International Inflation Spillovers Through Input Linkages*

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Abstract

We document that observed international input-output linkages contribute substantially to synchronizing producer price inflation (PPI) across countries. Using a multi-country, industry-level dataset that combines information on PPI and exchange rates with international and domestic input-output linkages, we recover the underlying cost shocks that are propagated internationally via the global input-output network, thus generating the observed dynamics of PPI. We then compare the extent to which common global factors account for the variation in actual PPI and in the underlying cost shocks. Our main finding is that across a range of econometric tests, input-output linkages roughly double the global component of PPI. We report two additional findings: (i) PPI synchronization across countries is driven primarily by common sectoral shocks and input-output linkages amplify co-movement primarily by propagating sectoral shocks; and (ii) the unbalanced nature of international input use preserves fat-tailed idiosyncratic shocks and thus leads to fat-tailed global inflation, i.e., periods of disinflation and high inflation.

JEL Classifications: F33, F41, F42

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1 Introduction

One of the most contentious issues in monetary policy is whether inflation rates are primarily driven by national or international factors (see, e.g., Yellen 2006, Bernanke 2007, Caruana 2012, Carney 2015, Fisher 2015, Jordan 2015, Draghi 2016). While it is well established that inflation comoves closely across countries, the reasons for this positive comovement are not well understood. The international correlation of inflation could be on the one hand due to common structural trends and similar policies, or on the other hand to cross-country propagation of inflationary shocks via real and financial channels. Different answers to the question of why inflation comoves across countries have far-reaching implications for the conduct of national monetary policy and the scope for international monetary co-operation. Understanding the mechanisms behind international inflation synchronization is important for inflation forecasting, optimal monetary policy, international policy coordination, and currency unions, among other areas (see, e.g., Corsetti, Dedola and Leduc 2010, Galí 2010).

This paper documents that the cross-border propagation of cost shocks through input-output linkages contributes substantially to synchronizing producer price inflation (PPI) across countries. In the first step of the analysis, we recover the cost shocks that are consistent with observed price dynamics and the global network of input-output trade. In the second step, we compare the extent of global synchronization in observed PPI and the recovered cost shock series, and attribute the difference to the impact of linkages.

The following simple expression conveys the main idea. Abstracting from the sectoral dimension, suppose that country c's production uses inputs from country s. Then, the log change in the PPI of country c can be expressed as

$$\widehat{PPI}_c = \gamma_{c,s} \times \beta \times \widehat{PPI}_s + \widehat{C}_c, \tag{1}$$

where $\widehat{C}_c$ is the change in the local costs in c (which could be due to changes in productivity, prices of primary factors, or local intermediate inputs). The extent to which s's inflation shocks propagate to c is a product of two values: the cost share of inputs from s in the value of output of c $\gamma_{c,s}$ and the cross-border pass-through β that governs how much of the local price change in s is actually passed on to foreign buyers.

We assemble a unique dataset that combines monthly disaggregated producer price indices (PPI_c) with data on sectoral domestic and international input trade from the World Input Output Database (WIOD). The WIOD provides information on cross-border input shares $\gamma_{c,s}$ by country pair and sector pair. Our data cover 30 countries and 17 sectors over the period 1995-2011. The baseline analysis assumes full pass-through of cost shocks to input buyers: $\beta = 1$. This allows us to focus more squarely on the properties of the global input-output structure, and is an appropriate benchmark in this context.[1]

We conduct three sets of empirical exercises to gauge the importance of international input linkages for PPI. As a preliminary investigation, we simulate hypothetical inflation shocks and use the WIOD to compute how they propagate across countries. The strength of international input-output linkages is such that global inflation shocks transmit significantly into countries. On average, a shock that raises inflation by 1% in every country in the world other than the country under observation raises domestic PPI by 0.23%. There is substantial cross-country heterogeneity in the extent to which international price changes affect domestic inflation. At the top end, there are four countries with elasticities with respect to global inflation of over 0.3: Hungary, Belgium, the Czech Republic, and Slovenia. Russia, Australia, Japan, and the US appear the least susceptible to global inflation shocks, with elasticities in the range of 0.08-0.12. Similarly, the propagation of shocks between individual countries is highly unbalanced. For instance, an inflationary shock to Germany transmits with an elasticity of 0.11 to Hungary, the Czech Republic, and Austria, whereas an inflationary shock to China transmits to Korea and Taiwan with an elasticity of 0.07. Similar magnitudes characterize other closely integrated countries, such as the US, Canada, and Mexico.

The main analysis then examines the extent to which international input-output linkages affect the comovement of actual PPI inflation ($\widehat{PPI}_c$). It uses a generalization of the relationship (1) and data on the $\widehat{PPI}_c$ and $\gamma_{c,s}$ to recover the underlying cost shocks $\widehat{C}_c$. It then compares the extent of cross-country synchronization in the actual $\widehat{PPI}_c$ with the extent of synchronization in the underlying cost shocks $\widehat{C}_c$. The incremental increase in synchronization of actual $\widehat{PPI}_c$ compared to $\widehat{C}_c$ is then attributed to the cross-border propagation of inflationary shocks through input linkages.[2] Our quantification of inflation synchronization builds on Ciccarelli and Mojon (2010) and Jackson, Kose, Otrok and Owyang (2015). The metrics of synchronization are based on the share of the variance of a country's inflation that is accounted for by either a single global factor or by a finer set of global and sector factors.

The main finding is that international input-output linkages can matter a great deal for inflation synchronization when pricing to market by input producers is limited. The extent of synchronization of observed PPI is roughly double the level of synchronization in the underlying cost shocks. For the median country, the global component accounts for 51% of the variance of PPI, whereas the global component accounts for only 28% of the variance of the cost shocks, according to the static factor analysis following Ciccarelli and Mojon (2010). These differences are even more pronounced in the dynamic factor analysis.

[1] Section 4.1.1 provides the detailed discussion and presents results under different assumptions on pass-through.

[2] The approach is akin to Foerster, Sarte and Watson (2011)'s analysis of the role of input linkages in US sectoral output comovement.

We next examine the channels through which global input-output linkages give rise to inflation comovement. We investigate the role of exchange rate movements, pricing to market, and the heterogeneity in cross-border input linkages in generating inflation comovement.

Exchange rate movements play no role in synchronizing inflation across countries. In a counterfactual that ignores exchange rate movements when recovering the underlying shocks, the common component in the recovered cost shocks is approximately the same as in the baseline.[3] Because the exchange rate is a relative price and a bilateral exchange rate movement thus tends to increase prices in one country but decrease them in another, one would expect exchange rate movements to result in less synchronization. However, it could also be the case that exchange rates are correlated among subgroups of countries, thereby also affecting inflation comovement. In our sample, these effects appear to balance and exchange rates have no net impact on the extent of synchronization.

The degree of pricing-to-market plays a crucial role in inflation synchronization, but even at low rates of cost pass-through, the impact of international input-output linkages on inflation synchronization is non-negligible. To document the sensitivity of the results to imperfect cost pass-through, we vary β between 0.3 (which is at the lower end of available estimates) and 1 and compute comovement in the resulting cost shocks. The conclusions are only mildly affected for β of 0.7 or higher. For low values of β, the contribution of input linkages to synchronization remains positive but is much lower than in the baseline. At the extreme, when $\beta = 0.3$, the share of variance in the recovered cost shocks explained by the global factor is 15–20% lower than for actual PPI. This is not surprising. Equation (1) makes it clear that, in the limit, as pass-through goes to zero ($\beta \to 0$), $\widehat{C}_c = \widehat{PPI}_c$ and the contribution of input linkages to synchronization is trivially nil. As β increases, the importance of input linkages for inflation synchronization rises monotonically.

We next document that the heterogeneity in the input coefficients across sectors and countries contributes to international comovement. We compute counterfactual PPIs that would arise under the recovered cost shocks, but in a world in which there was no sectoral or country heterogeneity in input linkages, and examine comovement of the resulting counterfactual PPIs. That is, we quantify the extent of global comovement under the cost shocks inferred in the baseline but fed through a different input-output structure. In the first such counterfactual, international input trade in all sectors in each country is set equal to the country-specific average. In the second counterfactual, international input trade in each sector and country is set equal to the average of input trade across all sectors and countries. The global factor explains 10–20% less of the variation in these counterfactual PPIs compared to the observed PPIs, suggesting that input

[3] In this exercise, exchange rate changes are assumed to have the pass-through coefficient $\beta = 0$, but PPI shocks have a cost pass-through coefficient $\beta = 1$.

linkage heterogeneity itself – over and above the average level of linkages – does contribute to the global inflation synchronization.

Finally, we find that PPI synchronization across countries is driven by common sectoral shocks and that input-output linkages amplify comovement primarily by propagating sectoral shocks. We implement a dynamic factor model that decomposes the underlying sector-level PPI fluctuations into the global, sectoral, and country factors following the methodology developed in Jackson et al. (2015). In this model, international comovement in PPI could be due to a common global factor affecting all PPI series or to sectoral factors that are also common across countries. The first main result is that global PPI comovement is not accounted for by global shocks (i.e., to all sectors and all countries) but rather by sectoral shocks (i.e., to a specific sector in all countries conditional on the global shock). Second, international input-output linkages increase global comovement by increasing the share of the variance explained by sectoral shocks. These results are consistent with the view that global comovement arises due to idiosyncratic developments in individual sectors such as the energy or transportation equipment industries, which spill over both across borders and sectors via input-output linkages, synchronizing national PPIs.

The last part of the paper assesses the role of global input linkages in transmitting tail inflation risks. The exercise is motivated by our findings that sectoral rather than global shocks give rise to comovement of aggregate PPI and that the heterogeneity in the input linkages contributes to inflation comovement. Using the approach in Acemoglu, Ozdaglar and Tahbaz-Salehi (2015), we show that country-level inflation rates have fat tails, when measured against a normal benchmark. These fat tails in actual inflation are inherited from the underlying cost shocks, which are themselves significantly more fat-tailed than a normal distribution. Comparing the distributions of actual PPI and the underlying cost shocks, it appears that the IO matrix neither accentuates nor dampens the underlying tail risks, as the PPI is approximately as fat-tailed as the cost shocks. However, this finding is itself evidence that the structure of input linkages is such that the fat-tailed shocks are preserved.[4] We obtain the same result when feeding simulated cost shocks into the global IO matrix. Both fat-tailed cost shocks (drawn from the Laplace distribution) and the global, sector, and country shocks simulated to match their relative variances estimated above produce fat-tailed PPI.

Our analysis contributes to the literature on cross-border inflation synchronization and its determinants. Monacelli and Sala (2009), Burstein and Jaimovich (2012), Andrade and Zachariadis (2015), and Beck, Hubrich and Marcellino (2015) study the comovement of international prices using micro data, while Ciccarelli and Mojon (2010), Mumtaz and Surico (2009, 2012) and Mumtaz, Simonelli and Surico (2011) examine the role of aggregate real linkages in inflation co-

[4]Acemoglu et al. (2015) show that a more "balanced" IO matrix would average out fat-tailed shocks and yield inflation outcomes well-approximated by a normal distribution.

movement. Borio and Filardo (2007) and Bianchi and Civelli (2015) address the related question of the extent to which global output gaps affect domestic inflation dynamics. Bems and Johnson (2012, 2015) and Patel, Wang and Wei (2014) combine data on global input linkages with domestic prices and exchange rates to construct theoretically founded measures of real exchange rates. Also related is the literature on the role of input linkages in business cycle synchronization more broadly (see, e.g., Kose and Yi 2006, Burstein, Kurz and Tesar 2008, di Giovanni and Levchenko 2010, Johnson 2014). Our paper is the first to use information on observed international input linkages to evaluate the hypothesis that these linkages synchronize PPI inflation across countries.

The remainder of the paper is organized as follows. Section 2 presents the conceptual framework and the empirical strategy. Section 3 describes the data and the basic features of the world input-output matrix, and Section 4 reports the main results. Sections 5 and 6 present the exercises of implementing the model on sector-level data and of computing inflation tail risks, respectively. Section 7 concludes.

2 Conceptual Framework

There are C countries, indexed by c and e, and S sectors, indexed by u and s. The world is characterized by global input linkages: sector u producing output in country c has a cost function

$$W_{c,u,t} = W(C_{c,u,t}, \mathbf{p}_{c,u,t}),$$

where $\mathbf{p}_{c,u,t} \equiv \{p_{c,u,e,s,t}\}_{e=1,\dots,C}^{s=1,\dots S}$ is the vector of prices of inputs from all possible source countries s and sectors e paid by sector u in country c. Input prices $p_{c,u,e,s,t}$ are indexed by the purchasing country-sector to reflect the fact that prices actually paid by each sector in each country for a given input may differ. The cost of value added is denoted by $C_{c,u,t}$. This cost embodies the wage bill and the cost of capital.[5]

Standard steps using Shephard's Lemma and Euler's Theorem yield the following approximation for the change in the cost function:

$$\widehat{W}_{c,u,t} \approx \gamma^{C}_{c,u,t-1}\widehat{C}_{c,u,t} + \sum_{e,s} \gamma^{I}_{c,u,e,s,t-1}\widehat{p}_{c,u,e,s,t}, \tag{2}$$

where the hat denotes proportional change ($\widehat{x}_t = x_t/x_{t-1} - 1$). In this expression, $\gamma^{C}_{c,u,t-1}$ is the

[5] In the exposition that follows, as a shorthand, we refer to $C_{c,u,t}$ as the cost of value added. As the PPI data used in the empirical implementation only cover industrial sectors, in the analysis below $C_{c,u,t}$ actually includes the cost of any inputs that are not in the set of sectors that comprise the PPI (such as service sector inputs). Section 4.1.3 and Appendix A present two robustness checks on this approach, and show that accounting in different ways for shock transmission through sectors outside of PPI if anything strengthens the results.

share of value added in the value of total output and $\gamma^I_{c,u,e,s,t}$ is the share of expenditure on input e,s by sector-country c,u in the value of total output of sector c,u at time t. Notice that the shares $\gamma^I_{c,u,e,s,t}$ depend on prices and may thus correlate with prices. Therefore, these shares are lagged by one period in equation (2).

To apply this expression to the data, we make two assumptions. First, the proportional change in the producer price index as measured in the data is the same as the change in the cost function: $\widehat{PPI}_{c,u,t} = \widehat{W}_{c,u,t}$. Two settings in which this holds are marginal cost pricing and constant markups over marginal cost. This assumption is violated when markups are variable. In that case, our procedure will attribute the change in the markup to a change in the cost of value added $\gamma^C_{c,u,t-1}\widehat{C}_{c,u,t}$.

Second, the change in the price paid by producers in c,u for inputs from e,s is given by

$$\widehat{p}_{c,u,e,s,t} = \beta^I_{c,u,e,s}\left(\widehat{W}_{e,s,t} + \widehat{E}_{c,e,t}\right), \tag{3}$$

where $\widehat{E}_{c,e,t}$ is the change in the exchange rate between c and e. That is, the changes in prices paid by c,e for inputs are proportional to the change in the cost function of the input-supplying sector $\widehat{W}_{e,s,t}$ and the change in the exchange rate. The proportionality constant $\beta^I_{c,u,e,s}$ can be less than 1, to account for imperfect pass-through of cost and exchange rate shocks to prices.

2.1 Recovering Underlying Cost Shocks

The cost shock $\widehat{C}_{c,u,t}$ for each country c and sector u is then recovered directly, based on combining equations (2) and (3):

$$\widehat{C}_{c,u,t} = \frac{1}{\gamma^C_{c,u,t-1}}\left[\widehat{PPI}_{c,u,t} - \sum_{e\in C, s\in S}\beta^I_{c,u,e,s}\gamma^I_{c,u,e,s,t-1}\left(\widehat{PPI}_{e,s,t} + \widehat{E}_{c,e,t}\right)\right], \tag{4}$$

In this expression, $\widehat{PPI}_{c,u,t}$, $\widehat{E}_{c,e,t}$, $\gamma^I_{c,u,e,s,t-1}$, and $\gamma^C_{c,u,t-1}$ are all taken directly from the data.

It will be convenient to express (4) in matrix notation:

$$\widehat{\mathbf{C}} = \mathbf{D}^{-1}\left[(\mathbf{I} - \mathbf{B}' \circ \mathbf{\Gamma}')\widehat{\mathbf{PPI}} - \widetilde{\mathbf{B}}' \circ \widetilde{\mathbf{\Gamma}}'\widehat{\mathbf{E}}\right]. \tag{5}$$

In this expression, $\widehat{\mathbf{C}}$ and $\widehat{\mathbf{PPI}}$ are the $CS \times 1$ vectors of all country-sector cost shocks and PPIs. The matrix $\mathbf{\Gamma}$ is the $CS \times CS$ global input-output matrix, the ij'th element of which is the share of spending on input i in the total value of sector j's output, where i and j index country-sectors. $\mathbf{B}'$ is the $CS\times CS$ matrix that collects the $\beta^I_{c,u,e,s}$ coefficients, and "$\circ$" denotes element-by-element multiplication. Finally, $\mathbf{D}$ is a $CS \times CS$ diagonal matrix whose diagonal entries are the $\gamma^C_{c,u,t-1}$ coefficients.

In the last term,

$$\widehat{\mathbf{E}} = \left(\begin{pmatrix} \widehat{E}_{1,t} \\ \vdots \\ \widehat{E}_{C,t} \end{pmatrix} \otimes 1_{S\times 1} \right)$$

where $\widehat{E}_{c,t}$ a $C \times 1$ vector of exchange rate changes experienced by country c relative to its trading partners, and thus $\widehat{\mathbf{E}}$ is the $CCS \times 1$ vector of stacked exchange rate changes that only vary by country pair. The matrix $\widetilde{\mathbf{\Gamma}}'$ is:

$$\widetilde{\mathbf{\Gamma}}' = \begin{pmatrix} \mathbf{\Gamma}_1^{'} & 0 & \dots & 0 \\ 0 & \mathbf{\Gamma}_2^{'} & 0 & \dots \\ 0 & 0 & \dots & 0 \\ 0 & \dots & 0 & \mathbf{\Gamma}_C^{'} \end{pmatrix}, \tag{6}$$

with $\mathbf{\Gamma}_c^{'}$ defined as the $S \times CS$ matrix whose rows are country c's rows of $\mathbf{\Gamma}'$, and $\widetilde{\mathbf{B}}'$ is defined analogously based on $\mathbf{B}'$. To streamline notation, the time subscripts are suppressed in the matrix notation.

Equation (4) is used together with monthly frequency PPI data to recover the underlying cost shocks $\widehat{C}_{c,u,t}$ for every country, sector, and month. Equation (4) does not involve any lags, amounting to the assumption that imported inputs are shipped and used within the month. Monthly data exhibit seasonality that potentially differs by country and sector, and correcting explicitly for such seasonality is not feasible in our data. Thus, we follow the common practice of transforming both the actual PPI data and the underlying cost shock data into 12-month changes:

$$\widehat{PPI12}_{c,u,t} = \prod_{\tau=0}^{11} (1 + \widehat{PPI}_{c,u,t-\tau}) - 1$$

and

$$\widehat{C12}_{c,u,t} = \prod_{\tau=0}^{11} (1 + \widehat{C}_{c,u,t-\tau}) - 1.$$

The ultimate object of interest is the country-level rather than sector-level inflation. With that objective, we aggregate sectoral PPI series and cost shocks using sectoral output weights:

$$\widehat{PPI12}_{c,t} = \sum_{u\in S} \omega_{c,u} \widehat{PPI12}_{c,u,t} \tag{7}$$

and

$$\widehat{C12}_{c,t} = \sum_{u\in S} \omega_{c,u} \widehat{C12}_{c,u,t}, \tag{8}$$

where $\omega_{c,u}$ is the share of sector u in the total output of country c. We employ the sectoral output weights from 2002, the year closest to the middle of the sample.

The object in (7) has a clear interpretation: it is the aggregate PPI of country c. The aggregate PPI series we build track closely (though not perfectly) the official aggregate PPIs in our sample of countries.[6] The object in (8) is the output-share-weighted composite cost shock in country c. It can be interpreted as the PPI in country c in the counterfactual world without input linkages in production. For maximum consistency between the two measures, the construction of $\widehat{C12}_{c,t}$ uses the same sectoral weights $\omega_{c,u}$ as that of $\widehat{PPI12}_{c,t}$. This ignores the possibility that had there been no input linkages, output shares would be different. Without a full-fledged model calibrated with all of the relevant elasticities, it would be impractical to specify a set of counterfactual output shares. Our approach has the virtue of transparency and maximum comparability between the actual PPIs and the counterfactual cost measures.

2.2 Metrics of Synchronization

We employ three metrics for the extent of international synchronization in $\widehat{PPI12}_{c,t}$ and $\widehat{C12}_{c,t}$. It is important to emphasize that these are simply statistical devices that summarize the extent of the comovement in a data sample. The first, following Ciccarelli and Mojon (2010), is the R^2 of the regression of each country's $\widehat{PPI12}_{c,t}$ and $\widehat{C12}_{c,t}$ on the corresponding global average of the same measure (excluding the country itself).

The second and third are based on estimating a factor model on the panel of PPI and cost shock series:

$$X_{c,t} = \lambda_c F_t + \epsilon_{c,t}, \tag{9}$$

where the left-hand side variable $X_{c,t}$ is, alternatively, $\widehat{PPI12}_{c,t}$ or $\widehat{C12}_{c,t}$. According to (9), the cross-section of inflation rates/cost shocks at any t is equal to a factor F_t common to all countries times a country-specific, non-time-varying coefficient λ_c, plus a country-specific idiosyncratic shock $\epsilon_{c,t}$. None of the objects on the right-hand side of (9) are observed, but they can be estimated. As is customary, the factor analysis is implemented after standardizing each country's data to have mean zero and standard deviation 1. This ensures that countries with more volatile inflation rates do not have a disproportionate impact on the estimated values of the common factor. After estimating the factor model, the metric for synchronization is the share of the variance of inflation in country c accounted for by the global factor F_t: $Var(\lambda_c F_t)/Var(X_{c,t})$.

We implement two variations of (9). The first is a static factor model in which the parameters are recovered through principal components, as in Ciccarelli and Mojon (2010). The second is a

[6] In our sample of countries, the mean correlation between our constructed aggregate PPI and the official PPI, in 12 month changes, is 0.69, and the median is 0.82. The minimum is 0.02 for Bulgaria, which experienced hyperinflation between 1995 and 1998 (after 1998, the correlation for Bulgaria is 0.77). The maximum is 0.99 (Japan).

dynamic factor model based on Jackson et al. (2015) in which both F_t and $\epsilon_{c,t}$ are assumed to follow AR(p) processes:

$$F_t = \sum_{l=1..p_F} \phi_l F_{t-l} + u_t \tag{10}$$

$$\epsilon_{c,t} = \sum_{l=1..p_\epsilon} \rho_{c,l} \epsilon_{c,t-l} + \mu_{c,t}. \tag{11}$$

The precise implementation of the Bayesian estimation of this model's parameters is a reduced, special case of the more general one described in Section 5 below.

3 Data and Basic Patterns

3.1 Data

Empirical implementation requires data on (i) industry-level PPI and (ii) cross-border input-output linkages. A contribution of our paper is the construction of a cross-country panel dataset of monthly sectoral producer prices that can be merged with existing datasets on input-output use.

The PPI data were collected from international and national sources. The frequency is monthly. The PPI series come from the Eurostat database for those countries covered by it. Because many important countries (the US, Canada, Japan, China) are not in Eurostat, we collected PPI data for these countries from national sources, such as the BLS for the US and StatCan for Canada. Unfortunately, the sectoral classifications outside of Eurostat tend to be country-specific and require manual harmonization.

Information on input linkages comes the World Input-Output database (WIOD) described in Timmer, Dietzenbacher, Los, Stehrer and de Vries (2015), which provides a global input-output matrix. It reports, for each country and output sector, input usage broken down by source sector and country. The WIOD is available at yearly frequency and covers approximately 40 countries. Merging the PPI and WIOD databases required further harmonization of the country and sector coverage. The sectoral classification of the original PPI series are concorded to a classification that can be merged with the WIOD database, which uses two-letter categories that correspond to the ISIC (rev. 2) sectoral classification. Appendix Table A1 shows the conversion tables used in the process.

The final sample includes 30 countries plus a composite Rest of the World (ROW) category, 17 tradable sectors, and runs from 1995m1 to 2011m12. Appendix Table A2 reports the list of countries and sectors used in the analysis. Additionally, some countries are included in the "Rest of the World" category because of an excessive share (> 0.4) of missing data in the PPI. These are summarized in Appendix Table A3.

The empirical methodology requires a balanced sample of countries×sectors×months, necessitating some interpolation. When the original PPI frequency is quarterly, the monthly PPI levels are interpolated from the quarterly information. Other missing PPI observations are extrapolated using a regression of a series inflation on seasonal monthly dummies (e.g., a missing observation for January is set to the average January inflation for that series). If a country-sector series is missing over the entire time horizon (9 cases out of the 527 series), its inflation values are extrapolated based on the rest of the country's series. Overall, 10.5% of the PPI values are extrapolated.

An important feature of the PPI index is that it only covers the industrial sector in the majority of countries. Thus, service sector prices are not included in the analysis.

Figure 1 reports the share of foreign inputs in the overall input usage in each country. On average in this sample of countries, 0.4 of the total input usage comes from foreign inputs, but there is considerable variation, from less than 0.2 for Russia, China, and Japan to nearly 0.8 for Belgium. Figure 2 reports the cross-sectoral variation in the same measure, defined as the share of imported inputs in the total input usage in a particular sector worldwide. Sectors differ in their input intensity, with over 0.4 of all inputs being imported in the Coke and Petroleum sector but only approximately 0.1 in the Food and Beverages sector.

Figure 3 gives a sense of the time variation in the intensity of foreign input usage. The share of foreign inputs in total input purchases rose from approximately 0.2 to nearly 0.3 from 1995 to the eve of the Great Trade Collapse and then fell to 0.24.

3.2 Tracing Inflation Shocks Through Input Linkages

Before using the PPI data in the estimation of the common factors, we use the WIOD to examine the nature of the cross-border input-output linkages. We make use of the relation (5) to go from the shocks to the resulting PPI. This requires solving for the equilibrium PPI series using the Leontief inverse. Stacking countries and sectors, assuming full-pass-through ($\beta^I_{c,u,e,s} = 1$), and ignoring exchange rate movements, the equilibrium PPI series given a vector of cost shocks are as follows:

$$\widehat{\mathbf{PPI}} = \left(\mathbf{I} - \mathbf{\Gamma}'\right)^{-1} \mathbf{D}\widehat{\mathbf{C}}. \tag{12}$$

To gauge the extent to which input linkages propagate inflationary shocks, we feed into the world input-output matrix several hypothetical underlying cost shocks $\widehat{\mathbf{C}}$. The first set are inflationary shocks to three largest economies in the world: the US, Japan, and China. In the case of the US, for instance, these are shocks to $\widehat{\mathbf{C}}$ that lead to a PPI inflation of 1% in the US. By construction, only US entries of the cost shock $\widehat{\mathbf{C}}$ are non-zero: the assumption is that only the US experiences a shock. Nonetheless, other countries' PPIs can react to the US shock because the US sectors are part of the global value chain (equation 12). Another shock we feed in is a worldwide 10% shock to the energy sector, intended to simulate an unexpected increase in oil prices. Note that the magnitude and sign of the shock do not matter in this exercise, as evidenced by (12), so these could be deflationary shocks to the key countries or declines in energy prices.

Figure 4 presents the results. Several conclusions are noteworthy. First, the foreign impact of a cost shock to an individual country is quantitatively limited. A 1% inflation rate in the US produces inflation of approximately one-tenth that amount in Canada and Mexico, by far the most closely connected economies to the US. In 5 other countries, the impact is 0.02% or greater, or one-twentieth of US inflation. In nearly half the countries, the impact is smaller than 0.01%, or one-hundredth of US inflation. The pattern is similar for the Japanese and Chinese shocks. In each case, there are 2-3 countries with an inflation rate of approximately one-tenth of the country being subjected to the shock, while the rest of the sample experiences small inflation changes.

Figure 5 presents the generalization of these three subfigures, by plotting the proportional impact of an inflationary shock affecting each source country on each destination country in the sample. That is, it reports

$$\frac{\Delta PPI_{dest}}{\Delta PPI_{source}}$$

when *source* is the country experiencing an inflation shock. To make the plot more readable, we drop the own impact entries ($source = dest$), which accounts for the “blank” spots on the graph. The source countries are sorted from most to least important in average outward impact, and the same is done for destination countries.

The impact of inflationary shocks is highly heterogeneous across both sources and destinations. Inflationary shocks to some countries, such as Lithuania, Greece, Slovenia, or Bulgaria, have virtually no discernible impact on inflation in other countries. This is because those countries are not important input suppliers to other countries. At the other end of the spectrum, the top 5 countries in terms of their impact on foreign inflation are Germany, China, Russia, the US, and Italy. Germany’s impact is both highest on average (0.04 of $\Delta PPI_{dest}/\Delta PPI_{DEU}$ when averaging over *dest*) across the whole sample and the most diffuse. For 10 countries (all of which are in Europe), the impact is above 0.05, and for the top 3 – Hungary, the Czech Republic, and Austria – the impact is above 0.1. Russia’s impact is approximately half of Germany’s (0.02) and more concentrated, with only 2 countries – Lithuania and Bulgaria – with an impact of over 0.05.

It is not surprising that the bilateral impact of an inflationary shock is limited. A related question is whether global inflation shocks transmit significantly into countries. We thus consider an experiment in which, for each country, we generate a shock that raises inflation by 1% in every other country in the world. Figure 6 reports the results. Global inflationary shocks can have substantial impacts on country-level inflation. On average, a 1% shock to global PPI inflation leads to a 0.23% increase in domestic PPI. There is substantial heterogeneity, and at the top end, there are 4 countries that exhibit elasticities with respect to global inflation of over 0.3: Belgium, Hungary, the Czech Republic, and Slovenia. Russia, Australia, Japan, and the US appear the least susceptible to global inflation shocks, with impacts in the range 0.07-0.12.

The last panel of Figure 4 reports the global impact of a 10% global energy sector shock. Unsurprisingly, as the shock is global, the impact is much stronger and much more widespread. Nonetheless, it is also remarkable how much heterogeneity there is, from a 3.5% impact in Lithuania and Russia to 0.3% in Ireland and Slovenia.

4 Input Linkages and Global Inflation Comovement

This section reports the main inflation synchronization results. To do so, we need to take a stand on the degree of pass-through of the price and exchange rate shocks into producer prices. We present the baseline results under full pass-through of cost shocks: $\beta^I_{c,u,e,s} = 1$. Section 4.1.1 returns to the question of pass-through, and contains a detailed justification of this baseline value as well as the complete sensitivity analysis of the results to the value of $\beta^I_{c,u,e,s}$.

Table 1 reports the main results. Panel A reports the R^2 metric, Panel B the static factor model metric, and Panel C the dynamic factor model metric. The columns labeled $\widehat{PPI}12_{c,t}$ present the results for the actual PPI. We confirm that there is considerable global synchronization in PPI, just as was found for CPI in previous work. The simple average of other countries' inflation produces an average R^2 of 0.385 in this sample of countries. The global static factor accounts for 0.455 of the variance of the average country's inflation at the mean and 0.506 at the median. The dynamic factor delivers very similar averages.

The three methods thus reveal quite similar levels of synchronization in actual PPI. They also produce similar answers regarding the cross-country variation. In the cross-section of countries, the R^2 metric has a 0.92 correlation with both the static and the dynamic variance shares. The static and dynamic variance shares have a 0.998 correlation across countries. According to all three measures, there is a fair bit of country heterogeneity around these averages, with Spain, Germany, and Italy being the most synchronized countries according to both metrics, and Romania, Slovenia, and Korea at the other extreme.

The columns labeled $\widehat{C12}_{c,t}$ present the same statistics for the cost shocks, and the columns labeled "Difference" report the simple difference between the metrics for PPI and the cost shocks. It is clear that input linkages have considerable potential to explain observed synchronization in PPI. The average R^2 for the cost shocks falls to 0.172 (mean) and 0.110 (median). The static global factor explains 0.268 (mean) and 0.286 (median) of the variation in $\widehat{C12}_{c,t}$ for the average country, and the dynamic factor explains 0.235 (mean) and 0.181 (median).

The difference between synchronization metrics for $\widehat{C12}_{c,t}$ and $\widehat{PPI12}_{c,t}$ can be interpreted as the contribution of global input linkages to the observed inflation synchronization. According to the most modest metric – the static factor – input linkages account for 41% (44%) of observed synchronization at the mean (median). The R^2 metric implies the largest contribution, with input linkages responsible for 56% (69%) of observed synchronization at the mean (median). The dynamic factor results lie in between.

4.1 Understanding the Mechanisms

We now perform a battery of alternative experiments designed to better understand the mechanisms behind the results. Namely, we examine the role of exchange rates; the importance of incomplete pass-through; and the nature of domestic and international linkages. Section 5 estimates the relative roles of global and sectoral shocks.

4.1.1 Exchange Rates vs. Price Spillovers and Various Degrees of Pass-Through

We begin by evaluating the role of exchange rates in the baseline results. Examining equation (5) that states how the cost shocks are recovered, it is clear that the procedure assumes that exchange rate shocks are transmitted to the input-importing country with the same intensity as price shocks. That is, a change in the local cost of the foreign input-supplying country is simply additive with the change in the exchange rate. While to us this appears to be the most natural case to consider, it is possible that the pass-through of exchange rate shocks is different from the pass-through of marginal cost shocks. It is also well-known that exchange rates are much more volatile than price levels, and thus, when we in effect recover the cost shocks as linear combinations of price and exchange rate changes, the variability in exchange rates can dominate and make the cost shocks more volatile. Note that this will not mechanically reduce comovement in the cost shocks compared to PPIs, as both data samples are standardized prior to applying factor analysis.

To determine the role of exchange rate shocks in our results, we carry out the same analysis of recovering the cost shocks and extracting a common component, while ignoring the exchange rate movements. Note that this is deliberately an extreme case: as discussed at length below, exchange rate pass-through is positive according to virtually all available estimates, whereas here we in effect set it to zero and retain only the PPI changes as cost shocks. Table 2 presents the results. To facilitate comparison across counterfactuals, the top panel of the table reproduces, from Table 1, the mean and median of the R^2s and of the shares of variance accounted for the static and dynamic factors for actual PPI and the baseline recovered cost shocks. The panel labeled "Alt. cost shocks: No $\widehat{E}_{c,e,t}$" reports the results ignoring exchange rate movements. It turns out that doing so leaves the implied contribution of input linkages to inflation synchronization virtually unchanged. According to all three metrics, the variance shares of the global factor for cost shocks recovered while ignoring exchange rates exchange rates are quite similar to the baseline.

The baseline analysis sets $\beta = 1$, i.e., we assume that producers fully pass on cost shocks to their consumers. A value of β close to 1 is consistent with some recent micro estimates of exchange rate pass-through at the border. Closest to our framework, Ahn, Park and Park (2016) construct effective input price indices using sector-level price and input usage data and show that the pass-through of imported input price shocks to domestic producer prices is nearly 1 for European countries and 0.7 for Korea. Berman, Martin and Mayer (2012) find that the pass-through into import prices is close to complete (0.93) and considerably higher than that into the prices of consumer goods. Similarly, Amiti, Itskhoki and Konings (2014) document that for non-importing Belgian firms, exchange rate pass-through into export prices is close to 1, again suggesting that exporters transmit their cost shocks almost fully to buyers.

Nonetheless, we acknowledge that for the purposes of the exercise in this paper, it is difficult to assign a value to β with a high degree of confidence, for three reasons. First, there is considerable uncertainty regarding the relevant exchange rate pass-through coefficient. One major pattern that has emerged in the literature is that pass-through is much higher when examining the response of import price indices than when examining the response of individual prices. For example, Goldberg and Campa (2010) report an estimate of the exchange rate pass-through rate into import prices of 0.61 in a sample of 19 advanced economies, and Burstein and Gopinath (2015) report an updated estimate of 0.69. However, pass-through into import prices is estimated to be much lower when looking at individual import prices. For example, Burstein and Gopinath (2015) report an average pass-through rate of 0.28 in the large micro dataset underlying the official US import price indices.[7]

The discrepancy between the pass-through for individual goods and that for aggregate series relates to the difficulty of handling product substitutions in microeconomic data and of aggregating microeconomic price fluctuations into import price indices when the bundle of goods is non-constant (see Nakamura and Steinsson 2012, Gagnon, Mandel and Vigfusson 2014). In this context, an important finding is that of Cavallo, Neiman and Rigobon (2014), who focus on the relative price of newly introduced products and document that the relative price of identical new goods introduced in two different markets tracks the nominal exchange rate with an elasticity of approximately 0.8.

The second difficulty concerns the distinction between exchange rate and cost pass-through.

[7] See also Gopinath and Rigobon (2008) or Auer and Schoenle (2016). Note however that studies examining the response of highly disaggregated firm-and-product-specific *unit values* to the exchange rate obtain much larger pass-through coefficients (Berman et al. 2012, Amiti et al. 2014).

While the literature has yielded a range of estimates for exchange rate pass-through, there is comparatively little work on the pass-through of cost shocks or on how the import content of exports affects pass-through (see Auer and Mehrotra, 2014 and Amiti, Itskhoki and Konings, 2014, 2016, however).

The third difficulty concerns the question of whether imported inputs are priced to market differently than final consumption goods. The structure of demand for input goods differs from that for final goods (see Burstein et al. 2008, Bussière, Callegari, Ghironi, Sestieri and Yamano 2013). Because the rate of cost pass-through is a direct consequence of the structure of demand, there are strong reasons to believe that pass-through for intermediate goods should differ substantially from that for final goods. Indeed, Neiman (2010) finds that in US micro data, intrafirm trade – which is to a large degree composed of imported inputs – exhibits higher exchange rate pass-through that does trade in other goods. To the best of our knowledge, however, no study exists that examines cost shock pass-through for input trade between different firms.

These three difficulties notwithstanding, it is likely that the relevant value of β for our purposes is not far below one. First, what matters for the spillovers of costs is how the entire basket of imported inputs is priced to a market rather than the pass-through rate estimated for individual goods. That is, for the analysis at hand, the pass-through coefficients corresponding to import price indices (0.6-0.7) or of the exchange rate of newly introduced goods (0.8) appear to be the conservative point estimates. These values should be seen as a lower bound, as the exchange rate drives costs less than one-for-one due to the presence of imported input goods (Amiti et al. 2014), and the findings of Neiman (2010) suggest that pass-through is higher for imported inputs relative to consumption items.

Nonetheless, to fully draw out the implications of imperfect pass-through of cost shocks, we treat β as a free parameter and present the results for a range of β's from 0.3 (the lower bound of available estimates, Gopinath and Rigobon 2008) to 1. The results are presented graphically in Figure 7. The top panel compares the mean R^2 metric of synchronization for PPI (horizontal line) to the mean R^2 metric for the cost shocks under the different values of β. The bottom panel does the same for the share of variance accounted for by the static factor. Thus, the values for $\beta = 1$ in the figure correspond to the means reported in Table 1.

Not surprisingly, as β falls, the share of variance of the cost shocks attributable to the global factors rises, approaching the share of variance of the PPIs. At the extreme, under $\beta = 0.3$, the international linkages are responsible for approximately 19% (14%) of the observed international comovement according to the R^2 (static factor) metric. This is sensible: a lower β mechanically reduces the difference between $\widehat{PPI}_{c,e,t}$ and $\widehat{C}_{c,e,t}$. Because under lower pass-through the two series become more similar, the share of variance explained by the global factor also becomes more similar. At intermediate values of β, input linkages explain yet more comovement. For instance, if one's preferred value of β were 0.6–0.7 (Burstein and Gopinath 2015), the impact of input linkages would be up to 34-40% for the R^2 metric and 24–28% for the share of variance metric. At β of 0.8–0.9, the impact is close to the baseline.

4.1.2 Heterogeneity in International Input Linkages

Next, we evaluate the role of heterogeneity in input usage across countries and sectors in generating these results. To this end, we construct two counterfactual scenarios for PPI under "balanced" input-output linkages. The first scenario preserves the cross-country heterogeneity in input usage but assumes that within each source country, each input-using country has the same input shares in all the sectors. That is, we assume a counterfactual input-output matrix $\mathbf{\Gamma}'^{b1}_{c,u,e,s}$ with the following elements:

$$\gamma^{b1}_{c,u,e,s} = \frac{1}{S^2} \sum_{k \in U, l \in U} \gamma_{c,k,e,l}.$$

That is, for any pair of countries c and e, there is an $S \times S$ matrix of input usage that gives how much of country e's inputs by sector are used in country c's output in each sector. This counterfactual, labeled "$b1$", suppresses heterogeneity across input and output sectors by country-pair. It is designed to mimic a one-sector model, in which countries use one another's aggregate inputs to produce a single output.

The second counterfactual instead focuses on cross-country heterogeneity. It implements a counterfactual scenario in which the input-output matrix $\mathbf{\Gamma}'^{b2}_{c,u,e,s}$ is assumed to have the elements

$$\gamma^{b2}_{c,u,e,s} = \begin{cases} \frac{1}{S^2} \sum\limits_{k \in U, l \in U} \gamma_{c,k,e,l,t} & \text{if } c = e \\ \frac{1}{(C-1)S^2} \sum\limits_{k \in U, l \in U, e' \in C \setminus \{c\}} \gamma_{c,k,e',l,t} & \text{if } c \neq e \end{cases}$$

That is, it assumes that all domestic linkages are equal to the average domestic linkage observed in the data and that all international linkages for all sectors and countries are equal to the average international linkage. Finally, these counterfactual γ values are rescaled such that the total share of value added in output in each sector and country $\gamma^{C}_{c,u}$ remains the same as in the baseline, to avoid confounding the heterogeneity in input linkages *per se* with overall input intensity.

The counterfactual PPI is given by

$$\widehat{\mathbf{PPI}}_{counter} = \left(\mathbf{I} - \mathbf{\Gamma}'_{counter}\right)^{-1} \left(\mathbf{D}\widehat{\mathbf{C}} + \widetilde{\mathbf{\Gamma}}'_{counter}\widehat{\mathbf{E}}\right), \tag{13}$$

for $counter = \{b1, b2\}$, where $\widetilde{\mathbf{\Gamma}}_{counter}$ is the counterfactual version of (6), which uses the elements of the counterfactual $\mathbf{\Gamma}$ matrix instead of the actual values. Equation (13) suppresses $\mathbf{B}$ and $\widetilde{\mathbf{B}}$, as in the baseline analysis, all the βs are assumed to be 1.

The panels "Balanced 1" and "Balanced 2" of Table 2 report the results. The variance shares accounted for by the common factors are lower than for the actual PPI in these counterfactuals, but these values are closer to the actual PPI than to the baseline cost shocks. The magnitudes also differ somewhat across metrics. The difference between the balanced counterfactual PPIs and the actual PPIs is highest according to the R^2 metric, with the mean R^2 being 30% lower in the Balanced 1 scenario and 17% lower in the Balanced 2 than the data. The factor models imply smaller differences, only approximately 20% for Balanced 1 and 10% for Balanced 2. This suggests there is some role for the input linkage heterogeneity in generating the observed comovement, but that the average overall linkages *per se* represent the single most important mechanism.

4.1.3 Robustness

A potential concern with our procedure is that not all sectors in WIOD are covered by PPI data. Thus, our baseline procedure will miss the transmission of price shocks through sectors for which PPI data are not available. For instance, if a sector uses imported service inputs, and there is an inflationary shock to services abroad, that would not be captured by our procedure. Similarly, if a PPI sector uses domestic service inputs, and the domestic service sector uses foreign intermediates, then the foreign inflationary shock will be transmitted indirectly through the domestic service sector. We do not have data for the full set of sectors available in WIOD. Nonetheless, to assess the importance of these omitted sectors, we perform the following two exercises.

First, we repeat the analysis using all of the sectors in WIOD, and attributing the overall PPI inflation to the sectors for which actual sectoral PPI data are not available. This procedure captures the transmission of non-PPI sector shocks under the assumption that the non-PPI sectors experience similar inflation as PPI sectors in each country, at least when it comes to the high-frequency movements. The panel "Imputed service inputs" of Table 2 presents the results. The cost shocks recovered in this way have an even lower common component than the baseline $\widehat{C12}_{c,u,t}$, making the results stronger.

Second, we explicitly model the higher-order effects. This exercise takes into account the second example above, namely that a sector uses service sector inputs, while the service sector in turn uses imported inputs from a PPI sector. We iterate through the second-, third-, etc. order effects to compute the infinite-order transmission of shocks via the unmeasured sectors. Appendix A presents the procedure for recovering the cost shocks that takes into account the higher-order effects transmitted through the non-PPI sectors.[8] Panel "Higher-order input linkages" of Table 2 reports the results. Once again, if anything the results are strengthened: the common component of $\widehat{C12}_{c,u,t}$ is lower than in the baseline, implying a greater contribution of input linkages to the

[8]The exercise is analogous to applying the Leontief inverse to calculate the Total Requirements Table from the Direct Requirements Table.

synchronization of PPI inflation.

As emphasized above, the baseline analysis simply aggregates the cost shocks and thus cleans out the effect of not only international but also domestic input linkages. There is no obvious reason why purely domestic linkages should synchronize inflation internationally. Nonetheless, we construct an alternative counterfactual to be compared to $\widehat{PPI12}_{c,t}$, that assumes away international input linkages but preserves the domestic linkages. This exercise constructs counterfactual PPI changes that would obtain under recovered cost shocks $\widehat{C12}_{c,u,t}$ in an economy in which there is input usage, but all of it domestic. Namely, we define the "autarky" counterfactual PPI change as follows:

$$\widehat{\mathbf{PPI}}_{AUT} = \left(\mathbf{I} - \mathbf{\Gamma}'_{AUT}\right)^{-1} \mathbf{D}\widehat{\mathbf{C}},$$

where $\mathbf{\Gamma}'_{AUT}$ is the counterfactual input-output matrix that forces all linkages to be domestic:

$$\mathbf{\Gamma}'_{AUT} = \begin{pmatrix} \mathbf{\Gamma}'_{AUT,1} & 0 & \dots & 0 \\ 0 & \mathbf{\Gamma}'_{AUT,2} & 0 & \dots \\ 0 & 0 & \dots & 0 \\ 0 & \dots & 0 & \mathbf{\Gamma}'_{AUT,C} \end{pmatrix},$$

and the elements of the $S \times S$ matrix $\mathbf{\Gamma}_{AUT,c}$ are defined as:

$$\gamma_{c,u,s,t} = \sum_{k=1}^{C} \gamma_{c,u,k,s,t}.$$

That is, in each country c, output sector u, all of the usage of sector s inputs observed in the global input-output matrix is reassigned to be supplied domestically.

The results are reported in the panel labeled "Autarky." These are between the observed PPI and the baseline $\widehat{C12}_{c,t}$, indicating that allowing for domestic linkages does not qualitatively change the main conclusion regarding the importance of cross-border linkages for international synchronization.

To summarize, the baseline results clearly show that the extent of input trade is at present sufficiently high that input linkages could be responsible for the bulk of observed PPI synchronization across countries. This finding is not sensitive to the assumptions placed on exchange rates or the role of non-PPI sectors and appears primarily driven by the average volumes of input trade rather than their heterogeneity across countries and sectors (though heterogeneity does play a modest role). On the other hand, the contribution of international linkages to synchronization declines substantially if we reduce the pass-through of foreign cost shocks into prices paid by input purchasers.

5 The Sectoral Dimension

Thus far, we have used different approaches to evaluate the importance of a common global component from the panel of aggregated country series in the model (9). Our underlying data, however, are disaggregated at the country-sector level. Examining sector-level data can tell us more about the nature of the common global factor found above. In particular, by implementing a sector-level decomposition, we can reveal how much of the common global component is in fact due to global sectoral shocks and how a country's sectoral composition affects its comovement with the global factor.

To that aim, we use the dynamic factor model developed in Jackson et al. (2015), that generalizes the model (9)–(11) and is implemented directly on sector-level data. Specifically, we estimate the following model:

$$X_{c,u,t} = \alpha_{c,u} + \lambda^w_{c,u} F^w_t + \lambda^c_{c,u} F^c_t + \lambda^u_{c,u} F^u_t + \epsilon_{c,u,t} \tag{14}$$

where $X_{c,u,t}$ is the 12-month inflation rate in country c, sector u, which can be either the actual $\widehat{PPI12}_{c,u,t}$, the recovered cost shock $\widehat{C12}_{c,u,t}$, or one of the other counterfactual price series. It is assumed to comprise of a global factor F^w_t common to all countries and sectors in the sample, the country factor F^c_t common to all u in country c, a sectoral factor F^u_t common to all sector u prices worldwide, and an idiosyncratic error term. Each of these factor series and the error term, in turn, are assumed to follow an AR process, parallel to (10):

$$F^k_t = \sum_{l=1..p_F} \phi_{k,l} F^k_{t-l} + u_{k,t}, \qquad k = w, c, u$$

and

$$\epsilon_{c,u,t} = \sum_{l=1..p_\epsilon} \rho_{c,u,l} \epsilon_{c,u,t-l} + \mu_{c,u,t}.$$

Under the assumptions that $u_{k,t} \sim N(0,1)$ for $k = w, c, u$, and the restriction that the sign of the loading of the first series on the global factor be positive, the decomposition is well-defined. The residuals $\mu_{cs,t}$ are assumed to be distributed

$$\mu_{c,u,t} \sim N(0, \sigma^2_{c,u}).$$

We follow the Bayesian estimation procedure from Jackson et al. (2015), briefly summarized here. First, we denote the parameter vector by $\boldsymbol{\xi}_{c,u} = [\, \boldsymbol{\alpha}_{c,u} \; \boldsymbol{\lambda}_{c,u} \; \boldsymbol{\rho}_{c,u} \,]$, where the vector $\boldsymbol{\alpha}_{c,u}$ collects the constant terms, $\boldsymbol{\lambda}_{c,u}$ summarizes all loadings and $\boldsymbol{\rho}_{c,u} = (\rho_{c,u,1}, ..., \rho_{c,u,p_\epsilon})$ all the AR coefficients of the errors. The priors of these model parameters are set to

$$\boldsymbol{\xi}_{c,u} \sim N(0, \bar{B}_{c,u}^{-1})$$

where $\bar{B}_{c,u}^{-1} = diag([.001 * \mathbf{1}_{1+n_{factors}}, \mathbf{1}_{p_\epsilon}])$, and $\mathbf{1}_n$ the n-dimensional vector with the elements 1. Thus, the constants, the loadings, and the error AR coefficients have a prior mean of 0, the constant and loading a prior variance of 0.001 and the error AR coefficients a prior variance of 1.

Next, the remaining model parameters $\boldsymbol{\phi}_k = (\phi_{k,1}, ..., \phi_{k,p_F})$ have the priors

$$\boldsymbol{\phi}_k \sim N(0, \bar{\Phi}_k^{-1}), \qquad k = w, c, u$$

where $\bar{\Phi}_k^{-1} = diag\left(1 \;\; \frac{1}{0.85} \;\; \cdots \;\; \frac{1}{0.85^{p_F}} \right)$. The prior variance is thus exponentially decreasing with the lag length, reflecting that further lags have a smaller probability of having a non-zero effect.

Moreover, the variances of $\mu_{c,u,t}$, $\sigma_{c,u}^2$, have the priors

$$\sigma_{c,u}^2 \sim IG(\bar{v}_{c,u}/2, \bar{\delta}_{c,u}/2),$$

where IG is the inverted gamma distribution, $\bar{v}_{c,u} = 6$, and $\bar{\delta}_{c,u} = 0.001$. Finally, we set $p_F = 3$ and $p_\epsilon = 2$. The starting values are 0 for all coefficients and random standard normal draws for the factors.

The algorithm then computes (implicitly determines) the posterior distribution of each of the parameters conditional on all other parameters, in the order $\boldsymbol{\xi}_{c,u}$, $\sigma_{c,u}^2$, $\boldsymbol{\phi}_k$, and F_t^k. At each step, a new draw from the posterior distribution replaces the starting value (if granted a likelihood-ratio criterion, see Chib and Greenberg 1994). Repeating this procedure, the (conditional) posterior distributions converge and the frequency of the draws approaches the joint posterior distribution of all coefficients and factors. The procedure is repeated 1500 times (3500 times in case of the reduced model (9) without the sector dimension). To avoid dependence on initial conditions (and after verifying convergence) the first 500 draws are discarded. The remaining draws are used to compute our statistics.

Because we are ultimately interested in the comovement of aggregate inflation, we aggregate the sector-level model (14) to the country level in the same manner as in the baseline analysis. To decompose the aggregate country inflation into the global, sectoral, country, and idiosyncratic components, we combine (14) with (7):

$$\begin{aligned} X_{c,t} &= \sum_{u \in S} \omega_{c,u} X_{c,u,t} \\ &= \sum_{u \in S} \omega_{c,u} \lambda_{c,u}^w F_t^w + \sum_{u \in S} \omega_{c,u} \lambda_{c,u}^c F_t^c + \sum_{u \in S} \omega_{c,u} \lambda_{c,u}^u F_t^u + \sum_{u \in S} \omega_{c,u} \epsilon_{c,u,t}. \end{aligned}$$

Denoting $\Lambda_c^w = \sum_{u \in S} \omega_{c,u} \lambda_{c,u}^w$, $\Lambda_c^c = \sum_{u \in S} \omega_{c,u} \lambda_{c,u}^c$, and $G_{c,t}^u = \sum_u w_{c,u} \lambda_{c,u}^u F_t^u$, we obtain

$$X_{c,t} = \Lambda_c^w F_t^w + \Lambda_c^c F_t^c + G_{c,t}^s + \sum_{u \in S} \omega_{c,u} \epsilon_{c,u,t}. \tag{15}$$

Equation (15) is the aggregation of the sector-level factor model (14). It states that country-level inflation rate $X_{c,t}$ can be decomposed into the component due to the global factor, the component due to the country factor, the component due to the sector factor, and an idiosyncratic component. We can then compute the variance share of the global and country factors as

$$share_{c,k} = \frac{(\Lambda_c^k)^2 Var(F_t^k)}{Var(X_{c,t})} \qquad k = w, c, \tag{16}$$

and the share of the variance attributable to sector factors as

$$share_{c,u} = \frac{Var(G_{c,t}^u)}{Var(X_{c,t})}. \tag{17}$$

We will be especially interested in the combined role of the global factors, that is, the sum of the share of variance of the global factor and the sectoral factors, $share_{c,w} + share_{c,u}$. This would tell us the total share of the variance of country c's inflation that is due to global factors, both overall and sectoral.

Although the factors are distributionally uncorrelated, the sample realizations might be correlated, and thus we orthogonalize F^w, F^c, and G^s before computing the decomposition to ensure that the variance shares sum to unity. We orthogonalize first on the global factor, then on the sectoral component. The share is computed for each draw, and the median share is reported.

We estimate a factor model directly on sector-level price data, extracting global, country, and sector shocks following (14), and then decompose aggregate inflation into the contribution of those components as in (15). Table 3 reports the shares of variance of overall country-level $\widehat{PPI12}_{c,t}$ and $\widehat{C12}_{c,t}$ accounted for by the different shocks, calculated as in (16)-(17).

Two observations stand out from the table. First, most of the global component in PPI inflation is due to global sectoral shocks, rather than a single global shock. Panel A shows that the global shock accounts for 0.072 (0.028) of the variance of country PPI for the mean (median) country. Sectoral shocks, by contrast, account for 0.421 (0.485) at the mean (median). The combined share of variance of actual $\widehat{PPI12}_{c,t}$ accounted for by the global and sectoral shocks (0.072 + 0.421 at the mean, 0.028 + 0.485 at the median) is quite comparable to the shares of variance reported in Table 1 that use much simpler factor models.

Second, the reductions in the extent of comovement in $\widehat{C12}_{c,t}$ compared to actual $\widehat{PPI12}_{c,t}$ come primarily from the reductions in the share of variance explained by sectoral rather than global shocks. Indeed, the global component accounts for slightly more of the variance of $\widehat{C12}_{c,t}$

on average than of $\widehat{PPI12}_{c,t}$. However, the share of variance explained by the sectoral shocks falls by almost the same amount as in the simpler models of Table 1.

These results suggest that common sectoral shocks are the primary driver of PPI synchronization across countries and that input linkages amplify comovement primarily by propagating sectoral shocks across countries.

6 Input Linkages and Inflation Tail Risks

As our third and final exercise, we examine to what extent international linkages amplify or dampen the distribution of country inflation. Working with GDP data, Acemoglu et al. (2015) emphasize that input-output linkages can generate macroeconomic tail risks if the structure of the input-output matrix is such that a few sectors play a disproportionately important role as input suppliers. In this section, we perform a related exercise by asking whether the observed world input-output linkages are such as to create tail risks in the inflation series.

Figure 8(a) presents the quantile-quantile (Q-Q) plot of the PPI series, standardized to have mean zero and standard deviation one in each country versus the standard normal distribution. Each circle is an observed (standardized) country-year realization of a PPI change. The fact that observations are above the 45-degree line at the top of the plot and below at the bottom indicates that PPI inflation has fatter tails than a normal distribution – large positive and negative deviations are both more likely than in a normal distribution. Indeed, the conventional tests of normality, such as the Jarque-Bera, Shapiro-Wilk, and D'Agostino-Belanger-D'Agostino tests, reject normality of PPI with p-values under 0.000. Figure 8(b) presents the Q-Q plot for the recovered cost shocks, once again standardized to mean zero and standard deviation one, country-by-country. It appears that the cost shocks are also fat-tailed, and once again all the formal tests reject normality with p-values under 0.000.

Acemoglu et al. (2015) prove that when the structure of the input-output matrix is balanced, even fat-failed shocks do not lead to fat-tailed aggregate fluctuations, as shocks are "diversified" and a Central Limit Theorem-type result implies that aggregate fluctuations are well-approximated by a normal distribution. This is clearly not happening in the PPI data: fat-tailed cost shocks do not "average out" in the input-output structure and instead lead to fat-tailed PPI series.

A related question is whether the input-output linkages amplify or dampen the cost shocks. To assess this, Figure 9 presents the Q-Q plot of the standardized PPI against standardized cost shocks. It seems that the PPI series is modestly less fat-tailed: the top and bottom quantiles of actual PPI inflation are somewhat smaller than the highest and lowest cost shock realizations. Overall, however, the distributions are similar, and thus it does not appear to be the case that the IO structure plays either a strong amplifying or a dampening role.

To determine whether this result is driven by this particular sample of shock realizations, Figure 10 instead presents the Q-Q plots that come from simulated data in which we know the distribution of shocks. That is, we draw a sample of $\widehat{\mathbf{C}}$ repeatedly from a known distribution and then compute the resulting changes in PPI by applying the Leontief inverse as in (12). We then aggregate to the country level to obtain the resulting country PPIs, standardize, and compare to the standard normal. We do this for 2 distributions, Laplace and Normal, and 3 variants of shocks: (i) shocks with standard deviation equal to the observed standard deviation of the $\widehat{C}$ in the data; (ii) shocks with standard deviation equal to 0.1; and (iii) global, country, sector, and idiosyncratic shocks simulated based on the factor model in Section 5.

The Laplace distribution has fatter tails than a Normal. By comparing PPI inflation implied by the Laplace and the Normal underlying cost shocks, we can establish whether the existing IO structure preserves the fat-tailed underlying shocks or averages them out. The top two panels reveal that, indeed, the IO structure preserves fat-tailed shocks. When the cost shocks are Laplace (Figures 10(a)-10(c)), the resulting country PPI inflation has fatter tails than a normal, reminiscent of Figure 8(a) that depicts the actual PPI distribution. By contrast, when underlying cost shocks are Normal (Figures 10(d)-10(f)), the resulting country PPI series inherit the absence of fat fails.

We conclude from this exercise that the observed structure of global IO linkages is such that the fat-tailed cost shocks do not average out and the observed PPI series inherits the fat tails of the underlying shock process.

7 Conclusion

Inflation rates are highly synchronized across countries. In our own data on PPI inflation for a large sample of countries, the single common factor explains nearly half of the fluctuations in inflation in the average economy. It is important to understand the reasons for this internationalization of inflation. This paper evaluates a particular hypothesis: inflation synchronization is at least partly due to international input linkages.

Our main finding is that input linkages indeed contribute substantially to the observed PPI comovement. We undertake a number of additional exercises to better understand this result. The main conclusion is not sensitive to the assumption on the exchange rate pass-through but is sensitive to the degree of pass-through of PPI cost shocks. Both the average level of input linkages and their heterogeneity matter for generating the full extent of synchronization. Finally, the bulk of observed synchronization is due to common sectoral shocks.

The policy relevance of our findings goes beyond potential usefulness in inflation forecasting, as the propagation channel we document also has implications for optimal monetary policy. In particular, the extent to which foreign marginal costs affect domestic distortions has been shown to play a pivotal role in whether optimal monetary policy in an open economy targets only domestic prices and output gaps (Corsetti et al. 2010). As international input-linkages represent a direct link between foreign marginal costs and domestic production costs, their prevalence has a first-order effect on the extent to which optimal monetary policy is inward-looking.

Appendix A Higher-Order Terms

This Appendix expands the model to include sectors outside the PPI coverage and describes the recovery of the cost shocks, accounting explicitly for second- and higher-order transmission. We suppress $\beta^I_{c,u,e,s}$ throughout the derivations below. Let there be two sets of sectors, those for which PPI data exist (superscripted by o for "observed") and those for which PPI data do not exist (superscripted by n for "non-PPI", or unobserved). The PPI change in any sector (o or n) is given by

$$\begin{aligned}\widehat{PPI}_{c,u,t} &= \gamma^{VA}_{c,u,t-1}\widehat{VA}_{c,u,t} + \sum_{e\in C,s\in S^o}\gamma^I_{c,u,e,s,t-1}\left(\widehat{PPI}^o_{e,s,t} + \widehat{E}_{c,e,t}\right) \\ &\quad + \sum_{e\in C,s\in S^n}\gamma^I_{c,u,e,s,t-1}\left(\widehat{PPI}^n_{e,s,t} + \widehat{E}_{c,e,t}\right),\end{aligned} \tag{A.1}$$

where $\widehat{VA}_{c,u,t}$ is the change in the cost of value added, and S^o (S^n) is the set of sectors with observed (unobserved) PPI. As noted in Section 2, the baseline analysis recovers the cost shock as a residual between actual $\widehat{PPI}_{c,u,t}$ and the price shocks in the observed sectors, $\sum_{e\in C,s\in S^o}\gamma^I_{c,u,e,s,t-1}\left(\widehat{PPI}^o_{e,s,t} + \widehat{E}_{c,e,t}\right)$. This expression makes it clear that this cost shock includes the changes in the cost of inputs in the unobserved sectors. The PPIs of the n sectors, in turn, will be affected by the PPI changes in the o sectors.

Plugging (A.1) into itself makes the second-order term apparent:

$$\begin{aligned}\widehat{PPI}_{c,u,t} &= \gamma^{VA}_{c,u,t-1}\widehat{VA}_{c,u,t} + \sum_{e\in C,s\in S^o}\gamma^I_{c,u,e,s,t-1}\left(\widehat{PPI}^o_{e,s,t} + \widehat{E}_{c,e,t}\right) \\ &\quad + \sum_{e\in C,s\in S^n}\gamma^I_{c,u,e,s,t-1}\left[\sum_{e\in C,s\in S^o}\gamma^{I'}_{c,u,e,s,t-1}\left(\widehat{PPI}_{e,s,t} + \widehat{E}_{c,e,t}\right)\right] \qquad \text{(A.2)} \\ &\quad + \sum_{e\in C,s\in S^n}\gamma^I_{c,u,e,s,t-1}\Bigg[\gamma^{VA}_{c,u,t-1}\widehat{VA}_{c,u,t} \\ &\quad + \sum_{e\in C,s\in S^n}\gamma^{I'}_{c,u,e,s,t-1}\left(\widehat{PPI}^n_{e,s,t} + \widehat{E}_{c,e,t}\right) + \widehat{E}_{c,e,t}\Bigg].\end{aligned}$$

The second line of this expression, (A.2), is the second-order term operating through the n sectors: the impact of input cost shocks in the observed sectors on PPI through the usage of n sector inputs and, in turn, the usage of o inputs by the n sectors. Now, the cost shock we recover can explicitly net out this second-order term, as everything in the second-order term (A.2) is observable.

To account for higher-order terms, it helps to switch to matrix notation. Collect (A.1) into matrices as follows:

$$\begin{pmatrix} \widehat{VA}_o^{unscal} \\ \widehat{VA}_n^{unscal} \end{pmatrix} = \left[\mathbf{I} - \begin{pmatrix} \Gamma_{o,o} & \Gamma_{o,n} \\ \Gamma_{n,o} & \Gamma_{n,n} \end{pmatrix}' \right] \begin{pmatrix} \widehat{PPI}_o \\ \widehat{PPI}_n \end{pmatrix} - \widetilde{\mathbf{\Gamma}}' \widehat{\mathbf{E}},$$

where $\widehat{VA}_o^{unscal}$ is the vector of the $\gamma^{VA}_{c,u,t-1}\widehat{VA}_{c,u,t}$'s, and thus *unscal* stands for "unscaled." The n sector PPI changes are equal to

$$\widehat{PPI}_n \quad = \quad \widehat{VA}_n^{unscal} + \Gamma_{u,o}\widehat{PPI}_o + \Gamma_{n,n}\widehat{PPI}_n + \tilde{\Gamma}_n \hat{\tilde{E}} \tag{A.3}$$

where the $\tilde{\Gamma}_n \hat{\tilde{E}}$ simply represent a rearrangement to take into account the exchange rate movements, and do not include any PPI terms. Substituting $\widehat{PPI}_n$ repeatedly into (A.3) yields

$$\begin{aligned} \widehat{PPI}_n &= \prod_{k=0} \Gamma^k_{n,n}(\widehat{VA}_n^{unscal} + \Gamma_{n,o}\widehat{PPI}_o + \tilde{\Gamma}_n \hat{\tilde{E}}) \\ &= (I - \Gamma_{n,n})^{-1}(\widehat{VA}_n^{unscal} + \Gamma_{n,o}\widehat{PPI}_o + \tilde{\Gamma}_n \hat{\tilde{E}}). \end{aligned}$$

In turn, $\widehat{PPI}_o$ can be expressed as

$$\begin{aligned} \widehat{PPI}_o &= \widehat{VA}_o^{unscal} + \Gamma_{o,o}\widehat{PPI}_o + \Gamma_{o,n}\widehat{PPI}_n + \tilde{\Gamma}_o \hat{\tilde{E}} \\ &= \widehat{VA}_o^{unscal} + \Gamma_{o,o}\widehat{PPI}_o + \Gamma_{o,n}(I - \Gamma_{n,n})^{-1}(\widehat{VA}_n^{unscal} + \Gamma_{n,o}\widehat{PPI}_o + \tilde{\Gamma}_u \hat{\tilde{E}}) + \tilde{\Gamma}_o \hat{\tilde{E}} \\ &= \widehat{VA}_o^{unscal} + \left(\Gamma_{o,o} + \Gamma_{o,n}(I - \Gamma_{n,n})^{-1}\Gamma_{n,o}\right)\widehat{PPI}_o \\ &+ \Gamma_{o,n}(I - \Gamma_{n,n})^{-1}\tilde{\Gamma}_n \hat{\tilde{E}} + \tilde{\Gamma}_o \hat{\tilde{E}} + \Gamma_{o,n}(I - \Gamma_{n,n})^{-1}\widehat{VA}_n^{unscal} \end{aligned}$$

Thus, the recovered cost shock, that takes into account higher-order effects, becomes

$$\begin{aligned} \widehat{C}_o^{\infty-order} &= \left[I - \Gamma_{o,o} - \Gamma_{o,n}(I - \Gamma_{n,n})^{-1}\Gamma_{n,o}\right]\widehat{PPI}_o \\ &\quad -\tilde{\Gamma}_o \hat{\tilde{E}} - \Gamma_{o,n}(I - \Gamma_{n,n})^{-1}\tilde{\Gamma}_n \hat{\tilde{E}} \\ &= \widehat{VA}_o^{unscal} + \Gamma_{o,n}(I - \Gamma_{n,n})^{-1}\widehat{VA}_n^{unscal}. \end{aligned} \tag{A.4}$$

Two points regarding (A.4) are worth noting. First, this approach to recovering cost shocks incorporates the transmission of exchange rate shocks through the n sectors. Thus, while we do not observe PPI in those sectors, we do observe the exchange rate movements, and thus if n sector inputs become more expensive due to the appreciation of the exchange rate, this procedure will reflect that. Second, because we do not have actual data on the n sectors, the recovered cost shock even in the observed sectors contains the value-added cost shocks from the n sectors $\widehat{VA}_n^{unscal}$. Without price data on the n sectors, this feature is unavoidable.

Section 4.1.3 presents the results of recovering the cost shocks (A.4).

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Table 1. Synchronization in Actual PPI and Cost Shocks

	Panel A: R^2			Panel B: Static Factor			Panel C: Dynamic Factor		
Country	$\widehat{PPI12}_{c,t}$	$\widehat{C12}_{c,t}$	Difference	$\widehat{PPI12}_{c,t}$	$\widehat{C12}_{c,t}$	Difference	$\widehat{PPI12}_{c,t}$	$\widehat{C12}_{c,t}$	Difference
AUS	0.565	0.217	0.348	0.592	0.283	0.309	0.546	0.165	0.382
AUT	0.303	0.043	0.261	0.562	0.075	0.487	0.523	0.179	0.344
BEL	0.686	0.475	0.212	0.749	0.597	0.153	0.740	0.447	0.293
BGR	0.522	0.031	0.491	0.475	0.005	0.470	0.436	0.030	0.406
CAN	0.599	0.197	0.402	0.607	0.434	0.174	0.596	0.185	0.411
CHN	0.394	0.106	0.288	0.640	0.293	0.347	0.644	0.233	0.412
CZE	0.345	0.187	0.158	0.280	0.238	0.042	0.262	0.354	-0.092
DEU	0.735	0.431	0.305	0.865	0.404	0.461	0.852	0.566	0.286
DNK	0.214	0.318	-0.105	0.236	0.406	-0.170	0.217	0.302	-0.085
ESP	0.776	0.506	0.269	0.931	0.812	0.119	0.916	0.761	0.155
FIN	0.386	0.121	0.264	0.647	0.380	0.267	0.621	0.346	0.275
FRA	0.606	0.526	0.080	0.695	0.469	0.226	0.675	0.558	0.117
GBR	0.277	0.032	0.245	0.508	0.323	0.185	0.492	0.173	0.319
GRC	0.119	0.025	0.094	0.099	0.004	0.094	0.091	0.010	0.081
HUN	0.248	0.113	0.135	0.084	0.029	0.055	0.078	0.069	0.008
IRL	0.095	0.051	0.043	0.098	0.025	0.073	0.088	0.028	0.060
ITA	0.753	0.273	0.480	0.832	0.517	0.315	0.848	0.494	0.355
JPN	0.526	0.102	0.424	0.726	0.235	0.491	0.717	0.179	0.538
KOR	0.023	0.000	0.023	0.038	0.002	0.036	0.033	0.002	0.032
LTU	0.428	0.019	0.409	0.679	0.181	0.498	0.661	0.243	0.418
MEX	0.085	0.000	0.085	0.067	0.038	0.028	0.071	0.009	0.063
NLD	0.750	0.527	0.223	0.812	0.711	0.101	0.823	0.552	0.271
POL	0.133	0.258	-0.125	0.180	0.315	-0.135	0.159	0.314	-0.155
PRT	0.557	0.147	0.410	0.503	0.148	0.355	0.508	0.172	0.336
ROM	0.006	0.096	-0.090	0.000	0.017	-0.017	0.002	0.036	-0.035
RUS	0.285	0.125	0.160	0.223	0.302	-0.078	0.231	0.127	0.104
SVN	0.082	0.030	0.052	0.031	0.009	0.022	0.030	0.071	-0.041
SWE	0.291	0.026	0.265	0.491	0.135	0.355	0.469	0.079	0.390
TWN	0.322	0.080	0.242	0.481	0.356	0.125	0.470	0.182	0.288
USA	0.437	0.104	0.333	0.527	0.289	0.238	0.530	0.192	0.338
Mean	0.385	0.172	0.213	0.455	0.268	0.188	0.444	0.235	0.209
Median	0.365	0.110	0.243	0.506	0.286	0.163	0.500	0.181	0.281
Min	0.006	0.000	-0.125	0.000	0.002	-0.170	0.002	0.002	-0.155
Max	0.776	0.527	0.491	0.931	0.812	0.498	0.916	0.761	0.538

Notes: Panel A reports the R^2s of the regression of the country's inflation ($\widehat{PPI12}_{c,t}$) or the cost shock ($\widehat{C12}_{c,t}$) on the simple average inflation or the cost shock of all the other countries in the sample and the difference between the two. Panel B reports the share of the variance in the country's inflation ($\widehat{PPI12}_{c,t}$) or the cost shock ($\widehat{C12}_{c,t}$) accounted for by the common static factor F_t and the difference between the two. Panel C reports the results when assuming a dynamic factor. Country code definitions are reported in Appendix Table A2.

Table 2. Alternative Implementations

	R^2	Static Factor	Dynamic Factor
	Baseline		
$\widehat{PPI12}_{c,t}$			
mean	0.385	0.455	0.444
median	0.365	0.506	0.500
$\widehat{C12}_{c,t}$			
mean	0.172	0.268	0.235
median	0.110	0.286	0.181
	Alt. cost shocks: No $\widehat{E}_{c,e,t}$		
$\widehat{C12}_{c,t}$			
mean	0.169	0.297	0.269
median	0.086	0.256	0.225
	Alternative input linkages		
Balanced 1 (sectors), $\widehat{PPI12}_{c,t}^{counter}$			
mean	0.266	0.364	0.350
median	0.210	0.387	0.359
Balanced 2 (countries+sectors), $\widehat{PPI12}_{c,t}^{counter}$			
mean	0.318	0.405	0.394
median	0.284	0.446	0.435
	Imputed service inputs		
$\widehat{C12}_{c,t}$			
mean	0.124	0.217	0.183
median	0.100	0.160	0.138
	Higher-order input linkages		
$\widehat{C12}_{c,t}$			
mean	0.150	0.232	0.201
median	0.073	0.159	0.127
	Domestic input linkages		
$\widehat{PPI12}_{c,t}^{counter}$			
mean	0.258	0.338	0.312
median	0.209	0.308	0.286

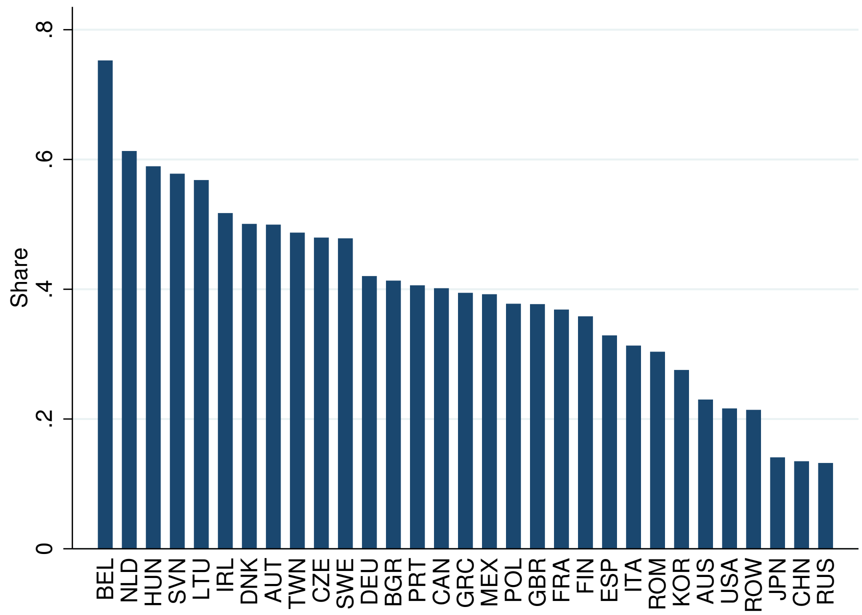
Notes: This table reports the mean and median of the R^2s (first column) and of the shares of variance explained by the static and dynamic factors (second and third columns) under alternative implementations of the analysis. The assumptions in each scenario are described in detail in the text.

Table 3. Global, Sector, and Country Shocks

	Panel A: $\widehat{PPI12}_{c,t}$			Panel B: $\widehat{C12}_{c,t}$		
Country	Global	Sector	Country	Global	Sector	Country
AUS	0.112	0.340	0.397	0.130	0.267	0.105
AUT	0.004	0.611	0.265	0.167	0.261	0.318
BEL	0.316	0.574	0.023	0.281	0.434	0.028
BGR	0.114	0.353	0.334	0.016	0.020	0.902
CAN	0.115	0.487	0.247	0.302	0.446	0.056
CHN	0.009	0.762	0.108	0.003	0.366	0.041
CZE	0.013	0.238	0.579	0.063	0.221	0.619
DEU	0.051	0.798	0.077	0.069	0.453	0.254
DNK	0.001	0.257	0.200	0.000	0.001	0.000
ESP	0.051	0.849	0.044	0.005	0.713	0.088
FIN	0.109	0.540	0.210	0.030	0.417	0.182
FRA	0.027	0.641	0.174	0.025	0.460	0.172
GBR	0.005	0.669	0.082	0.002	0.392	0.251
GRC	0.110	0.085	0.404	0.294	0.016	0.300
HUN	0.193	0.029	0.672	0.003	0.075	0.843
IRL	0.007	0.039	0.667	0.018	0.044	0.486
ITA	0.134	0.701	0.101	0.007	0.458	0.342
JPN	0.003	0.706	0.189	0.017	0.180	0.517
KOR	0.014	0.060	0.830	0.061	0.045	0.634
LTU	0.013	0.730	0.113	0.127	0.362	0.192
MEX	0.009	0.134	0.598	0.005	0.019	0.026
NLD	0.188	0.692	0.062	0.299	0.480	0.129
POL	0.037	0.188	0.550	0.001	0.154	0.585
PRT	0.003	0.482	0.398	0.098	0.151	0.455
ROM	0.028	0.006	0.945	0.002	0.026	0.897
RUS	0.398	0.170	0.341	0.505	0.134	0.129
SVN	0.025	0.040	0.784	0.050	0.045	0.775
SWE	0.050	0.375	0.321	0.074	0.103	0.651
TWN	0.013	0.536	0.243	0.170	0.124	0.290
USA	0.012	0.541	0.319	0.050	0.159	0.427
Mean	0.072	0.421	0.343	0.096	0.234	0.356
Median	0.028	0.485	0.292	0.050	0.169	0.295
Min	0.001	0.006	0.023	0.000	0.001	0.000
Max	0.398	0.849	0.945	0.505	0.713	0.902

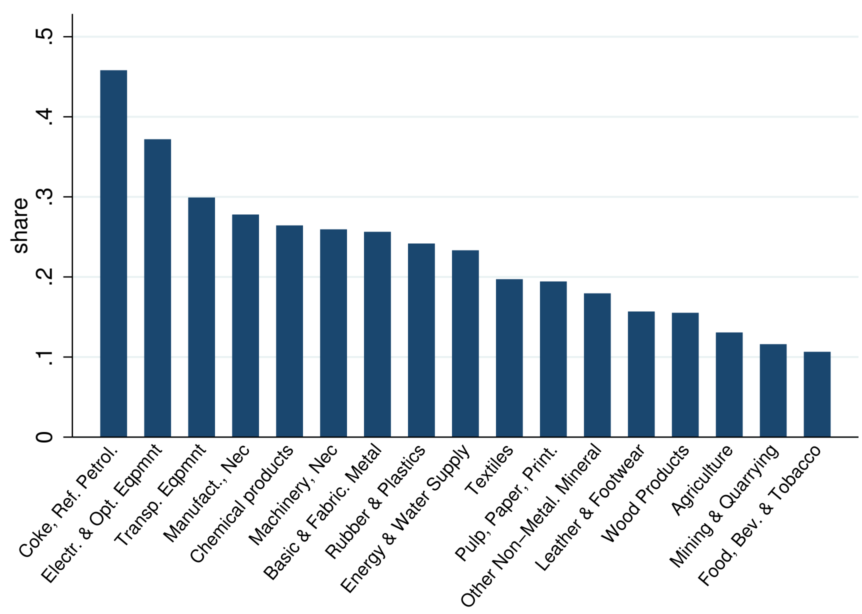
Notes: This table reports the shares of the variances of country PPIs and cost shocks accounted for by global, sector, and country shocks, estimated as described in Section 5. Country code definitions are reported in Appendix Table A2.

Figure 1. Imported Input Use by Country



Notes: This figure displays the share of imported inputs in total input purchases, by country.

Figure 2. Imported Input Use by Sector

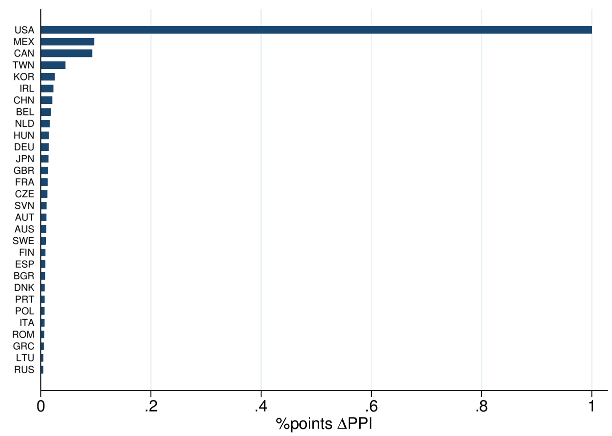


Notes: This figure displays the share of imported inputs in total input purchases, by sector.

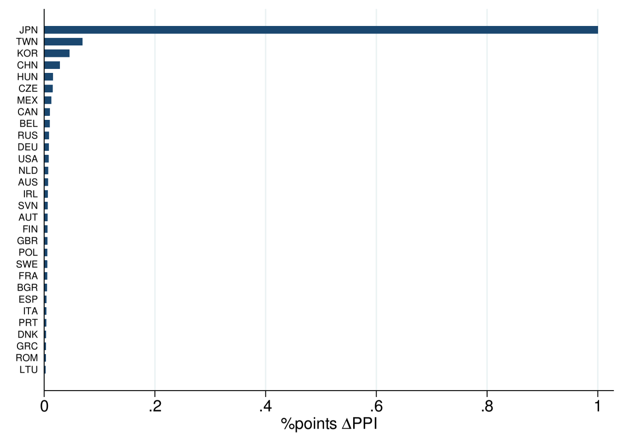
Figure 3. Imported Input Use over Time

Notes: This figure displays the share of imported inputs in total input purchases, over time.

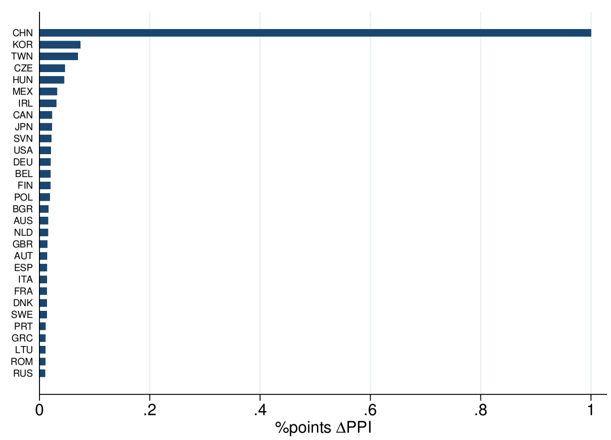
Figure 4. Global Impact, Hypothetical Shocks



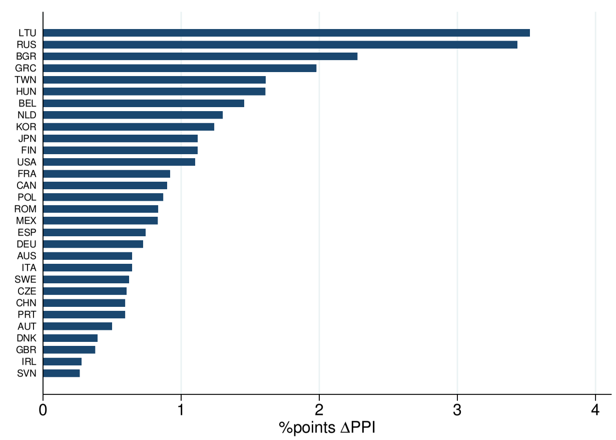
(a) A 1% US Inflationary Shock



(b) A 1% Japan Inflationary Shock



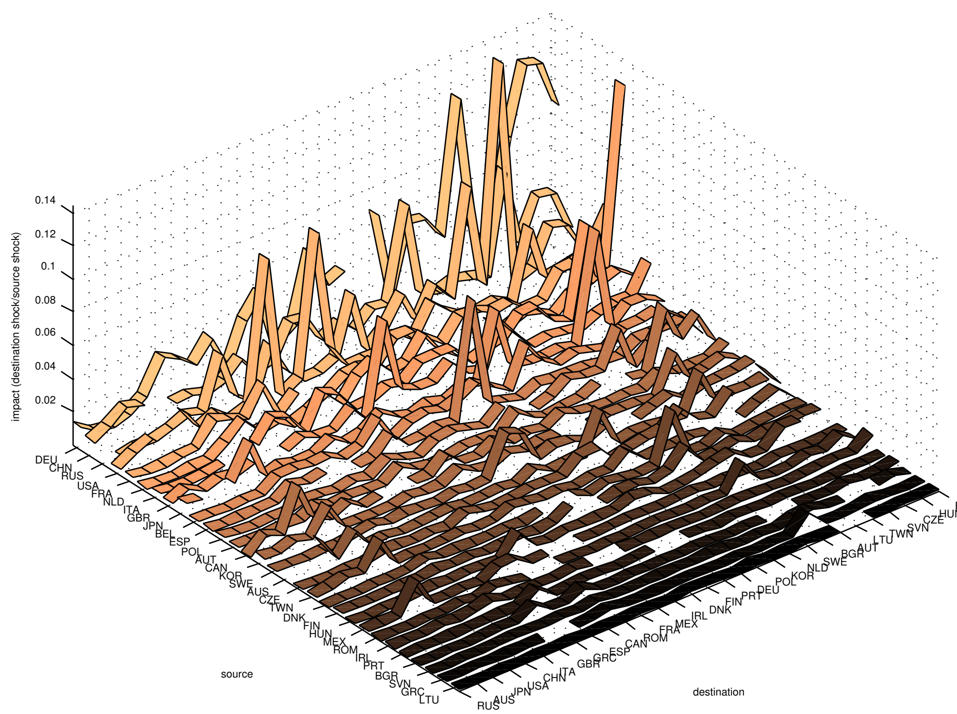
(c) A 1% China Inflationary Shock



(d) A 10% Rise in Energy Prices Worldwide

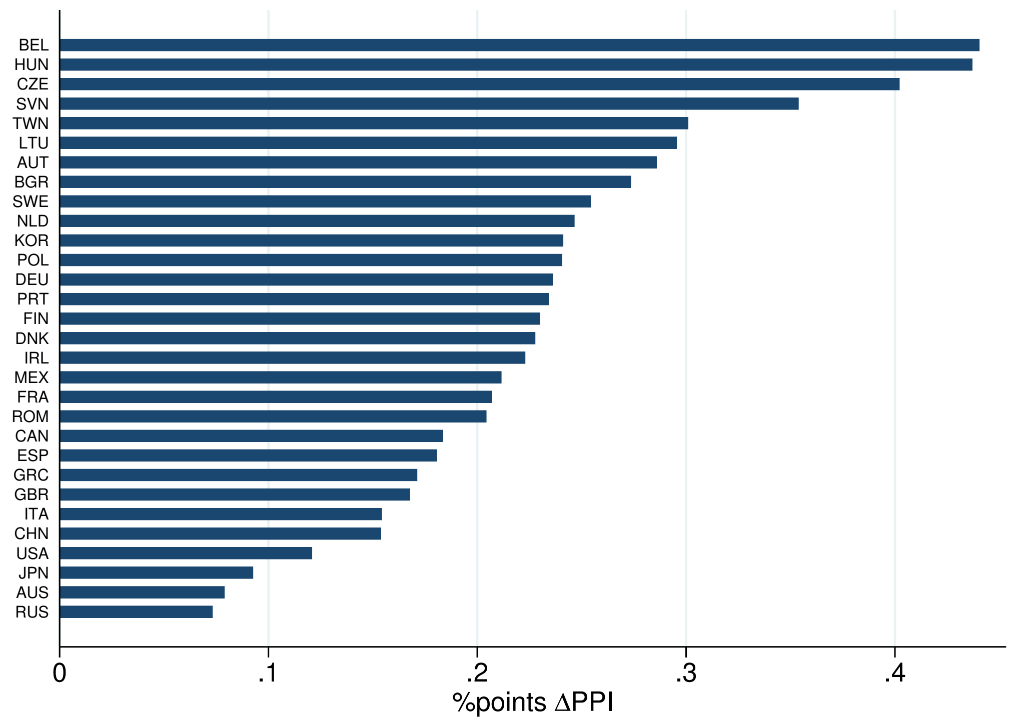
Notes: This figure presents the change in PPI in each country in our sample following 4 hypothetical shocks: (a) a shock that leads to 1% inflation in the US; (b) a shock that leads to 1% inflation in Japan; (c) a shock that leads to 1% inflation in China; and (d) a worldwide 10% increase in energy prices.

Figure 5. The Proportional Impact of Each Source Country's Inflation Shock on Each Destination Country's Inflation



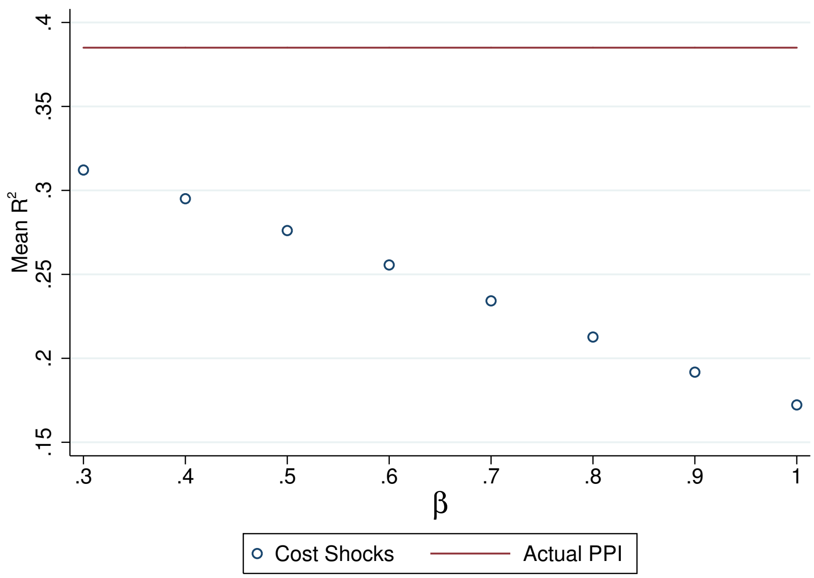
Notes: This figure displays the proportional impact of an inflationary shock in each source country on inflation in each destination country.

Figure 6. Country Impact of a 1% Inflationary Shock in Every Other Country

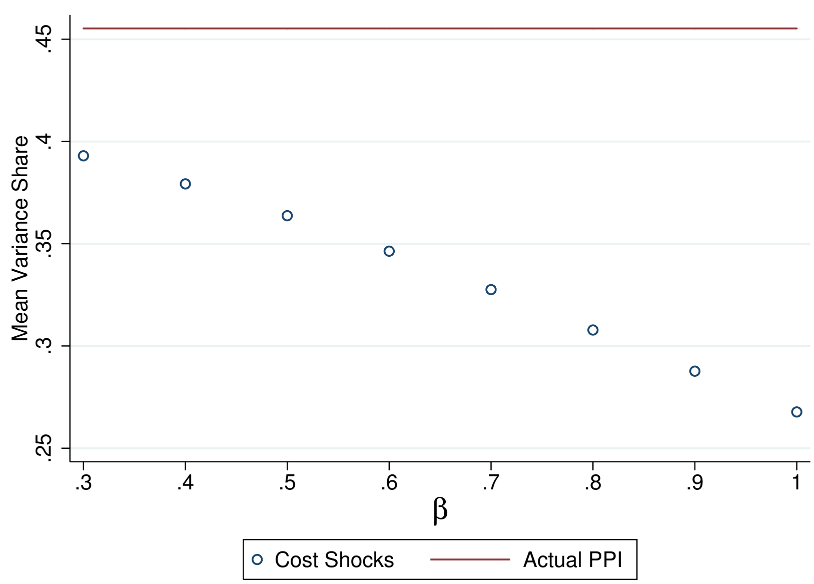


Notes: This figure displays the impact of an inflationary shock that leads to 1% inflation in every other country in the world.

Figure 7. Inflation Synchronization Under Different Values of β



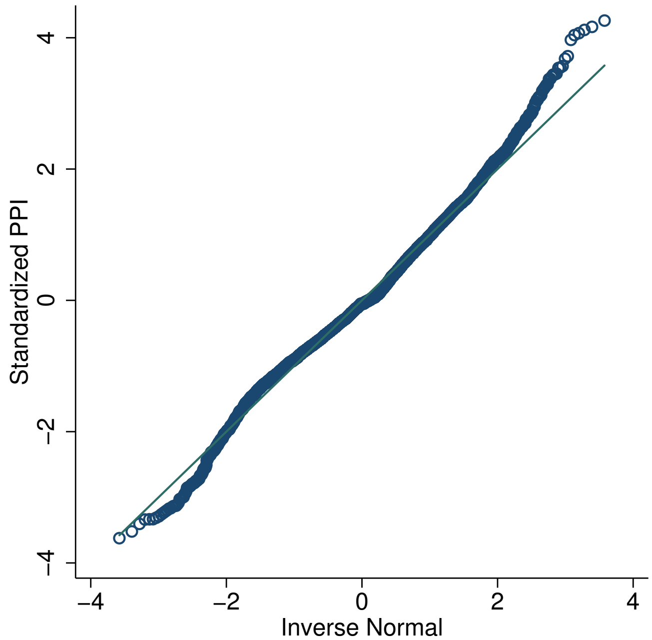
(a) R^2 Metric



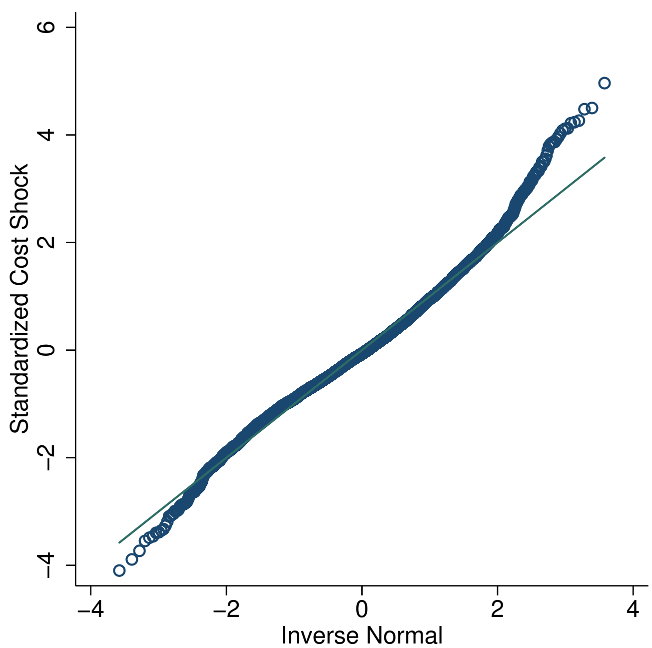
(b) Share of Variance Due to Global Factor

Notes: The top panel presents the cross-country mean R^2 of the regression of country actual PPI inflation on global average PPI inflation (solid line) and of the cost shocks under different values of β. The bottom panel presents the cross-country mean of the share of the variance of actual PPI inflation due to the common static factor (solid line) and of the cost shocks under different values of β.

Figure 8. Quantile-Quantile Plots vs. Normal Distribution



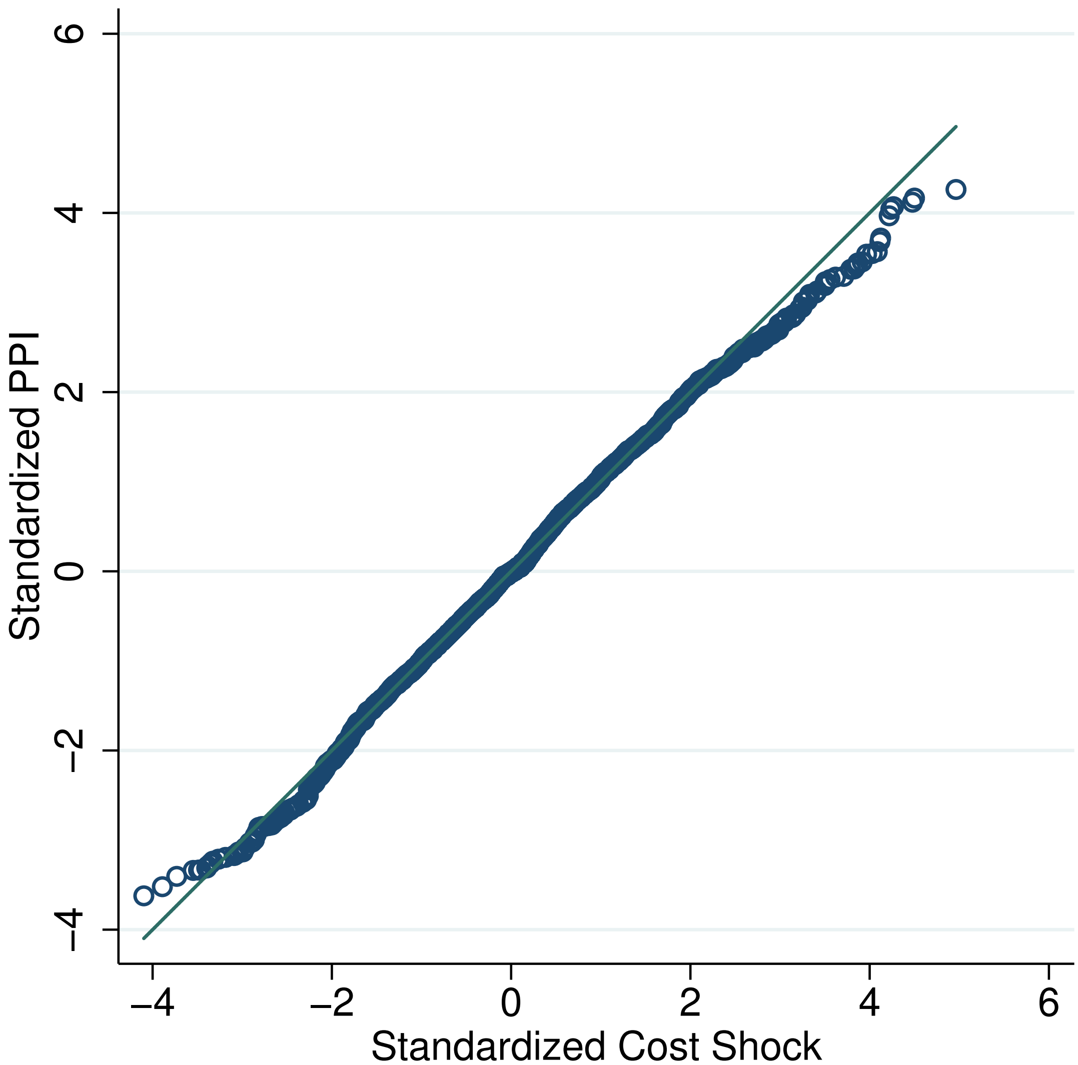
(a) Actual PPI



(b) Recovered Cost Shocks

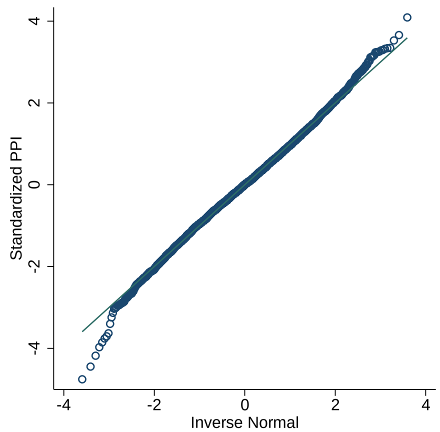
Notes: This figure presents the Q-Q plots of PPI and cost shocks against a normal distribution. Each has been standardized to have mean zero and standard deviation 1 in each country.

Figure 9. Quantile-Quantile Plot, Actual PPI and Recovered Cost Shocks

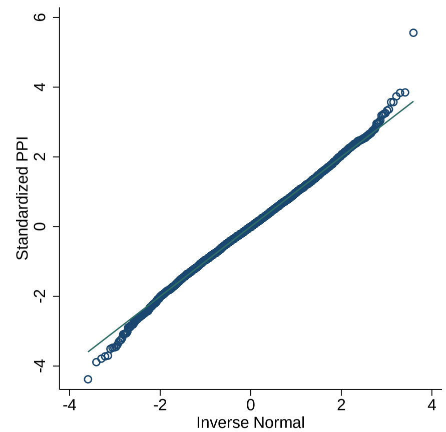


Notes: This figure displays quantile-quantile plot of the actual PPI series and the recovered cost shocks. Each has been standardized to have mean zero and standard deviation 1 in each country.

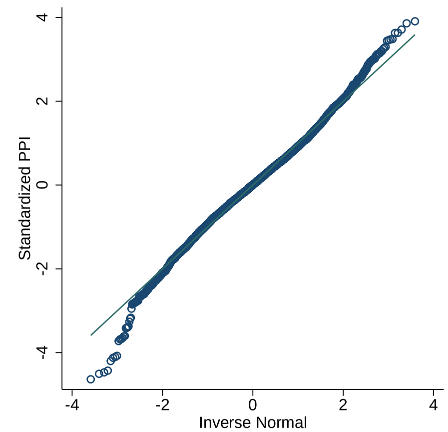
Figure 10. Quantile-Quantile Plot, Simulated Cost Shocks



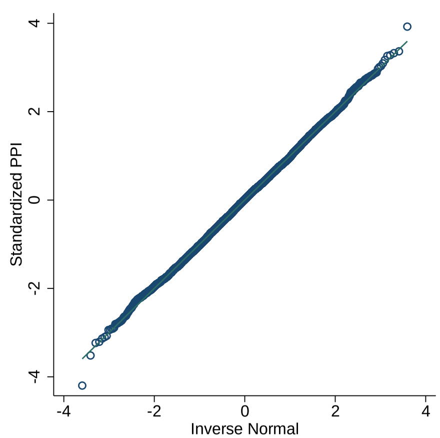
(a) Laplace, st.dev = observed



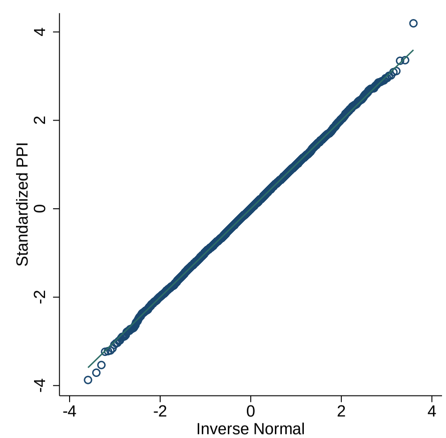
(b) Laplace, st.dev = 0.1



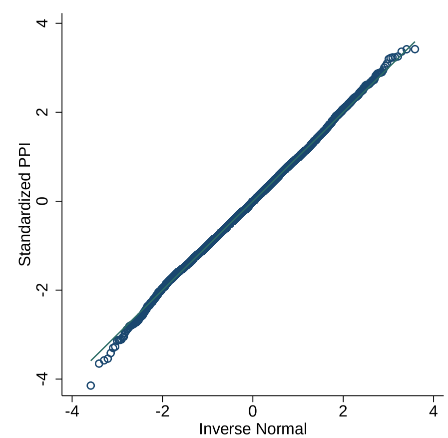
(c) Laplace, factor model



(d) Normal, st.dev = observed



(e) Normal, st.dev = 0.1



(f) Normal, factor model

Notes: This figure displays quantile-quantile plots of the PPI resulting from shocks simulated from a Laplace distribution and the normal distribution. Panels (c) and (f) simulate shocks based on the global-sector-country factor model from Section 5.

Table A1. PPI Data Origin Summary Table

Country	Original source	Original classification	Conversion table
AUS	Aust. Bureau of Stats.	ANZSIC	5
AUT	Eurostat	NACE rev. 2	1
BEL	Eurostat	NACE rev. 2	1
BGR	Eurostat	NACE rev. 2	1
CAN	Statistics Canada	NAICS 2007	3,4
CHN	NBS of China	CSIC	5
CZE	Eurostat	NACE rev. 2	1
DNK	Eurostat	NACE rev. 2	1
FIN	Eurostat	NACE rev. 2	1
FRA	Eurostat	NACE rev. 2	1
DEU	Eurostat	NACE rev. 2	1
GRC	Eurostat	NACE rev. 2	1
HUN	Eurostat	NACE rev. 2	1
IRL	Eurostat	NACE rev. 2	1
ITA	Eurostat	NACE rev. 2	1
JPN	Bank of Japan	JSIC	5
KOR	The Bank of Korea	KSIC	5
LTU	Eurostat	NACE rev. 2	1
MEX	INEGI Mexico	SCIAN	5
NLD	Eurostat	NACE rev. 2	1
POL	Eurostat	NACE rev. 2	1
PRT	Eurostat	NACE rev. 2	1
ROM	Eurostat	NACE rev. 2	1
RUS	FSSS (Rosstat)	OKVED	5
SVN	Eurostat	NACE rev. 2	1
ESP	Eurostat	NACE rev. 2	1
SWE	Eurostat	NACE rev. 2	1
TWN	DGBAS, Taiwan	SIC of ROC	5
GBR	Eurostat	NACE rev. 2	1
USA	BLS	NAICS 2012	2,3,4

Notes: Legend for last column:

1. Eurostat NACE rev. 2 to rev. 1.1 (http://ec.europa.eu/eurostat/web/nace-rev2/correspondence_tables). Once the series are in NACE rev. 1.1, conversion to the ISIC 2-letters categories used in WIOD is straightforward.
2. US Census Bureau: NAICS 2012 to NAICS 2007 (https://www.census.gov/eos/www/naics/concordances/concordances.html).
3. US Census Bureau: NAICS 2007 to NAICS 2002.
4. US Census Bureau: NAICS 2002 to NACE rev. 1.1. Once the series are in NACE rev. 1.1, conversion to the ISIC 2-letters categories used in WIOD is straightforward.
5. PPI series downloaded through Datastream. We manually match the description of these series in the original classification to match them with the ISIC 2-letters description used in the WIOD.

Table A2. Country and Sector Coverage

Country	Code	Sector
Australia	AUS	Agriculture, Hunting, Forestry, and Fishing
Austria	AUT	Basic Metals and Fabricated Metal
Belgium	BEL	Chemicals and Chemical Products
Bulgaria	BGR	Coke, Refined Petroleum and Nuclear F..
Canada	CAN	Electrical and Optical Equipment
China	CHN	Electricity, Gas and Water Supply
Czech Republic	CZE	Food, Beverages and Tobacco
Denmark	DNK	Leather, Leather and Footwear
Finland	FIN	Machinery, Nec
France	FRA	Manufacturing, Nec; Recycling
Germany	DEU	Mining and Quarrying
Greece	GRC	Other Non-Metallic Mineral
Hungary	HUN	Pulp, Paper, Paper , Printing and Pub..
Ireland	IRL	Rubber and Plastics
Italy	ITA	Textiles and Textile Products
Japan	JPN	Transport Equipment
Korea	KOR	Wood and Products of Wood and Cork
Lithuania	LTU	
Mexico	MEX	
Netherlands	NLD	
Poland	POL	
Portugal	PRT	
Rest of the World	ROW	
Romania	ROM	
Russian Federation	RUS	
Slovenia	SVN	
Spain	ESP	
Sweden	SWE	
Taiwan, POC	TWN	
United Kingdom	GBR	
United States	USA	

Notes: This table reports the countries (along with 3-letter codes) and the sectors used in the analysis.

Table A3. PPI Data Origin Summary Table for ROW Countries

Country	Original source	Original classification	Conversion table
BRA	IBGE	CNAE	5
CYP	Eurostat	NACE rev. 2	1
EST	Eurostat	NACE rev. 2	1
IDN	Statistics Indonesia	KBLI	5
IND	Office of Econ. Advisor to the Gov. of India	NIC	5
LUX	Eurostat	NACE rev. 2	1
LVA	Eurostat	NACE rev. 2	1
MLT	Eurostat	NACE rev. 2	1
SVK	Eurostat	NACE rev. 2	1
TUR	Eurostat	NACE rev. 2	1

Notes: Legend for last column:

1. Eurostat conversion table (http://ec.europa.eu/eurostat/web/nace-rev2/correspondence_tables). Once the series are in NACE rev. 1.1, conversion to the ISIC 2-letters categories used in WIOD is straightforward.

5. PPI series downloaded through Datastream. We manually match the description of these series in the original classification to match them with the ISIC aggregates used in the WIOD.