt}, while non-technology shocks can be captured in reduced form as shifts in factor supply ξ_{nj} as in (2). Since H_{njt} is the only primary factor, a shock ξ_{njt} at time t would account for all the movements in real value added that are inexplicable based on only the Solow residual changes in general equilibrium. Analogously to the composite shock recovery (17), one

Figure 2: Structural change, OECD



Shares in final use — Shares in input use

Notes: The left panel displays the average share of each sector in final expenditure. The right panel shows the average share of each sector in intermediate input spending. The sample contains countries that were members of the OECD since the beginning of the sample in the 1970s.

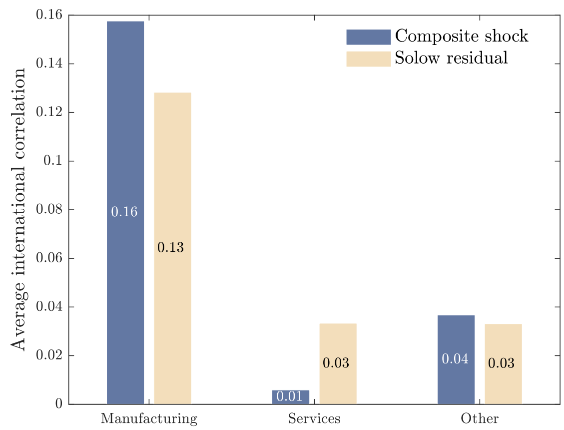
could extract a vector of non-technology shocks ξ_{njt} to perfectly match value added conditional on the Solow residuals. It turns out that such a non-technology shock is isomorphic to TFP in its effect on value added, up to a sector-specific constant. Therefore, the composite shock recovered in (17) is simply a linear combination of the Solow residual and the factor supply shock: $Z_{njt} = S_{njt} + \frac{\eta_j}{1+\psi}\xi_{njt}$. Thus, simulating this 2-shock model produces results identical to simulating the 1-shock model with Z_{njt} from (17), and we do not report the results for this 2-shock model to conserve space.

In turn, the interpretation of the factor supply shock ξ_{njt} can include disturbances – such as sentiments (Angeletos and La'O, 2013; Huo and Takayama, 2015) or news (Beaudry and Portier, 2006; Barsky and Sims, 2012) – that manifest themselves as shifts in factor supply that are not driven by contemporaneous changes in productivity. These points are discussed in detail by Huo, Levchenko, and Pandalai-Nayar (2023).

We now present two basic facts that motivate the focus on structural change as a driver of international comovement.

The rise in the service share. Figure 2 displays the expenditure shares on the 4 sectors in our data, separating final and intermediate usage. As has been documented in many studies, over this period the share of services rose, at the expense of manufacturing and agriculture. The figure also conveys the relative importance of different sectors. Agriculture and non-manufacturing industries are considerably smaller than services and manufacturing.

Figure 3: Overall sectoral shock correlations



Notes: This figure plots the correlations of the sectoral Solow residual and the composite shocks extracted using equation (17), with foreign aggregate shocks over the 1978-2007 sample. The correlations are averaged across country pairs.

Differences in shock correlations. Less well-known is how the correlation of business cycle shocks differs across broad sectors. Figure 3 reports the sectoral shock correlations, averaged across country pairs, for the composite shock (blue bars) and the Solow residual (beige bars). By both measures, manufacturing shocks are the most correlated, while the service sector shocks are the least correlated. While all measures of shocks rely on some underlying model structure, Appendix Figure C2 shows that manufacturing value added in the data is also more correlated across countries than services value added. Appendix Figure C3 illustrates that the same pattern holds for all 10-year rolling correlations in the sample. Appendix Figure C4 shows the international sectoral correlation using more disaggregated sectoral classifications using the long-run WIOD's 23 sectors. The average correlation of manufacturing subsectors is also higher than that of services and other subsectors.[7]

4. Quantification

4.1. Decomposition of International Comovement

Panel A of Figure 4 plots the evolution of GDP correlation and its decomposition into transmission and shock correlation. The left panel shows the decomposition for the composite

[7] In that figure, we need to restrict the sample to 1978-2000 as the long-run WIOD data is only available until 2000.

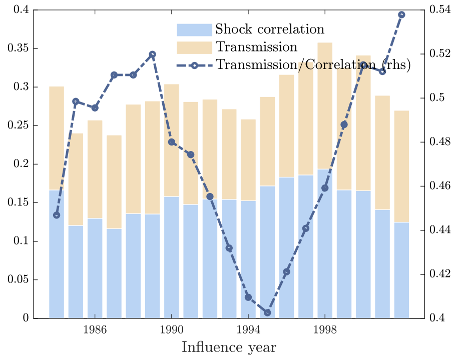
supply shock for OECD country pairs, while the right panel illustrates the decomposition with the Solow residual as the supply shock. We first use every year's corresponding influence vector to compute the growth in GDP attributable to different countries' shocks as in equation (13). Then, we compute the decomposition of GDP correlations into Shock Correlation and Transmission as in equation (14), in rolling 10-year windows. Each bar is the average bilateral correlation of GDP growth across OECD countries as in Figure 1. The blue part of the bar displays the shock correlation term, and the beige part displays the transmission terms. The superimposed black line (right axis) shows the fraction of transmission in total correlation.

As in Figure 1, there is no clear increase in GDP correlations over this period. The decomposition helps understand why. Structural change leads to an erosion of the shock correlation term, as economic activity is reallocated to the less correlated service sector. Correspondingly, the relative importance of transmission in total correlation rises over this period, from about 45% at the beginning to 55% for the composite shock. However, the transmission share is also volatile and not monotonic over time. Appendix Table C1 displays some summary statistics behind these plots.

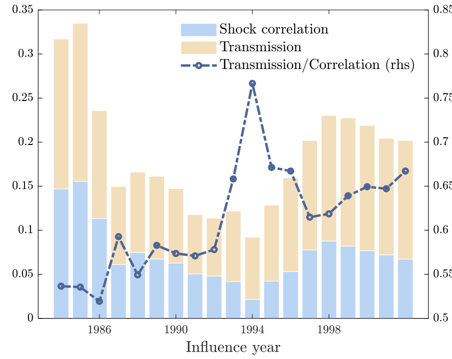
Because Panel A of Figure 4 displays correlations in 10-year rolling windows, 2 things change over time in this figure: the structure of the economy, and the realizations of shocks. The advantage of doing it this way is that the GDP correlations match the GDP correlations in the data. The disadvantage is that it cannot separate changing sample shock correlations over time from the changing production structure. This issue is exacerbated by the fact that 10 yearly growth rates is quite a small sample, so changes in 10-year shock correlations between one period and the next could be dominated by small sample variability rather than true changes in the shock process. To isolate the importance of the changing influence matrix from changes in shock realizations, we follow the approach of Carvalho and Gabaix (2013) and di Giovanni, Levchenko, and Méjean (2014) and feed the entire 30-year time series of shocks into the influence matrix for each year. This exercise answers the question: what would be the GDP correlations in, say, 1978 if the world as it was in 1978 experienced 30 years of business cycle shocks that occurred over 1978-2007? It is a less noisy estimate of the true GDP comovement in the 1978 world economy, as it uses a longer time series as the estimation sample. Panel B of Figure 4 shows the results of this exercise. The trends are more evident. For the composite shock, the total correlation falls substantially. For both shocks, the trend is driven by a fall in the shock correlation component (blue bars). The share of transmission rises over time by a similar amount as in the rolling 10-year exercise. Appendix Table C2 displays additional statistics of the decomposition.

Figure 4: Correlation decompositions through time: OECD country pairs

Panel A: Decomposition, rolling 10-year windows

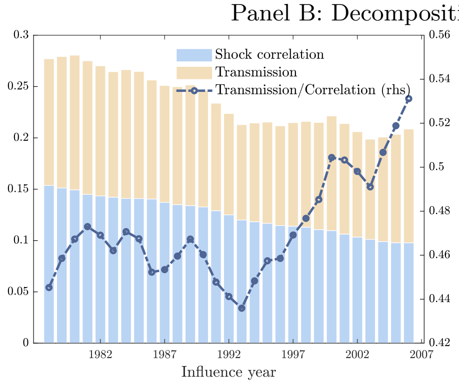


Composite shock

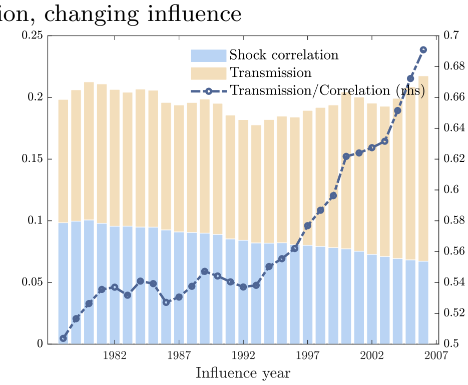


Solow residual

Panel B: Decomposition, changing influence



Composite shock



Solow residual

Notes: This figure displays the decompositions of the total correlation (the height of the bar) into shock correlation (blue bars) and transmission (stacked beige bars). Panel A displays the average 10-year rolling correlations. Panel B applies the full time-series of shocks, 1978-2007, to the influence matrix of each year. Hence, the x-axis corresponds to the year of the influence matrix used for the decomposition but not the shock extraction. In both panels, we use the formula for real GDP (10) and the yearly influence vector in equation (11) to compute the decomposition in (14). In both panels, the shocks used are the composite supply shocks on the left and the Solow residuals on the right. The solid line in each figure shows the median of ratio between the transmission and total correlation across country pairs (right axis). The sample of countries are all OECD country pairs. We present the summary statistics underlying the Figure in Appendix Tables C1 and C2.

Appendix Figures C5 and C6 display robustness checks for the importance of the changing influence matrix. Figure C5 displays the decomposition using all 23 sectors from the long-run WIOD, and Figure C6 extends the sample of year of influence matrices from 1965 to 2014 by combining two releases of WIOD. In all cases, the share of transmission rises.

4.2. Counterfactuals

Figure 4 summarizes the evolution of GDP correlations over the 1978-2007 period taking the changes in the structure of the economy directly from the data. In this section, we separate the different proximate sources of structural change, to assess how each of these affected international comovement. Specifically, we isolate reductions in trade costs (Cravino and Sotelo, 2019), differentials in productivity growth cross sectors (Baumol, 1967), and a residual "taste" component that would be a reduced-form way of capturing non-homotheticicities in the demand for services (e.g. Kongsamut, Rebelo, and Xie, 2001; Boppart, 2014; Comin, Lashkari, and Mestieri, 2021), among other demand-side forces driving structural transformation.

Shock extraction for the long run. Let $\Delta \ln$ denote the long log-difference. We invert the model to jointly recover the changes in the taste shifters $\Delta \ln \zeta_{nj}$ and $\Delta \ln \vartheta_{i,nj}$ and trade costs-cum-tastes $\Delta \ln \left(\mu_{mnj} \left(\tau^f_{mnj} \right)^{1-\gamma} \right)$ and $\Delta \ln \left(\mu_{mi,nj} \left(\tau^x_{mi,nj} \right)^{1-\gamma} \right)$ to rationalize the long-run (1978-2007) changes in (i) sectoral final and intermediate expenditure shares $\Delta \ln \pi^f_{nj}$ and $\Delta \ln \pi^x_{i,nj}$; and (ii) international trade shares $\Delta \ln \pi^f_{mnj}$ and $\Delta \ln \pi^x_{mi,nj}$ for each country-sector and bilateral pair. As an example, taking the log-difference of a bilateral final trade share relative to the domestic share yields:

$$\Delta \ln \left(\frac{\pi^f_{mnj}}{\pi^f_{nnj}} \right) = \Delta \ln \left(\mu_{mnj} \left(\tau^f_{mnj} \right)^{1-\gamma} \right) + (1-\gamma) \Delta \ln \left(\frac{P_{mj}}{P_{nj}} \right), \tag{18}$$

where we normalized domestic trade costs/taste shifters to 1. Similarly, for the sectoral absorption shares:

$$\Delta \ln \left(\frac{\pi^f_{nj}}{\pi^f_{ni}} \right) = \Delta \ln \left(\frac{\zeta_{nj}}{\zeta_{ni}} \right) + (1-\rho) \Delta \ln \left(\frac{P^f_{nj}}{P^f_{ni}} \right). \tag{19}$$

The expressions for intermediate trade and sectoral shares are analogous and we do not restate them here. The left-hand sides of (18) and (19) are observable. The right-hand sides are the shocks we are extracting $\Delta \ln \left(\mu_{mnj} \left(\tau^f_{mnj} \right)^{1-\gamma} \right)$ and $\Delta \ln \left(\frac{\zeta_{nj}}{\zeta_{ni}} \right)$, and the endogenous relative prices that depend in a complex way on the full matrix of these trade costs and taste shifters, as well as the supply shifts $\Delta \ln Z_{nj}$. We proceed to solve analytically for the global vector of prices as a function of $\Delta \ln \left(\mu_{mnj} \left(\tau^f_{mnj} \right)^{1-\gamma} \right)$, $\Delta \ln \left(\frac{\zeta_{nj}}{\zeta_{ni}} \right)$, and $\Delta \ln Z_{nj}$. This allows us to invert (18)- (19) for the global vectors of trade cost and taste changes that match the evolution of sectoral and bilateral expenditure shares. Details of the procedure are in Appendix B.

Since this exercise is applied to long-run changes, for the purposes of extracting these shifters we switch to the specification of factor supply typical in models of structural change as well as textbook international trade. Namely, we set the Frisch elasticity of *aggregate* labor supply to $\psi = 0$, and assume that labor is perfectly mobile across sectors: $\mu \to \infty$. This approach is a reduced form way of capturing long-run wealth and substitution effects that offset each other, resulting in the labor supply staying constant in the long run.[8] In addition, there is evidence that the trade elasticity differs between the short-run applicable to business cycle frequencies, and the long-run relevant for structural change (Boehm, Levchenko, and Pandalai-Nayar, 2023). We thus apply the long-run trade elasticities estimated in that paper, setting $\gamma = \nu = 2$.

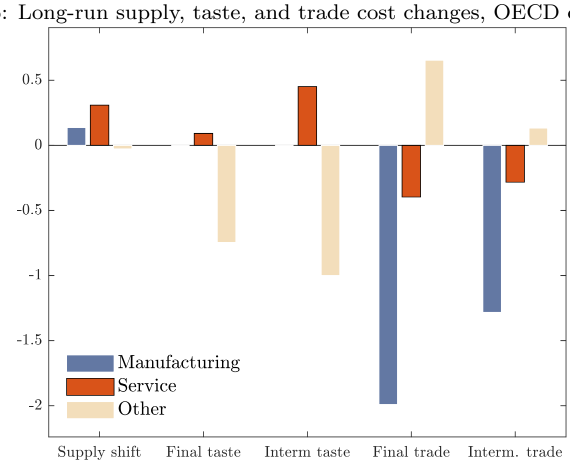
In this exercise, we must take a stand on how to treat the long-run supply shifts $\Delta \ln Z_{nj}$. Our business cycle frequency shock extraction procedure described in Section 3 delivers yearly time series of $\ln Z_{njt}$ that rationalize year-to-year changes in sectoral value added. Our baseline approach is to cumulate those yearly productivity changes to build a long-run change $\Delta \ln Z_{nj}$ over the period 1978-2007. We then extract the taste and trade cost shocks that match the sectoral expenditure and trade shares conditional on these long-run $\Delta \ln Z_{nj}$'s. We also carry out the analysis under two alternative approaches. In the first alternative, we compute long-run log-differences in sectoral real value added, and extract long-run $\Delta \ln Z_{nj}$'s jointly with taste and trade cost shifters in one step. In the second alternative, we use the cumulated sectoral Solow residual to build long-run changes in $\Delta \ln Z_{nj}$. In all three cases, when all three types of shocks are fed into the model, they perfectly reproduce observed structural change (the changes in sectoral expenditure shares) and trade opening (changes in international trade shares) over the period 1978-2007. The implications of the two alternative approaches for international comovement and our counterfactuals are similar, so we relegate them to the Appendix C.4.

Figure 5 presents the supply, taste shifter, and trade cost changes. As is clear from the figure, trade costs have fallen dramatically over this period in manufacturing, relative to services.[9] This pattern, which has been documented in numerous studies, holds for both intermediate and final trade. Our model also implies that the supply shifter in services rose more than in manufacturing over this period. Note that the $\Delta \ln Z_{nj}$ shock should be interpreted broadly.

[8]Note that this specification accommodates trend shifts in aggregate factor supplies driven by population changes and physical and human capital accumulation through sector-neutral changes in the composite shock $\Delta \ln Z_{nj}$. As an alternative, we could have kept $\psi > 0$ and set the labor disutility shock χ_n to match any long-run change in observed quantities of equipped labor. Since our procedure does not target the long-run changes in the equipped labor input, those two approaches are isomorphic for our purposes.

[9]Without data on import prices, we cannot separate changes in tastes for foreign goods μ_{mnj} and $\mu_{mi,nj}$ from true iceberg costs τ^f_{mnj} and $\tau^x_{mi,nj}$, as their effects on international expenditure shares are isomorphic. In what follows, for expositional purposes we attribute the entirety of the change in trade shares to τ^f_{mnj} and $\tau^x_{mi,nj}$, for instance when plotting it in Figure 5. This is purely to streamline discussion. None of the conclusions with respect to international GDP correlations are sensitive to whether trade globalization has been driven by trade cost or taste changes.

Figure 5: Long-run supply, taste, and trade cost changes, OECD countries



Notes: The figure displays the long-run changes in supply shifters, taste shifters (relative to manufacturing), and trade costs. The units on the y-axis are log-differences. The long-run supply shock is the cumulative change in the yearly composite shock extracted in Section 3.

It encompasses TFP but also changes in the supply of primary factors to the sector. When it comes more narrowly to TFP, the existing evidence on this shift is mixed. While some studies use a relative increase in manufacturing productivity as a driver of structural change, a large literature studying the introduction of cognitive-intensive technologies such as Information and Communications Technology (ICT) since 1978 finds that they disproportionately benefited workers in many service sectors (e.g. Autor, Levy, and Murnane, 2003; Adão, Beraja, and Pandalai-Nayar, 2024).[10] At the same time, there is a modest increase in the service taste shifters, and a substantial fall in the taste for agriculture and non-manufacturing industry.

Counterfactual correlations. Figure 6 presents the results of the counterfactuals. Throughout, to compute business cycle correlations, we take each model and feed in 30 years of shocks to either Z_{njt} or the Solow residual, as in Panel B of Figure 4. The left-most bar summarizes the average GDP correlation in the world characterized by the 1978 production structure. The beige and blue bars depict the Transmission and Shock Correlation components, respectively. The second bar displays the globalization counterfactual, that starts with the 1978 world economy, and applies only the 1978-2007 change in trade costs. Intriguingly, in spite of a large reduction in trade costs,

[10] Jovanovic and Rousseau (2005) discuss the introduction and adoption of two "General-Purpose Technologies" in the last century – electricity and ICT. The first resulted in the structural transformation towards manufacturing between 1900-1940, while the latter benefited sectors intensive in cognitive skills. Additionally, they find the productivity increase due to the ICT technology has been slower, consistent with the small relative productivity change in Figure 5.

average correlations change relatively little compared to the 1978 world. They actually fall in the composite shock exercise (left panel), and rise modestly when Solow residuals are used (right panel). The breakdown between transmission and shock correlation components helps understand why. Globalization increases international trade shares, and thus raises international shock transmission (the beige bar widens). However, as discussed above, when manufacturing and services are complements, a fall in trade costs lowers the manufacturing expenditure shares in favor of services (Appendix Figure C8). Services have less correlated shocks, so a fall in trade costs moves value added into less correlated sectors, shrinking the shock correlation component of GDP comovement (the blue bar).

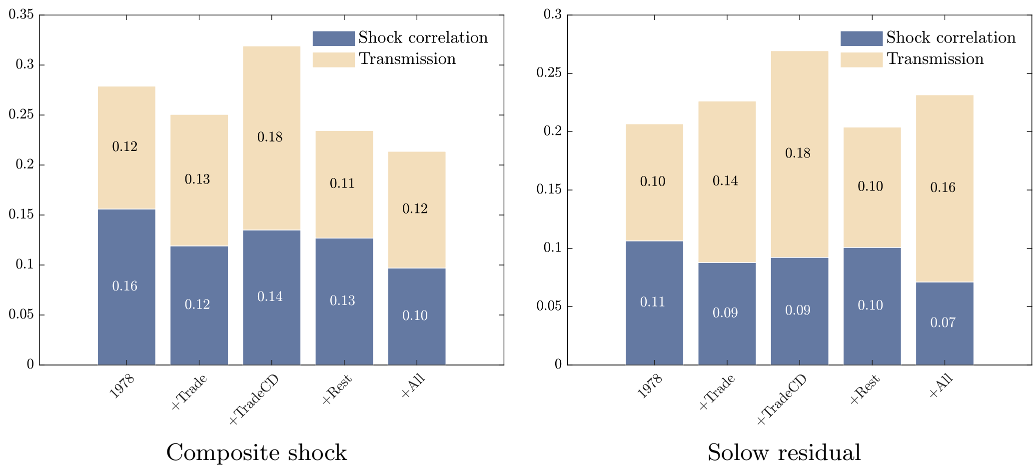
To separate these two forces of globalization, the third bar displays GDP correlations under an alternative "globalization-only" counterfactual, that reduces the trade costs by the same amount, but forces the manufacturing/services expenditure shares to stay constant.[11] When trade costs fall but expenditure shares are not allowed to change, comovement increases noticeably, because greater international transmission is not accompanied by a large fall in the shock correlation components.[12]

To complete the picture, the bars labeled "+Rest" display international comovement in the alternative world in which only taste and supply experienced long-run changes starting from 1978, while trade costs stayed fixed. As expected, applying the long-run taste and supply shifts to the 1978 world economy lowers comovement relative to 1978, as these shocks favor the service sector which is less correlated. The transmission term remains constant or drops slightly as well in the "+Rest" scenario, because while there is no change in overall openness and trade linkages, the shift away from manufacturing – the most open sector – also lowers the importance of foreign shocks. Finally, the last bar plots the comovement in the 2007 world economy, that experienced all three drivers of globalization and structural change. It is by and large a combination of the two shock-by-shock counterfactuals.

[11] This is accomplished by applying the trade cost changes to a model where sectors are Cobb-Douglas in both final consumption and production to compute the long-run changes in all expenditure shares. Given the resulting structure of the economy, when we simulate business cycle comovement, we still use the baseline (complementary) elasticities.

[12] Even when expenditure shares are Cobb-Douglas, the Shock Correlation component falls somewhat relative to the 1978 baseline in this counterfactual. This is because an increase in foreign trade shares reduces the domestic influence terms s_{nnj} that enter the Shock Correlation component (15), as a more open economy is mechanically less susceptible to domestic shocks. See Huo, Levchenko, and Pandalai-Nayar (2023) and Bonadio et al. (2021) for an elaboration of this effect.

Figure 6: Counterfactual correlations: OECD pairs



Notes: The bars display the average GDP growth correlations, decomposed into a shock correlation term (in blue) and transmission term (in beige). Each bar represents a different scenario. “1978” is a counterfactual world in which the influence remained the same as the 1978 world, “+Trade” is a world in which only trade costs changed, “+TradeCD” is a world in which only trade costs changed but sectoral expenditure shares remained constant, “+Rest” is a world in which only taste and supply evolved since 1978. “+All” performs the decomposition using the 2007 influence vector. In all cases, the correlation decomposition is computed on the same time series of shocks from 1978 to 2007. Appendix Table C3 displays the numbers underlying the figure and additional statistics.

4.3. Discussion

Additional exercises and robustness. Appendices C.3-C.5 describe a number of additional exercises and sensitivity checks: (i) cross-sectional variation among countries; (ii) alternative shocks and elasticities; (iii) trade deficits; (iv) dynamics and delayed propagation; (iv) financial integration.

Non-homotheticities. Demand-side explanations for structural change often explicitly model non-homothetic utility (e.g. Kongsamut, Rebelo, and Xie, 2001; Boppart, 2014; Comin, Lashkari, and Mestieri, 2021). Our approach is more reduced form and relies instead on shifters $\zeta_{nj}/\vartheta_{nj}$. Note that whether structural change is introduced via non-homotheticities or taste shifters should not matter for the factual decompositions in Figure 4. Those decompositions use sectoral shares directly from the data, and compute the components of the resulting comovement. Comovement in turn is a function of the exogenous shocks and the changes in hours worked (equation 10), which at the business cycle frequency should not be affected by non-homotheticity to first order.[13]

That said, non-homotheticities might matter more in the counterfactuals (Figure 6), that involve potentially large changes in the overall trade costs. In our model, the gains from trade are positive. Thus a significant trade costs reduction, such as the one that occurred 1978-2007, would make households richer. Normally, services are considered more income-elastic. In that case, following a fall in the trade costs the reallocation towards services would be even stronger than in our analysis, and trade cost reductions would decrease comovement even more. In that case, our counterfactual results that abstract from explicit non-homotheticities are conservative.

Profits. de Soyres and Gaillard (2024) show that in the presence of profits, international input trade synchronizes reduced-form Solow residuals across countries. Because we use actual Solow residuals (and the composite shocks in turn subsume the Solow residuals), any joint distribution of bilateral trade intensity and Solow residual synchronization in the cross-section of country-sectors is picked up in our baseline calibration. Thus, the decomposition of the factual correlations in Figure 4 into the different components takes into account any Solow residual correlations generated by trade itself.

Some of our counterfactuals simulate trade cost reductions. If greater trade volumes increased synchronization of the Solow residuals, trade cost reductions would have a greater chance of increasing comovement, as a trade cost reduction would increase not only the Transmission, but also the Shock Correlation component. Thus our trade cost counterfactuals would understate the full impact of trade cost reductions on GDP synchronization.

However, we would argue that profits appearing in the correlated Solow residual is unlikely to be a large force, for the following two reasons. First, measured Solow residuals are only weakly correlated across countries (the mean aggregate Solow correlation is 0.05 in our sample of countries, and only 0.13 in the manufacturing sectors, see Figure C2). Second, if more trade had synchronized Solow residuals, we would have expected to see an upward trend in the Solow residual correlations, at least in manufacturing. We do not see this type of trend (Figure C3).

[13]Non-homotheticities are not commonly modeled for regular business cycle shocks. Such an effect would involve, for example, a relative demand shift towards services following a positive aggregate productivity shock year-to-year. For business cycle-size shocks – a couple of percentage points in either direction – this is typically not considered quantitatively relevant.

5. Conclusion

We provide a resolution to the apparent puzzle that greater globalization, coupled with stronger transmission of shocks, has not resulted in a noticeable increase in international comovement in recent decades. We show that structural change towards the service sectors in advanced economies is an important countervailing force, as services are relatively less correlated internationally. Additionally, when services and goods are complements in both consumption and production, globalization – decreasing trade costs – itself induces structural change towards services because it reduces the relative price of goods to services. Thus the overall impact of globalization on international comovement is actually ambiguous – the shift it induces towards services can offset the increased transmission through stronger trade and input linkages.

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ONLINE APPENDIX TO

Globalization, Structural Change and International Comovement

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(NOT FOR PUBLICATION)

Appendix A Data

Trade and input shares. For our baseline analysis, we use the annual world input-output data compiled by Johnson and Noguera (2017). The data cover 4 sectors ("Agriculture", "Non-Manufacturing Industries", "Manufactures" and "Services") and years 1970 to 2009, and we use it to construct the trade and expenditure shares. For robustness and auxiliary exercises, we also use the long-run annual World Input-Output Database (WIOD), covering the years 1965-2000. These data contain sectors at the ISIC-Rev.3 level of detail (23 sectors), and we use these more disaggregated data in some exercises.[14] We stop the sample in 2007, as trade integration remained flat after the Great Trade Collapse.

Sectoral production data. Sectoral quantities and prices come from the 2009 EU-KLEMS release (O'Mahony and Timmer, 2009) for the majority of the countries, as well as national statistical offices for some countries. The KLEMS data are also available at a finer level of disaggregation than our baseline 4 sectors. In the quantification, we aggregate it to the 4 sectors by using the so called cyclical expansion procedure detailed below, which also provides the exact mapping of sectors to the ISIC classification and the mapping between the variables in the data and objects in the model.

Country coverage. After merging the trade and sectoral data, the final dataset consists of 21 countries and a composite Rest of the World. Table A1 lists the countries. The countries in our sample cover 96% of the OECD's GDP and 84% of the world's GDP in 1978. We refer to countries that were members of the OECD at the beginning of the sample as "OECD countries."

Sectoral classification and aggregation. Our baseline analysis uses the four broad sectors ("Agriculture", "Non-Manufacturing Industries", "Manufactures" and "Services") as defined in Johnson and Noguera (2017). To aggregate the sectoral data from KLEMS to those four sectors, we use the mapping displayed in Table A2. Table A3 lists the key to sector codes.

To aggregate to the four sectors, we follow Herrendorf, Rogerson, and Valentinyi (2013) and use the so called cyclical expansion procedure. Dropping country subscripts, denote by $\mathcal{Y}_{\iota t}$ be the nominal value of output in some subsector $\iota \in j$, $Y_{\iota t}$ the quantity index, and $P_{\iota t}$ the price index (so that $\mathcal{Y}_{\iota t} = P_{\iota t} Y_{\iota t}$). These are the values taken directly from KLEMS disaggregated data. The KLEMS data comes from EU-KLEMS for most countries, from RIETI (for China, "China Industrial Productivity (CIP) Database Round 3.0") and the Reserve Bank of India (for India). The goal is to compute real values (Y_{jt}) and deflators (P_{jt}) for the aggregate $\mathcal{Y}_{jt} = \sum_{\iota \in j} \mathcal{Y}_{\iota t}$. We define the growth rate of the real value of the aggregate as:

$$\frac{Y_{jt}}{Y_{jt-1}} = \sqrt{\frac{\sum_{\iota \in j} P_{\iota t-1} Y_{\iota t}}{\sum_{\iota \in j} P_{\iota t-1} Y_{\iota t-1}} \frac{\sum_{\iota \in j} P_{\iota t} Y_{\iota t}}{\sum_{\iota \in j} P_{\iota t} Y_{\iota t-1}}}$$

From there, we compute $\frac{P_{jt}}{P_{jt-1}} = \frac{\mathcal{Y}_{jt}}{\mathcal{Y}_{jt-1}} / \frac{Y_{jt}}{Y_{jt-1}}$ for the 4 sectors we use in the analysis. To avoid contamination from outliers, we winsorize the growth of real value added and of the Solow residual to the 1% and 99% level.

Table A4 displays the variables we use from KLEMS and the trade flows (from Johnson and Noguera (2017) in the baseline or WIOD in robustness checks), and how they map to model objects.

[14] While other releases of the WIOD database cover years post-2000, they are based on different versions of the Systems of National Accounts (SNA) and are not well suited to be combined. Indeed, the authors of the WIOD advise against splicing the long-run WIOD with the versions of WIOD that cover the more recent years (Woltjer, Gouma, and Timmer, 2021). Hence we rely on the Johnson and Noguera (2017) dataset for the input-output data in our baseline.

Table A1: Country list

Country code	Country name	Country code	Country name
AUS	Australia	GRC	Greece
AUT	Austria	IRL	Ireland
BEL	Belgium	ITA	Italy
CAN	Canada	IND	India*
CHN	China*	JPN	Japan
DEU	Germany	KOR	Korea*
DNK	Denmark	NLD	Netherlands
ESP	Spain	PRT	Portugal
FIN	Finland	ROW	Rest of the World*
FRA	France	SWE	Sweden
GBR	United Kingdom	USA	United States

Notes: Countries denoted with a star (*) are not part of our group of OECD countries, which only includes countries that were in the OECD at the beginning of the sample.

Table A2: Sectoral conversion list

Sector	KLEMS code
Agriculture	AtB
NMI	C, E, F
Manufactures	D15t16, D17t19, D20t22, D23t24, D25, D26, D27t28, D29t37
Services	G, H, I60t63, I64, J, 70, 71t74, L, M, N, O, P, Q

Table A3: Sector key

Code	Description
AtB	Agriculture, hunting, forestry and fishing
C	Mining and quarrying
D15t16	Food, beverages and tobacco
D17t19	Textiles, apparel, leather and footwear
D20	Wood and products of wood and cork
D21t22	Pulp, paper, paper products, printing and publishing
D23	Coke, refined petroleum and nuclear fuel
D24	Chemicals and chemical products
D25	Rubber and plastics
D26	Other non-metallic mineral products
D27t28	Basic metals and fabricated metal products
D29	Machinery, nec
D30t33	Electrical and optical equipment
D34t35	Transport equipment
D36	Manufacturing nec
D37	Recycling
E	Electricity, gas and water supply
F	Construction
G	Wholesale and retail trade
H	Hotels and restaurants
I60t63	Transport and storage
I64	Post and telecommunications
J	Financial intermediation
K	Real estate, renting and business activities
K70	Real estate activities
K71t74	Renting of m& eq and other business activities
LtQ	Community social and personal services (incl. public admin, education and health)

Table A4: Link with data variable

Model object	Description	Link with KLEMS variable
$\mathcal{Y}_{\iota t} = P_{\iota t} Y_{\iota t}$	gross output	GO
P_{nj}	producer price	GO_P
Y_{nj}	real output	$\ln Y_{nj} = \ln GO - \ln GO\_P$
X_{nj}	intermediate inputs	$\ln X_{nj} = \ln II - \ln II\_P$
		Link with trade variable (JN or WIOD)
η_j	Share of value added	$\eta_j = \frac{1}{N} \sum_n 1 - \frac{\sum_{m,i} X^{int}_{mi,nj}}{\sum_{m,i} X^{int}_{nj,mi} + \sum_m X^{fin}_{nmj}}$

Appendix B Model

B.1 Influence matrices

Prices as a function of output and exogenous shocks. Combining the goods market clearing condition (7) with the balanced trade condition (8) and log-linearizing for changes in Z, ζ, τ^f, ϑ and τ^x yields:[15]

$$\begin{aligned}\ln P_{nj} + \ln Y_{nj} = & \sum_m \sum_i \frac{\eta_i P_{mi} Y_{mi}}{P_m \mathcal{F}_m} \frac{\pi^f_{mj} \pi^f_{nmj} P_m \mathcal{F}_m}{P_{nj} Y_{nj}} \left(\ln \pi^f_{mj} + \ln \pi^f_{nmj} + \ln P_{mi} + \ln Y_{mi} \right) \\ & + \sum_m \sum_i (1-\eta_i) \frac{P_{mi,t} Y_{mi,t}}{P_{nj,t} Y_{nj,t}} \pi^x_{j,mi,t} \pi^x_{nj,mi,t} \left(\ln \pi^x_{j,mi} + \ln \pi^x_{nj,mi} + \ln P_{mi} + \ln Y_{mi} \right)\end{aligned} \tag{B.1}$$

where the changes in shares are given by:

$$\begin{aligned}\ln \pi^f_{nj} = & \ln \zeta_{nj} + (1-\rho) \sum_m \pi^f_{mnj} \left(\ln \tilde{\tau}^f_{mnj} + \ln P_{mj} \right) \\ & - \sum_k \pi^f_{nk} \ln \zeta_{nk} - (1-\rho) \sum_k \pi^f_{nk} \left[\sum_m \pi^f_{mnk} \left(\ln \tilde{\tau}^f_{mnk} + \ln \hat{P}_{mk} \right) \right],\end{aligned}$$

$$\ln \pi^f_{mnj} = (1-\gamma) \left(\ln \tilde{\tau}^f_{mnj} + \ln P_{mj} - \sum_o \pi^f_{onj} \left(\ln \tilde{\tau}^f_{onj} + \ln P_{oj} \right) \right),$$

$$\begin{aligned}\ln \pi^x_{i,nj} = & \ln \vartheta_{i,nj} + (1-\varepsilon) \left(\sum_m \pi^x_{mi,nj,t} \left(\ln \tilde{\tau}^x_{mi,nj} + \ln \hat{P}_{mi} \right) \right) \\ & - \sum_k \pi^x_{k,nj,t} \ln \vartheta_{k,nj} - (1-\varepsilon) \sum_k \pi^x_{k,nj,t} \sum_m \pi^x_{mk,nj,t} \left(\ln \tilde{\tau}^x_{mk,nj} + \ln \hat{P}_{mk} \right),\end{aligned}$$

and

$$\ln \pi^x_{mi,nj} = (1-\nu) \left(\ln \tilde{\tau}^x_{mi,nj} + \ln P_{mi} - \sum_k \pi^x_{ki,nj} \left(\ln \tilde{\tau}^x_{ki,nj} + \ln P_{ki} \right) \right),$$

Define the following matrices:

- $\mathbf{\Psi^f}$ is a $NJ \times N$ matrix whose (nj, m)th element is $\frac{\pi^f_{mj} \pi^f_{nmj} P_m \mathcal{F}_m}{P_{nj} Y_{nj}}$, the share of nj's total revenue that comes from final sales to country m.
- $\mathbf{\Upsilon}$ is a $N \times NJ$ matrix whose (m, mi)th element is $\frac{\eta_i P_{mi} Y_{mi}}{P_m \mathcal{F}_m}$, the share of value added of sector i in country m's GDP. Elements (n, mi) are 0 whenever $n \neq m$.

[15] An equivalent expression with exogenous trade deficits can be obtained as:

$$\begin{aligned}\ln P_{nj} + \ln Y_{nj} = & \sum_m \sum_i \frac{\eta_i P_{mi} Y_{mi}}{P_m \mathcal{F}_m} \frac{\pi^f_{mj} \pi^f_{nmj} P_m \mathcal{F}_m}{P_{nj} Y_{nj}} \left(\ln \pi^f_{mj} + \ln \pi^f_{nmj} + \ln P_{mi} + \ln Y_{mi} \right) \\ & + \sum_m \frac{\pi^f_{mj} \pi^f_{nmj} P_m \mathcal{F}_m}{P_{nj} Y_{nj}} \frac{D_m WGDP}{P_m \mathcal{F}_m} \left(\left(\hat{D}_m - 1 \right) + \sum_o \sum_k \frac{\eta_k P_{ok} Y_{ok}}{WGDP} \left(\ln P_{ok} + \ln Y_{ok} \right) \right) \\ & + \sum_m \sum_i (1-\eta_i) \frac{P_{mi,t} Y_{mi,t}}{P_{nj,t} Y_{nj,t}} \pi^x_{j,mi,t} \pi^x_{nj,mi,t} \left(\ln \pi^x_{j,mi} + \ln \pi^x_{nj,mi} + \ln P_{mi} + \ln Y_{mi} \right)\end{aligned}$$

where the trade deficits D_n are expressed as share of world GDP, and $\hat{D} - 1 = \frac{D'_n - D_n}{D_n}$ is the proportional change in D_n that can accommodate potentially negative values of trade deficits.

- $\mathbf{\Psi^x}$ is a $NJ \times NJ$ matrix whose $(nj,mi)th$ element is $\frac{\pi^x_{nj,mi}\pi^x_{j,mi}(1-\eta_i)P_{mi}Y_{mi}}{P_{nj,t}Y_{nj,t}}$, the share of country m,sector i's purchases from country n, sector j, in country n, sector j's total output.
- $\mathbf{\Pi^{1f}}$ is a $N \times NJ$ matrix whose $(m,nj)th$ element is $\pi^f_{mj}\pi^f_{nmj}$, the share of country n, sector j in country m's total consumption.
- $\mathbf{\Pi^{2f}}$ is a $N \times NJ$ matrix whose $(m,nj)\,th$ element is π^f_{nmj}, the share of country n in country m, sector j's spending.
- $\mathbf{\Pi^{1x}}$ is a $NJ \times NJ$ matrix whose $(nj,mi)th$ element is $\pi^x_{i,nj}\pi^x_{mi,nj}$, the share of country m, sector i in country n, sector j's total inputs.
- $\mathbf{\Pi^{2x}}$ is a $NJ \times NJ$ matrix whose $(mi,nj)th$ element is $\pi^x_{mi,nj}$.
- $\boldsymbol{\Psi^\zeta}$ a $NJ \times NJ$ matrix such that $\boldsymbol{\Psi^\zeta} = \boldsymbol{\Psi^{1\zeta}} + \boldsymbol{\Psi^{2\zeta}}$, where:
  - $\boldsymbol{\Psi}^{\boldsymbol{1\zeta}}_{nj,mj} = \boldsymbol{\Psi}^{\boldsymbol{f}}_{nj,m}$, and $\boldsymbol{\Psi}^{\boldsymbol{1\zeta}}_{nj,mi} = 0, \forall i \neq j$
  - $\boldsymbol{\Psi}^{\boldsymbol{2\zeta}}_{nj,mj} = -\boldsymbol{\Psi}^{\boldsymbol{f}}_{nj,m}\pi^f_{mk}$
- $\boldsymbol{\Psi^{\tau^f}}$ a $NJ \times NNJ$ matrix such that $\boldsymbol{\Psi^{\tau^f}} = \boldsymbol{\Psi^{1\tau^f}} + \boldsymbol{\Psi^{2\tau^f}} + \boldsymbol{\Psi^{3\tau^f}}$, where:
  - $\boldsymbol{\Psi}^{\boldsymbol{1\tau^f}}_{nj,nmj} = (1-\gamma)\,\boldsymbol{\Psi}^{\boldsymbol{f}}_{nj,m}$, and $\boldsymbol{\Psi}^{\boldsymbol{1\tau^f}}_{nj,omi} = 0, \forall i \neq j$ or $n \neq o$
  - $\boldsymbol{\Psi}^{\boldsymbol{2\tau^f}}_{nj,omj} = [(1-\rho)-(1-\gamma)]\,\boldsymbol{\Psi}^{\boldsymbol{f}}_{nj,m}\pi^f_{omj}$, and $\boldsymbol{\Psi}^{\boldsymbol{2\tau^f}}_{nj,omi} = 0, \forall j \neq i$
  - $\boldsymbol{\Psi}^{\boldsymbol{3\tau^f}}_{nj,omi} = -(1-\rho)\,\boldsymbol{\Psi}^{\boldsymbol{f}}_{nj,m}\pi^f_{mi}\pi^f_{omi}$
- $\boldsymbol{\Psi^\vartheta}$ a $NJ \times NJJ$ matrix such that $\boldsymbol{\Psi^\vartheta} = \boldsymbol{\Psi^{1\vartheta}} + \boldsymbol{\Psi^{2\vartheta}}$, where:
  - $\boldsymbol{\Psi}^{\boldsymbol{1\vartheta}}_{nj,mij} = \boldsymbol{\Psi}^{\boldsymbol{x}}_{nj,mi}$, and $\boldsymbol{\Psi}^{\boldsymbol{1\vartheta}}_{nj,mik} = 0, \forall j \neq k$
  - $\boldsymbol{\Psi}^{\boldsymbol{2\vartheta}}_{nj,mik} = -\boldsymbol{\Psi}^{\boldsymbol{x}}_{nj,mi}\pi^x_{k,mi}$
- $\boldsymbol{\Psi^{\tau^x}}$ a $NJ \times NJNJ$ matrix such that $\boldsymbol{\Psi^{\tau^x}} = \boldsymbol{\Psi^{1\tau^x}} + \boldsymbol{\Psi^{2\tau^x}} + \boldsymbol{\Psi^{3\tau^x}}$, where:
  - $\boldsymbol{\Psi}^{\boldsymbol{1\tau x}}_{nj,njmi} = (1-\nu)\,\Psi^x_{nj,mi}$, and $\boldsymbol{\Psi}^{\boldsymbol{1\tau^x}}_{nj,okmi} = 0, \forall n \neq o$ or $k \neq j$
  - $\boldsymbol{\Psi}^{\boldsymbol{2\tau x}}_{nj,ojmi} = [(1-\varepsilon)-(1-\nu)]\,\Psi^x_{nj,mi}\pi^x_{oj,mi}$, and $\boldsymbol{\Psi}^{\boldsymbol{2\tau x}}_{nj,okmi} = 0, \forall j \neq k$
  - $\boldsymbol{\Psi}^{\boldsymbol{3\tau x}}_{nj,okmi} = -(1-\varepsilon)\,\Psi^x_{nj,mi}\pi^x_{k,mi,t}\pi^x_{ok,mi}$

The market clearing can be written in matrix form as:[16]

$$
\begin{aligned}
\ln \boldsymbol{P} + \ln \boldsymbol{Y} = {} & \left(\boldsymbol{\Psi^f}\boldsymbol{\Upsilon} + \boldsymbol{\Psi^x}\right)(\ln \boldsymbol{P} + \ln \boldsymbol{Y}) \\
& + \left[(1-\gamma)\,diag\left(\boldsymbol{\Psi^f}\mathbf{1}\right) + [(1-\rho)-(1-\gamma)]\,\boldsymbol{\Psi^c}\boldsymbol{\Pi^{2f}} - (1-\rho)\,\boldsymbol{\Psi^f}\boldsymbol{\Pi^{1f}}\right]\ln \boldsymbol{P} \\
& + \left[(1-\nu)\,diag\left(\boldsymbol{\Psi^x}\mathbf{1}\right) + [(1-\varepsilon)-(1-\nu)]\,\boldsymbol{\Psi^x}\boldsymbol{\Pi^{2x}} - (1-\varepsilon)\,\boldsymbol{\Psi^x}\boldsymbol{\Pi^{1x}}\right]\ln \boldsymbol{P} \\
& + \boldsymbol{\Psi^\zeta}\ln\boldsymbol{\zeta} + \boldsymbol{\Psi^{\tau f}}\ln\boldsymbol{\tau^f} + \boldsymbol{\Psi^\vartheta}\ln\boldsymbol{\vartheta} + \boldsymbol{\Psi^{\tau x}}\ln\boldsymbol{\tau^x}
\end{aligned}
$$

which allows us to solve for prices as a function of quantities Y and shocks:

$$
\ln \boldsymbol{P} = \boldsymbol{\mathcal{P}^Y}\ln\boldsymbol{Y} + \boldsymbol{\mathcal{P}^\zeta}\ln\boldsymbol{\zeta} + \boldsymbol{\mathcal{P}^{\tau f}}\ln\boldsymbol{\tau^f} + \boldsymbol{\mathcal{P}^\vartheta}\ln\boldsymbol{\vartheta} + \boldsymbol{\mathcal{P}^{\tau x}}\ln\boldsymbol{\tau^x}, \tag{B.2}
$$

where

$$
\boldsymbol{\mathcal{P}^Y} = -\left(I - \boldsymbol{\mathcal{M}}\right)^{+}\left(\mathbf{I} - \mathbf{\Psi^f}\mathbf{\Upsilon} - \mathbf{\Psi^x}\right),
$$

[16] In the case of trade deficits, two additional terms should be added to the equation:

1. $\boldsymbol{\Psi^\Delta\Delta}$, where $\boldsymbol{\Psi^\Delta}$ is a $(NJ)\times N$ matrix, where $\Psi^\Delta_{nj,m} = \frac{\pi^f_{mj}\pi^f_{nmj}P^D_m\mathcal{F}_m}{P_{nj}Y_{nj}}\frac{D_m WGDP}{P_m\mathcal{F}_m}$.
2. $\boldsymbol{\Psi^{PY\Delta}}(\ln\boldsymbol{Y} + \ln\boldsymbol{P})$, where $\Psi^{PY\Delta}_{nj,ok} = \frac{\eta_k P_{ok}Y_{ok}}{WGDP}\sum_m \Psi^\Delta_{nj,m}$

and

$$\boldsymbol{\mathcal{M}} = \mathbf{\Psi^f \Upsilon} + \mathbf{\Psi^x} + \left[(1-\gamma)\, diag\left(\mathbf{\Psi^f 1}\right) + [(1-\rho)-(1-\gamma)]\,\mathbf{\Psi^c \Pi^{2f}} - (1-\rho)\,\mathbf{\Psi^f \Pi^{1f}}\right]$$
$$+ \left[(1-\nu)\, diag\left(\mathbf{\Psi^x 1}\right) + [(1-\varepsilon)-(1-\nu)]\,\mathbf{\Psi^x \Pi^{2x}} - (1-\varepsilon)\,\mathbf{\Psi^x \Pi^{1x}}\right].$$

and for the other shocks $s \in \{\zeta, \tau^f, \vartheta, \tau^x\}$:

$$\boldsymbol{\mathcal{P}^s} = -\left(\boldsymbol{I} - \boldsymbol{\mathcal{M}}\right)^{+} \boldsymbol{\Psi^s}.$$

Hours as a function of output, prices and exogenous shocks. Taking the log deviation of equation (2) and plugging in for the log deviation in W_n gives:

$$\ln H_{nj} = -\psi \ln P_n^f + (\mu - 1)\ln W_{nj} + (\psi - \mu + 1)\sum_j \pi_{nj}^H d\ln W_{nj}.$$

Using the firms' optimal labor choice and substituting in for the sectoral wage $\ln W_{nj}$ yields:

$$\ln H_{nj} = -\psi \ln P_n^f + (\mu-1)\left(\ln P_{nj} + \ln Y_{nj} - \ln H_{nj}\right) + (\psi - \mu + 1)\sum_k \pi_{nk}^H \left(\ln P_{nk} + \ln Y_{nk} - \ln H_{nk}\right)$$

which can be rewritten in matrix form as

$$\mu \ln \boldsymbol{H} = -\psi\left(\boldsymbol{I}_N \otimes \boldsymbol{1}_J\right)\ln \boldsymbol{P^f} + (\mu-1)\left(\ln \boldsymbol{P} + \ln \boldsymbol{Y}\right) + (\psi-\mu+1)\left(\boldsymbol{\Pi^H} \otimes \boldsymbol{1}_J\right)\left(\ln \boldsymbol{P} + \ln \boldsymbol{Y} - \ln \boldsymbol{H}\right),$$

where $\boldsymbol{\Pi^H}$ is a block diagonal $N \times NJ$ matrix whose $(n,nj)th$ element is π_{nj}^H[17], and $\ln \boldsymbol{P^f}$ is a $N \times 1$ vector whose n's element is $\ln P_n^f$ which is given by:

$$\ln P_n^f = \sum_k \pi_{nk}^f \left[\frac{1}{1-\rho}\ln \zeta_{nk} + \sum_m \pi_{mnk}^f \left(\ln \tilde{\tau}_{mnk}^f + \ln P_{mk}\right)\right]$$

which can be written as:

$$\ln \mathbf{P^f} = \frac{1}{1-\rho}\boldsymbol{\Pi^f} \ln \boldsymbol{\zeta} + \boldsymbol{\Pi^{1f}} \ln \boldsymbol{P} + \boldsymbol{\Pi^{3f}} \ln \boldsymbol{\tilde{\tau}^f},$$

where $\boldsymbol{\Pi^f}$ is a $N \times J$ matrix whose (n,j)'s element is π_{nj}^f and $\boldsymbol{\Pi^{3f}}$ is a $N \times NNJ$ block-diagonal matrix whose (n, mnk)'s element is equal to $\boldsymbol{\Pi}^{\boldsymbol{1f}}_{n,mj}$. As a result, the vector of sectoral hours can be solved as a function of prices, output and other shocks:

$$\begin{aligned}\left[\mu \boldsymbol{I} + (\psi-\mu+1)\left(\boldsymbol{\Pi^H} \otimes \boldsymbol{1}_J\right)\right]\ln \mathbf{H} \quad = \quad & \left[-\psi\left(\boldsymbol{\Pi^{1f}} \otimes \boldsymbol{1}_J\right) + (\mu-1) + (\psi-\mu+1)\left(\boldsymbol{\Pi^H} \otimes \boldsymbol{1}_J\right)\right]\ln \boldsymbol{P} \\ & + \left[(\mu-1) + (\psi-\mu+1)\left(\boldsymbol{\Pi^H} \otimes \boldsymbol{1}_J\right)\right]\ln \boldsymbol{Y} \\ & -\psi\left(\boldsymbol{I}_N \otimes \boldsymbol{1}_J\right)\frac{1}{1-\rho}\boldsymbol{\Pi^f} \ln \boldsymbol{\zeta} - \psi \boldsymbol{\Pi^{3f}} \ln \boldsymbol{\tilde{\tau}^f}.\end{aligned}$$

Plugging in for (B.2) gives

$$\ln \mathbf{H} = \boldsymbol{\mathcal{H}^Y} \ln \boldsymbol{Y} + \boldsymbol{\mathcal{H}^P} \ln \boldsymbol{P} + \boldsymbol{\mathcal{H}^\zeta} \ln \boldsymbol{\zeta} + \boldsymbol{\mathcal{H}^{\tilde{\tau}^f}} \ln \boldsymbol{\tilde{\tau}^f} \tag{B.3}$$

[17] In the model, π_{nj}^H is also equal to the share of the sector's value added in total GDP. To see that, notice that the sectoral value added is equal to the wage bill $W_{nj}H_{nj}$, so the share of sector j in total value added is given by $\frac{W_{nj}H_{nj}}{\sum_i W_{ni}H_{ni}}$. Plugging in equation (2) shows that this is also equal to π_{nj}^H. Hence, we calibrate π_{nj}^H using the data on sectoral value added.

where

$$\begin{aligned}
\boldsymbol{\mathcal{H}}^{\boldsymbol{Y}} &= \left[\mu \boldsymbol{I} + (\psi - \mu + 1)\left(\boldsymbol{\Pi^H} \otimes \mathbf{1}_J\right)\right]^{-1} \left[(\mu - 1) + (\psi - \mu + 1)\left(\boldsymbol{\Pi^H} \otimes \mathbf{1}_J\right)\right] \\
\boldsymbol{\mathcal{H}}^{\boldsymbol{P}} &= \left[\mu \boldsymbol{I} + (\psi - \mu + 1)\left(\boldsymbol{\Pi^H} \otimes \mathbf{1}_J\right)\right]^{-1} \left[-\psi\left(\boldsymbol{\Pi^{1f}} \otimes \mathbf{1}_J\right) + (\mu - 1) + (\psi - \mu + 1)\left(\boldsymbol{\Pi^H} \otimes \mathbf{1}_J\right)\right] \\
\boldsymbol{\mathcal{H}}^{\zeta} &= -\frac{\psi}{1-\rho}\left[\mu \boldsymbol{I} + (\psi - \mu + 1)\left(\boldsymbol{\Pi^H} \otimes \mathbf{1}_J\right)\right]^{-1} \left(\boldsymbol{I}_N \otimes \mathbf{1}_J\right) \\
\boldsymbol{\mathcal{H}}^{\tilde{\boldsymbol{\tau}}^{\boldsymbol{f}}} &= -\psi\left[\mu \boldsymbol{I} + (\psi - \mu + 1)\left(\boldsymbol{\Pi^H} \otimes \mathbf{1}_J\right)\right]^{-1} \boldsymbol{\Pi^{3f}}
\end{aligned}$$

Output as a function of exogenous shocks. Turning to the intermediates, the firm's optimality conditions imply that:

$$\ln \mathbf{P} + \ln \mathbf{Y} = \ln \mathbf{P^x} + \ln \mathbf{X},$$

where

$$\ln \mathbf{P^x} = \boldsymbol{\Pi}^{\mathbf{1x}} \ln \mathbf{P},$$

so that

$$\ln \mathbf{X} = \ln \mathbf{Y} + \left(\mathbf{I} - \boldsymbol{\Pi}^{\mathbf{1x}}\right) \ln \mathbf{P}.$$

Plugging for intermediates, hours (B.3) and prices (B.2) in the production function gives:

$$\begin{aligned}
\ln \boldsymbol{Y} &= \ln \boldsymbol{Z} + \boldsymbol{\eta} \ln \boldsymbol{H} + (\boldsymbol{I} - \boldsymbol{\eta}) \ln \boldsymbol{X} \\
&= \ln \boldsymbol{Z} + (\boldsymbol{I} - \boldsymbol{\eta}) \ln \mathbf{Y} + \left(\mathbf{I} - \boldsymbol{\Pi}^{\mathbf{1x}}\right) \ln \mathbf{P} \\
&\quad + \boldsymbol{\eta}\left[\boldsymbol{\mathcal{H}}^{\boldsymbol{Y}} \ln \boldsymbol{Y} + \boldsymbol{\mathcal{H}}^{\boldsymbol{P}} \ln \boldsymbol{P} + \boldsymbol{\mathcal{H}}^{\zeta} \ln \boldsymbol{\zeta} + \boldsymbol{\mathcal{H}}^{\tilde{\boldsymbol{\tau}}^{\boldsymbol{f}}} \ln \tilde{\boldsymbol{\tau}}^{\boldsymbol{f}}\right] \\
&= \ln \boldsymbol{Z} + \left[(\boldsymbol{I} - \boldsymbol{\eta}) + \boldsymbol{\eta}\boldsymbol{\mathcal{H}}^{\boldsymbol{Y}}\right] \ln \mathbf{Y} + \left[\left(\mathbf{I} - \boldsymbol{\Pi}^{\mathbf{1x}}\right) + \boldsymbol{\eta}\boldsymbol{\mathcal{H}}^{\boldsymbol{P}}\right] \ln \mathbf{P} \\
&\quad + \boldsymbol{\eta}\left[\boldsymbol{\mathcal{H}}^{\zeta} \ln \boldsymbol{\zeta} + \boldsymbol{\mathcal{H}}^{\tilde{\boldsymbol{\tau}}^{\boldsymbol{f}}} \ln \tilde{\boldsymbol{\tau}}^{\boldsymbol{f}} + \boldsymbol{\mathcal{H}}^{\chi} \ln \boldsymbol{\chi}\right] \\
&= \ln \boldsymbol{Z} + \left[(\boldsymbol{I} - \boldsymbol{\eta}) + \boldsymbol{\eta}\boldsymbol{\mathcal{H}}^{\boldsymbol{Y}}\right] \ln \mathbf{Y} + \boldsymbol{\eta}\left[\boldsymbol{\mathcal{H}}^{\zeta} \ln \boldsymbol{\zeta} + \boldsymbol{\mathcal{H}}^{\tilde{\boldsymbol{\tau}}^{\boldsymbol{f}}} \ln \tilde{\boldsymbol{\tau}}^{\boldsymbol{f}}\right] \\
&\quad + \left[\left(\mathbf{I} - \boldsymbol{\Pi}^{\mathbf{1x}}\right) + \boldsymbol{\eta}\boldsymbol{\mathcal{H}}^{\boldsymbol{P}}\right]\left[\boldsymbol{\mathcal{P}}^{\boldsymbol{Y}} \ln \boldsymbol{Y} + \boldsymbol{\mathcal{P}}^{\zeta} \ln \boldsymbol{\zeta} + \boldsymbol{\mathcal{P}}^{\boldsymbol{\tau f}} \ln \boldsymbol{\tau}^{\boldsymbol{f}} + \boldsymbol{\mathcal{P}}^{\boldsymbol{\vartheta}} \ln \boldsymbol{\vartheta} + \boldsymbol{\mathcal{P}}^{\boldsymbol{\tau x}} \ln \boldsymbol{\tau}^{\boldsymbol{x}}\right]
\end{aligned}$$

where $\boldsymbol{\eta}$ is a diagonal matrix where element (nj, nj) is equal to η_j. This leads to:

$$\ln \boldsymbol{Y} = \boldsymbol{\Lambda}^{\boldsymbol{Y}}_{\boldsymbol{Z}} \ln \boldsymbol{Z} + \boldsymbol{\Lambda}^{\boldsymbol{Y}}_{\zeta} \ln \boldsymbol{\zeta} + \boldsymbol{\Lambda}^{\boldsymbol{Y}}_{\boldsymbol{\tau^f}} \ln \tilde{\boldsymbol{\tau}}^{\boldsymbol{f}} + \boldsymbol{\Lambda}^{\boldsymbol{Y}}_{\boldsymbol{\vartheta}} \ln \boldsymbol{\vartheta} + \boldsymbol{\Lambda}^{\boldsymbol{Y}}_{\boldsymbol{\tau^x}} \ln \tilde{\boldsymbol{\tau}}^{\boldsymbol{x}}, \tag{B.4}$$

where

$$\boldsymbol{\Lambda}^{\boldsymbol{Y}}_{\boldsymbol{Z}} = \left[\mathbf{I} - (\boldsymbol{I} - \boldsymbol{\eta}) - \boldsymbol{\eta}\boldsymbol{\mathcal{H}}^{\boldsymbol{Y}} - \left[\left(\mathbf{I} - \boldsymbol{\Pi}^{\mathbf{1x}}\right) + \boldsymbol{\eta}\boldsymbol{\mathcal{H}}^{\boldsymbol{P}}\right]\boldsymbol{\mathcal{P}}^{\boldsymbol{Y}}\right]^{-1}, \tag{B.5}$$

and for the other shocks:

$$\boldsymbol{\Lambda}^{\boldsymbol{Y}}_{\boldsymbol{s}} = \boldsymbol{\Lambda}^{\boldsymbol{Y}}_{\boldsymbol{Z}}\left[\boldsymbol{\eta}\boldsymbol{\mathcal{H}}^{\boldsymbol{s}} + \left[\left(\boldsymbol{I} - \boldsymbol{\Pi}^{\boldsymbol{1x}}\right) + \boldsymbol{\eta}\boldsymbol{\mathcal{H}}^{\boldsymbol{P}}\right]\boldsymbol{\mathcal{P}}^{\boldsymbol{s}}\right].$$

Hours as a function of exogenous shocks. To get equation (11), plug in (B.4) and (B.2) in (B.3) to get:

$$\ln \boldsymbol{H} = \boldsymbol{\Lambda}^{\boldsymbol{H}}_{\boldsymbol{Z}} \ln \boldsymbol{Z} + \boldsymbol{\Lambda}^{\boldsymbol{H}}_{\zeta} \ln \boldsymbol{\zeta} + \boldsymbol{\Lambda}^{\boldsymbol{H}}_{\boldsymbol{\tau^f}} \ln \boldsymbol{\tau}^{\boldsymbol{f}} + \boldsymbol{\Lambda}^{\boldsymbol{H}}_{\boldsymbol{\vartheta}} \ln \boldsymbol{\vartheta} + \boldsymbol{\Lambda}^{\boldsymbol{H}}_{\boldsymbol{\tau^x}} \ln \boldsymbol{\tau}^{\boldsymbol{x}} + \boldsymbol{\Lambda}^{\boldsymbol{H}}_{\boldsymbol{\chi}} \ln \boldsymbol{\chi}$$

where

$$\boldsymbol{\Lambda}^{\boldsymbol{H}}_{\boldsymbol{s}} = \left(\boldsymbol{\mathcal{H}}^{\boldsymbol{Y}} + \boldsymbol{\mathcal{H}}^{\boldsymbol{P}}\boldsymbol{\mathcal{P}}^{\boldsymbol{Y}}\right)\boldsymbol{\Lambda}^{\boldsymbol{Y}}_{\boldsymbol{s}} + \boldsymbol{\mathcal{H}}^{\boldsymbol{P}}\boldsymbol{\mathcal{P}}^{\boldsymbol{s}} + \boldsymbol{\mathcal{H}}^{\boldsymbol{s}}. \tag{B.6}$$

B.2 Long-run shocks extraction

To extract the set of long-run shocks $\{\boldsymbol{Z}, \boldsymbol{\zeta}, \boldsymbol{\tau^f}, \boldsymbol{\vartheta}, \boldsymbol{\tau^x}\}$, we match the long-run changes in value added, final consumption sectoral shares (π^f_{nj}), final trade shares (π^f_{mnj}), intermediates sectoral shares ($\pi^x_{,nj}$) and intermediate trade shares ($\pi^x_{mi,nj}$). In practice, because the taste shifters and trade costs are only defined up to a normalization, we match the change in sectoral shares relative to the first sector, and the change in trade shares relative to domestic share, and we impose $\ln \zeta_{n1} = 0$, $\ln \tilde{\tau}^f_{nnj} = 0$, $\ln \vartheta_{1,nj} = 0$, and $\ln \tilde{\tau}^x_{ni,nj} = 0$. It will be convenient to define $\boldsymbol{\theta}$ as the $NJ + NJ + NNJ + NJJ + NJNJ$ long vector of all shocks: $\boldsymbol{\theta} = [\boldsymbol{Z}, \boldsymbol{\zeta}, \boldsymbol{\tau^f}, \boldsymbol{\vartheta}, \boldsymbol{\tau^x}]$

Change in sectoral value added. The change in sectoral value added at constant prices is computed as:

$$\begin{aligned}
\ln V^{data}_{nj} &= \frac{1}{\eta_j} \ln Y_{nj} - \frac{1-\eta_j}{\eta_j} \ln X^{data}_{nj} \\
&= \frac{1}{\eta_j} \left(\ln Z_{nj} + \eta_j \ln H_{nj} + (1-\eta_j) \ln X_{nj} \right) - \frac{1-\eta_j}{\eta_j} \ln X^{data}_{nj} \\
&= \frac{1}{\eta_j} \left(\ln Z_{nj} + \eta_j \ln H_{nj} \right) - \frac{1-\eta_j}{\eta_j} \left(\ln X^{data}_{nj} - \ln X_{nj} \right)
\end{aligned}$$

In the data, $\ln X^{data}_{nj}$ is computed as the change in gross inputs minus the change in the input price index. The price index is computed from changes in input prices, ignoring any changes in ϑ that would also affect the (ideal) input price.

$$\ln V^{data}_{nj} = \underbrace{\frac{1}{\eta_j} \left[\ln Z_{njt} - (1-\eta_j) \frac{1}{1-\varepsilon} \sum_k \pi^x_{k,nj} \ln \vartheta_{k,nj} \right]}_{\tilde{Z}_{nj}} + \ln H_{njt}$$

To circumvent this issue, we reinterpret the long-run productivity shock as $\tilde{Z}_{nj}$, the productivity-cum-taste shifter.[18] After this reinterpretation we can relate the data change in value added to the model implied changes due to the vector of shocks:

$$\begin{aligned}
\ln \boldsymbol{V} &= \boldsymbol{\eta}^{-1} \ln \boldsymbol{Z} + \ln \boldsymbol{H} \\
&= \boldsymbol{\mathcal{V}^{\theta}} \ln \boldsymbol{\theta},
\end{aligned} \tag{B.7}$$

where

$$\boldsymbol{\mathcal{V}^{\theta}} = \left[\boldsymbol{\eta}^{-1}, \boldsymbol{0} \right] + \boldsymbol{\Lambda^H}.$$

Change in final sectoral shares. The change in relative final sectoral shares is given by:

$$\ln \pi^f_{nj} - \ln \pi^f_{n1} = \ln \zeta_{nj} + (1-\rho) \sum_m \pi^f_{mnj} \left(\ln \tilde{\tau}^f_{mnj} + d \ln P_{mj} \right) - (1-\rho) \sum_m \pi^f_{mn1} \left(\ln \tilde{\tau}^f_{mn1} + \ln P_{m1} \right), \tag{B.8}$$

where $\tilde{\tau}^f_{mnj} = \mu^{\frac{1}{1-\gamma}}_{mnj} \tau^f_{mnj}$ is the trade cost-cum-tastes shock.

In matrix form, this can be rewritten as:

$$\begin{aligned}
\ln \boldsymbol{\Pi^{1fv}} &= \ln \boldsymbol{\zeta} + \boldsymbol{A^{\tau^f}} \ln \boldsymbol{\tau^f} + \boldsymbol{A^P} \ln \boldsymbol{P} \\
&= \boldsymbol{\Phi^{1fv}} \ln \boldsymbol{\theta}
\end{aligned} \tag{B.9}$$

where

- $\ln \boldsymbol{\Pi^{1fv}}$ is a NJ long vector where element (nj) is equal to $\ln \pi^f_{nj} - \ln \pi^f_{n1}$.
- $\boldsymbol{A^{\tau^f}}$ is a block diagonal $NJ \times NNJ$ matrix where $\boldsymbol{A^{\tau^f}_{nj,mnj}} = (1-\rho)\pi^f_{mnj}$ and $\boldsymbol{A^{\tau^f}_{nj,mn1}} = -(1-\rho)\pi^f_{mn1}$, $\forall j \neq 1$.
- $\boldsymbol{A^P}$ is a $NJ \times NJ$ matrix where $\boldsymbol{A^P_{nj,mj}} = (1-\rho)\pi^f_{mnj}$ and $\boldsymbol{A^P_{nj,m1}} = -(1-\rho)\pi^f_{mn1}$, $\forall j \neq 1$.

[18] In the short-run, we assume that the only business cycle shock is the productivity shock, so ϑ is constant and doesn't enter the equation.

- $\boldsymbol{\Phi^{1fv}}$ collects all the direct (for ζ and τ^f) and indirect effects (through P) of each shocks sectoral shares

Change in final trade shares. The change in relative final trade shares is given by:

$$\ln \pi^f_{mnj} - \ln \pi^f_{nnj} = (1-\gamma)\left(\ln \tilde{\tau}^f_{mnj} + \ln P_{mj} - \ln P_{nj}\right).$$

In matrix form, this can be written as

$$\begin{aligned} \ln \boldsymbol{\Pi^{2fv}} &= \boldsymbol{B^{\tau f}} \ln \boldsymbol{\tilde{\tau}^f} + \boldsymbol{B^P} \ln \boldsymbol{P} \\ &= \boldsymbol{\Phi^{2fv}} \ln \boldsymbol{\theta} \end{aligned} \tag{B.10}$$

where

- $\ln \boldsymbol{\Pi^{2fv}}$ is a NNJ long vector where element (mnj) is equal to $\ln \pi^f_{mnj} - \ln \pi^f_{nnj}$.
- $\boldsymbol{B^{\tau^f}}$ is an almost-diagonal $NNJ \times NNJ$ matrix where $\boldsymbol{B}^{\boldsymbol{\tau^f}}_{mnj,mnj} = (1-\gamma)$ and $\boldsymbol{B}^{\boldsymbol{\tau^f}}_{mnj,nnj} = -(1-\gamma)$, $\forall m \neq n$.
- $\boldsymbol{B^P}$ is a $NNJ \times NJ$ matrix where $\boldsymbol{B}^{\boldsymbol{P}}_{mnj,mj} = (1-\gamma)$ and $\boldsymbol{A}^{\boldsymbol{P}}_{mnj,nj} = -(1-\gamma)$, $\forall m \neq n$.
- $\boldsymbol{\Phi^{2fv}}$ collects all the direct (for τ^f) and indirect effects (through P) of each shocks on trade shares

Change in intermediate sectoral shares. The change in relative final sectoral share is given by:

$$\begin{aligned} \ln \pi^x_{i,nj} - \ln \pi^x_{1,nj} =& \ln \vartheta_{i,nj} + (1-\varepsilon)\left(\sum_m \pi^x_{mi,nj}\left(\ln \tilde{\tau}^x_{mi,nj} + \ln P_{mi}\right)\right) \\ & - (1-\varepsilon)\left(\sum_m \pi^x_{m1,nj}\left(\ln \tilde{\tau}^x_{m1,nj} + \ln P_{m1}\right)\right), \end{aligned}$$

where $\tilde{\tau}^x_{minj} = \mu^{\frac{1}{1-\nu}}_{minj} \tau^x_{minj}$ is the trade cost-cum-tastes shock.

In matrix form:

$$\begin{aligned} \ln \boldsymbol{\Pi^{1xv}} &= \boldsymbol{B^{\tau x}} \ln \boldsymbol{\tilde{\tau}^x} + \boldsymbol{B^P} \ln \boldsymbol{P} \\ &= \boldsymbol{\Phi^{1xv}} \ln \boldsymbol{\theta} \end{aligned} \tag{B.11}$$

where

- $\ln \boldsymbol{\Pi^{1xv}}$ is a NJJ long vector where element (nji) is equal to $\ln \pi^x_{i,nj} - \ln \pi^x_{1,nj}$.
- $\boldsymbol{C^{\tau^x}}$ is a block diagonal $NJJ \times NJNJ$ matrix where $\boldsymbol{C}^{\boldsymbol{\tau^x}}_{nji,minj} = (1-\varepsilon)\pi^x_{mi,nj}$ and $\boldsymbol{C}^{\boldsymbol{\tau^x}}_{nj,mn1} = -(1-\varepsilon)\pi^x_{mi,n1}$, $\forall j \neq 1$.
- $\boldsymbol{C^P}$ is a $NJ \times NJ$ matrix where $\boldsymbol{C}^{\boldsymbol{P}}_{nj,mj} = (1-\varepsilon)\pi^f_{mnj}$ and $\boldsymbol{C}^{\boldsymbol{P}}_{nj,m1} = -(1-\varepsilon)\pi^f_{mn1}$, $\forall j \neq 1$.
- $\boldsymbol{\Phi^{1xv}}$ collects all the direct (for ϑ and τ^x) and indirect effects (through P) of each shocks sectoral shares

Change in intermediate trade shares. The change in relative final trade shares is given by:

$$\ln \pi^x_{mi,nj} - \ln \pi^x_{ni,nj} = (1-\nu)\left(\ln \tilde{\tau}^x_{mi,nj} + \ln P_{mi} - \ln P_{ni}\right).$$

In matrix form, this can be written as

$$\begin{aligned} \ln \boldsymbol{\Pi^{2xv}} &= \boldsymbol{D^{\tau x}} \ln \boldsymbol{\tilde{\tau}^f} + \boldsymbol{D^P} \ln \boldsymbol{P} \\ &= \boldsymbol{\Phi^{2xv}} \ln \boldsymbol{\theta} \end{aligned} \tag{B.12}$$

where

- $\ln \boldsymbol{\Pi^{2xv}}$ is a $NJNJ$ long vector where element $(minj)$ is equal to $\ln \pi^{x}_{mi,nj} - \ln \pi^{x}_{ni,nj}$.
- $\boldsymbol{D^{\tau^x}}$ is an almost-diagonal $NJNJ \times NJNJ$ matrix where $\boldsymbol{D}^{\boldsymbol{\tau^x}}_{minj,minj} = (1-\nu)$ and $\boldsymbol{D}^{\boldsymbol{\tau^x}}_{minj,ninj} = -(1-\nu)$, $\forall m \neq n$.
- $\boldsymbol{D^P}$ is a $NJNJ \times NJ$ matrix where $\boldsymbol{D}^{\boldsymbol{P}}_{minj,mi} = (1-\nu)$ and $\boldsymbol{D}^{\boldsymbol{P}}_{minj,ni} = -(1-\nu)$, $\forall m \neq n$.
- $\boldsymbol{\Phi^{2xv}}$ collects all the direct (for τ^x) and indirect effects (through P) of each shocks on trade shares

Inversion procedure. Stacking equations (B.7) to (B.12) gives:

$$\underbrace{\begin{bmatrix} \ln \boldsymbol{V} \\ \ln \boldsymbol{\Pi^{1fv}} \\ \ln \boldsymbol{\Pi^{2fv}} \\ \ln \boldsymbol{\Pi^{1xv}} \\ \ln \boldsymbol{\Pi^{2xv}} \end{bmatrix}}_{\text{Data}} = \begin{bmatrix} \boldsymbol{\Phi^{V}} \\ \boldsymbol{\Phi^{1fv}} \\ \boldsymbol{\Phi^{2fv}} \\ \boldsymbol{\Phi^{1xv}} \\ \boldsymbol{\Phi^{2xv}} \end{bmatrix} \begin{bmatrix} \ln \boldsymbol{Z} \\ \ln \tilde{\boldsymbol{\zeta}} \\ \ln \boldsymbol{\tau^f} \\ \ln \boldsymbol{\vartheta} \\ \ln \boldsymbol{\tau^x} \end{bmatrix} = \boldsymbol{\Phi} \underbrace{\ln \boldsymbol{\theta}}_{\text{shocks}} \tag{B.13}$$

One can solve for $\boldsymbol{\theta}$ by inverting the matrix $\boldsymbol{\Phi}$ and premultiplying the data on value added growth and share changes to obtain a vector of shocks $\boldsymbol{\theta}$ that matches the data exactly. This approach gives a vector of long-run productivity changes that might be different from the cumulated yearly changes given by equation (17).

Thus, in our baseline, instead compute the cumulated composite shock to construct a long-run productivity shock, and invert the rest of the shocks (trade changes, taste changes) to match trade and sectoral shares conditional on the productivity shock. To be precise, we drop the value-added equation from the moments to be matched and remove the effect of the cumulative composite shock on the sectoral and trade shares. We then use the residual changes to invert the shock and recover $\boldsymbol{\zeta}$, $\boldsymbol{\tau^f}$, $\boldsymbol{\vartheta}$ and $\boldsymbol{\tau^x}$:

$$\begin{bmatrix} \ln \boldsymbol{\Pi^{1fv}} \\ \ln \boldsymbol{\Pi^{2fv}} \\ \ln \boldsymbol{\Pi^{1xv}} \\ \ln \boldsymbol{\Pi^{2xv}} \end{bmatrix} - \begin{bmatrix} \boldsymbol{\Phi^{1fv,Z}} \\ \boldsymbol{\Phi^{2fv,Z}} \\ \boldsymbol{\Phi^{1xv,Z}} \\ \boldsymbol{\Phi^{2xv,Z}} \end{bmatrix} \left(\sum_t \ln Z^{SR}_t \right) = \begin{bmatrix} \boldsymbol{\Phi^{1fv}} \\ \boldsymbol{\Phi^{2fv}} \\ \boldsymbol{\Phi^{1xv}} \\ \boldsymbol{\Phi^{2xv}} \end{bmatrix} \begin{bmatrix} \ln \tilde{\boldsymbol{\zeta}} \\ \ln \boldsymbol{\tau^f} \\ \ln \boldsymbol{\vartheta} \\ \ln \boldsymbol{\tau^x} \end{bmatrix} \tag{B.14}$$

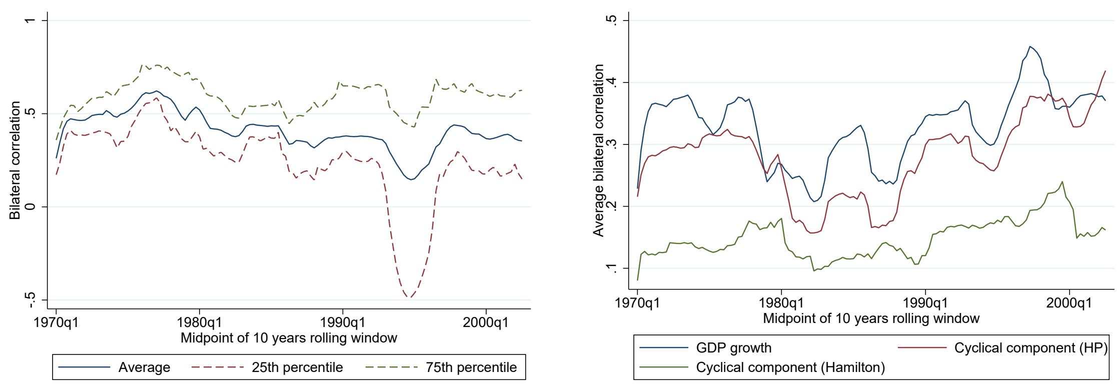
Figures C7, C8 and C9 compare the results when shocks are computed from equation (B.13) compared to our baseline where shocks are computed from equation (B.14).

Appendix C Quantification

C.1 Additional Basic Facts

The left panel of Figure C1 depicts the rolling 10-year GDP correlations for the G7. The right panel of Figure C1 displays the average bilateral correlations of GDP growth in the OECD (reproduced from Figure 1), together with the correlation of the growth in the cyclical component of GDP extracted using the HP filer (in red) and the detrending method suggested in Hamilton (2018). Figure C2 displays the average international correlation of sectoral value added, Solow residual, and our composite shock, across countries. Figure C3 displays the rolling correlations of the different shocks. It is apparent that throughout the sample, the manufacturing sector is always the most internationally correlated. Figure C4 displays the shock correlations of more disaggregated sectors.

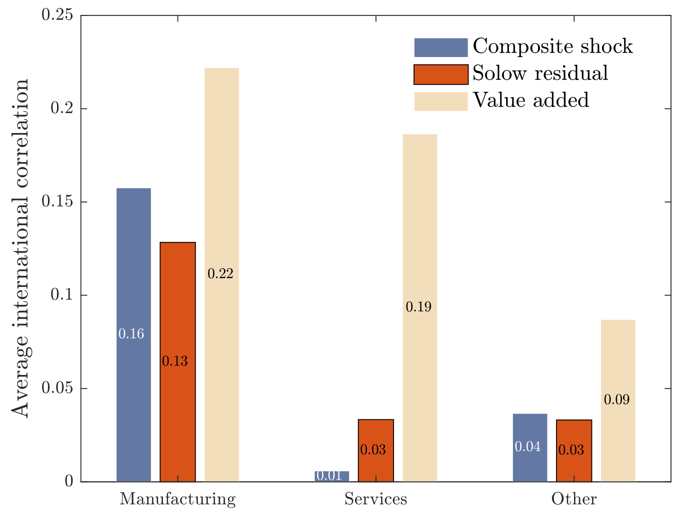
Figure C1: Trends in GDP Comovement, Robustness



G7 pairs | OECD, alternative detrending methods

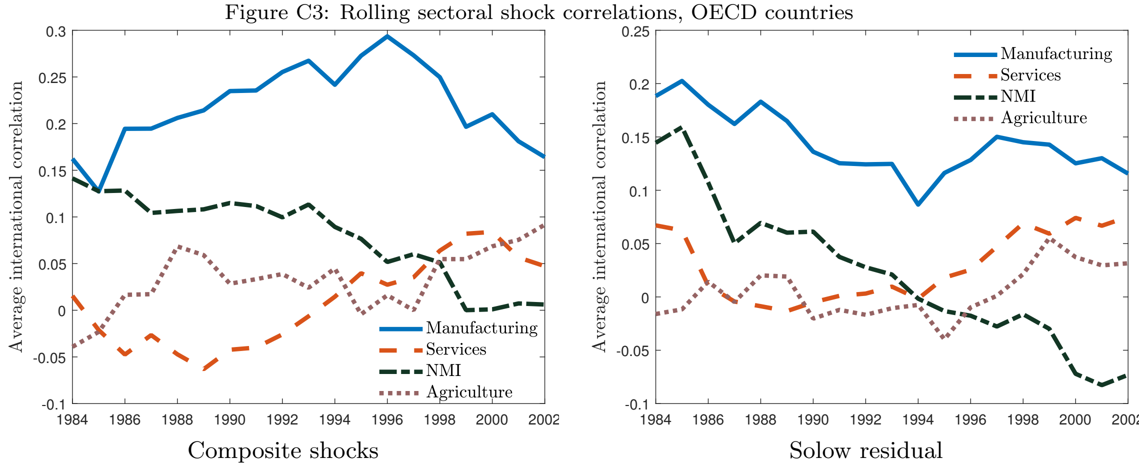
Notes: The left panel displays the average bilateral rolling quarterly (year-on-year) GDP growth correlations among the G7 countries. The left panel displays the average bilateral rolling quarterly (year-on-year) GDP growth correlations among the OECD countries, along with two alternative detrending methods. The date denotes the midpoint of the 10 year rolling window. The OECD sample refers to countries members of the OECD since the beginning of the sample in the 1970s.

Figure C2: Sectoral correlations, OECD countries



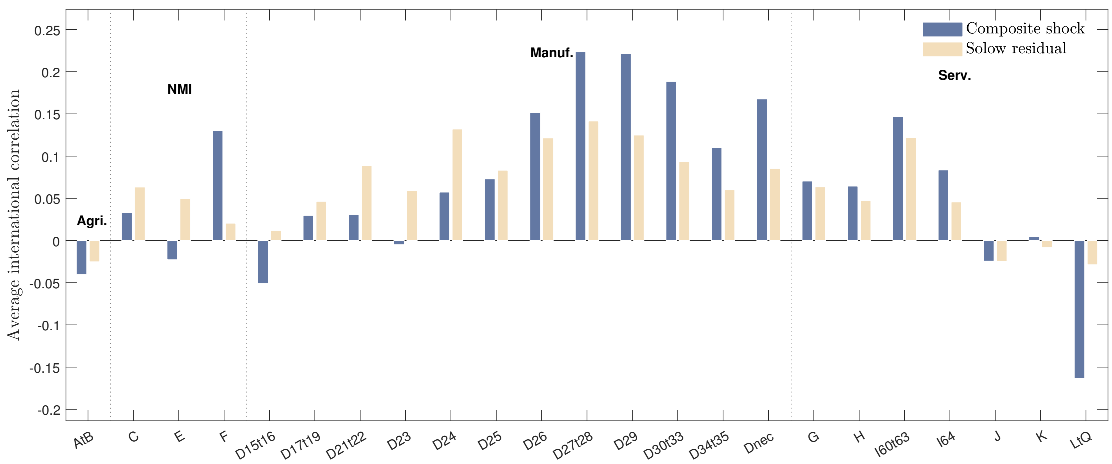
Notes: The figure displays the average correlation between growth in a country-sector with the foreign aggregate growth. For sectoral value added, the foreign aggregate is simply the foreign GDP growth. For the Solow residual (resp., composite) shocks, the foreign aggregate is the Domar-weighted Solow residual (resp., composite) shocks. That is, the bars display the average $corr(d \ln Z_{njt}, \sum_i w_{mit} Z_{mit})$ for $m \neq n$, where w_{mit} is the Domar weight.

Figure C3: Rolling sectoral shock correlations, OECD countries



Notes: This figure plots the rolling correlations of the sectoral composite shock and Solow residual with aggregate growth (foreign GDP for the composite shock, foreign Domar-aggregated Solow residual for the Solow residual).

Figure C4: Overall sectoral shock correlations, 23 sectors, OECD countries



Notes: This figure plots the correlation of the sectoral Solow residual and composite shock with foreign aggregate shocks over the 1978-2000 sample. The foreign aggregate is foreign GDP for the composite shock, and foreign Domar-aggregated Solow residuals for the Solow residual. The correlations are averaged across country pairs. The key to sector codes is listed in Table A3.

C.2 Additional Historical Decompositions and Counterfactual Summary Statistics

Table C1: Changes in correlation decomposition (first and last decade)

	OECD countries, composite shock				OECD countries, Solow residuals			
Tot corr	Mean	Median	p25	p75	Mean	Median	p25	p75
1984	0.301	0.326	0.099	0.534	0.317	0.331	0.130	0.555
2002	0.270	0.286	0.004	0.570	0.202	0.241	-0.053	0.481
Shock corr								
1984	0.167	0.197	-0.004	0.372	0.147	0.166	-0.008	0.361
2002	0.125	0.157	-0.070	0.381	0.067	0.094	-0.157	0.300
Trans.								
1984	0.135	0.129	0.094	0.169	0.170	0.157	0.118	0.217
2002	0.145	0.138	0.07	4 0.202	0.135	0.130	0.081	0.199

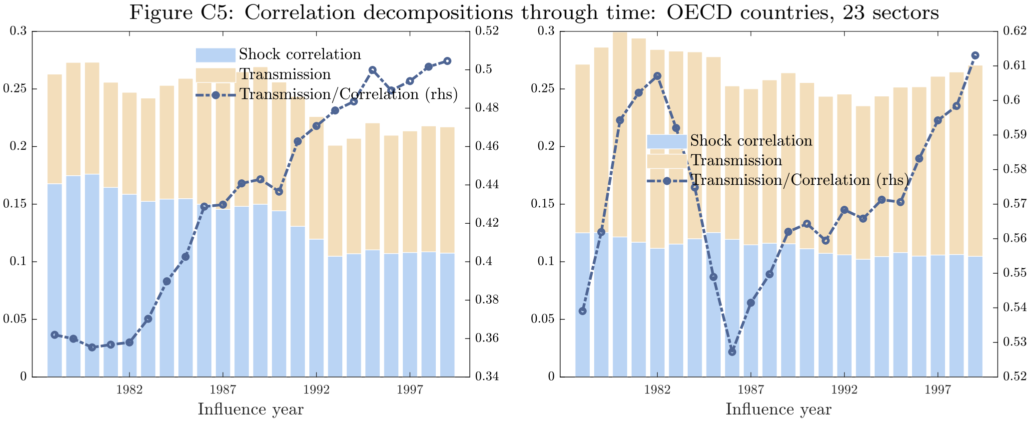
Notes: This table presents the average, median, and percentiles of the correlation decomposition in the first and last available decades (1978-1988, mid-year 1984 and 1997-2007, midyear 2002). "Tot corr" denotes the correlations, "Shock corr" the Shock Correlation component, and "Trans" the Transmission component. The left panel displays the decomposition using the composite shock and the right panel shows the decomposition using the Solow residual. The statistics correspond to the top panel of Figure 4.

Table C2: Changes in correlation decomposition (first and last influence year)

	OECD countries, composite shock				OECD countries, Solow residuals			
Tot corr	Mean	Median	p25	p75	Mean	Median	p25	p75
1978	0.277	0.275	0.139	0.418	0.198	0.229	0.037	0.346
2007	0.209	0.215	0.046	0.384	0.218	0.233	0.079	0.356
Shock corr								
1978	0.154	0.151	0.026	0.290	0.098	0.128	-0.027	0.236
2007	0.098	0.107	-0.045	0.255	0.067	0.077	-0.046	0.215
Trans.								
1978	0.123	0.119	0.080	0.154	0.100	0.089	0.065	0.127
2007	0.111	0.105	0.071	0.150	0.150	0.136	0.103	0.178

Notes: This table presents the average, median, and percentiles of the correlation decomposition when using the start year influence vector (1978) and last year influence vector (2007). "Tot corr" denotes the correlations, "Shock corr" the Shock Correlation component, and "Trans" the Transmission component. The left panel displays the decomposition using the composite shock and the right panel shows the decomposition using the Solow residual. The statistics correspond to the first and last bar of bottom panel of Figure 4.

Figure C5: Correlation decompositions through time: OECD countries, 23 sectors

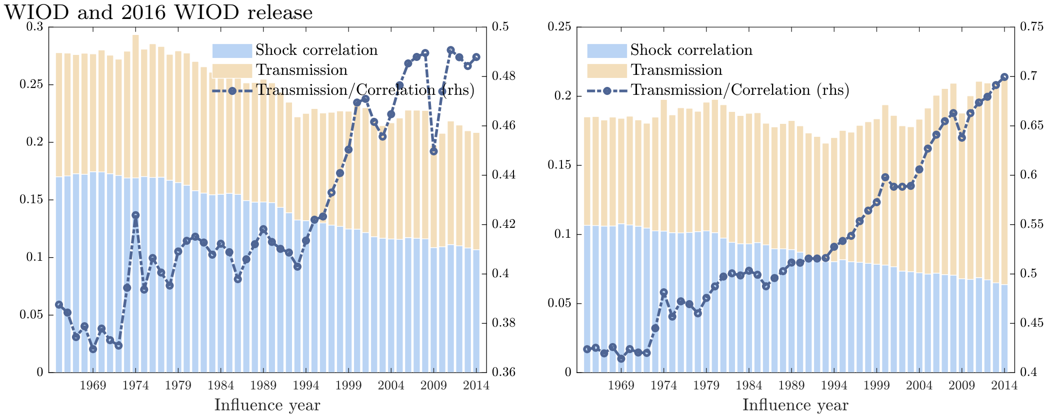


Composite shock

Solow residual

Notes: This figure displays the decompositions of the total correlation (the height of the bar) into shock correlation (blue bars) and transmission (stacked beige bars), in the 23-sector model. We use the formula for real GDP (10) and the yearly influence vector in equation (11) to compute the decomposition in (14). We apply the full time-series of shocks, 1978-2007, to the influence matrix of each year. Hence, the x-axis corresponds to the year of the influence matrix used for the decomposition but not the shock extraction. The shocks used are the composite supply shocks on the left and the Solow residuals on the right. The solid line in each figure shows the median of ratio between the transmission and total correlation across country pairs (right axis). The sample of countries are all OECD country pairs.

Figure C6: Correlation decompositions through time: OECD country pairs, 4 sectors and combined Long-Run WIOD and 2016 WIOD release



Composite shock

Solow residual

Notes: This figure displays the decompositions of the total correlation (the height of the bar) into shock correlation (blue bars) and transmission (stacked beige bars), in the 4-sector model applied to the longest possible data, sourced from the long-run WIOD (pre-2001) and the 2016 WIOD release (post-2000). We use the formula for real GDP (10) and the yearly influence vector in equation (11) to compute the decomposition in (14). We apply the full time-series of shocks, 1978-2007, to the influence matrix of each year. Hence, the x-axis corresponds to the year of the influence matrix used for the decomposition but not the shock extraction. The shocks used are the composite supply shocks on the left and the Solow residuals on the right. The solid line in each figure shows the median of ratio between the transmission and total correlation across country pairs (right axis). The sample of countries are all OECD country pairs.

Table C3: Counterfactual correlation details

	OECD countries, composite shock				
Total correlation	1978	Trade	Trade (CD)	Rest	2007
mean	0.279	0.251	0.319	0.234	0.214
median	0.287	0.249	0.335	0.238	0.220
p25	0.138	0.091	0.178	0.067	0.046
p75	0.427	0.404	0.478	0.424	0.393
Shock correlation					
mean	0.156	0.119	0.135	0.127	0.097
median	0.157	0.121	0.142	0.134	0.107
p25	0.025	-0.036	0.024	-0.036	-0.051
p75	0.293	0.277	0.266	0.286	0.263
Transmission					
mean	0.123	0.131	0.184	0.108	0.117
median	0.115	0.124	0.171	0.091	0.113
p25	0.080	0.093	0.124	0.058	0.072
p75	0.155	0.172	0.241	0.140	0.151

	OECD countries, Solow residual				
Total correlation	1978	Trade	Trade (CD)	Rest	2007
mean	0.207	0.226	0.269	0.204	0.232
median	0.230	0.222	0.291	0.203	0.232
p25	0.039	0.087	0.108	0.075	0.116
p75	0.349	0.378	0.420	0.336	0.360
Shock correlation					
mean	0.106	0.088	0.092	0.101	0.071
median	0.130	0.091	0.114	0.115	0.076
p25	-0.025	-0.031	-0.022	-0.015	-0.036
p75	0.241	0.215	0.218	0.238	0.211
Transmission					
mean	0.100	0.138	0.177	0.103	0.160
median	0.089	0.127	0.159	0.087	0.144
p25	0.066	0.100	0.121	0.060	0.111
p75	0.126	0.177	0.228	0.126	0.191

Notes: This table presents the average, median, and percentiles of the correlation decomposition in each counterfactuals. The "mean" row corresponds to the bars plotted in figure 6. "1978" is a counterfactual world in which the influence remained the same as the 1978 world, "Trade" is a world in which only trade costs changed, "Trade (CD)" is a world in which only trade costs changed but sectoral expenditure shares remained constant, "Rest" is a world in which only taste and supply shocks evolved since 1978. "2007" performs the decomposition using the 2007 influence vector. In all cases, the correlation decomposition is computed on the same time series of shock from 1978 to 2007.

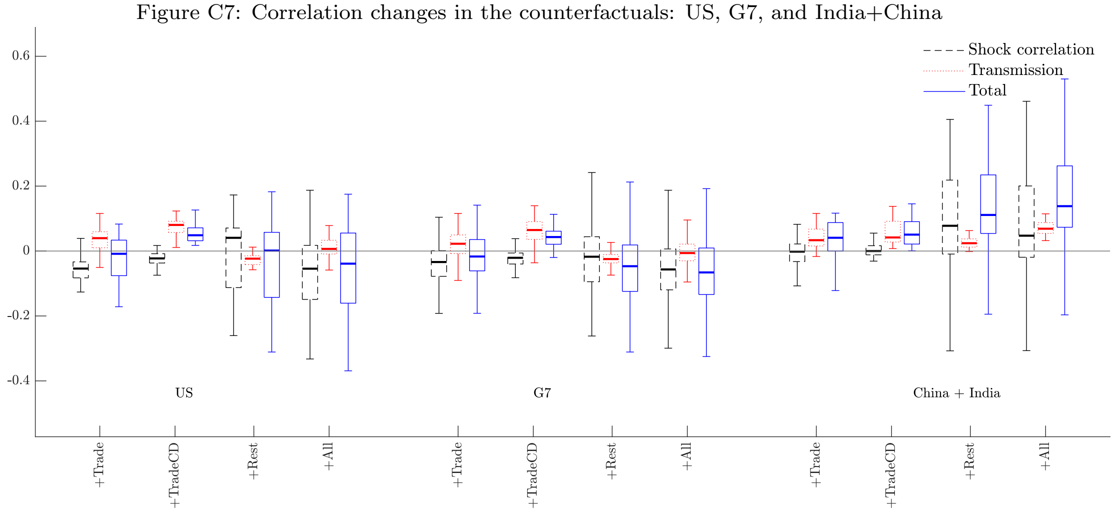
C.3 Variation across country pairs

To illustrate the variation across country pairs, Figure C7 plots the range of the changes in the Shock Correlation, Transmission and overall bilateral correlation terms for each counterfactual relative to the 1978 baseline for (i) the US, (ii) the G7 countries and (iii) India and China. A value of 0 on the y-axis thus implies that the GDP correlation, Shock Correlation or Transmission component did not change compared to the 1978 world. For all of these, the figures display the distribution of changes in correlations with all partner countries in our sample and their components. The boxes cover the interquartile range of the distribution, and the "whiskers" going out display the full range of outcomes excluding extreme outliers.

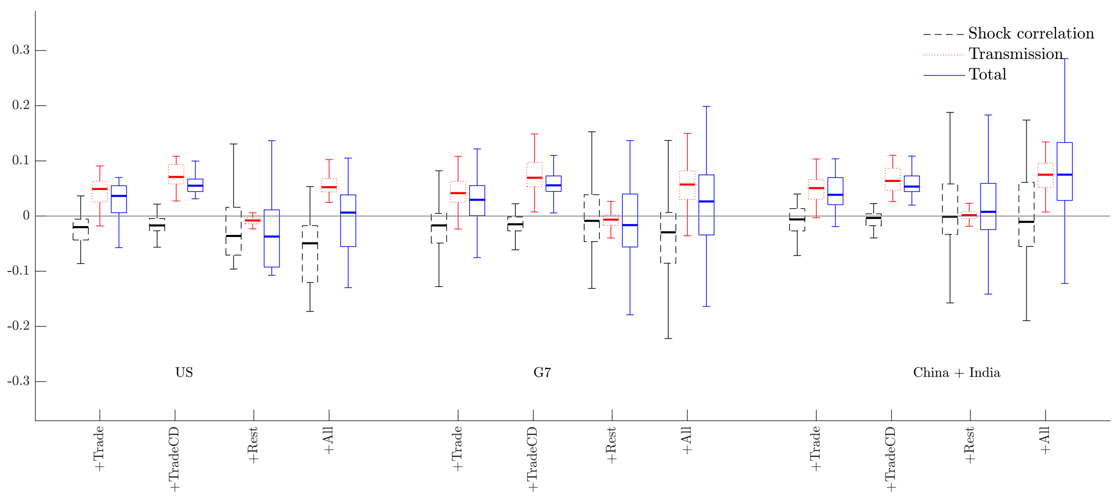
A few salient patterns emerge. First, while the impact differs across country pairs, the range of changes in the Transmission component is generally positive in the Trade, Trade-CD and All scenarios, illustrating the expected role of increased globalization in strengthening transmission forces. Second, globalization counterfactuals lead to a much tighter distribution of outcomes than the supply+taste counterfactuals, reflecting the pervasive reductions in trade costs/increases in trade volumes over this period. On the other hand, the other drivers of structural change are more heterogeneous, leading to a wide distribution of correlation changes, especially in the Shock Correlation components.

Third, there are important differences between the developed industrial economies and China and India. The changes in the Shock Correlation components are largely negative for the US and the G7. On the other hand, for China and India the Shock Correlation components tend to increase GDP comovement. This is especially evident in the "+Rest" counterfactual that applies taste and supply changes. These forces have reshaped China and India's economy towards manufacturing over this period. The opposite direction of structural change relative to the advanced economies also implies that the Shock Correlation component leads to increased comovement between these countries and the rest of the world. It also implies that the Transmission components are more consistently positive in these countries, as the manufacturing sector is where transmission of shocks happens most strongly. Since both of these forces increase comovement, the total effect over this period is an increase in average correlation with the other countries in our sample (the "Total" box).

Figure C7: Correlation changes in the counterfactuals: US, G7, and India+China



Composite shock



Solow residual

Notes: This figure shows the range of changes relative to 1978 for each counterfactual for (a) the U.S., (b) the G7 and (c) India and China. In each case, the range of outcomes is shown for the change in Transmission terms (in red), Shock Correlation terms (in black) and Total Correlation (in blue), with all possible partner countries. The boxes show the interquartile range, with the solid line denoting the mean. The whiskers show the maximum and minimum change, excluding extreme outliers. The top panel uses the composite shocks for constructing the counterfactuals, while the bottom panel uses the Solow residuals.

C.4 Sensitivity

Alternative shocks. This appendix repeats the counterfactual analysis under two alternative approaches for recovering the long-run shocks. In the first alternative, we compute long-run log-differences in sectoral real value added, and extract long-run $\Delta \ln Z_{nj}$'s jointly with taste and trade cost shifters in one step. In the second alternative, we use the cumulated sectoral Solow residual to build long-run changes in $\Delta \ln Z_{nj}$. In all three cases, when all three types of shocks are fed into the model, they perfectly reproduce observed structural change (the changes in sectoral expenditure shares) and trade opening (changes in international trade shares) over the period 1978-2007. The advantage of the baseline approach in the main text is that the supply shocks used for the short-run (correlations) and the long-run (structural change) purposes coincide. The advantage of the first alternative approach is that when all three sets of shocks are fed back into the model, it also replicates the 1978-2007 changes in real value added by sector, which the baseline approach does not. The second alternative also doesn't replicate the change in value added, but has the advantage of using the Solow residual which is easily interpretable and less model dependent.

Panel A of Figure C7 plots the changes in supply, tastes, and trade costs under the alternative approaches, in which we extract the Z simultaneously with the other long-run shifters, or use the cumulated Solow residual. The mix between supply and tastes is a bit different. The second approach implies a more even supply shift between the sectors, and a lack of a positive taste shift towards services. The third approach implies a slight increase in the manufacturing TFP relative to services, and a smaller magnitude for taste shifters. At the same time, Panel B of Figure C7 shows that the changes in trade costs implied by the three approaches are virtually identical. The changes in trade costs are essentially the changes in trade shares, modulo within-sector relative price changes between the foreign and domestic producers (see eq. 18). Quantitatively, the changes in relative prices within a sector across countries appear similar across the three methods of treating the supply shocks Z. This implies that the results of the globalization counterfactuals are robust to these choices.

Because the breakdown between supply and tastes is sensitive to the exact approach to extracting Z, in the counterfactuals we combine them together as a catch-all for other sources of structural change besides globalization. Figure C8 displays the counterfactual changes in final and intermediate sectoral shares relative to manufacturing implied by the long-run changes in trade costs and by the supply-cum-taste shocks under all three approaches. Trade costs lead to an increase in the service share, explaining the majority of the observed change in the service share in final use, and slightly less than half of the change intermediate input service share. The supply-cum-taste shocks explain a substantial amount of the movement towards services in intermediate use, and unlike trade costs, act strongly to reduce the size of agriculture and non-manufacturing industries.

Figure C8 shows that while the three approaches generate different mixes between supply and taste shocks as drivers of structural change, when these shocks are combined they produce virtually identical structural change on average across countries. To illustrate this further, Figure C9 plots the changes in services shares across countries in the counterfactuals combining supply and taste shocks under all three approaches to obtaining Z. The country-level changes in services shares are exceedingly similar across the three methods.

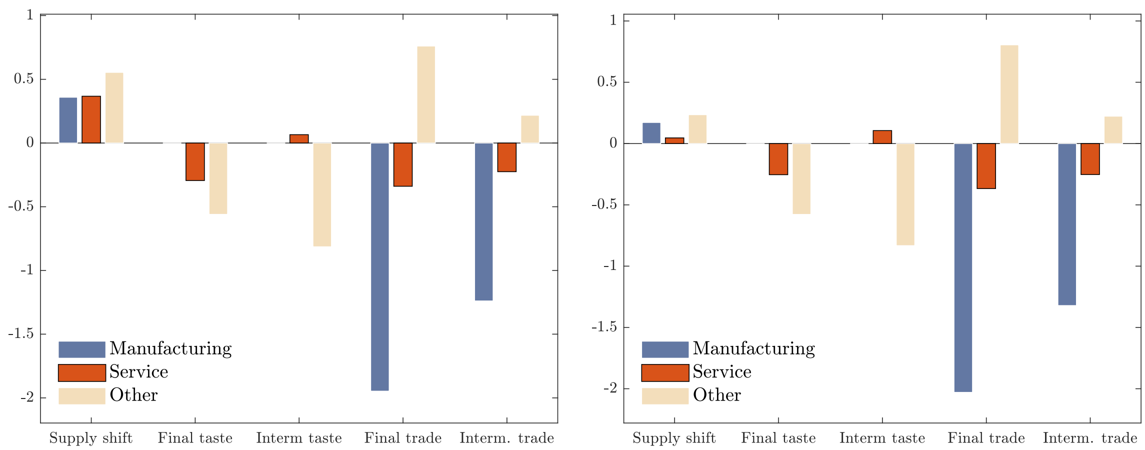
Figure C10 documents the similar patterns across counterfactuals for the alternative approaches to constructing the long run supply shock. While the details of whether structural change is driven by supply or taste shifts differ across approaches, all three tell the same story about (i) the changes in trade costs, and (ii) the joint impact of supply and taste. Thus, the results of the counterfactuals that apply the trade cost changes, as well as those that apply the supply and taste shocks together are robust across methods.

Figure C11 presents the results of the counterfactuals when feeding shocks from each decade within the sample. The patterns differ slightly in the last decade, as during this period the correlation of services shocks was noticeably higher than in previous decades (see Figure C3).

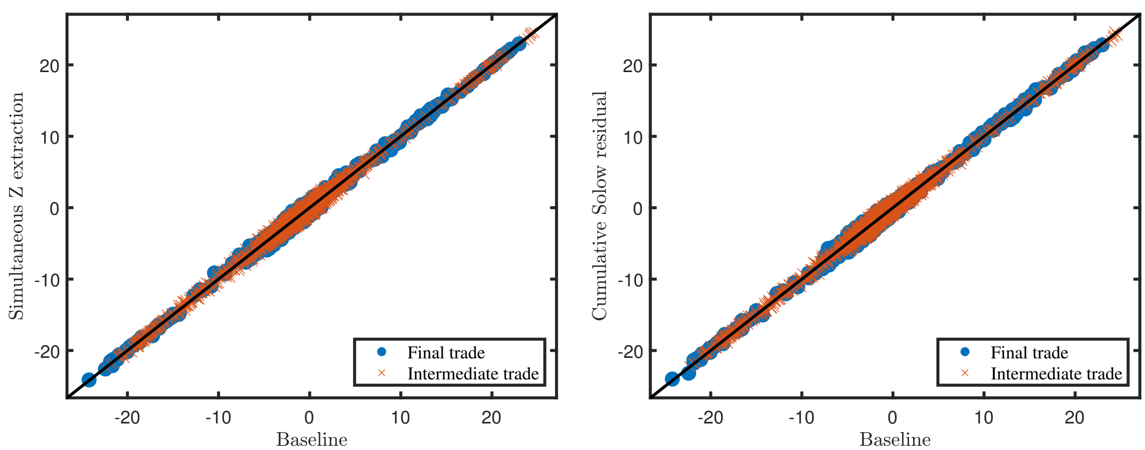
Figure C7: Long-run supply, taste, and trade cost changes, simultaneous Z extraction or long-run Solow residual change

Simultaneous Z extraction | Cumulated Solow residual

Panel A: Long run supply, trade cost and taste changes, OECD countries



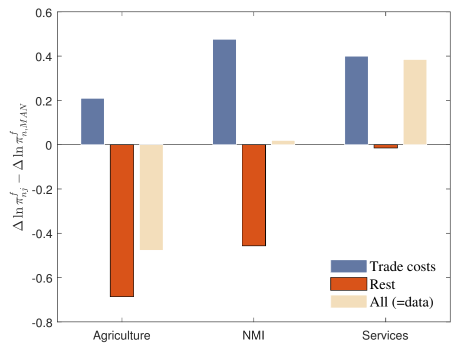
Panel B: Trade cost changes relative to baseline



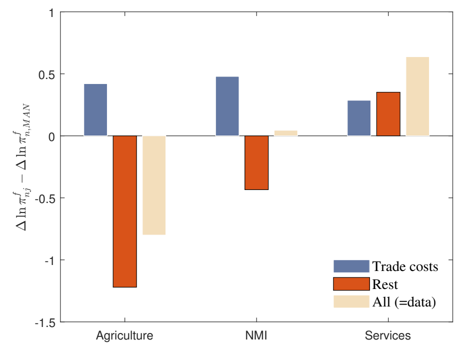
Notes: The figure displays the long-run changes in supply shifters, taste shifters (relative to manufacturing), and trade costs in Panel A, and compares the trade costs relative to the baseline values in Panel B, when extracting the change in supply to match the long-run sectoral value-added change (left panel, see eq. B.13) or using the cumulated Solow residual as long-run sectoral productivity shock (right panel).

Figure C8: Counterfactual changes in sectoral shares (relative to manufacturing), OECD countries

Cumulative short-run shock as long-run $\Delta \ln Z_{nj}$

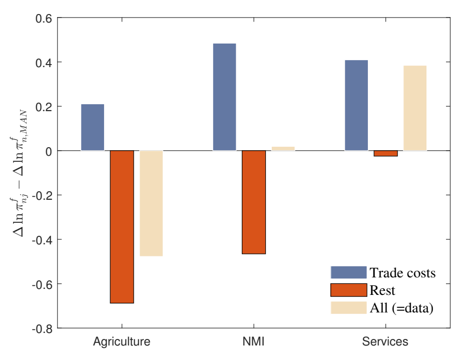


Final consumption

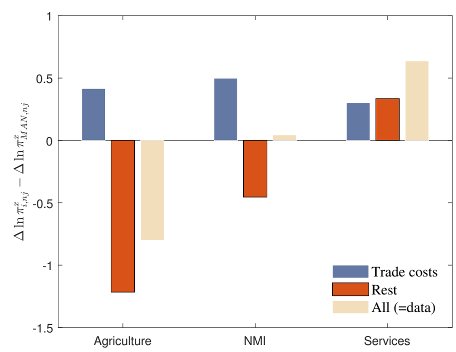


Intermediate use

Simultaneous long-run $\Delta \ln Z_{nj}$ shock extraction (see eq. B.13)

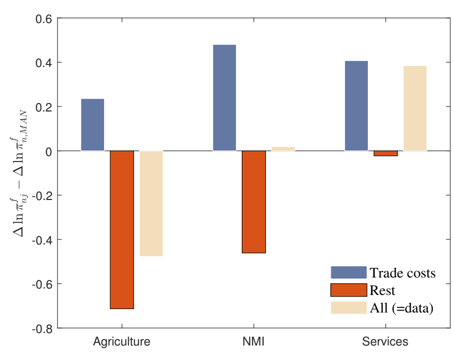


Final consumption

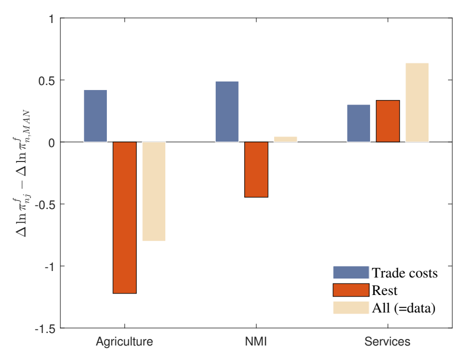


Intermediate use

Cumulative Solow residual as long-run $\Delta \ln Z_{nj}$



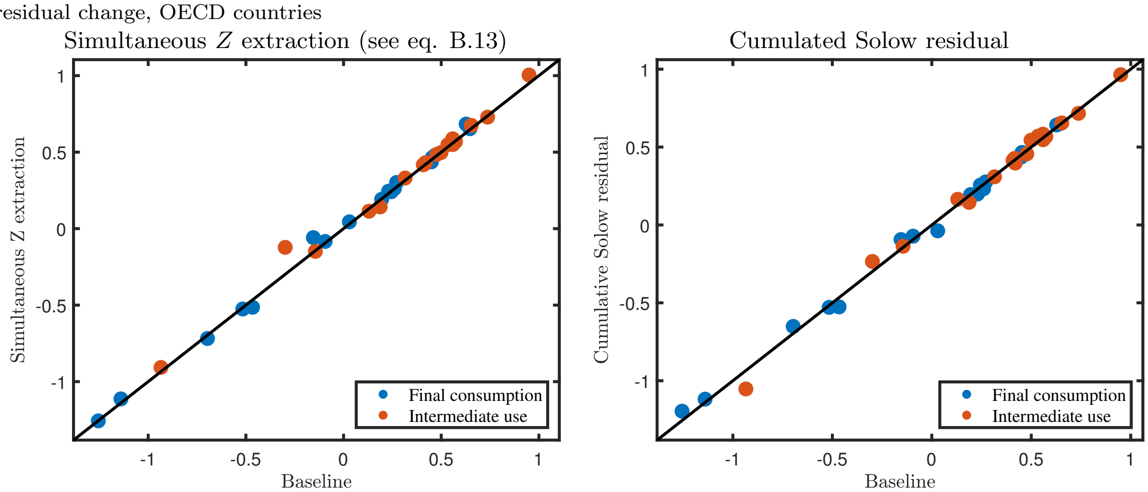
Final consumption



Intermediate use

Notes: The figures display the sectoral share changes relative to manufacturing in the counterfactuals ($\Delta \ln \pi^f_{nj} - \Delta \ln \pi^f_{n,MAN}$ and $\Delta \ln \pi^x_{nj} - \Delta \ln \pi^x_{n,MAN}$). "Trade" refers to the trade counterfactual where only trade costs are allowed to change between 1978 and 2007. "Rest" refers to a counterfactual where supply and taste shocks are allowed to change between 1978 and 2007.

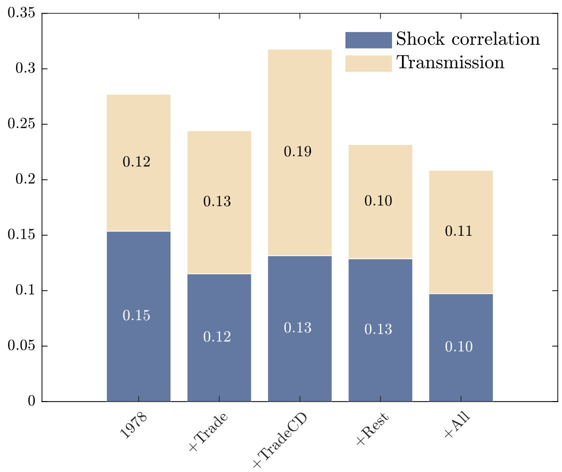
Figure C9: Changes in service shares in the "+Rest" counterfactual, simultaneous Z extraction or long-run Solow residual change, OECD countries



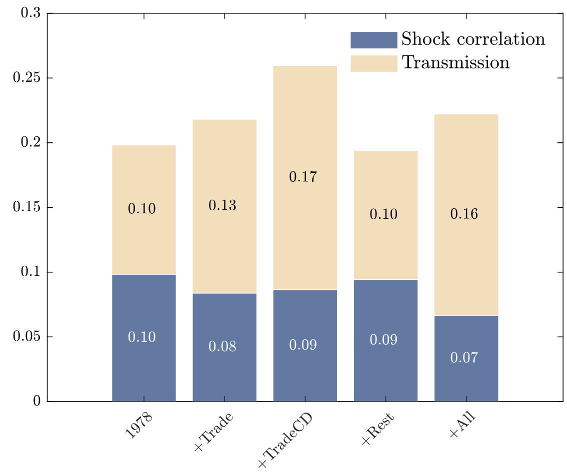
Notes: The figure compares the long-run changes in service shares when extracting the change in supply to match the long-run sectoral value-added change (left panel) or using the cumulated Solow residual as long-run sectoral productivity shock (right panel), relative to the baseline. The service share changes are computed in the counterfactual when the only shocks are taste shocks and supply shocks (the "+Rest" counterfactual),

Figure C10: Counterfactual correlations, simultaneous Z extraction, OECD countries

Simultaneous long-run $\Delta \ln Z_{nj}$ shock extraction

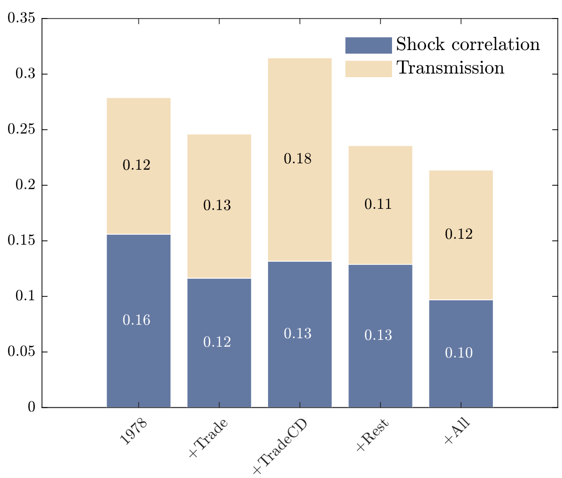


Composite shock

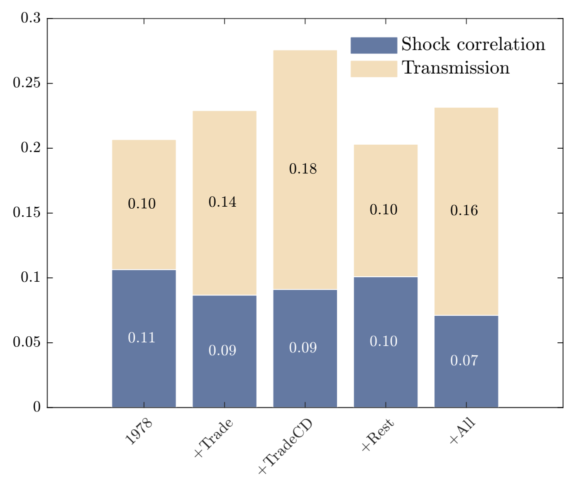


Solow residuals

Cumulated Solow residual as long-run $\Delta \ln Z_{nj}$



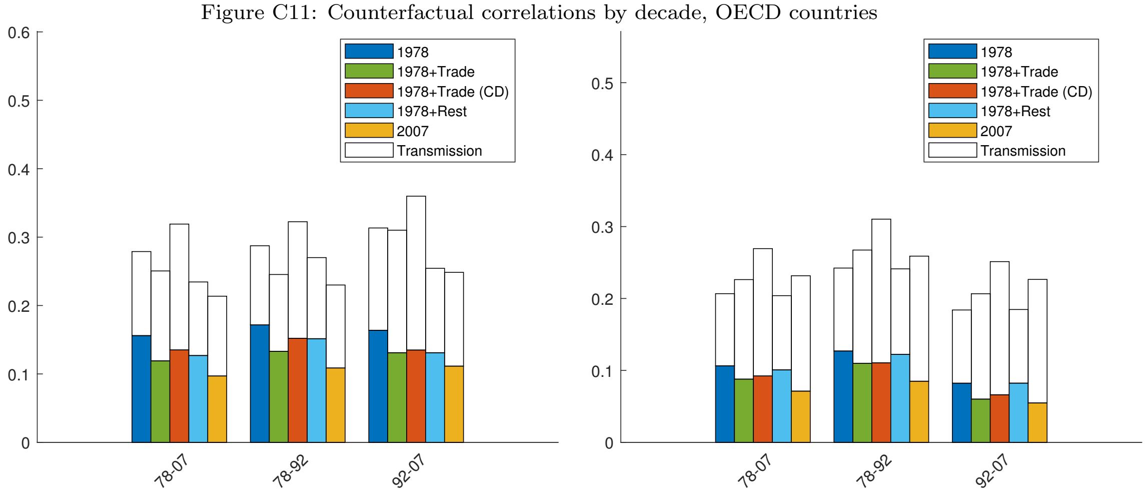
Composite shock



Solow residual

Notes: The bars display the average GDP growth correlations, decomposed into a shock correlation term (in blue) and transmission term (in beige). Each bar represents a different scenario. "1978" is a counterfactual world in which the influence remained the same as the 1978 world, "Trade" is a world in which only trade costs changed, "Trade (CD)" is a world in which only trade costs changed but sectoral expenditure shares remained constant, "Rest" is a world in which only taste and supply shocks evolved since 1978. "2007" performs the decomposition using the 2007 influence vector. In all cases, the correlation decomposition is computed on the same time series of shock from 1978 to 2007.

Figure C11: Counterfactual correlations by decade, OECD countries



Composite shock

Solow residuals

Notes: The bars display the average GDP growth correlations, decomposed into a shock correlation term (in blue) and transmission term (in beige). Each bar represents a different scenario. "1978" is a counterfactual world in which the influence remained the same as the 1978 world, "1978+Trade" is a world in which only trade costs changed, "1978+TradeCD" is a world in which only trade costs changed but sectoral expenditure shares remained constant, "1978+Rest" is a world in which only supply and taste shocks evolved since 1978. "1978" performs the decomposition using the 2007 influence vector. Each bar group represents the results of feeding different time periods of the shock.

Alternative elasticities. The counterfactual results show that the impact of globalization on sectoral shares can dampen the increase in transmission. We perform two sensitivity checks designed to alter the strength of globalization as a source of structural change.

In the first case, we increase the upper nest sectoral elasticities ($\rho = \nu = 0.8$) and the trade elasticities ($\gamma = \varepsilon = 5$). The higher trade elasticity dampens the recovered trade cost changes, which implies a lower increase in the relative price of services due to globalization. The higher sectoral elasticities also decrease the complementarity between manufacturing and services, which lower the impact of the price differential on sectoral expenditure shares. Hence, this calibration attenuates the strength of globalization-implied structural change compared to the baseline. In the second case, we reduce the sectoral elasticities to $\rho = \nu = 0.1$ and the trade elasticities to $\gamma = \varepsilon = 1.5$. This calibration thus amplifies the strength of the globalization-implied structural change forces.

We redo our counterfactual exercises, changing the long-run elasticities but keeping the short-run elasticities the same. Tables C4 and C5 summarize the results of the two alternative calibrations, for the composite shock and the Solow residual, respectively. Figures C12 to C15 display the extracted long-run shocks and counterfactual correlation results. In the lower bound scenario, shock correlation decreases by less than in the upper bound scenario as trade doesn't induce such a large sectoral reallocation toward services. The "Rest" counterfactual plays a larger role as well, as a greater share of sectoral reallocation is now attributed to taste shifters in that case. Under the lower elasticities, globalization induces such a large decrease in the manufacturing shares that transmission also decreases because of the strong reallocation of the economy towards the less tradable service sector.

Table C4: Robustness counterfactual correlation changes, composite shock

	Trade	Trade CD	Rest	All
	baseline ($\rho = \epsilon = 0.2,\ \nu = \gamma = 2$)			
Δ shock correlation	-0.04	-0.02	-0.03	-0.06
Δ transmission	0.01	0.06	-0.01	0.00
Δ transmission share	0.9	0.13	0.03	0.12
	$\rho = \epsilon = 0.8,\ \nu = \gamma = 5$			
Δ shock correlation	-0.02	-0.02	-0.05	-0.06
Δ transmission	0.04	0.05	-0.03	0.00
Δ transmission share	0.10	0.12	0.02	0.12
	$\rho = \epsilon = 0.1,\ \nu = \gamma = 1.5$			
Δ shock correlation	-0.06	-0.03	-0.01	-0.06
Δ transmission	-0.03	0.06	0.01	0.00
Δ transmission share	0.05	0.15	0.04	0.12

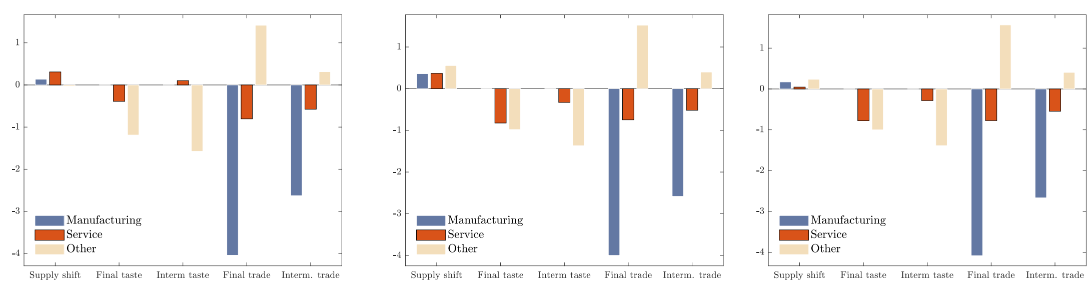
Notes: This table shows the counterfactual correlation decompositions, when the long-run shock inversion and counterfactual economies are computed using alternative long-run elasticities. The correlation decompositions are computed using the same short-run elasticities as the baseline, and the composite supply shock as the source of business cycle fluctuations.

Table C5: Robustness counterfactual correlation changes, Solow residual

	Trade	Trade CD	Rest	All
	baseline ($\rho = \epsilon = 0.2,\ \nu = \gamma = 2$)			
Δ shock correlation	-0.02	-0.02	-0.01	-0.04
Δ transmission	0.04	0.08	0	0 .06
Δ transmission share	0.13	0.19	0.02	0.22
	$\rho = \epsilon = 0.8,\ \nu = \gamma = 5$			
Δ shock correlation	-0.03	-0.03	-0.02	-0.04
Δ transmission	0.12	0.12	0	0.06
Δ transmission share	0.26	0.26	0.05	0.22
	$\rho = \epsilon = 0.1,\ \nu = \gamma = 1.5$			
Δ shock correlation	-0.02	-0.02	0.01	-0.04
Δ transmission	0.01	0.08	0.02	0.06
Δ transmission share	0.05	0.15	0.02	0.22

Notes: This table shows the counterfactual correlation decompositions, when the long-run shock inversion and counterfactual economies are computed using alternative long-run elasticities. The correlation decompositions are computed using the same short-run elasticities as the baseline, and the composite supply shock as the source of business cycle fluctuations.

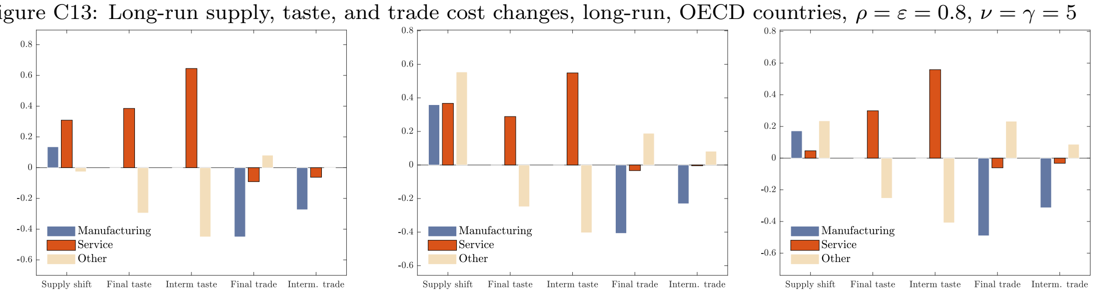
Figure C12: Long-run supply, taste, and trade cost changes, long-run, OECD countries $\rho = \varepsilon = 0.1$, $\nu = \gamma = 1.5$



Cumulated composite for $\Delta \ln Z_{nj}$ Long-run shocks for $\Delta \ln Z_{nj}$ Cumulated Solow for $\Delta \ln Z_{nj}$

Notes: The figure displays the long-run changes in supply shifters, taste shifters (relative to manufacturing), and trade costs. The left panel displays the changes under the assumption that the long-run supply shock is the cumulative change in the composite shock. The right panel extracts the change in supply to match the long-run sectoral value-added change. The elasticities used to recover the long-run shocks are the same as the baseline except for $\rho = \varepsilon = 0.1$, $\nu = \gamma = 1.5$.

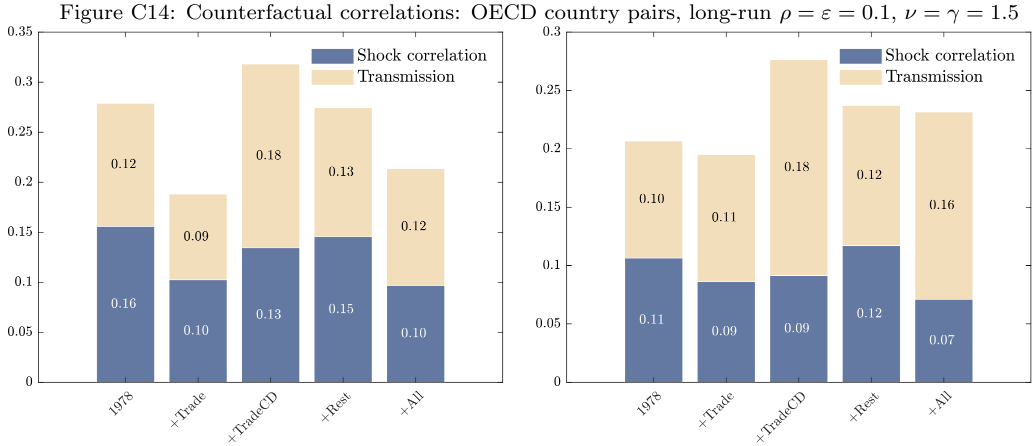
Figure C13: Long-run supply, taste, and trade cost changes, long-run, OECD countries, $\rho = \varepsilon = 0.8$, $\nu = \gamma = 5$



Cumulated composite for $\Delta \ln Z_{nj}$ Long-run shocks for $\Delta \ln Z_{nj}$ Cumulated Solow for $\Delta \ln Z_{nj}$

Notes: The figure displays the long-run changes in supply shifters, taste shifters (relative to manufacturing), and trade costs. The left panel displays the changes under the assumption that the long-run supply shock is the cumulative change in the composite shock. The right panel extracts the change in supply to match the long-run sectoral value-added change. The elasticities used to recover the long-run shocks are the same as the baseline except for $\rho = \varepsilon = 0.8$, $\nu = \gamma = 5$.

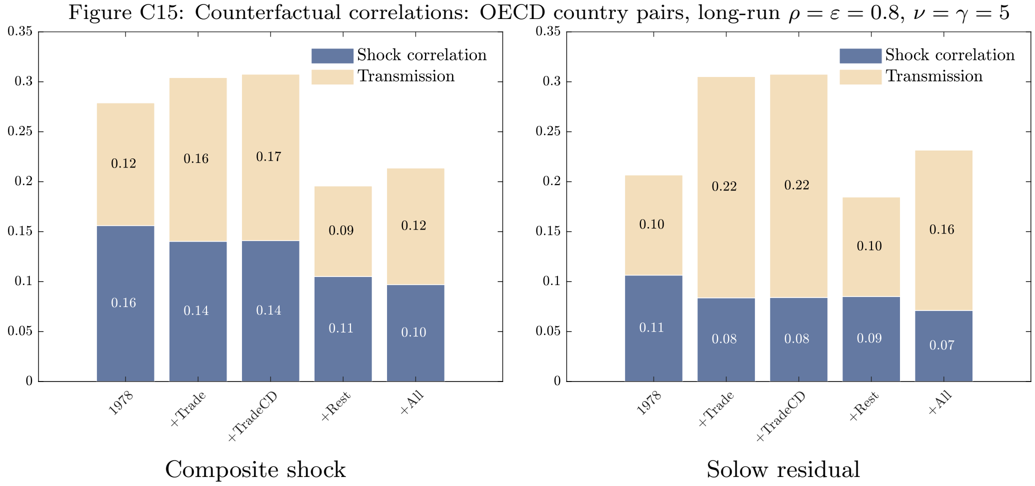
Figure C14: Counterfactual correlations: OECD country pairs, long-run $\rho = \varepsilon = 0.1$, $\nu = \gamma = 1.5$



Composite shock Solow residual

Notes: The bars display the average GDP growth correlations, decomposed into a shock correlation term (in blue) and transmission term (in beige). Each bar represents a different scenario. "1978" is a counterfactual world in which the influence remained the same as the 1978 world, "+Trade" is a world in which only trade costs changed, "+TradeCD" is a world in which only trade costs changed but sectoral shares remained constant, "+Rest" is a world in which only taste and supply evolved since 1978. "+All" performs the decomposition using the 2007 influence vector. In all cases, the correlation decomposition is computed on the same time series of shocks from 1978 to 2007. Short-run elasticities are the same as the baseline. Long-run elasticities are the same as the baseline except for long-run $\rho = \varepsilon = 0.1$ and $\nu = \gamma = 1.5$. The counterfactuals are constructed under the assumption that the long-run supply shock is the cumulative change in the composite shock.

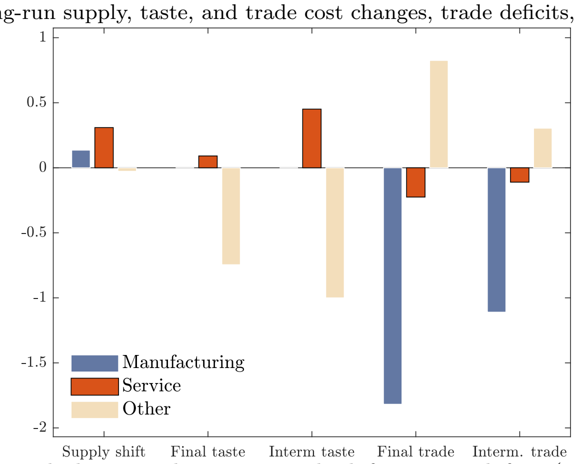
Figure C15: Counterfactual correlations: OECD country pairs, long-run $\rho = \varepsilon = 0.8$, $\nu = \gamma = 5$



Notes: The bars display the average GDP growth correlations, decomposed into a shock correlation term (in blue) and transmission term (in beige). Each bar represents a different scenario. "1978" is a counterfactual world in which the influence remained the same as the 1978 world, "+Trade" is a world in which only trade costs changed, "+TradeCD" is a world in which only trade costs changed but sectoral shares remained constant, "+Rest" is a world in which only taste and supply evolved since 1978. "+All" performs the decomposition using the 2007 influence vector. In all cases, the correlation decomposition is computed on the same time series of shocks from 1978 to 2007. Short-run elasticities are the same as the baseline. Long-run elasticities are the same as the baseline except for long-run $\rho = \varepsilon = 0.8$ and $\nu = \gamma = 5$. The counterfactuals are constructed under the assumption that the long-run supply shock is the cumulative change in the composite shock.

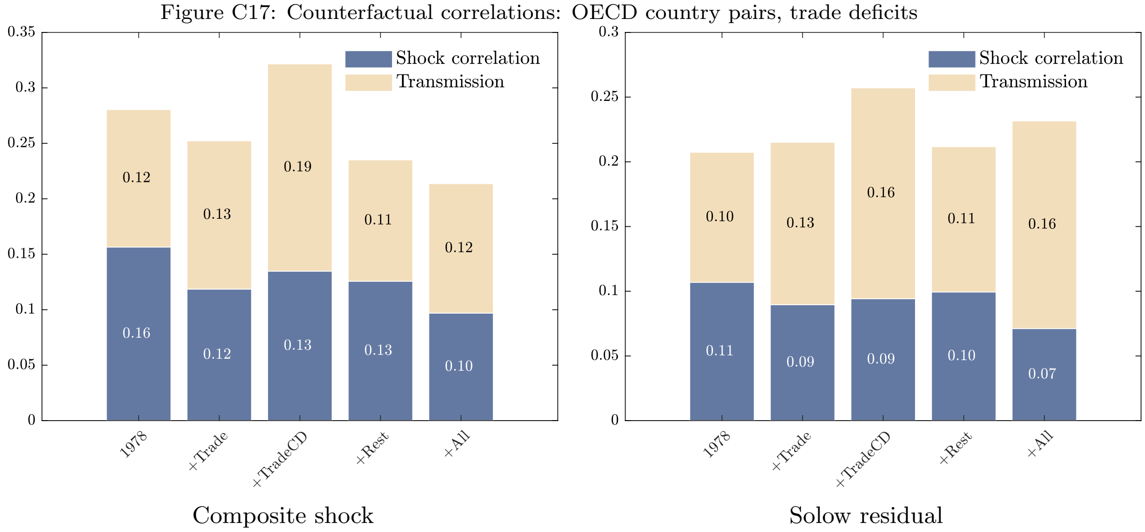
Unbalanced trade. To compute the long-run changes, we first remove all trade deficits from the data to make it consistent with our model. Kehoe, Ruhl, and Steinberg (2018) argue that trade deficits might have been a source of structural change in the United States. As a robustness check, Figure C16 displays the results from extracting the long-run shocks while letting the trade deficits evolve exogenously as in the data, and Figure C17 presents the counterfactual results. The average shocks, and the resulting counterfactual conclusions, are virtually unchanged.

Figure C16: Long-run supply, taste, and trade cost changes, trade deficits, OECD countries



Notes: The figure displays the long-run changes in supply shifters, taste shifters (relative to manufacturing), and trade costs under the assumption that the long-run supply shock is the cumulative change in the composite shock.

Figure C17: Counterfactual correlations: OECD country pairs, trade deficits



Notes: The bars display the average GDP growth correlations, decomposed into a shock correlation term (in blue) and transmission term (in beige). Each bar represents a different scenario. "1978" is a counterfactual world in which the influence remained the same as the 1978 world, "+Trade" is a world in which only trade costs changed, "+TradeCD" is a world in which only trade costs changed but sectoral expenditure shares remained constant, "+Rest" is a world in which only taste and supply shifts evolved since 1978. "+All" performs the decomposition using the 2007 influence vector. In all cases, the correlation decomposition is computed on the same time series of shocks from 1978 to 2007. The counterfactuals are constructed under the assumption that the long-run supply shock is the cumulative change in the composite shock.

C.5 *Dynamics and Financial Integration*

Dynamics and delayed propagation. Our analysis explores the correlations driven by contemporaneous responses to shocks, and abstracts from delayed responses to shocks. Huo, Levchenko, and Pandalai-Nayar (2023), henceforth HLP, use a dynamic global network model with endogenous capital accumulation to establish a number of results regarding the role of dynamics and delayed propagation in international comovement. First, under GHH preferences and financial autarky, the contemporaneous response of hours and value added to shocks in their fully dynamic model coincides with the response in the static network model given by (11). Thus, in an explicitly dynamic setting, (11) still accurately characterizes the contemporaneous output response of the world economy to the shock. Second, in the calibrated dynamic model it is still the case that quantitatively, the large majority of the overall GDP correlation is accounted for by the contemporaneous component despite the fact that the model features rich intertemporal propagation. Third, the shocks obtained by inverting the fully dynamic and the static models produce comovement with very similar properties.[19]

Based on these findings, we employ a static network model in this paper as our baseline. The benefits of doing so are transparency, tractability, and simplicity. Additionally, in a dynamic setting recovering the shocks that match the data requires positing an explicit stochastic process for the vector of shocks, and iterating between model inversion and the update to the shock process. While this can be done for a relatively small set of shocks as in HLP, it becomes less practical in a relatively large set of countries and shocks used in this paper.

Nevertheless, we now replicate the key result from the paper in the fully dynamic model of HLP that features persistent shocks and forward-looking investment decisions. The left panel of Figure C18 displays the same decomposition as for our baseline Figure 4, but using the dynamic model from HLP. The exercise feeds in the same productivity shocks as our baseline. The conclusions regarding the overall comovement, the share of transmission, and the role of correlated shocks are very similar to the baseline. This is not surprising, as HLP shows that most of the correlation in GDP can be recovered from a static version of the model.

While the framework in HLP is closely related to the framework in this paper, the HLP model has somewhat simpler labor supply and production function nests. Though the results regarding the role of structural change are nonetheless quite similar, to compare apples to apples we can engineer a version of our model to be isomorphic to their static version. This can be done by setting our sectoral elasticity of labor supply to $\mu = \psi + 1$, and by setting the production elasticities ε and ν equal to each other. The HLP model also has a Cobb Douglass utility function over sectors, which we can replicate by setting our elasticity of substitution ρ to 1. The rightmost panel of Figure C18 reports the results using our baseline static model, but calibrated with the elasticities that match the structure in HLP.[20]

Financial integration. Our baseline model assumes financial autarky, as models with financial autarky often outperform models with financial integration in reproducing observed international comovement (e.g. Heathcote and Perri, 2002). Nonetheless, the middle panel of Figure C18 replicates the key result from the paper under complete markets in the fully dynamic model from HLP (see their appendix D.6). Again, we use the same time series of shocks as in our baseline, but use the complete markets model to compute the decomposition.[21] The key patterns are very similar to the baseline and to the dynamic model with financial autarky.[22]

[19] See in particular Proposition 3.1, Figure 4 and Table 3 in HLP.

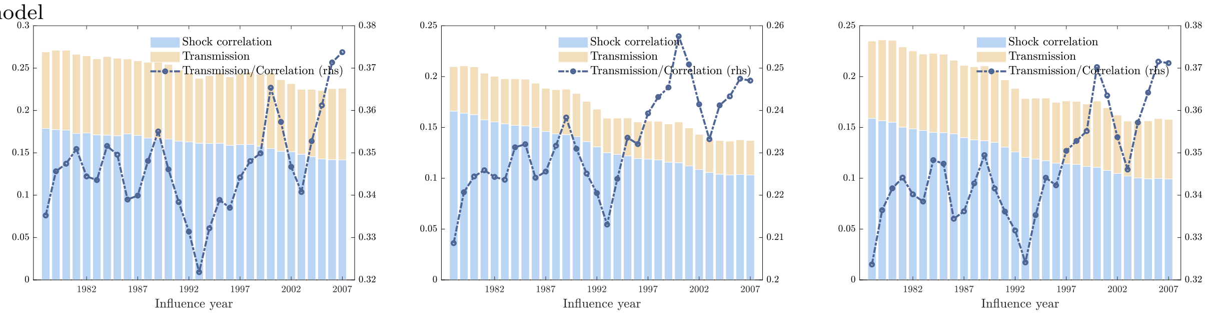
[20] Using our model's notation, that would translate to $\rho = 1$, $\gamma = 1.43$, $\varepsilon = \nu = 0.88$, $\psi = 0.723$ and $\mu = \psi + 1$.

[21] The dynamic model also requires an additional discount factor that we set to $\beta = 0.96$, and the complete markets model requires a coefficient of relative risk aversion that we set to $\sigma = 0.2$ following Angeletos and La'o (2010).

[22] It is worth noting that our key object of interest is comovement of GDP. Much of the international business cycle literature focuses on whether or how financial integration synchronizes consumption, not output. In fact, it has been recognized repeatedly since early on in this literature that financial integration need not actually increase comovement of GDP, and may actually decrease it (e.g. Backus, Kehoe, and Kydland, 1992; Heathcote and Perri, 2004; Kalemli-Özcan, Papaioannou, and Peydró, 2013). We also note that asset prices across countries are highly correlated, a phenomenon dubbed the "Global Financial Cycle" (Miranda-Agrippino and Rey, 2022).

All three versions (dynamic with financial autarky, complete markets, and our baseline static model) deliver similar results.

Figure C18: Correlation decompositions through time: Financial autarky dynamic model, complete market model



Dynamic financial autarky model | Complete markets model | Baseline with consistent elasticities

Notes: This figure displays the decompositions of the total correlation (the height of the bar) into shock correlation (blue bars) and transmission (stacked beige bars), as in the left figure of panel B in Figure 4. The left panel displays the results using the dynamic model with financial autarky from Huo, Levchenko, and Pandalai-Nayar (2023) (HLP). The middle panel displays a complete market version of the model. The right panel displays the results from the baseline model, changing the elasticities so the model is isomorphic to the static version of HLP. In all cases, we use the same time series of shocks as in the left figure of panel B in Figure 4, but we use the (potentially dynamic) solution of the different model to compute the changes in GDP and comovement divided into shock correlation and transmission. See Appendix Section C.5 for details. The sample of countries are all OECD country pairs.

This empirical pattern is often taken as suggestive that financial integration synchronizes business cycles across countries. However, it is not yet known to what extent the GFC synchronizes real GDP as opposed to asset prices. In addition, as we stress throughout the paper, correlation can be produced by either transmission or correlated shocks, and it has not yet been established how much of the GFC can be attributed to international transmission rather than correlated shocks. We are agnostic on whether financial integration in general or the GFC in particular are GDP-synchronizing forces. Regardless, Figure C18 shows that the basic message of the paper – structural change reallocates activity towards sectors with less correlated shocks – is not materially affected by the assumptions on the international asset markets.

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