

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 among 22 countries over the period 1978-2007. In recent decades, trade integration between advanced economies has increased rapidly while business cycle comovement has remained stable. We show that structural change – trend reallocation of economic activity towards services – plays an important part in solving this apparent puzzle. Business cycle shocks in the service sector are less internationally correlated than in manufacturing, and thus structural change lowers GDP correlations by increasing the share of less correlated sectors in GDP. Globalization – trend reductions in trade costs – exerts two opposing effects on cross-border GDP comovement. On the one hand, greater trade linkages increase international transmission of shocks and therefore comovement. On the other, globalization induces structural change towards services because it reduces the relative price of traded goods, and services and goods are complements in both consumption and production. Thus the overall impact of globalization on international comovement is ambiguous. We use a multi-country, multi-sector model of international production and trade to quantify these effects. Quantitatively, the two opposing effects of globalization on comovement partly cancel each other out, limiting the net contribution of globalization to increasing international comovement over this period.

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 top panel of Figure 1 plots the evolution of the trade to GDP ratio from the late 1970s to 2007 for both the G7 and a wider group of wealthy OECD countries. As documented in countless studies, international trade in goods grew much faster than GDP over this period.

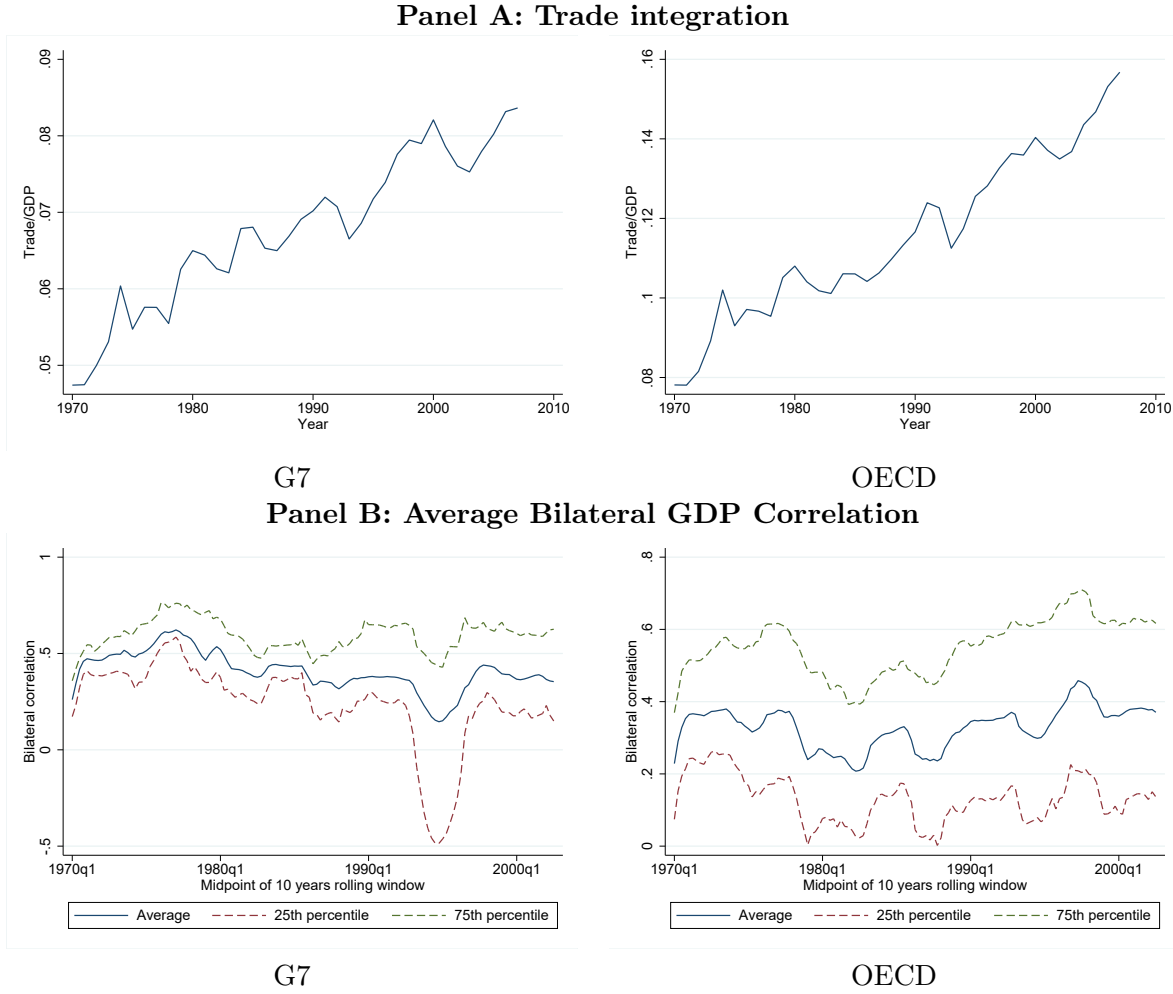
Both theory and empirical evidence show that trade linkages transmit business cycle shocks across countries. It is thus a natural conjecture that these decades of ever closer trade integration should have seen an increase in business cycle comovement across countries. The bottom panel of Figure 1 plots the average 10-year rolling GDP growth correlations in the same two samples of countries. Surprisingly, there is little to no upward trend in GDP comovement over these 3 decades. Indeed, short-run variability in these rolling correlations is often larger than long-run changes. The stable GDP comovement is a puzzle: transmission through increasingly important trade and production networks does not appear to have translated into greater GDP synchronization.

This paper resolves this apparent puzzle, along the way providing a broad narrative of the evolution of GDP comovement over this period. We isolate two forces that acted on international comovement over this period: structural change and globalization. Structural change is the secular rise in the share of services in value added and employment, and the corresponding fall in the share of manufacturing. It matters for comovement because, as documented below, business cycle shocks to services are less correlated internationally than business cycle shocks to manufacturing. Thus a secular reallocation of economic activity towards services increases the GDP share of the sector that is less correlated internationally. Structural change thus acts to push down cross-country GDP correlations, all else equal.

Globalization – changes in trade costs and tastes that lead to greater import shares – has two opposing effects. The first is the obvious one prominent in much of the literature: greater share of international trade in gross output produces stronger cross-border transmission of shocks and *ceteris paribus* increases comovement. The second one is underappreciated in the literature: 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). This force shifts economic activity towards the service sector, whose shocks are less correlated internationally, lowering international comovement all else equal. Thus, globalization actually has an ambiguous effect on international comovement.

We build on the conceptual framework and modeling tools from Huo, Levchenko, and Pandalai-Nayar (2020), and combine it with data on the long-run evolution of the world input-output matrix and real output data from EU KLEMS (O’Mahony and Timmer, 2009). We work with a tractable

FIGURE 1: Trends in Trade/GDP and GDP Comovement



Notes: The top panel of this figure displays the total trade between pairs of countries as a fraction of total GDP. The lower panel displays the average bilateral rolling quarterly (yoy) GDP growth correlation. The year 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 1978s. Appendix Figure C1 shows the correlation patterns hold under various detrending methods.

multi-country, multi-sector model of production and international trade adapted to studying business cycle questions. The model admits a first-order analytical solution, permitting simple additive decompositions of international comovement that illuminate the forces at work. In particular, GDP correlation between any two countries can be decomposed additively into components that capture correlated shocks and cross-border shock transmission. Another important benefit of the linear analytical solution is that the model can be inverted to obtain the vector of country-sector-specific shocks that rationalizes observed real value added growth in every country and every sector given

the observed structure of production and trade. By construction, when these 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 GDP correlations in the data.

We apply the model to production and trade data from 1978 to 2007, and provide an account of the evolution of international GDP comovement over this period. 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 trended downward at the same time. This is because shocks to the service sector are less correlated than shocks to the manufacturing sector, and thus the rise in the service share of GDP lowers international GDP correlations.

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 non-homotheticities and trend sectoral productivity growth differentials), we then present several counterfactuals designed to separate the impact 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 in 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 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 the 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 30% higher than comovement in the scenario in which globalization also leads to structural change.

The next counterfactual evaluate the role of other drivers of structural change: productivity and preferences. Comovement falls slightly when long-run productivity and long-run preference shifters

are applied to the 1978 economy. This is expected, since demand shifts lead the economy to reallocate towards the less correlated services.¹

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, 2020](#)) 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](#); [Imbs and Pauwels, 2019](#); [Ko, 2020](#); [Miyamoto and Nguyen, 2020](#)). This paper quantifies how the forces of globalization and structural change interacted to generate the observed evolution of comovement. In our quantification, the main international shock transmission mechanism is through trade in final goods and inputs, following, among others, [Burstein, Kurz, and Tesar \(2008\)](#), [Johnson \(2014\)](#), and our previous work.² This paper highlights how the heterogeneity across goods vs. service sectors in 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](#); [Alessandria, Johnson, and Yi, 2021](#); [Alviarez et al., 2021](#)). 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.

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

¹Our 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, 2020](#)), among other forces.

²Several recent papers provide micro empirical evidence on the role of input trade for transmitting shocks within and across countries ([Barrot and Sauvagnat, 2016](#); [Atalay, 2017](#); [Boehm, Flaaen, and Pandalai-Nayar, 2019](#); [Carvalho et al., 2016](#)). Also related is the large empirical and quantitative literature on the positive association between international trade and comovement (e.g. [Frankel and Rose, 1998](#); [Imbs, 2004](#); [Kose and Yi, 2006](#); [di Giovanni and Levchenko, 2010](#); [Ng, 2010](#); [Liao and Santacreu, 2015](#); [di Giovanni, Levchenko, and Mejean, 2018](#); [Drozd, Kolbin, and Nosal, 2020](#)).

2 Theoretical Framework

2.1 Setup

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

$$\max_{\mathcal{F}_{nt}(\omega), L_{nt}(\omega)} \left(F_{nt}(\omega) - \chi_n \frac{H_{nt}(\omega)^{1+1/\psi}}{1+1/\psi} \right) \quad (2.1)$$

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_n 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 work in sector j , they supply $b_{nj}(\omega) H_{nt}(\omega)$ effective units of labor and collect 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 $b_{nj}(\omega) \sim \text{Fréchet}(\xi_{nj}, \mu)$, with dispersion parameter μ and central tendency parameter ξ_{nj} that can potentially vary by country and sector:

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

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:

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

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

$$\pi_{njt}^H = \frac{\xi_{nj} (W_{njt})^\mu}{\sum_s \xi_{ns} (W_{nst})^\mu}.$$

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:

$$H_{njt} = \xi_{nj} \left(\frac{1}{\chi_n} \frac{W_{nt}}{P_{nt}} \right)^\psi \left(\frac{W_{njt}}{W_{nt}} \right)^{\mu-1}, \quad (2.2)$$

up to a normalization constant and under the regularity condition that $\mu > \psi + 1$, where $W_{nt} \equiv (\sum_s \xi_{ns} W_{nst}^\mu)^{\frac{1}{\mu}}$ is an economywide wage index. Aggregate labor supply is:

$$H_{nt} = \left(\frac{W_{nt}}{P_{nt} \chi_n} \right)^\psi \quad (2.3)$$

up to a normalization constant.

We highlight two features of the household problem. First, our formulation of the disutility of the within-period labor supply is based on [Greenwood, Hercowitz, and Huffman \(1988\)](#) preferences. Indeed, the aggregate labor supply (2.3) coincides with the textbook GHH formulation in which only one type of labor is supplied to the market. GHH preferences mute the interest rate effects and income 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, $\psi > 0$.

Second, below the aggregate level, labor is differentiated by sector as in [Galle, Rodríguez-Clare, and Yi \(2017\)](#). The labor supply elasticity to a given sector conditional on a fixed aggregate labor supply is $\mu - 1$ (eq. 2.2). Canonical trade and macro models labor with perfectly mobile labor across sectors correspond to $\mu \rightarrow \infty$. 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:

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

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} to ship good j from country m to country n (throughout, we adopt 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:

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

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} .

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

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

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

$$Y_{njt} = Z_{njt} H_{njt}^{\eta_j} X_{njt}^{1-\eta_j}, \quad (2.4)$$

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_{nj} should be interpreted as "equipped labor" that encompasses 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:

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

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 the taste shifter, and $P_{i,njt}^X$ is the price index of sector i inputs in production of

sector j in country n .

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

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

To summarize, both final and intermediate input use 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 the payments to primary factors and intermediate inputs are:

$$W_{njt} H_{njt} = \eta_j P_{njt} Y_{njt} \quad (2.5)$$

$$P_{mi,njt} X_{mi,njt} = \pi_{i,nj}^x \pi_{mi,njt}^x (1 - \eta_j) P_{njt} Y_{njt}, \quad (2.6)$$

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.

At the sectoral level, the following market clearing condition has to hold for each country n sector j :

$$P_{njt} Y_{njt} = \sum_m P_{mt} \mathcal{F}_{mt} \pi_{mj}^f \pi_{nmjt}^f + \sum_m \sum_i (1 - \eta_i) P_{mit} Y_{mit} \pi_{j,mit}^x \pi_{nj,mit}^x. \quad (2.7)$$

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

$$P_{mt} \mathcal{F}_{mt} = \sum_i \eta_i P_{mit} Y_{mit}. \quad (2.8)$$

Note that once we know the share of value added in production η_j , the expenditure shares π_{mj}^f , π_{nmjt}^f , $\pi_{j,mit}^x$, and $\pi_{nj,mit}^x$ for all n, m, i, j , we can compute the nominal output $P_{njt} Y_{njt}$ for all country-sectors (n, j) after choosing a numeraire good. There is no need to specify further details of the model, and we will utilize this property to derive the influence matrix.

Analytical solution At a formal level, the only business cycle shocks in this economy are productivity shocks Z_{njt} in every country and sector. However, as emphasized by [Huo, Levchenko,](#)

and Pandalai-Nayar (2020), their interpretation could be broadened to include other factor supply shocks, as well as shocks – 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. Thus, we refer to Z_{njt} as a composite supply shock.

As shown in Huo, Levchenko, and Pandalai-Nayar (2020), this model can be solved analytically to first order. Denote by “ln” the log-deviation from steady state/pre-shock equilibrium. Let the vector $\ln \mathbf{Y}_t$ of length NJ collect the worldwide sectoral output changes. The response of $\ln \mathbf{Y}_t$ to the global vector of supply shocks $\ln \mathbf{Z}_t$ is to a first order approximation given by

$$\ln \mathbf{Y}_t = \mathbf{\Lambda}^Y \ln \mathbf{Z}_t. \quad (2.9)$$

The matrix $\mathbf{\Lambda}^Y$ is the influence matrix. It encodes the general equilibrium response of sectoral output 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. The expression for $\mathbf{\Lambda}^Y$ is provided in Appendix B (eq. B.5). While in general analytical solutions for $\mathbf{\Lambda}^Y$ are hard to obtain, in our framework the elements of $\mathbf{\Lambda}^Y$ are (i) observable final and intermediate expenditure shares, domestic and international and (ii) model elasticities. Thus, the model is easily parameterized and yields itself to quantification.³

The closed-form solution for $\mathbf{\Lambda}^Y$ in equation (B.5) shows that it 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.

Real GDP Equation (2.9) states the change in gross output, whereas real GDP is defined as value added evaluated at base prices b :

$$V_{nt} = \sum_{j=1}^J (P_{nj,b} Y_{njt} - P_{nj,b}^X X_{njt}), \quad (2.10)$$

³While our model does not explicitly feature a delayed response to shocks, Huo, Levchenko, and Pandalai-Nayar (2020) show that the large majority of business-cycle comovement is accounted for by the contemporaneous impact of composite supply shocks, captured by $\mathbf{\Lambda}^Y$, in this framework. Therefore, abstracting from capital accumulation and related dynamics simplifies the analysis and comes at little cost for the key questions in this paper.

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

$$\ln V_{nt} = \sum_{j=1}^J \frac{P_{nj} Y_{nj}}{V_n} \ln Z_{njt} + \sum_{j=1}^J \eta_j \frac{P_{nj} Y_{nj}}{V_n} \ln H_{njt}, \quad (2.11)$$

where the values without t -subscripts denote the steady state/pre-shock values. The global vector of changes in hours is given by:

$$\ln \mathbf{H}_t = \mathbf{\Lambda}^H \ln \mathbf{Z}_t, \quad (2.12)$$

where the formula for the influence matrix for hours $\mathbf{\Lambda}^H$ is given by equation (B.6) in Appendix B. The first term in equation (2.11) captures the impact of domestic shocks on GDP. Note that there is no direct dependence of country n 's GDP on foreign shocks. The second term in (2.11) captures the changes in hours. Equation (2.12) underscores that the labor input in every country and sector depend on the entire vector of $\ln Z_{njt}$ worldwide.

These expressions also highlight the need for within-period elastic labor supply in our model. Frameworks of structural change commonly assume inelastic labor supply – a reasonable assumption in the long run. However, in business cycle models with an input-output structure, the fixed aggregate labor supply assumption would imply that foreign shocks have no effect on domestic 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.

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 of GDP comovement.

The linear representation of the GDP change in country n as a function of the global vector of shocks (2.11) lends itself to an additive decomposition of the GDP change into the components due to domestic and foreign shocks. To first order, the log deviation of real GDP of country n from steady state can be written as:

$$d \ln V_{nt} \approx \sum_m \sum_i s_{mni} Z_{mit}, \quad (2.13)$$

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 (2.11)-(2.12). To highlight the sources of international GDP comovement, write real GDP growth as

$$d \ln V_{nt} = \underbrace{\sum_j s_{nnj} Z_{njt}}_{\mathcal{D}_n} + \underbrace{\sum_{n' \neq n} \sum_j s_{n'nj} Z_{n'jt}}_{\mathcal{T}_n}. \quad (2.14)$$

This equation simply breaks out the double sum in (2.13) into the component due to country n 's own shocks (\mathcal{D}_n), the component due to its trading partners' shocks \mathcal{T}_n .

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

$$\begin{aligned} \text{Cov}(d \ln V_n, d \ln V_m) &= \underbrace{\text{Cov}(\mathcal{D}_n, \mathcal{D}_m)}_{\text{Shock Correlation}} \\ &+ \underbrace{\text{Cov}(\mathcal{D}_n, \mathcal{T}_m) + \text{Cov}(\mathcal{T}_n, \mathcal{D}_m) + \text{Cov}(\mathcal{T}_n, \mathcal{T}_m)}_{\text{Transmission}}. \end{aligned} \quad (2.15)$$

This expression underscores the sources of international comovement. The first term, $\text{Cov}(\mathcal{D}_n, \mathcal{D}_m)$, captures the fact that economies might be correlated even in the absence of trade if the underlying shocks themselves are correlated, especially in sectors influential in the two economies. The shock correlation term can be written as:

$$\text{Cov}(\mathcal{D}_n, \mathcal{D}_m) = \sum_j \sum_i s_{nnj} s_{mni} \text{Cov}(Z_{nj}, Z_{mi}). \quad (2.16)$$

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

$$\begin{aligned} \text{Cov}(\mathcal{D}_n, \mathcal{T}_m) &= \sum_j \sum_{n' \neq m} \sum_i s_{nnj} s_{n'mi} \text{Cov}(Z_{nj}, Z_{n'i}) \\ &= \sum_{n' \neq m} s'_{nn} \Sigma_{n'n} s_{n'm}, \end{aligned} \quad (2.17)$$

where $\Sigma_{n'n}$ is the $J \times J$ covariance matrix of shocks between countries n' and n , and $s_{n'm}$ 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 (2.17) for $n' = n$ captures the sensitivity of both countries n and m to shocks in country n : $s'_{nn} \Sigma_n s_{nm}$. 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.

This paper provides an account of how the evolution of the influence terms s_{mni} interacted with the differences across sectors in shock correlations $\text{Cov}(Z_{nj}, Z_{n'i})$ to shape the long-run changes in international comovement. Both structural change and globalization act on the s_{mni} . Structural change can be thought of as a trend increase in the domestic influence of the service sector 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} , $n \neq i$. On the other, if the substitution elasticities between services and manufacturing ρ and ε are below unity, a reduction in trade costs lowers the relative price of manufacturing to services, and increases 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} , $n \neq i$ 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 and Basic Facts

3.1 Data

We use data from two main sources to calibrate the model and estimate the key elasticities.

Trade 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 1978 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 data (WIOD) from EU-KLEMS. The data cover years from 1965-2000. While the data contain sectors at the ISIC-Rev.3 level of detail, we aggregate the sectors to 4 for the model and counterfactuals, but use all 23 sectors to illustrate the basic stylized facts hold in a more detailed sectoral classification. The results from these exercises are in [Appendix C](#).

Sectoral data Sectoral quantities and prices come from the 2009 EU-KLEMS release ([O’Mahony and Timmer, 2009](#)). The KLEMS data are also available at a finer level of disaggregation than our baseline 4 sectors. For the model, we aggregate it to the 4 sectors by using the so called cyclical expansion procedure detailed in [Appendix A.1](#), where we also provide the exact mapping of sectors to ISIC classification and detail the variables we use and how they map to the model.

The resulting dataset is composed of 21 countries listed in [Appendix Table A3](#) and a composite Rest of the World. The countries in our sample cover 97% of the OECD’s GDP and 77% of world’s GDP in 1978.

Elasticities We estimate the elasticities of substitution in the production and consumption aggregators. The details are discussed in [Appendix A.2](#).

Extracting shocks We now describe how to recover the supply shocks Z_{njt} in such a way as to match actual value added growth in every country-sector (and therefore actual GDP growth in every country), as in [Huo, Levchenko, and Pandalai-Nayar \(2020\)](#).

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 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:

$$\ln \mathbf{Z}_t = \left(\boldsymbol{\Lambda}^H + \boldsymbol{\eta}^{-1} \right)^{-1} \ln \mathbf{V}_t. \quad (3.1)$$

In other words, the structure of the model world economy and the observed/measured objects can be used to infer a global vector of supply shocks $\ln \mathbf{Z}_t$ that rationalizes 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. As stressed above, the recovered $\ln \mathbf{Z}_t$ should be viewed more broadly as a general sector-level supply shock. In the quantitative implementation below, as an alternative supply shock we will also consider the standard Solow residual.

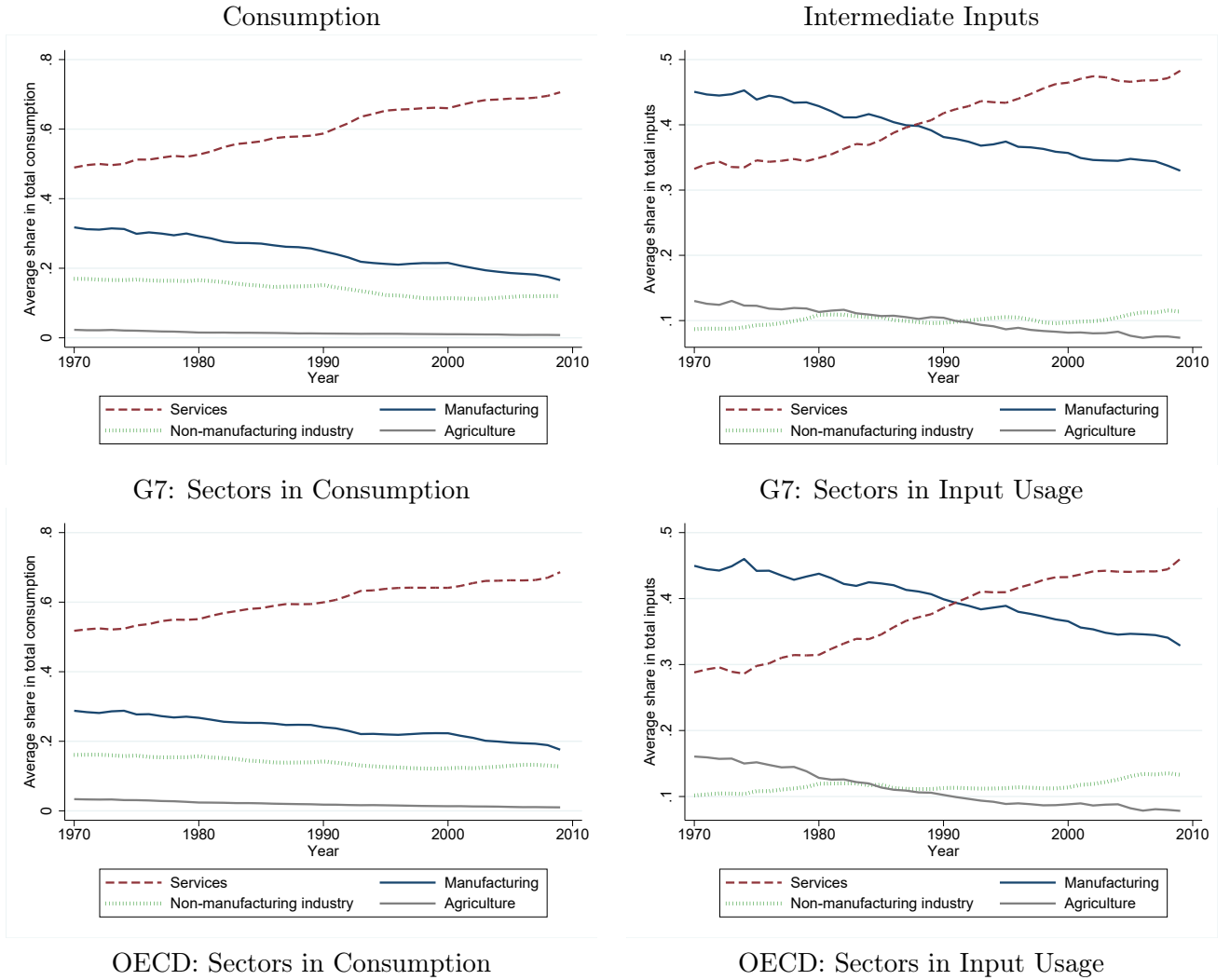
3.2 Basic Facts

We now present two basic facts that motivate the focus on the rise in the service share 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 consumption 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.

Differences in shock correlations Less well-known is how the correlation of business cycle shocks differs across broad sectors. We will work with two types of shocks in the paper: (i) Solow residuals and (ii) composite supply shocks (3.1) extracted to match value added perfectly. The advantage of the former is that it is relatively model-free and easy to interpret, and has been the main shock considered by the international business cycle literature. The disadvantage is that when fed into the model, it does not reproduce actual value added growth, and by extension actual GDP correlations in the data. The latter shock does that by construction, but is a composite shock that is more difficult

FIGURE 2: Structural change



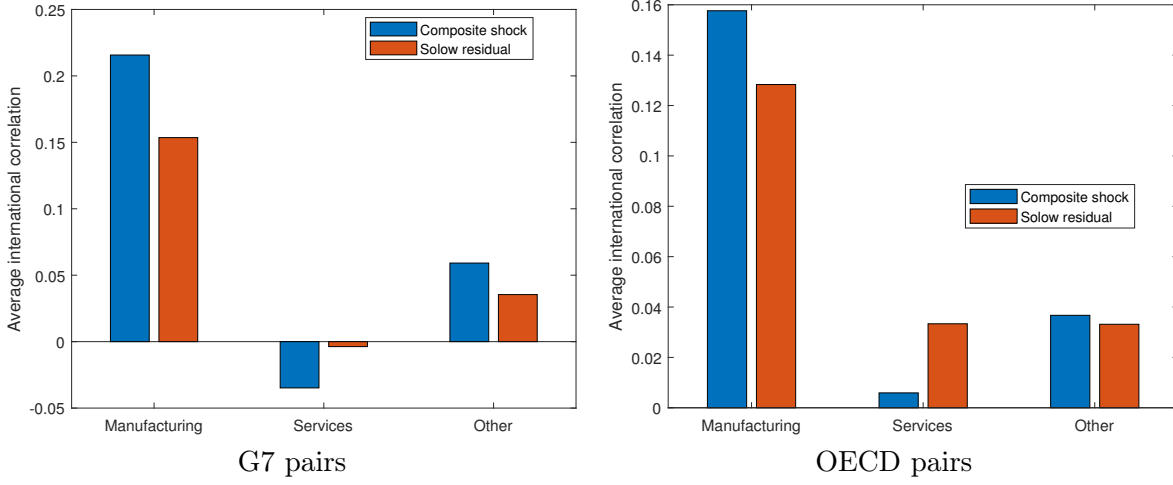
Notes: The left panels of this figure display the average share of each sector in consumption expenditure. The right panel shows the average share of each sector in intermediate input spending. The OECD sample refers to countries members of the OECD since the beginning of the sample in the 1978s.

to interpret structurally. Extracting the composite supply shock requires the full model solution and calibration.

Figure 3 reports the sectoral shock correlations, averaged across country pairs, for the composite shock (blue bars) and the Solow residual (red bars). By both measures, manufacturing shocks are the most correlated, while the service sector shocks are the least correlated. Appendix Figure C3 illustrates that the same pattern holds for nearly all 10-year rolling correlations on the samples.

While all measures of shocks rely on some underlying model structure, Appendix figure C2 shows

FIGURE 3: Overall sectoral shock correlations



Notes: This figure plots the correlation of the sectoral Solow residual and composite shock, extracted using equation (3.1), with foreign aggregate shocks over the 1978-2007 sample. The correlations are averaged across country pairs.

that manufacturing value added in the data is more correlated across countries than services value added as well.

4 Quantification

4.1 Calibration and parameter estimation

Table 1 summarizes the parameters we use. We provide our own estimates for the substitution elasticities between goods and service bundles in final consumption (ρ) and intermediate use (ε). The details are in Appendix A.2. For the Armington elasticities of substitution between domestic and foreign goods in final (γ) and intermediate (ν), we use the short-run estimates from [Boehm, Levchenko, and Pandalai-Nayar \(2022\)](#). Similar estimates are obtained by [Huo, Levchenko, and Pandalai-Nayar \(2020\)](#) using a different dataset. The only remaining structural parameters are the Frisch labor supply elasticity, which we set to 1 following the business cycle literature ([Chetty et al., 2011](#)), and parameter μ which governs the sectoral labor supply elasticity. We set μ to 1.5 following [Galle, Rodríguez-Clare, and Yi \(2017\)](#). Production function parameters and final/input shares are taken directly from the data.

4.2 Decomposition

The top panel of Figure 4 plots the evolution of GDP correlation and its decomposition into transmission and shock correlation. We first use every year's corresponding influence vector to compute the growth in GDP attributable to different countries' shocks as in equation (2.14). Then, we compute

TABLE 1: Parameter Values

Param.	Value	Source	Related to
ρ	0.2	Herrendorf, Rogerson, and Valentinyi (2013a) , own estimates	final cross-sector substitution elasticity
ε	0.2	own estimates	intermediate cross-sector subst. elasticity
γ	1	Boehm, Levchenko, and Pandalai-Nayar (2022)	trade elasticity in final consumption
ν	1	Boehm, Levchenko, and Pandalai-Nayar (2022)	trade elasticity in intermediate inputs
ψ	1	Chetty et al. (2011)	Frisch elasticity of labor supply
μ	1.5	Galle, Rodríguez-Clare, and Yi (2017)	Sectoral labor supply elasticity
η_j		Johnson and Noguera (2017)	value added share in gross output
π_{njt}^f		Johnson and Noguera (2017)	sectoral consumption shares
π_{mnjt}^f		Johnson and Noguera (2017)	trade shares in final trade
$\pi_{i,njt}^x$		Johnson and Noguera (2017)	sectoral intermediate use
$\pi_{mi,njt}^x$		Johnson and Noguera (2017)	trade shares in sectoral intermediate use

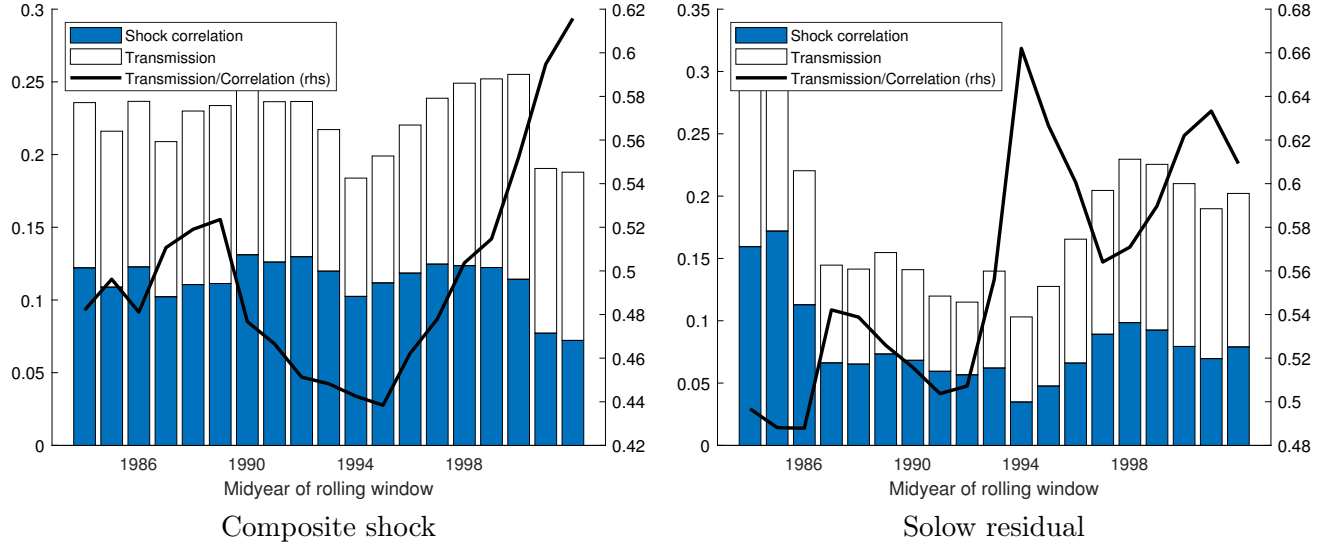
Notes: This table summarizes the parameters and data targets used in the baseline quantitative model and their sources. Alternative parameters are considered in [Appendix C](#).

the rolling correlations of those terms following equation (2.15), in 10-year windows. Each bar is the average bilateral correlation of GDP growth across countries as in [Figure 1](#). The blue part of the bar displays the shock correlation term, and the white part displays the transmission terms. The superimposed black line (right axis) shows the fraction of transmission in total correlation.

The left panel shows the decomposition for the composite supply shock for all country pairs, while the right panel illustrates the decomposition with the Solow residual as the supply shock. 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 50% at the beginning to 60%. A similar picture emerges for just the set of G7 countries: transmission increases while shock correlation remains stable or even decreases ([Appendix Table C1](#)).

[Figure 4](#) displays correlations in 10-year rolling windows. Thus, 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](#)

FIGURE 4: Correlation decomposition through time: OECD country pairs



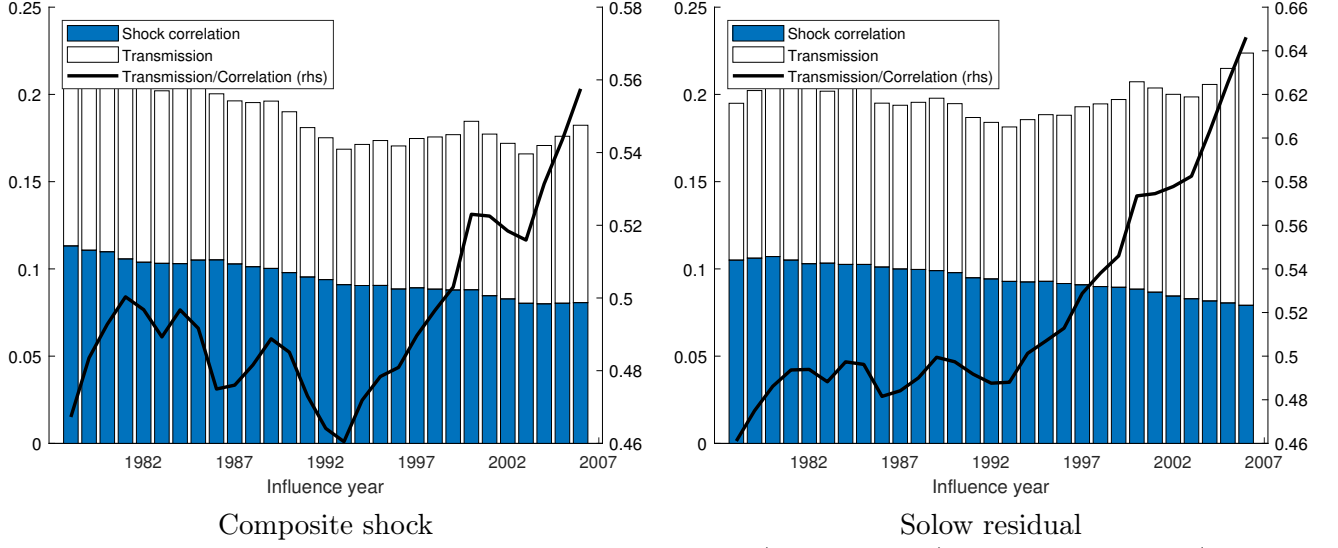
Notes: The figure displays the rolling decomposition of the total correlation (the height of the bar) into shock correlation (blue bars) and transmission (stacked white bars). We use the yearly influence vector in equation (2.9) to compute the decomposition in (2.4). The shocks used are the composite supply shocks on the left and the Solow residual on the right. The solid line shows the median of ratio between the transmission and total correlation across country pairs.

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 may be 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. Figure 5 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. 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 for the G7 country pairs.

4.3 Counterfactuals

Figures 4-5 summarize 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-homotheticities in the demand for services (e.g. Kongsamut,

FIGURE 5: Correlation decomposition from changing influence: OECD country pairs



Notes: The figure displays the decomposition of the total correlation (total bar height) into shock correlation (blue bars) and transmission (white bars) for all OECD country pairs. We use the yearly influence vector in equation (2.9) to compute the decomposition in (2.4) using the full time-series of shocks. Hence, the x-axis corresponds to the year of the influence vector used for the decomposition but not the shock extraction. The shocks used are the composite supply shocks on the left panel and the Solow residual on the right panel. The solid line shows the ratio between transmission and total correlation.

Rebelo, and Xie, 2001; Boppart, 2014; Comin, Lashkari, and Mestieri, 2020), among other things.

Shock extraction for the long run We invert the model to jointly recover the changes in the taste shifters $d \ln \zeta_{nj}$ and $d \ln \vartheta_{i,nj}$ and trade costs-cum-tastes $d \ln \left((\mu_{mnj})^{\frac{1}{1-\gamma}} \tau_{mnj} \right)$ and $d \ln \left((\mu_{mi,nj})^{\frac{1}{1-\nu}} \tau_{mni} \right)$ to rationalize long-run (1978-2007) changes in (i) sectoral final and intermediate expenditure shares $d \ln \pi_{nj}^f$ and $d \ln \pi_{i,nj}^x$; and (ii) international trade shares $d \ln \pi_{mnj}^f$ and $d \ln \pi_{mi,nj}^x$ for each country-sector and bilateral pair. 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 instead that labor is perfectly mobile across sectors: $\mu \rightarrow \infty$. Notice that this approach is a reduced form way to capture a long-run wealth and substitution effect that offset each other, resulting in labor supply staying constant in the long run.⁴ In addition, there is evidence that the trade elasticity differs between the short-run applicable to business cycle frequencies, and long-run relevant for structural change (Boehm, Levchenko, and Pandalai-Nayar, 2022). We thus apply the long-run trade elasticities estimated in that paper, setting $\gamma = \nu = 2$.

⁴Note 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 $\ln Z_{njt}$. As an alternative, we could have kept $\psi > 0$ and set the labor disutility shock χ_n such that aggregate labor supply remains constant in the counterfactual. Since our procedure does not target the long-run changes in the labor input, those two approaches are isomorphic for our purposes.

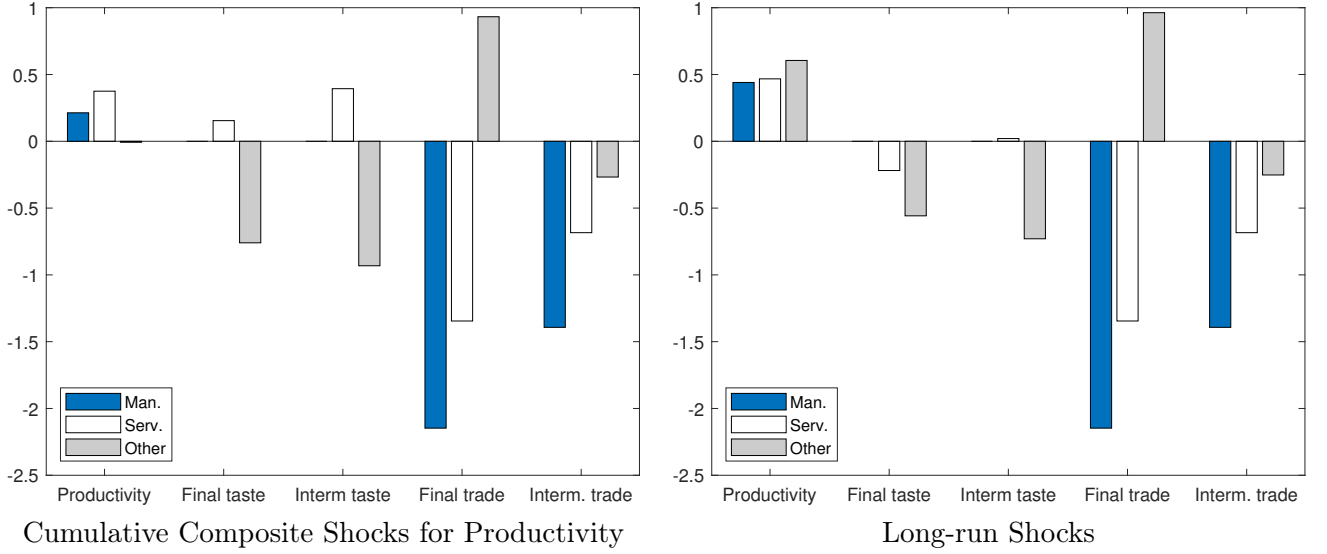
In this exercise, we must take a stand on how to treat long-run productivity changes $\ln Z_{njt}$. Our business cycle frequency shock extraction procedure described in Section 3.1 delivers yearly time series of productivity changes that rationalize year-to-year changes in sectoral value added. Our first approach is to cumulate those yearly productivity changes to build a long-run productivity change over the period 1978-2007. We then extract taste and trade cost shocks that match the sectoral expenditure and trade shares conditional on these long-run $\ln Z_{nj}$'s. In another approach, we compute long-run differences in sectoral value added, and extract long-run TFP differences jointly with taste and trade cost shifters in one step. In both cases, when all three types of shocks are fed into the model, they reproduce the changes in sectoral expenditure shares and international trade shares over the period 1978-2007. The advantage of the former approach is that the productivity shocks used for short-run (correlations) and long-run (structural change) purposes coincide. The advantage of the second approach is that when all three sets of shocks are fed back into the model, it replicates the 1978-2007 changes in real value added by sector as well, which the first approach does not. The implications of the two approaches for international comovement and our counterfactuals are similar, so we relegate the second to the appendix.

Figure 6 presents the productivity, taste shifter, and trade cost changes under the two approaches. As is clear from the figure, trade costs have fallen dramatically over this period in manufacturing, relative to services.⁵ This pattern, which has been documented in numerous studies, holds for both intermediate goods trade and final goods trade. Our model also implies that relative productivity in services has slightly increased (using the cumulative shocks) or stayed flat (using the long run shocks) over this period. 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 find that they disproportionately benefited workers in many service sectors (see for instance Autor, Levy, and Murnane, 2003; Adão, Beraja, and Pandalai-Nayar, 2020)⁶ At the same time, there is no robust pattern for whether tastes for services relative to manufacturing have increased or decreased. The first shock extraction approach implies a modest increase in the service taste shifters, whereas the second approach implies a modest decrease. In both cases there

⁵Without data on import prices, we cannot separate changes in tastes for foreign goods μ_{mnj} and $\mu_{mi,nj}$ from true iceberg costs τ_{mnj} , 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_{mnj} , for instance when plotting it in Figure 6. 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.

⁶Jovanovic 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 6. Adão, Beraja, and Pandalai-Nayar (2020) illustrate this pattern is consistent with this technology being adopted slower, as the skills required to adopt it are not prevalent in the existing workforce. This additionally leads to the implication that purely productivity-driven structural transformation towards services would be slower, as we find in our counterfactuals below.

FIGURE 6: Long-run productivity, taste, and trade cost changes



Notes: The figure displays the long-run changes in productivity, taste shifters (relative to manufacturing), and trade costs. The left panel displays the changes under the assumption that the long-run productivity shock is the cumulative change in the composite shock. The right panel extracts the change in productivity to match the long-run sectoral value-added change.

is a substantial fall in the relative taste for the other sectors, agriculture and non-manufacturing industry.

Counterfactual correlations Figure 7 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 Figure 5. The left-most bar summarizes the average GDP correlation in the world characterized by the 1978 production structure. The white and blue bars depict the transmission and shock correlation components, respectively. The second bar displays the “globalization-only” counterfactuals, that starts with the 1978 world economy, and feeds in only the 1978-2007 change in trade costs. Intriguingly, in spite of a large reduction in trade costs, average correlations change relatively little compared to the 1978 world. The actually fall modestly 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 white 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.⁷ 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).

⁷Appendix Figure C4 displays the change in sectoral shares in the data and counterfactuals.

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 manufacturing/services expenditure shares to stay constant.⁸ When trade costs fall but expenditure shares are not allowed to change, comovement increases noticeably, because the increase in international transmission is not accompanied by a large fall in the shock correlation components.⁹

To complete the picture, the bars labeled “+Rest” display international comovement in the alternative worlds in which only taste and productivity experienced long-run changes starting from 1978, while trade costs stayed fixed. As expected, applying long-run taste and productivity changes to the 1978 world economy lowers comovement relative to 1978, as these shocks favor the service sector which is less correlated. 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 the sum of the two shock-by-shock counterfactuals.

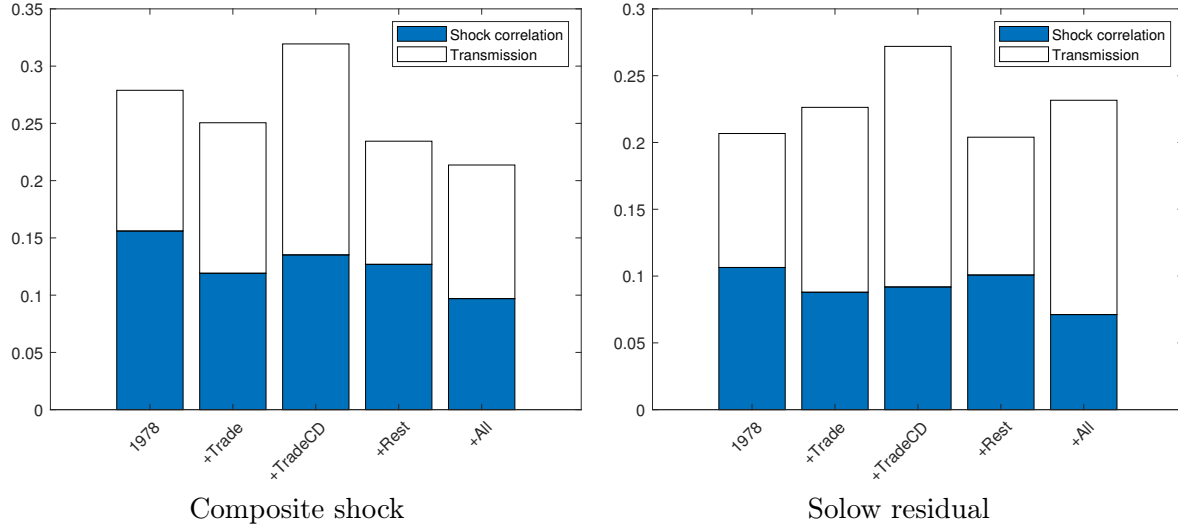
To illustrate the variation across country pairs, Figure 8 plots the kernel densities of the changes in the Shock Correlation and Transmission terms between each counterfactual and the 1978 baseline. Thus, a value of 0 on the x-axis implies that the Shock Correlation/Transmission component of the GDP correlation did not change compared to the 1978 world. The top left panel displays the trade counterfactual. While the impact differs across country pairs, the change in the Transmission component tends to be positive, and of the Shock Correlation component negative. In the trade + Cobb-Douglas scenario, both densities are shifted to the right. Applying the taste and productivity changes robustly reduces the transmission component, but leads to a fairly diffuse distribution of the Shock Correlation changes. The bottom right panel puts all the changes together. Both Shock Correlation and Transmission fall on average. All in all, the distribution of changes in the Shock Correlation terms is quite a bit more diffuse, reflecting the heterogeneity in the underlying sectoral shock correlations across country pairs. The changes in Transmission are relatively more homogeneous across countries.

Appendix figures C5 and C7 document similar patterns across counterfactuals for the alternative approach to constructing the long run productivity shock, as well as for 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).

⁸This is accomplished by applying the trade cost changes to a model where sectors are Cobb-Douglas in both final consumption and production. When we simulate business cycle comovement, we still use the baseline (complementary) elasticities.

⁹Even when expenditure shares are Cobb-Douglas, the Shock Correlation component falls somewhat relative to the 1978 baseline. This is because an increase in foreign trade shares reduces the domestic influence terms s_{nnj} that enter the Shock Correlation component (2.16), as a more open economy is mechanically less susceptible to domestic shocks. See Huo, Levchenko, and Pandalai-Nayar (2020) and Bonadio et al. (2021) for an elaboration of this effect.

FIGURE 7: Counterfactual correlations: OECD pairs



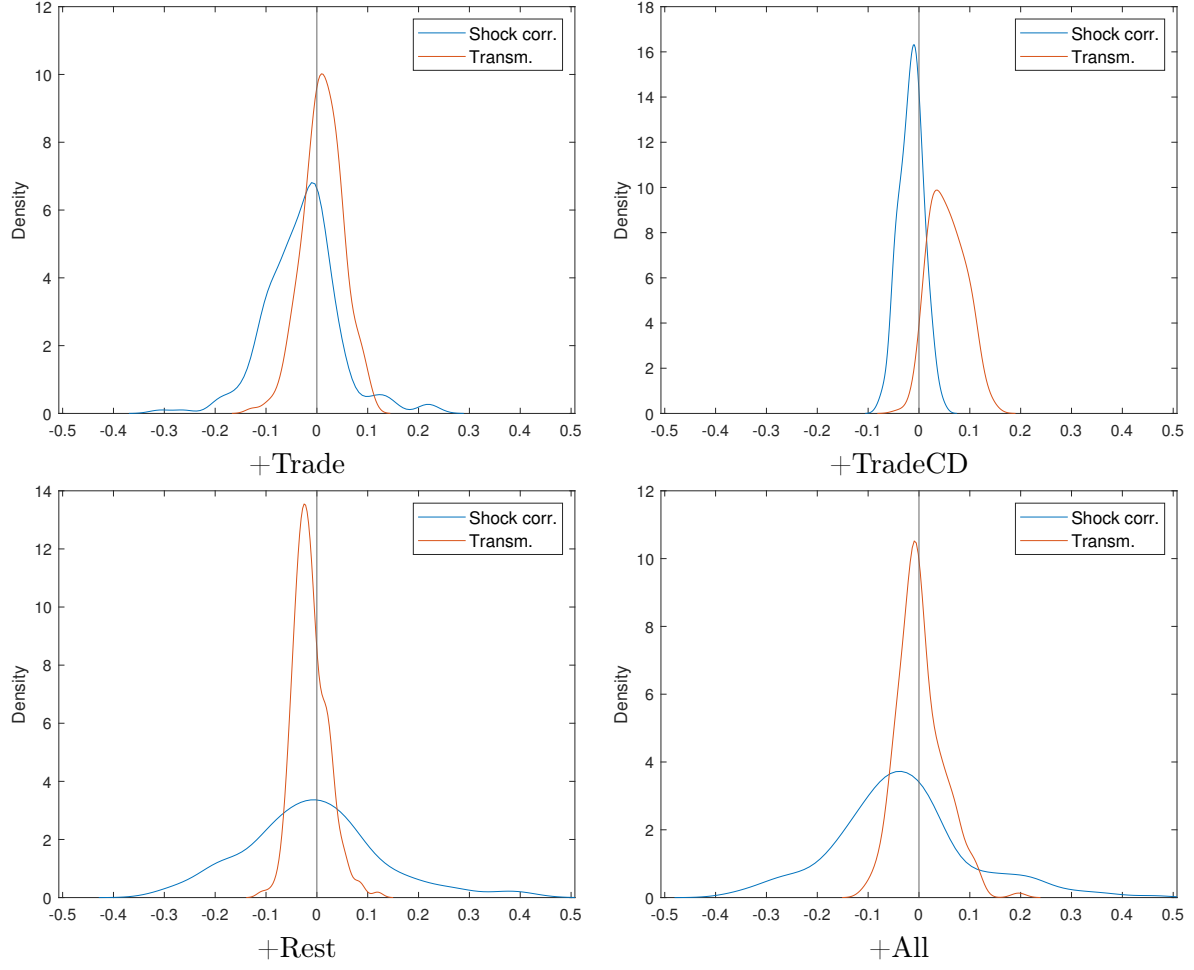
Notes: The bars display the average GDP growth correlations, decomposed into a shock correlation term (in blue) and transmission term (in white). Each bar represents a different scenario. “1978” is a counterfactual world in which the influence remained the same as the 1978 world, “+Trade” is a world 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 productivity 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.

5 Conclusion

We provide a resolution to the puzzle that increasing globalization, coupled with increased transmission of shocks, has not resulted in an increase in international comovement in recent decades. We show that structural change towards services sectors in both final consumption and in input usage in advanced economies is important to understand why not. The service sector, which has been growing over time, displays shocks with lower international correlation than the manufacturing sector. Additionally, when services and goods are complements in both consumption and production, globalization – in the form of 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 theoretically offset the increased transmission through increasing trade and input linkages. We quantify these opposing effects using a multi-country, multi-sector model of international production implemented on the OECD countries. We find that while transmission due to increased trade and input linkages would have increased comovement all else equal, the offsetting effects due to both structural change and the decreased relative price of manufacturing from globalization have both contributed to keeping overall comovement stable over time. Comovement on average would have declined if structural change had been the only force at work, while it would

FIGURE 8: Densities, Composite shock, Δ Correlation



Notes: The figure displays the kernel densities across country-pairs in the Shock Correlation and Transmission component changes in each counterfactual compared to the 1978 baseline scenario.

have increased if globalization occurred without inducing a shift towards service sectors through complementarity.

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TABLE A1: Sectoral conversion list

Sector	KLEMS code
Agriculture	AtB
NMI	C, E, F
Manufactures	15t16, 17t19, 20t22, 23t24, 25, 26, 27t28, 29t37
Services	G, H, 60t63, 64, J, 70, 71t74, L, M, N, O, P, Q

TABLE A2: Link with KLEMS variable

Model object	Description	Link with KLEMS variable
Y_{nj}	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
η_j	Share of value added	$\eta_j = \frac{1}{N} \sum_n 1 - \frac{\sum_{m,i} X_{mi,nj}^{int}}{\sum_{m,i} X_{nj,mi}^{int} + \sum_m X_{nmj}^{fin}}$

Appendix A Data and Estimation Appendix

A.1 Data description details

Sectoral classification and aggregation Our final 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 A1.

To aggregate to the four sectors, we follow [Herrendorf, Rogerson, and Valentinyi \(2013b\)](#) and use the so called cyclical expansion procedure. Denote by Y_{it} the nominal value, Q_{it} the quantity index, and P_{it} the price index for a sub-sector i at time t . These are the values taken directly from KLEMS disaggregated data. The KLEMS data comes from EU-KLEMS for most countries, and 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 (Q_t) and deflators (P_t) for the aggregate $Y_t = \sum_i Y_{it}$. We define the growth rate of the real value of the aggregate as:

$$\frac{Q_t}{Q_{t-1}} = \sqrt{\frac{\sum_i P_{it-1} y_{it}}{\sum_i P_{it-1} y_{it-1}} \frac{\sum_i P_{it} y_{it}}{\sum_i P_{it} y_{it-1}}}$$

From there, we compute $\frac{P_t}{P_{t-1}} = \frac{Y_t}{Y_{t-1}} / \frac{Q_t}{Q_{t-1}}$.

Table A2 displays the variables we use from KLEMS and the trade flows, and how they map to model objects.

Country coverage After merging the trade and sectoral data, the final dataset consists of 19 countries and a composite Rest of the World. The list of countries is presented in table A3, and covers 75% of the countries that were part of the OECD at the beginning of our sample (96% in terms of GDP).

A.2 Elasticity Estimation

To calibrate the model, we require a few key elasticities of substitution in the intermediate and final goods bundles. We estimate these key elasticities using optimality conditions from the model.

TABLE A3: 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

Elasticity of substitution between sectors in production The elasticity of substitution in production between sectors ε is estimated by regressing changes in the relative shares of spending on sectors (eg manufacturing relative to services), on changes in relative prices in the sectors:

$$\ln \frac{\Delta \pi_{i,nj,t}^x}{\Delta \pi_{k,nj,t}^x} = (1 - \varepsilon) \ln \frac{\Delta P_{i,nj,t}}{\Delta P_{k,nj,t}} + \omega_{ikt} + u_{ik,nj,t}. \quad (\text{A.1})$$

Here, the price of the sector composites used in the input bundle $P_{i,nj,t}$ are constructed by aggregating weighted domestic producer price indices from all source countries for that sector, where the weights are lagged shares of spending on a source country.¹⁰ This implies that, if the true purchaser price $P_{mi,nj,t} = \tau_{mi,nj,t} P_{mi,t}$ where $\tau_{mi,nj,t}$ are unobserved “iceberg” trade costs, then the structural error $u_{ik,nj,t}$ includes the ratios of deviations of these costs in the numerator and denominator sectors from the average captured by the weights in the aggregator. Iceberg trade costs include both transport/tariff changes as well as changes in local distribution margins and idiosyncratic bilateral preferences for country m sector i ’s output as an input. Further, the destination country-sector’s relative preference changes for between the two sectors will also be in the structural error term. We include sector-pair time fixed effects ω_{ijt} to soak up much of this variation. For instance, a worldwide shift in preferences between services and manufacturing in a particular period will be absorbed by this fixed effect, as would a worldwide reduction in the relative trade cost of services to manufacturing.

Residual threats to identification then are a correlation in the domestic PPI change in country m sector i with changes in bilateral trade costs or preference shifts, broadly defined, between country m sector i and country n sector j . Additionally, deviations of the destination country’s relative preferences for i and j from the world average in period t might be correlated with the relative price changes between i and j . Such correlations are unlikely in an annual differenced specification, but might be more of a concern in a long differenced specification (for instance, a persistent preference shift towards manufacturing correlated with a decrease in the relative manufacturing price). We therefore present the results both of an OLS estimation of this relative differences specification, as well as the results of an IV specification. For instruments, we use oil and defense spending shocks, as well as upstream and downstream versions of these shocks, constructed as detailed below in subsection A.3. Additionally, we estimate ε using an annual differenced specification and a long differenced specification. For the latter we do not use an IV, as the exclusion restriction is more likely

¹⁰Each domestic PPI is appropriately multiplied by an exchange rate to convert all prices to US dollars, as KLEMS reports the PPIs in domestic currency.

to be violated (a persistent relative change in demand due to a persistent relative defense spending shock can spur technological changes in a sector and changes in sectoral prices).

Elasticity of substitution across countries, within sectors in production The estimating equation for the elasticity of substitution across countries, within a sector of production, is given by:

$$\ln \frac{\Delta \pi_{mi,nj,t}^x}{\Delta \pi_{m'i,nj,t}^x} = (1 - \nu) \ln \frac{\Delta P_{mi,nj,t}}{\Delta P_{m'i,nj,t}} + \omega_{mm',t} + u_{mm',inj,t}. \quad (\text{A.2})$$

As above, we use the fact that $P_{mi,nj,t} = \tau_{mi,nj,t} P_{mi,t}$, and use data on relative PPIs of sector i in countries m and m' to measure the price ratio. Then the structural error $u_{mm',inj,t}$ includes changes in relative trade costs as well as relative taste shifters. We soak up most of this unobserved variation by including an importer country-exporter country pair-year fixed effect. Any relative trade or taste shifter common to all sectors within the triplet of countries will be absorbed by the fixed effect.

A residual threat to our identification strategy involves a correlation between the exporter countries price and the importer-exporter taste for a specific sector. This could arise, for example, from a positive taste shock for inputs of sector i from country m relative to country m' , that results in an increased price if the importer is large enough. We alleviate this concern in two ways. First, we run the estimation on a subsample of G7 exporter and non-G7 importers. In this sample, it is unlikely that taste shocks in the small importer countries lead to price changes in the large exporter countries. Second, we use an IV estimation based on similar instruments as above.

Elasticities of substitution in consumption The estimation of the elasticities ρ and γ uses the optimality conditions on the household side that lead to very similar estimating equations as for the production side. These elasticities have been previously estimated by [Herrendorf, Rogerson, and Valentinyi \(2013b\)](#), and [Huo, Levchenko, and Pandalai-Nayar \(2020\)](#) among others. For consistency we re-estimate the parameters in our data using the following two estimating equations:

$$\ln \frac{\Delta \pi_{nj,t}^f}{\Delta \pi_{nk,t}^f} = (1 - \rho) \ln \frac{\Delta P_{nj,t}^f}{\Delta P_{nk,t}^f} + \omega_{jkt} + u_{nj,nk,t} \quad (\text{A.3})$$

$$\ln \frac{\Delta \pi_{mnj,t}^f}{\Delta \pi_{m'nj,t}^f} = (1 - \gamma) \ln \frac{\Delta P_{mj,t}}{\Delta P_{m'j,t}} + \omega_{mm',t} + u_{mm',nj,t} \quad (\text{A.4})$$

A.3 Instruments

We use two sources of exogenous variation. The first is an oil price shock, defined as the difference between the (log) oil price and the maximum (log) price in the preceding year. The oil shock - denoted OIL_t - is either zero (when the difference is negative), or positive (when the difference is positive). The second source of exogenous variation is the lagged change in real government defense spending and denoted DEF_{nt} .

The instruments are constructed by exploiting the difference in input exposure to oil and demand exposure to government spending. Formally, define $OIL_{njt} = OIL_t \sum_{m,i=oil} \pi_{mi,nj}^x$ and $DEF_{njt} = DEF_{nt} G_{nj} / Y_{nj}$, where G_{nj} are the sales of sector j , country n , to the government in country n .¹¹ OIL_{njt} and DEF_{njt} are the *direct* shocks. We further construct upstream and downstream versions of these shocks by exploiting variation

¹¹In practice, because our sectors are highly aggregated, we use the WIOD disaggregated IO matrix to construct sub-sectors specific exposure to the oil sector or government spending, and aggregate the exposure using a weighted average, where the weight is equal to the sub-sector's output.

in up- and down-stream exposure to sectors with different direct exposure to the shock.¹²

A.4 Elasticities estimates

Table A4 displays the results of the estimation of the elasticity of substitution across input types. Our results suggest complementarity between input sectors, with elasticities significantly lower than 1 even at the 10 year horizon. Table A5 displays the results of the estimation of the elasticity of substitution across origin countries within input type.

Table A6 displays the results of the estimation of the elasticity of substitution across consumption types. Again, our results suggest complementarity between sectors, with elasticities significantly lower than 1 even at the 10 year horizon. Table A7 displays the results of the estimation of the elasticity of substitution across origin countries within consumption type.

TABLE A4: Estimation of the elasticity between input types, ε

	1 year difference				10 year difference	
	G7		All countries		G7	All countries
	OLS	IV	OLS	IV	OLS	OLS
ε	0.368 (0.058)	0.409 (0.349)	0.167 (0.200)	3.160 (1.193)	0.285 (0.209)	0.742 (0.187)
KP-F		19.42		18.15		
N	4,704	4,704	12,765	12,765	3,192	8,661
FE	✓	✓	✓	✓	✓	✓

Notes: This table presents the results of estimating equation A.1. FE refers to supplier sector pairs fixed effects. Standard errors are clustered at the user country-sector times supplier pair level and displayed in parenthesis. KP-F refers to the first stage Kleibergen-Paap F-statistic.

¹²For a *direct* instrument Z_{njt} , define the upstream instrument Z^{up} and downstream instrument Z^{down} as:

$$Z_{njt}^{up} = \sum_{mi} \pi_{mi,nj}^x Z_{mi,t}$$

and

$$Z_{mit}^{down} = \sum_{nj} \pi_{mi,nj}^x Z_{nj,t}$$

TABLE A5: Estimation of the elasticity across origins in inputs, ν

	1 year difference				10 year difference	
	G7, non-G7		All countries		G7, non-G7	All countries
	OLS	IV	OLS	IV	OLS	OLS
ν	1.196 (0.144)	0.876 (0.858)	1.080 (0.104)	0.968 (1.012)	1.480 (0.153)	1.574 (0.115)
KP-F		4230.33		1664.54		
N	112,471	110,383	1,279,025	1,269,993	75,795	848,538
FE	✓	✓	✓	✓	✓	✓

Notes: This table presents the results of estimating equation A.2. “G7, non-G7” refers to the sample using G7 exporters and non-G7 importers only. FE refers to supplier sector pairs fixed effects. Standard errors are clustered at the user country-sector times supplier sector pair level and displayed in parenthesis. KP-F refers to the first stage Kleibergen-Paap F-statistic.

TABLE A6: Estimation of the elasticity between consumption types, ρ

	1 year difference				10 year difference	
	G7		All countries		G7	All countries
	OLS	IV	OLS	IV	OLS	OLS
ρ	0.397 (0.051)	0.305 (0.142)	0.457 (0.033)	0.300 (0.097)	0.433 (0.092)	0.525 (0.070)
KP-F		11.66		30.92		
N	1,218	1,218	3,306	3,306	840	2280
FE	✓	✓	✓	✓	✓	✓

Notes: This table presents the results of estimating equation A.3. FE refers to supplier sector pairs fixed effects. Standard errors are clustered at the user country-sector times supplier pair level and displayed in parenthesis. KP-F refers to the first stage Kleibergen-Paap F-statistic.

TABLE A7: Estimation of the elasticity across origins in consumption, γ

	1 year difference				10 year difference	
	G7, non-G7		All countries		G7, non-G7	All countries
	OLS	IV	OLS	IV	OLS	OLS
γ	1.146 (0.297)	-0.434 (1.604)	0.887 (0.248)	1.214 (3.490)	1.943 (0.381)	1.501 (0.346)
KP-F		682.03		233.23		
N	22,291	21,903	251,627	249,947	14,199	159,376
FE	✓	✓	✓	✓	✓	✓

Notes: This table presents the results of estimating equation A.4. “G7, non-G7” refers to the sample using G7 exporters and non-G7 importers only. FE refers to supplier country pairs fixed effects. Standard errors are clustered at the user country-sector times supplier sector pair level and displayed in parenthesis. KP-F refers to the first stage Kleibergen-Paap F-statistic.

Appendix B Model Appendix

B.1 Influence matrices

Prices as a function of output and exogenous shocks Combining the goods market clearing condition (2.7) with the balanced trade equation (2.8) and log-linearizing for changes in Z , ζ , τ^f , ϑ and τ^x yields:¹³

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

where the changes in shares are given by:

$$\begin{aligned} \ln \pi_{nj}^f &= \ln \zeta_{nj} + (1 - \rho) \sum_m \pi_{mnj}^f \left(\ln \tilde{\tau}_{mnj}^f + \ln P_{mj} \right) \\ &- \sum_k \pi_{nk}^f \ln \zeta_{nk} - (1 - \rho) \sum_k \pi_{nk}^f \left[\sum_m \pi_{mnk}^f \left(\ln \tilde{\tau}_{mnk}^f + \ln \hat{P}_{mk} \right) \right], \\ \ln \pi_{mnj}^f &= (1 - \gamma) \left(\ln \tilde{\tau}_{mnj}^f + \ln P_{mj} - \sum_o \pi_{onj}^f \left(\ln \tilde{\tau}_{onj}^f + \ln P_{oj} \right) \right), \\ \ln \pi_{i,nj}^x &= \ln \vartheta_{i,nj} + (1 - \varepsilon) \left(\sum_m \pi_{mi,nj,t}^x \left(\ln \tilde{\tau}_{mi,nj}^x + \ln \hat{P}_{mi} \right) \right) \\ &- \sum_k \pi_{k,nj,t}^x \ln \vartheta_{k,nj} - (1 - \varepsilon) \sum_k \pi_{k,nj,t}^x \sum_m \pi_{mk,nj,t}^x \left(\ln \tilde{\tau}_{mk,nj}^x + \ln \hat{P}_{mk} \right), \end{aligned}$$

and

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

Define the following matrices:

- Ψ^f is a $NJ \times NJ$ matrix whose (nj, m) th element is $\frac{\pi_{mj}^f \pi_{nmj}^f P_m \mathcal{F}_m}{P_{nj} Y_{nj}}$, the share of nj 's total revenue that comes from final sales to country m .

¹³An equivalent expression with exogenous trade deficits can be obtained as:

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

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.

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

The market clearing can be written in matrix form as:¹⁴

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

¹⁴In the case of trade deficits, two additional terms should be added to the equation:

1. $\Psi^\Delta \Delta$, where Ψ^Δ is a $(NJ) \times N$ matrix, where $\Psi_{nj,m}^\Delta = \frac{\pi_{mj}^f \pi_{nmj}^f P_m^D \mathcal{F}_m}{P_{nj} Y_{nj}} \frac{D_m W GDP}{P_m \mathcal{F}_m}$.
2. $\Psi^{PY\Delta} (\ln Y + \ln P)$, where $\Psi_{nj,ok}^{PY\Delta} = \frac{\eta_k P_{ok} Y_{ok}}{W GDP} \sum_m \Psi_{nj,m}^\Delta$

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

$$\ln \mathbf{P} = \mathcal{P}^Y \ln \mathbf{Y} + \mathcal{P}^\zeta \ln \zeta + \mathcal{P}^{\tau^f} \ln \tau^f + \mathcal{P}^\vartheta \ln \vartheta + \mathcal{P}^{\tau^x} \ln \tau^x, \quad (\text{B.2})$$

where

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

and

$$\begin{aligned} \mathcal{M} = & \Psi^f \Upsilon + \Psi^x + [(1 - \gamma) \text{diag}(\Psi^f \mathbf{1}) + [(1 - \rho) - (1 - \gamma)] \Psi^c \Pi^{2f} - (1 - \rho) \Psi^f \Pi^{1f}] \\ & + [(1 - \nu) \text{diag}(\Psi^x \mathbf{1}) + [(1 - \varepsilon) - (1 - \nu)] \Psi^x \Pi^{2x} - (1 - \varepsilon) \Psi^x \Pi^{1x}]. \end{aligned}$$

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

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

Hours as a function of output, prices and exogenous shocks Taking the log deviation of equation (2.2) 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:

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

which can be rewritten in matrix form as

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

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

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

which can be written as:

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

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

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

Plugging in for (B.2) gives

$$\ln \mathbf{H} = \mathcal{H}^Y \ln \mathbf{Y} + \mathcal{H}^P \ln \mathbf{P} + \mathcal{H}^\zeta \ln \zeta + \mathcal{H}^{\tilde{\tau}^f} \ln \tilde{\tau}^f \quad (\text{B.3})$$

where

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

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

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

so that

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

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

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

where $\boldsymbol{\eta}$ is a diagonal matrix where element (nj, nj) is equal to η_j . This leads to equation (2.9):

$$\ln \mathbf{Y} = \boldsymbol{\Lambda}_Z^Y \ln \mathbf{Z} + \boldsymbol{\Lambda}_\zeta^Y \ln \zeta + \boldsymbol{\Lambda}_{\tau^f}^Y \ln \tilde{\tau}^f + \boldsymbol{\Lambda}_\vartheta^Y \ln \vartheta + \boldsymbol{\Lambda}_{\tau^x}^Y \ln \tau^x, \quad (\text{B.4})$$

where

$$\boldsymbol{\Lambda}_Z^Y = [\mathbf{I} - (\mathbf{I} - \boldsymbol{\eta}) - \boldsymbol{\eta} \mathcal{H}^Y - [(\mathbf{I} - \boldsymbol{\Pi}^{1x}) + \boldsymbol{\eta} \mathcal{H}^P] \mathcal{P}^Y]^{-1}. \quad (\text{B.5})$$

and for the other shocks:

$$\boldsymbol{\Lambda}_s^Y = \boldsymbol{\Lambda}_Z^Y [\boldsymbol{\eta} \mathcal{H}^s + [(\mathbf{I} - \boldsymbol{\Pi}^{1x}) + \boldsymbol{\eta} \mathcal{H}^P] \mathcal{P}^s]$$

Hours as a function of exogenous shocks To get equation (2.12), plug in (B.4) and (B.2) in (B.3) to get:

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

where

$$\Lambda_s^H = (\mathcal{H}^Y + \mathcal{H}^P \mathcal{P}^Y) \Lambda_s^Y + \mathcal{H}^P \mathcal{P}^s + \mathcal{H}^s \quad (\text{B.6})$$

B.2 Long-run shocks extraction

To extract the set of long-run shocks $\{\mathbf{Z}, \boldsymbol{\zeta}, \boldsymbol{\tau}^f, \boldsymbol{\vartheta}, \boldsymbol{\tau}^x\}$, we match the long-run changes in value added, final consumption sectoral shares (π_{nj}^f), final trade shares (π_{mnj}^f), intermediates sectoral shares (π_{nj}^x) and intermediate trade shares ($\pi_{mi,nj}^x$). 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 $\ln \zeta_{n1} = 0$, $\ln \tilde{\tau}_{nnj}^f = 0$, $\ln \vartheta_{1,nj} = 0$, and $\ln \tilde{\tau}_{ni,nj}^x = 0$. It will be convenient to define $\boldsymbol{\theta}$ as the $NJ + NJ + NNJ + NJJ + NJNJ$ long vector of all shocks: $\boldsymbol{\theta} = [\mathbf{Z}, \boldsymbol{\zeta}, \boldsymbol{\tau}^f, \boldsymbol{\vartheta}, \boldsymbol{\tau}^x]$

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

$$\begin{aligned} \ln V_{nj}^{data} &= \frac{1}{\eta_j} \ln Y_{nj} - \frac{1 - \eta_j}{\eta_j} \ln X_{nj}^{data} \\ &= \frac{1}{\eta_j} (\ln Z + \eta_j \ln H_{nj} + (1 - \eta_j) \ln X_{nj}) - \frac{1 - \eta_j}{\eta_j} \ln X_{nj}^{data} \\ &= \frac{1}{\eta_j} (\ln Z + \eta_j \ln H_{nj}) - \frac{1 - \eta_j}{\eta_j} (\ln X_{nj}^{data} - \ln X_{nj}) \end{aligned}$$

In the data, $\ln X_{nj}^{data}$ 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.

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

To circumvent this issue, we reinterpret the long-run productivity shock as \tilde{Z}_{nj} , the productivity-cum-taste shifter.¹⁵ After this reinterpretation we can relate the data change in value added to the model implied changes due to the vector of shocks:

$$\begin{aligned} \ln \mathbf{V} &= \boldsymbol{\eta}^{-1} \ln \mathbf{Z} + \ln \mathbf{H} \\ &= \boldsymbol{\nu}^\theta \ln \boldsymbol{\theta}, \end{aligned} \quad (\text{B.7})$$

where

$$\boldsymbol{\nu}^\theta = [\boldsymbol{\eta}^{-1}, \mathbf{0}] + \boldsymbol{\Lambda}^H.$$

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

$$\ln \pi_{nj}^f - \ln \pi_{n1}^f = \ln \zeta_{nj} + (1 - \rho) \sum_m \pi_{mnj}^f \left(\ln \tilde{\tau}_{mnj}^f + d \ln P_{mj} \right) - (1 - \rho) \sum_m \pi_{mn1}^f \left(\ln \tilde{\tau}_{mn1}^f + \ln P_{m1} \right), \quad (\text{B.8})$$

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

¹⁵In 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.

In matrix form, this can be rewritten as:

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

where

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

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

In matrix form, this can be written as

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

where

- $\ln \Pi^{2fv}$ is a NNJ long vector where element (mnj) is equal to $\ln \pi_{mnj}^f - \ln \pi_{nnj}^f$.
- \mathbf{B}^{τ^f} is an almost-diagonal $NNJ \times NNJ$ matrix where $\mathbf{B}_{mnj,mnj}^{\tau^f} = (1-\gamma)$ and $\mathbf{B}_{mnj,nnj}^{\tau^f} = -(1-\gamma)$, $\forall m \neq n$.
- \mathbf{B}^P is a $NNJ \times NJ$ matrix where $\mathbf{B}_{mnj,mj}^P = (1-\gamma)$ and $\mathbf{B}_{mnj,nj}^P = -(1-\gamma)$, $\forall m \neq n$.
- Φ^{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:

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

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

In matrix form:

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

where

- $\ln \Pi^{1xv}$ is a NJJ long vector where element (nji) is equal to $\ln \pi_{i,nj}^x - \ln \pi_{1,nj}^x$.

- C^{τ^x} is a block diagonal $NJJ \times NJNJ$ matrix where $C_{nji,minj}^{\tau^x} = (1 - \varepsilon)\pi_{mi,nj}^x$ and $C_{nj,mn1}^{\tau^x} = -(1 - \varepsilon)\pi_{mi,n1}^x$, $\forall j \neq 1$.
- C^P is a $NJ \times NJ$ matrix where $C_{nj,mj}^P = (1 - \varepsilon)\pi_{mnj}^f$ and $C_{nj,m1}^P = -(1 - \varepsilon)\pi_{mn1}^f$, $\forall j \neq 1$.
- Φ^{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:

$$\ln \pi_{mi,nj}^x - \ln \pi_{ni,nj}^x = (1 - \nu) (\ln \tilde{\tau}_{mi,nj}^x + \ln P_{mi} - \ln P_{ni}).$$

In matrix form, this can be written as

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

where

- $\ln \Pi^{2xv}$ is a $NJNJ$ long vector where element ($minj$) is equal to $\ln \pi_{mi,nj}^x - \ln \pi_{ni,nj}^x$.
- D^{τ^x} is an almost-diagonal $NJNJ \times NJNJ$ matrix where $D_{minj,minj}^{\tau^x} = (1 - \nu)$ and $D_{minj,ninj}^{\tau^x} = -(1 - \nu)$, $\forall m \neq n$.
- D^P is a $NJNJ \times NJ$ matrix where $D_{minj,mi}^P = (1 - \nu)$ and $D_{minj,ni}^P = -(1 - \nu)$, $\forall m \neq n$.
- Φ^{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) and inverting for θ gives the long-run shocks matching the desired moments:

$$\begin{bmatrix} \ln V \\ \ln \Pi^{1fv} \\ \ln \Pi^{2fv} \\ \ln \Pi^{1xv} \\ \ln \Pi^{2xv} \end{bmatrix} = \begin{bmatrix} \Phi^V \\ \Phi^{1fv} \\ \Phi^{2fv} \\ \Phi^{1xv} \\ \Phi^{2xv} \end{bmatrix} \begin{bmatrix} \ln Z \\ \ln \tilde{\zeta} \\ \ln \tau^f \\ \ln \vartheta \\ \ln \tau^x \end{bmatrix} = \Phi \ln \theta \quad (\text{B.13})$$

When we use the cumulative composite shock as long-run productivity shock, 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 ζ , τ^f , ϑ and τ^x :

$$\begin{bmatrix} \ln V \\ \ln \Pi^{1fv} \\ \ln \Pi^{2fv} \\ \ln \Pi^{1xv} \\ \ln \Pi^{2xv} \end{bmatrix} - \begin{bmatrix} \Phi^{1fv,Z} \\ \Phi^{2fv,Z} \\ \Phi^{1xv,Z} \\ \Phi^{2xv,Z} \end{bmatrix} \left(\sum_t \ln Z_t^{SR} \right) = \begin{bmatrix} \Phi^{1fv} \\ \Phi^{2fv} \\ \Phi^{1xv} \\ \Phi^{2xv} \end{bmatrix} \begin{bmatrix} \ln \tilde{\zeta} \\ \ln \tau^f \\ \ln \vartheta \\ \ln \tau^x \end{bmatrix}$$

Appendix C Quantitative Appendix

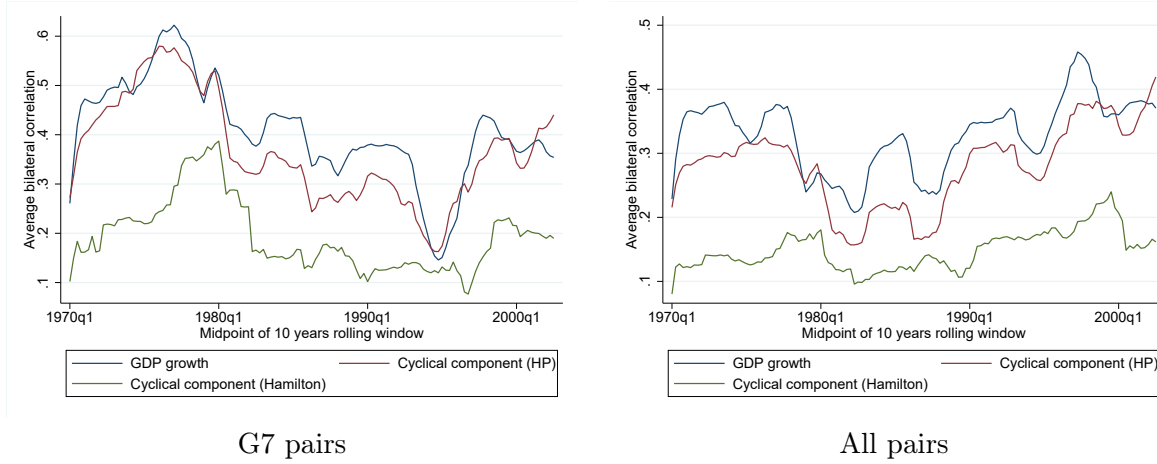
C.1 Basic facts appendix

Figure C1 displays the average bilateral correlations of GDP growth (as depicted in Figure 1), together with the correlation of the growth in the cyclical component of GDP extracted using the HP filter (in red) and the method suggested in Hamilton (2018). In all cases, no clear upward trend is noticeable.

Figure C2 displays the average international correlation of sectoral value added, Solow residual, and our composite shock, across countries.

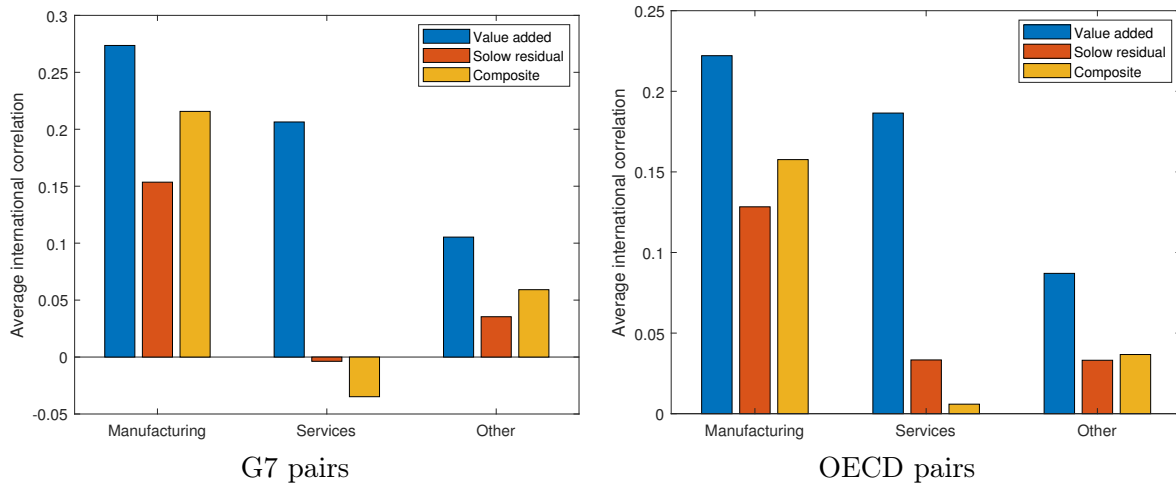
Figure C3 displays the rolling correlations of the different shocks. It is apparent that throughout the sample, the manufacturing sector is always the most internationally correlated.

FIGURE C1: Trends in GDP Comovement Robustness



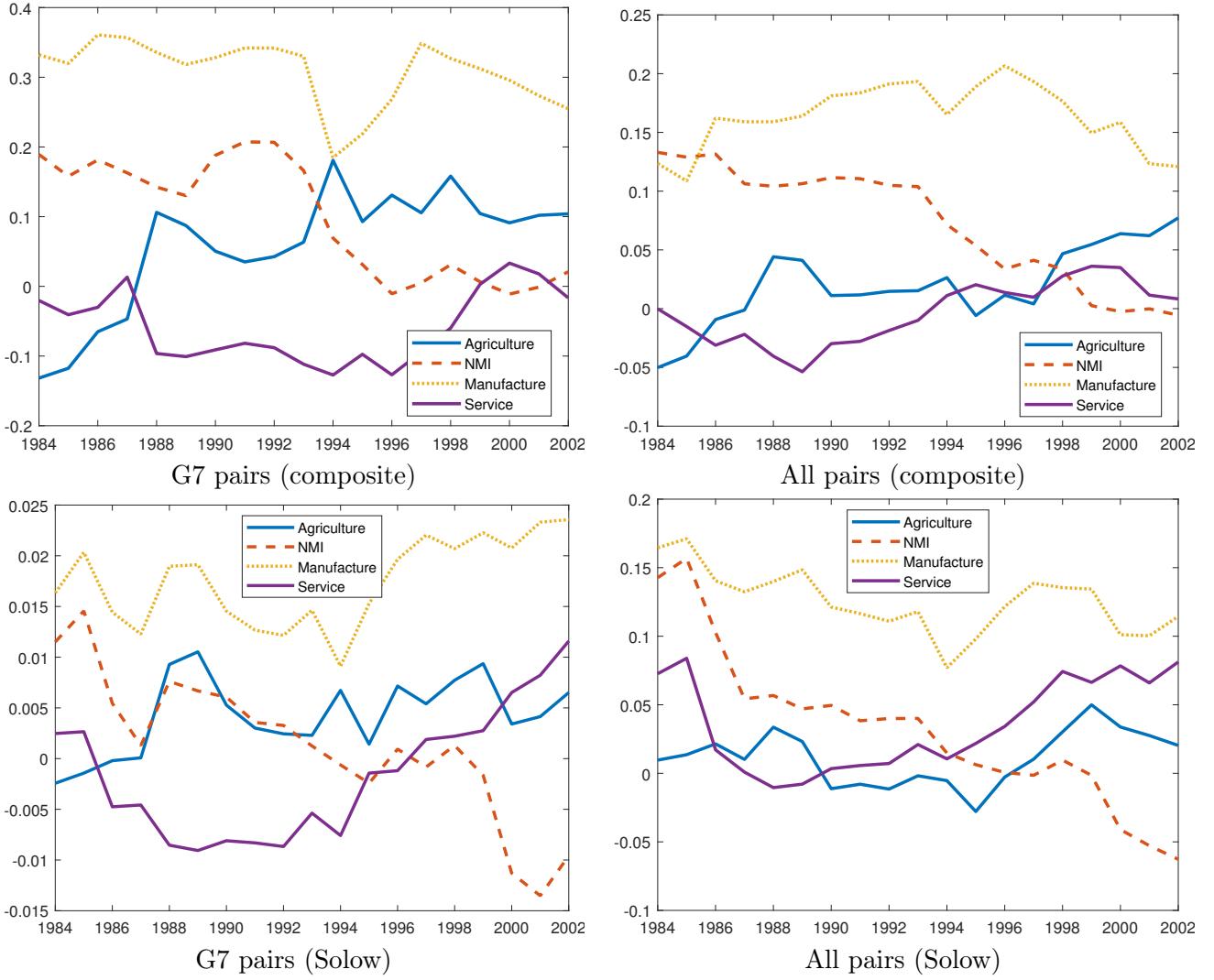
Notes: The date denotes the midpoint of the 10 year rolling window. The OECD sample refers to countries members of the OECD since the beginning of the sample in the 1970s.

FIGURE C2: Sectoral correlations



Notes: The figure displays the average correlation between growth in a country-sector with the foreign aggregate (foreign GDP growth for the sectoral value added, foreign aggregate (domar-weighted) Z_n shock for the Solow and composite productivity shocks: $corr(d \ln Z_{njt}, \sum_j w_{njt} Z_{mjt})$ for $n \neq m$, where w_{njt} is the Domar weight).

FIGURE C3: Rolling sectoral shock correlations



Notes: This figure plots the rolling correlation 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).

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

	All countries, composite shock				G7 pairs, composite shock			
Tot corr	Mean	Median	p25	p75	Mean	Median	p25	p75
1984	0.235	0.275	0.053	0.484	0.425	0.484	0.250	0.591
2002	0.187	0.207	-0.106	0.541	0.293	0.335	0.015	0.621
Shock corr								
1984	0.122	0.148	-0.064	0.338	0.263	0.324	0.083	0.443
2002	0.072	0.106	-0.152	0.332	0.161	0.191	-0.077	0.440
Trans.								
1984	0.113	0.112	0.063	0.155	0.161	0.152	0.133	0.199
2002	0.115	0.087	0.039	0.172	0.132	0.128	0.056	0.178
	All countries, Solow residuals				G7 pairs, Solow residuals			
Tot corr	Mean	Median	p25	p75	Mean	Median	p25	p75
1984	0.316	0.325	0.130	0.541	0.251	0.159	0.026	0.524
2002	0.202	0.245	-0.045	0.469	0.309	0.258	0.167	0.471
Shock corr								
1984	0.159	0.167	0.005	0.360	0.099	0.059	-0.158	0.357
2002	0.079	0.096	-0.140	0.310	0.154	0.088	-0.001	0.300
Trans.								
1984	0.157	0.147	0.100	0.204	0.152	0.137	0.105	0.192
2002	0.123	0.102	0.069	0.181	0.155	0.157	0.096	0.195

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). The top panel displays the decomposition using the composite shock and the bottom panel shows the decomposition using the Solow residual. G7 country pairs' results are displayed on the right.

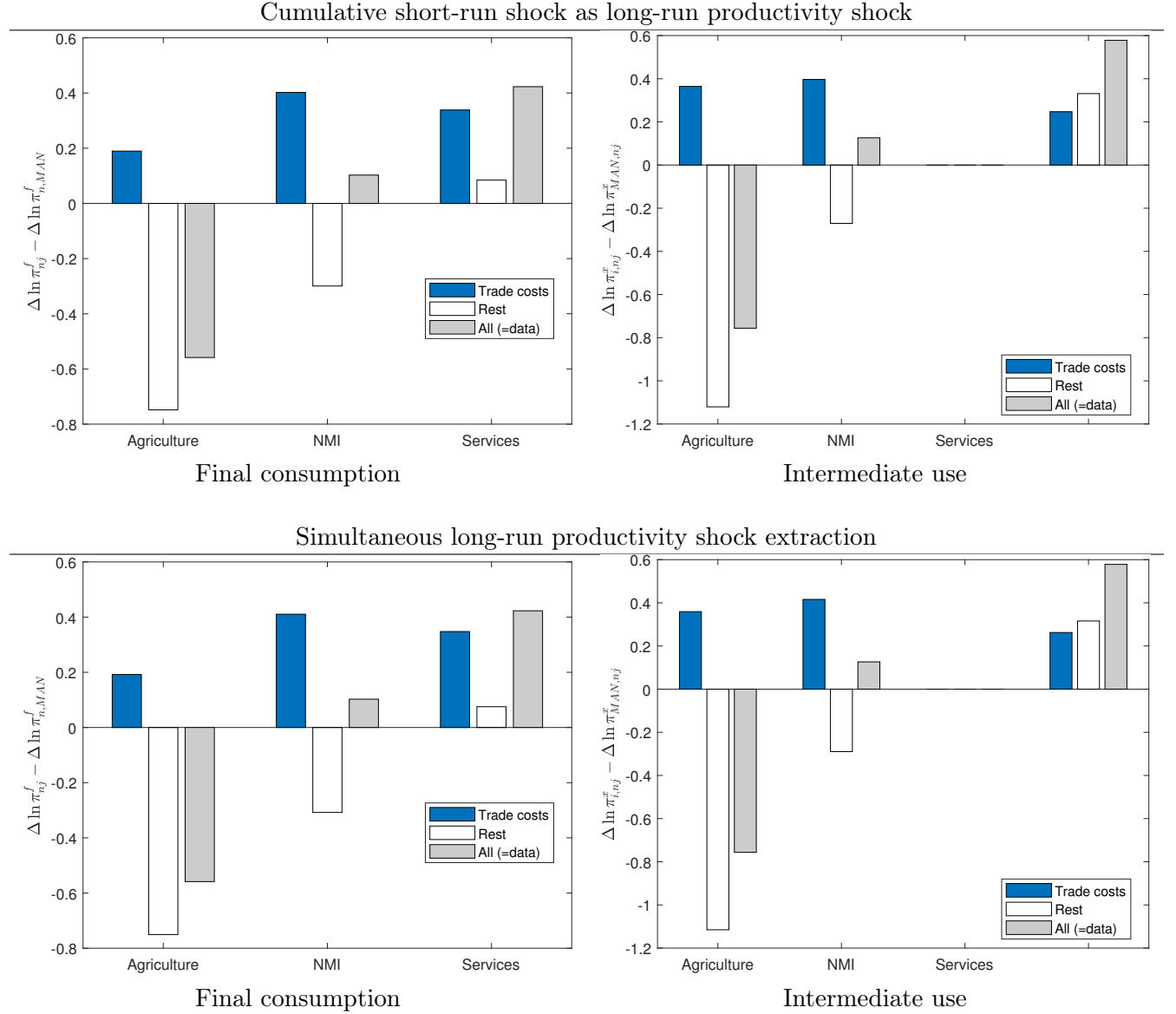
TABLE C2: Changes in correlation decomposition (first and last influence year)

	All countries, composite shock				G7, composite shock			
Tot corr	Mean	Median	p25	p75	Mean	Median	p25	p75
1978	0.212	0.225	0.048	0.377	0.361	0.312	0.226	0.512
2007	0.182	0.180	0.027	0.347	0.273	0.250	0.094	0.454
Shock corr								
1978	0.113	0.116	-0.022	0.261	0.236	0.216	0.106	0.370
2007	0.080	0.090	-0.057	0.229	0.147	0.111	-0.019	0.338
Trans.								
1978	0.099	0.096	0.059	0.140	0.125	0.121	0.091	0.149
2007	0.101	0.090	0.063	0.131	0.125	0.136	0.081	0.151
	All countries, Solow residuals				G7, Solow residuals			
Tot corr	Mean	Median	p25	p75	Mean	Median	p25	p75
1978	0.194	0.219	0.045	0.339	0.207	0.218	0.042	0.341
2007	0.223	0.234	0.098	0.366	0.183	0.162	0.021	0.306
Shock corr								
1978	0.105	0.131	-0.021	0.232	0.109	0.103	-0.028	0.269
2007	0.079	0.081	-0.039	0.221	0.043	-0.003	-0.049	0.175
Trans.								
1978	0.089	0.078	0.053	0.118	0.098	0.092	0.075	0.126
2007	0.144	0.130	0.102	0.173	0.140	0.139	0.099	0.173

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). The top panel displays the decomposition using the composite shock and the bottom panel shows the decomposition using the Solow residual. G7 country pairs' results are displayed on the right.

C.2 Counterfactual results appendix

FIGURE C4: Counterfactual changes in sectoral shares (relative to manufacturing)



Notes: The figures display the sectoral share changes relative to manufacturing in the counterfactuals ($\Delta \ln \pi_{n,j}^f - \Delta \ln \pi_{n,MAN}^f$). “Trade” refers to the trade counterfactual where only trade costs are allowed to change between 1978 and 2007. “Rest” refers to a counterfactual where productivity and taste shocks are allowed to change between 1978 and 2007.

TABLE C3: Counterfactual correlation details

All countries, composite shock					
Total correlation	1978	Trade	Trade (CD)	Rest	2007
mean	0.212	0.194	0.253	0.190	0.182
median	0.225	0.206	0.259	0.190	0.186
p25	0.048	0.036	0.088	0.001	0.025
p75	0.377	0.348	0.412	0.367	0.348
Shock correlation					
mean	0.113	0.083	0.098	0.104	0.080
median	0.116	0.104	0.106	0.098	0.092
p25	-0.022	-0.074	-0.026	-0.054	-0.062
p75	0.261	0.230	0.239	0.259	0.228
Transmission					
mean	0.099	0.111	0.155	0.086	0.102
median	0.096	0.105	0.137	0.070	0.091
p25	0.059	0.069	0.092	0.039	0.064
p75	0.140	0.148	0.213	0.118	0.131
All countries, Solow residual					
Total correlation	1978	Trade	Trade (CD)	Rest	2007
mean	0.194	0.224	0.258	0.188	0.228
median	0.219	0.227	0.277	0.199	0.234
p25	0.045	0.097	0.114	0.041	0.106
p75	0.339	0.370	0.397	0.339	0.374
Shock correlation					
mean	0.105	0.093	0.093	0.099	0.078
median	0.131	0.093	0.115	0.119	0.080
p25	-0.021	-0.018	-0.019	-0.025	-0.040
p75	0.232	0.226	0.220	0.250	0.220
Transmission					
mean	0.089	0.130	0.165	0.089	0.149
median	0.078	0.123	0.153	0.075	0.135
p25	0.053	0.093	0.108	0.049	0.106
p75	0.118	0.157	0.208	0.112	0.179

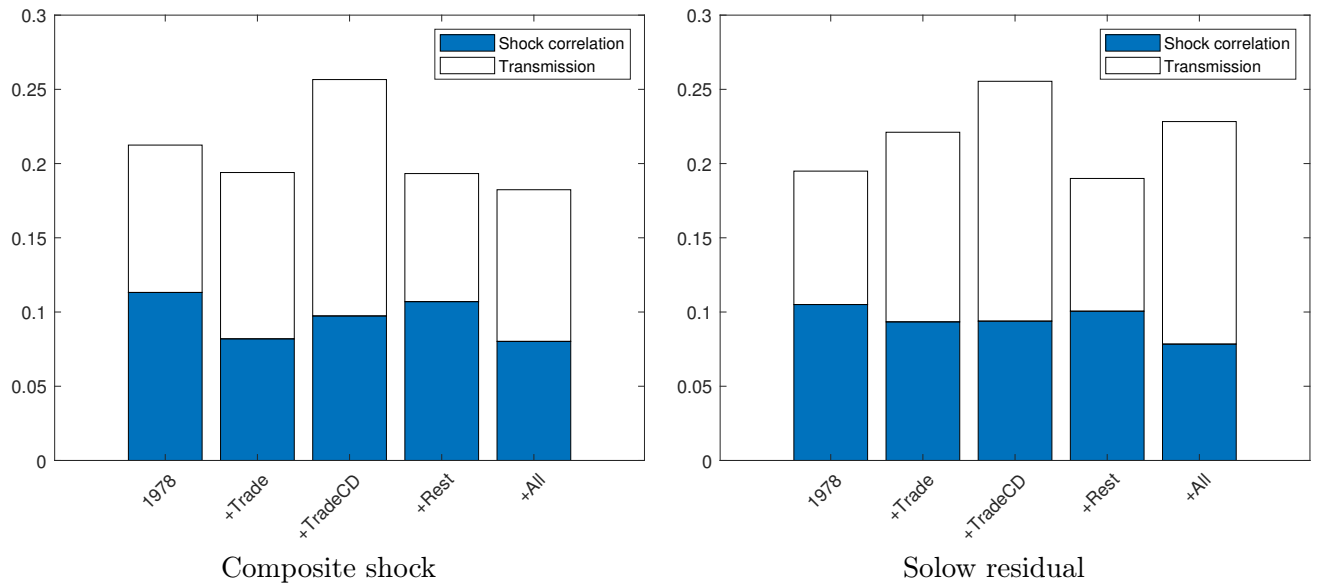
Notes: This table presents the average, median, and percentiles of the correlation decomposition in each counterfactuals. The “mean” row corresponds to the bars plotted in figure C5. “1978” is a counterfactual world in which the influence remained the same as the 1978 world, “Trade” is a world in which only trade costs changed, “Trade (CD)” is a world in which only trade costs changed but sectoral shares remained constant, “Rest” is a world in which only taste and productivity 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.

TABLE C4: Counterfactual correlation details: G7 country pairs

G7 countries, composite shock					
Total correlation	1978	Trade	Trade (CD)	Rest	2007
mean	0.361	0.358	0.400	0.278	0.270
median	0.312	0.298	0.367	0.281	0.245
p25	0.226	0.202	0.238	0.103	0.094
p75	0.512	0.540	0.540	0.498	0.453
Shock correlation					
mean	0.236	0.193	0.209	0.181	0.146
median	0.216	0.151	0.173	0.194	0.108
p25	0.106	0.046	0.082	0.015	-0.016
p75	0.370	0.385	0.339	0.357	0.343
Transmission					
mean	0.125	0.165	0.191	0.097	0.124
median	0.121	0.170	0.190	0.093	0.133
p25	0.091	0.116	0.146	0.066	0.080
p75	0.149	0.191	0.227	0.124	0.148
G7 countries, Solow residual					
Total correlation	1978	Trade	Trade (CD)	Rest	2007
mean	0.207	0.234	0.273	0.154	0.185
median	0.218	0.233	0.278	0.118	0.171
p25	0.042	0.071	0.114	0.035	0.028
p75	0.341	0.356	0.392	0.294	0.309
Shock correlation					
mean	0.109	0.077	0.091	0.071	0.042
median	0.103	0.052	0.083	0.048	-0.003
p25	-0.028	-0.058	-0.035	-0.033	-0.048
p75	0.269	0.218	0.248	0.223	0.174
Transmission					
mean	0.098	0.156	0.182	0.082	0.143
median	0.092	0.145	0.177	0.077	0.143
p25	0.075	0.118	0.143	0.058	0.102
p75	0.126	0.194	0.226	0.108	0.173

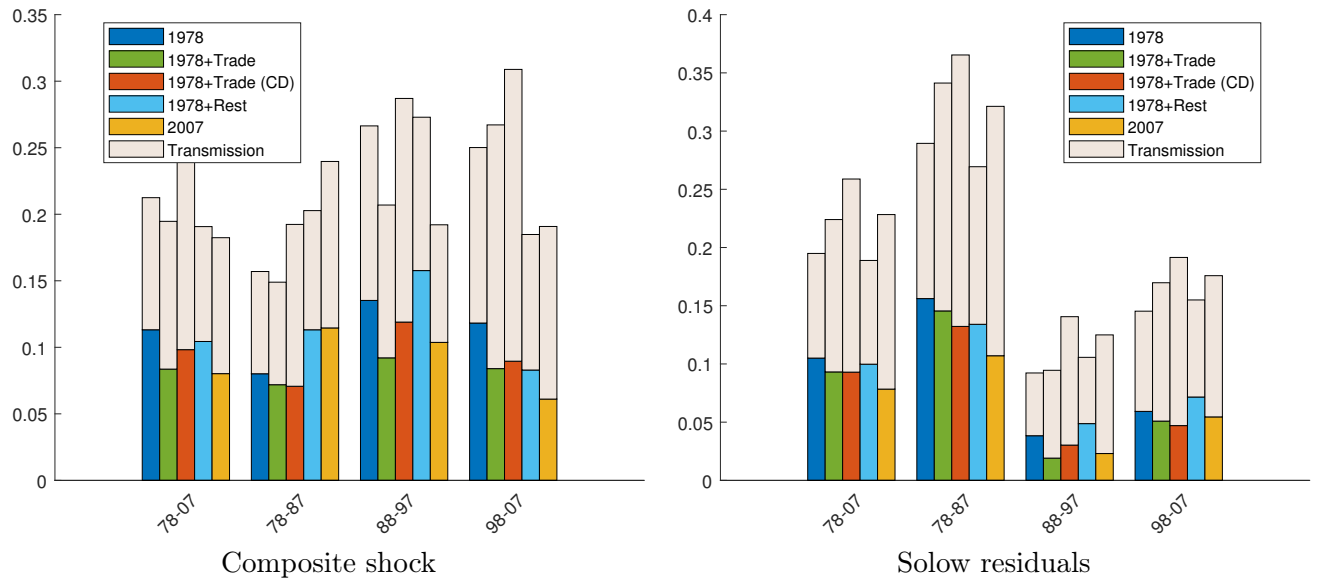
Notes: This table presents the average, median, and percentiles of the correlation decomposition in each counterfactuals for G7 country pairs. “1978” is a counterfactual world in which the influence remained the same as the 1978 world, “Trade” is a world in which only trade costs changed, “Trade (CD)” is a world in which only trade costs changed but sectoral shares remained constant, “Rest” is a world in which only taste and productivity 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 C5: Counterfactual correlations (simultaneous Z extraction)



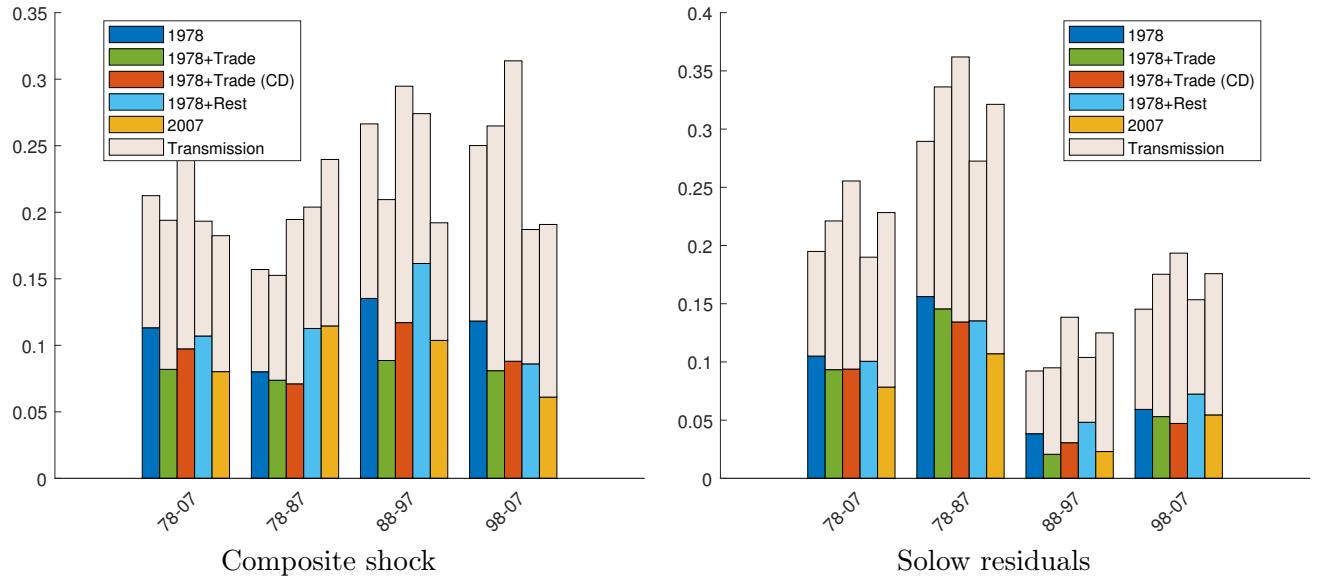
Notes: The bars display the average GDP growth correlations, decomposed into a shock correlation term (in blue) and transmission term (in white). Each bar represents a different scenario. “1978” is a counterfactual world in which the influence remained the same as the 1978 world, “Trade” is a world in which only trade costs changed, “Trade (CD)” is a world in which only trade costs changed but sectoral shares remained constant, “Rest” is a world in which only taste and productivity 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 C6: Counterfactual correlations by decade



Notes: The bars display the average GDP growth correlations, decomposed into a shock correlation term (in blue) and transmission term (in white). 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 shares remained constant, “1978+Rest” is a world in which only productivity 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.

FIGURE C7: Counterfactual correlations by decade (simultaneous Z)



Notes: The bars display the average GDP growth correlations, decomposed into a shock correlation term (in blue) and transmission term (in white). 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 shares remained constant. “1978+Rest” is a world in which only productivity and taste shocks evolved since 1978. “2007” performs the decomposition using the 2007 influence vector. Each bar group represents the results of feeding different time periods of the shock.