INTERNATIONAL INFLATION SPILLOVERS THROUGH INPUT LINKAGES

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Abstract—We document that international input-output linkages contribute substantially to synchronizing producer price inflation (PPI) across countries. Using a multicountry, industry-level data set that combines information on PPI and exchange rates with global 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. Across a range of econometric tests, input-output linkages account for half of the global component of PPI inflation.

I. Introduction

ONE of the most contentious issues in monetary policy is whether inflation rates are primarily driven by national or international factors (Bernanke, 2007; Fischer, 2015; Draghi, 2016; Carney, 2017). While it is well established that inflation comoves closely across countries, the reasons for this synchronization are not well understood. The international synchronization of inflation could be due, on the one hand, to common structural trends and similar policies, or on the other, to cross-country propagation of inflationary shocks via real and financial channels. Understanding the mechanisms behind international inflation synchronization is important for inflation forecasting, optimal monetary policy, international policy coordination, and currency unions, among other areas (Corsetti, Dedola, & Leduc, 2010; Gali, 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 unobserved 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 e. Then the log change in the PPI of country c can be expressed as

$$\dddot{PPI} = \gamma_{c,e} \times \dddot{PPI} + (1 - \gamma_{c,e}) \times \dddot{C},$$

where \(\dddot{C}\) is the change in the local costs in c (which could be due, for example, to changes in productivity or prices of primary factors). The extent to which c’s inflation shocks propagate to e is governed by the cost share \(\gamma_{c,e}\) of inputs from e in the value of output of c.

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As a preliminary investigation, we simulate hypothetical inflation shocks and use the WIOD to compute how they propagate across countries. Input-output linkages transmit global inflation shocks significantly into countries. On average, a shock that raises inflation by 1% in all countries in the world other than the one under observation increases domestic inflation by 0.19%; and by well over 0.3% in some small open economies. The propagation of shocks between individual countries is highly imbalanced. For instance, an inflationary shock to Germany transmits with an elasticity of more than 0.1 to Hungary, the Czech Republic, and Austria. Similar magnitudes characterize other closely integrated regions, such as China and Chinese Taipei, and the United States, Canada, and Mexico.

The main analysis then examines the extent to which international input-output linkages affect the comovement of actual PPI inflation (\(\dddot{PPI}\)). It uses a generalization of the relationship (1) and data on \(\dddot{PPI}\) and \(\gamma_{c,e}\) to recover the underlying cost shocks \(\dddot{C}\). It then compares the extent of cross-country synchronization in the actual \(\dddot{PPI}\) with the extent of synchronization in the underlying cost shocks \(\dddot{C}\). The incremental increase in synchronization of actual \(\dddot{PPI}\) compared to \(\dddot{C}\) is then attributed to the cross-border propagation of inflationary shocks through input linkages.2 Our quantification

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1The baseline analysis assumes full pass-through of cost shocks to input buyers. This allows us to focus more squarely on the properties of the global input-output structure and is an appropriate benchmark in this context. Section IVA provides the detailed discussion and presents results under different assumptions on pass-through. In the baseline implementation, we analyze the synchronization of PPIs expressed in local currency rather than converting all countries’ prices to a common currency, since policymakers ultimately care about and target domestic currency inflation. Section IVA and appendix B explore the role of exchange rate movements and currency denomination for the results.

2 Our quantification...
of inflation synchronization builds on Ciccarelli and Mojon (2010) and Jackson et al. (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 a finer set of global and sector factors.

The main finding is that international input-output linkages matter a great deal for inflation synchronization. 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.

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. 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 might 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 also does not play a large role in inflation synchronization. We implement a scenario that features price complementarities following Burstein and Gopinath (2015), such that each seller’s pricing rule is a function of both its cost shock and the prices of all other sellers supplying that market. Under a range of values of this pass-through parameter, the recovered cost shocks exhibit, if anything, even less synchronization than in the baseline. Thus, the main result that input linkages contribute substantially to synchronization is unchanged when allowing for pricing-to-market.

We next document that the heterogeneity in the input coefficients across sectors and countries contributes modestly to international comovement. We compute two different balanced linkages counterfactual PPIs that would arise under the baseline recovered cost shocks, but in a world in which there was no sectoral or country heterogeneity in input linkages. The first counterfactual eliminates differences across sectors but keeps differences across countries. Specifically, for each importer-exporter country pair, sectoral input use is set equal to the average input use in the country. The second counterfactual in addition eliminates differences across foreign source countries. The global factor explains 10% to 20% less of the variation in these balanced linkages counterfactual PPIs compared to the observed PPIs, suggesting that input linkage heterogeneity itself, over and above the average level of linkages, does contribute to global inflation synchronization, but rather modestly.

Our baseline procedure infers the underlying cost shocks from PPI data and the extent of input linkages. We supplement the main analysis by collecting direct data on one type of underlying cost: unit labor costs (ULC). The extent of synchronization in ULC is, if anything, lower than in the baseline cost shocks, and much closer to the cost shocks than to actual PPI. Thus, direct measurement confirms the main finding of the paper.

Finally, we document 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 (those common to all sectors and all countries) but rather by sectoral ones (those 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, thereby synchronizing national PPIs.

Our finding that input linkages contribute substantially to the international synchronization of producer price inflation is directly relevant for monetary policy. There is empirical evidence that the microprices underlying the PPI are sticky (see Nakamura & Steinsson, 2008; Boivin, Giannoni, & Mihov, 2009; Goldberg & Hellerstein, 2009; Bhattarai & Schoenle, 2014). In the presence of nominal rigidities in both final goods and intermediate goods markets, theoretical contributions have shown that optimal monetary policy involves stabilizing both consumer and producer price inflation (Huang & Liu, 2005; de Gregorio, 2012; Lombardo & Ravenna, 2014). In addition, even if central banks cared only about consumer price inflation, our work is still informative, since producer prices pass through into consumer prices. Although we leave the formal modeling of the link between the CPI and the PPI for future work, the statistical association between these two inflation rates is substantial.3

3In our sample of thirty countries, simple country-by-country regressions of rolling twelve-month CPI inflation on twelve-month PPI inflation rates...

The role of input linkages for inflation synchronization is receiving increasing attention. Auer and Sauré (2013) and Antoun de Almeida (2016) adapt the approach of di Giovanni and Levchenko (2010) to examine whether sector pairs trading more intensively with one another display greater inflation synchronization. Auer, Borio, and Filardo (2017) present evidence that cross-border trade in intermediate goods and services is the main channel through which global economic slack influences domestic CPI inflation. Our approach accounts not only for direct cross-country spillovers through input linkages but also spillovers that travel through third markets.

The remainder of the paper is organized as follows. Section II presents the conceptual framework and the empirical strategy. Section III describes the data and the basic features of the world input-output matrix, and section IV reports the main results. Section V presents the exercise of implementing the model on sector-level data. Section VI concludes.

II. Conceptual Framework

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

$$W_{c,u,t} = W (C_{c,u,t}, p_{c,u,t}),$$

where $p_{c,u,t} \equiv \{p_{c,u,e,s,t}\}_{e=1,...,E}^{s=1,...,S}$ is the vector of prices of inputs from all possible source countries $e$ and sectors $s$ 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 nonmaterials inputs is denoted by $C_{c,u,t}$. This cost embodies the wage bill, the cost of capital, and the cost of service inputs.\(^4\)

Standard steps using Shephard’s lemma yield the following first-order approximation for the change in the cost function:

$$\hat{W}_{c,u,t} \approx \gamma_{c,u,t-1} C_{c,u,t-1} + \sum_{e,s} \gamma_{c,u,e,s,t-1} \hat{p}_{c,u,e,s,t},$$

(2)

where the hat denotes proportional change ($\hat{x}_t = x_t / x_{t-1} - 1$). In this expression, $\gamma_{c,u,t-1}$ is the share of nonmaterials inputs in the value of total output and $\gamma_{c,u,e,s,t-1}$ 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 $t - 1$.

To apply this expression to the data, we make two assumptions. First, the percentage change in the producer price index as measured in the data equals the change in the cost function:

$$\frac{\Delta PPI_{c,u,t}}{PPI_{c,u,t-1}} = \hat{W}_{c,u,t-1}.$$  

(3)

Two settings that would satisfy this assumption are marginal cost pricing and constant markups over marginal cost.

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

$$\hat{p}_{c,u,e,s,t} = \hat{W}_{c,s,t} + \hat{E}_{c,e,s,t},$$

(4)

where $\hat{E}_{c,e,s,t}$ is the change in the exchange rate between $c$ and $e$. That is, the changes in prices paid by $c$, $u$ for inputs are proportional to the change in the functional form of the input-supplying sector $\hat{W}_{c,s,t}$ and the change in the exchange rate. A complete pass-through rate is consistent with some recent microestimates of input cost shock 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 exchange rate pass-through into import prices is close to complete (0.93) and considerably higher than that into the prices of consumer goods. Similarly, Amiti, Itskhoiki, and Konings (2014) document that for nonimporting 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. Section IV A returns to the question of pass-through, and examines the

\(^4\)As the PPI data used in the empirical implementation cover only industrial sectors, in the analysis below, $C_{c,u,t}$ includes the cost of any inputs that are not in the set of sectors that comprise the PPI. The procedure adopted in the baseline analysis is valid if the nonmaterials inputs are nontraded and do not use traded inputs. Appendices B and C present a series of robustness checks on this approach and show that accounting in different ways for shock transmission through sectors outside PPI, if anything, strengthens the results.
sensitivity of the results to the various assumptions on imperfect pass-through.

A. Recovering Underlying Cost Shocks

The cost shock $\tilde{\epsilon}_{c,u,t}$ for each country $c$ and sector $u$ is then recovered directly, based on combining equations (2), (3), and (4):

$$\tilde{\epsilon}_{c,u,t} = \frac{1}{\gamma_{c,u,t-1}} \left[ \frac{\text{PPI}_{c,u,t}}{\gamma_{c,u,t}} - \sum_{s \in N, s \neq S} \gamma_{c,u,s,t-1} \left( \frac{\text{PPI}_{c,s,t} + \tilde{\gamma}_{c,s,t}}{\gamma_{c,s,t}} \right) \right]. \quad (5)$$

In this expression, $\text{PPI}_{c,u,t}$, $\tilde{\gamma}_{c,u,t}$, $\gamma_{c,u,s,t-1}$, and $\gamma_{c,u,t-1}$ are all taken directly from the data.

It will be convenient to express equation (5) in matrix notation:

$$\tilde{\Gamma} = \mathbf{D}^{-1} \left[ (1 - \Gamma') \mathbf{PPI} - \tilde{\Gamma} \mathbf{E} \right]. \quad (6)$$

$\tilde{\Gamma}$ and $\mathbf{PPI}$ are the $NS \times 1$ vectors of all country-sector cost shocks and PPIs. The matrix $\Gamma$ is the $NS \times NS$ 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. Finally, $\mathbf{D}$ is an $NS \times NS$ diagonal matrix whose diagonal entries are the $\gamma_{c,u,t-1}$ coefficients.

In the last term,

$$\tilde{\mathbf{E}} = \begin{pmatrix} \tilde{\gamma}_{1,t} \\ \vdots \\ \tilde{\gamma}_{N,t} \end{pmatrix} \otimes \mathbf{I}_{S \times 1},$$

where $\tilde{\gamma}_{c,t}$ is an $N \times 1$ vector of exchange rate changes experienced by country $c$ relative to its trading partners, and thus $\tilde{\mathbf{E}}$ is the $NSS \times 1$ vector of stacked exchange rate changes that vary only by country pair. The matrix $\tilde{\Gamma}'$ is

$$\tilde{\Gamma}' = \begin{pmatrix} \Gamma_1 & 0 & \ldots & 0 \\ 0 & \Gamma_2 & 0 & \ldots \\ 0 & 0 & \ldots & 0 \\ 0 & 0 & \ldots & \Gamma_N \end{pmatrix}, \quad (7)$$

with $\Gamma_i$ defined as the $S \times NS$ matrix whose rows are country $c$'s rows of $\Gamma'$.

Our procedure takes the exchange rate changes as given and thus ignores the possibility that exchange rates themselves react to cost shocks and other inflationary shocks. To capture the endogenous responses of exchange rates to inflation would require a full-fledged model with various levels of rigidities and monetary authorities. Such an exercise exceeds the scope of this paper. At the same time, a large literature going back to Meese & Rogoff (1983) documents that exchange rates follow a random walk and that movements in nominal exchange rates are difficult to tie to macrofundamentals (see Itskhoki & Mukhin, 2017, for a recent treatment). Thus, the assumption of exogenous nominal exchange rates may not be a bad approximation in our context. Below, we assess robustness of the results to assuming that PPIs react only to cost shocks and not to exchange rates.

Equation (5) is used together with PPI data at monthly frequency to recover the underlying cost shocks $\hat{\epsilon}_{c,u,t}$ for every country, sector, and month. Equation (5) 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 twelve-month changes:

$$\text{PPI}_{12,c,u,t} = \prod_{\tau=0}^{11}(1 + \text{PPI}_{c,u,t-\tau}) - 1$$

and

$$\text{C}_{12,c,u,t} = \prod_{\tau=0}^{11}(1 + \hat{\epsilon}_{c,u,t-\tau}) - 1.$$ 

This transformation has the additional advantage that lagged effects due to shipping time and delayed price reactions are captured by the year-to-year changes.

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

$$\text{PPI}_{12,c,t} = \sum_{u \in S} \omega_{c,u} \text{PPI}_{12,c,u,t} \quad (8)$$

and

$$\text{C}_{12,c,t} = \sum_{u \in S} \omega_{c,u} \text{C}_{12,c,u,t}, \quad (9)$$

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 equation (8) 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

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6In our sample of countries, the mean correlation between our constructed aggregate PPI and the official PPI in twelve-month changes, is 0.70, and the median is 0.83. The minimum is 0.02 for Bulgaria, which experienced...
equation (9) 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 \( \tilde{C}_{12,c,t} \) uses the same sectoral weights \( \omega_{c,a} \) as that of \( \tilde{PPI}_{12,c,t} \). This approach ignores the possibility that in the absence of 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.

\[ \epsilon_{c,t} = \sum_{l=1}^{p} \rho_{c,l} \epsilon_{c,t-l} + \mu_{c,t}. \]  

The precise implementation of the Bayesian estimation of this model’s parameters is a simplified special case of the more general one described in section V.

### III. Data and Basic Patterns

#### A. Data

The empirical implementation requires data on industry-level PPI and cross-border input-output linkages. A contribution of our paper is the construction of a cross-country panel data set of monthly sectoral producer prices that can be merged with existing data sets 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 United States, Canada, Japan, China) are not in Eurostat, we collected PPI data for these countries from national sources, such as the BLS for the United States and StatCan for Canada. Unfortunately, the sectoral classifications outside Eurostat tend to be country specific and require manual harmonization.

Information on input linkages comes from the World Input-Output database (WIOD) described in Timmer et al. (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 forty countries. Merging the PPI and WIOD databases required further harmonization of the country and sector coverage. The sectoral classifications 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. 3) sectoral classification. Appendix table A1 shows the conversion tables used in the process.

The final sample includes thirty countries plus a composite Rest of the World (ROW) category, seventeen 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 ROW category because of an excessive share (>$0.4) of missing data in the PPI. These are summarized in appendix table A3. While the PPI data are recorded monthly, the input coefficients \( \gamma_{c,i,c,t} \) come from WIOD and thus change annually.

The empirical methodology requires a balanced sample of countries \( \times \) sectors \( \times \) 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...

hyperinflation between 1995 and 1998 (after 1998, the correlation for Bulgaria is 0.76). The maximum is 0.99 (Japan).
average January inflation for that series). If a country-sector series is missing over the entire time horizon nine cases out of the 527 series, its inflation values are extrapolated based on the rest of the country’s series. Overall, 9.8% of the PPI values are extrapolated.

An important feature of the PPI index is that it covers only the industrial sector in the majority of countries. Thus, service sector prices are not included in the baseline analysis. Appendixes B and C present a battery of robustness exercises that assess the role of non-PPI sectors in the cost shock transmission across countries.

Appendix figure A1 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. Appendix figure A2 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.

Appendix figure A3 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 2008–2009 Great Trade Collapse and then fell to 0.24.

B. 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 relation (6) 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, and ignoring exchange rate movements, the equilibrium PPI series, given a vector of cost shocks, are as follows:

$$\Delta \text{PPI}_{\text{dest}} = (I - \Gamma)^{-1} \Delta \text{C}.$$  

To gauge the extent to which input linkages propagate inflationary shocks, we feed into the world input-output matrix several hypothetical underlying cost shocks $\text{C}$. The first set are inflationary shocks to three largest economies in the world: the United States, Japan, and China. In the case of the United States, for instance, these are shocks to $\text{C}$ that lead to a PPI inflation of 1% in the United States. By construction, only U.S. entries of the cost shock $\text{C}$ are nonzero: the assumption is that only the United States experiences a shock. Nonetheless, other countries’ PPIs can react to the U.S. shock because the U.S. sectors are part of the global value chain (see equation (13)). Another shock we feed in is a worldwide 10% shock to the energy sector, intended to simulate an increase in oil prices. Note that the magnitude and sign of the shock do not matter in this exercise, as evidenced by the linear system (13), so these could be deflationary shocks to the key countries or declines in energy prices.

Figure 1 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 United States produces inflation of approximately one-tenth that amount in Canada and Mexico, by far the most closely connected economies to the United States. In five other countries, the impact is 0.02% or greater, or one-fiftieth of U.S. inflation. In nearly half the countries, the impact is smaller than 0.01%, or one-hundredth of U.S. inflation. The pattern is similar for the Japanese and Chinese shocks. In each case, there are two or three 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.

The last panel of figure 1 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.

Figure 2 presents the generalization of figures 1a to 1c by plotting the proportional impact of an inflationary shock affecting each source country on each destination country in the sample. That is, it reports

$$\frac{\Delta \text{PPI}_{\text{dest}}}{\Delta \text{PPI}_{\text{source}}}$$

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 five countries in terms of their impact on foreign inflation are Germany, China, Russia, the United States, and Italy. Germany’s impact is both highest on average (0.04 of $\Delta \text{PPI}_{\text{dest}}/\Delta \text{PPI}_{\text{DEU}}$ when averaging over dest) across the whole sample and the most diffuse. For ten countries (all of them in Europe), the impact is above 0.05, and for the top three—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 two 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 an average of 1% in all the other countries in the world. The blue/dark bars in figure 3 report 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 0.19% increase in domestic PPI. There is substantial heterogeneity, and at the top end, three countries exhibit elasticities with respect to global inflation of over 0.3: Belgium, Hungary, and the Czech Republic. Russia, Australia, Japan, and the United States appear the least susceptible to global inflation shocks, with impacts in the range 0.06 to 0.10.

We also assess the extent to which the total impact of foreign inflation on domestic prices is due to the direct (first round) versus indirect effects. The direct effect is simply the change in domestic prices due to the change in foreign input prices following the cost shock:

$$\text{PPI} = (1 + \gamma') \Delta C.$$  

The indirect effect captures the fact that a country’s foreign inputs in turn use other inputs, which also experienced a cost shock, and so on ad infinitum. The white and gray/light bars of figure 3 report the direct and indirect effects, respectively. Both are quantitatively important. The mean of the indirect component, at 0.06, is about one-third of the mean total impact. In three countries—China, South Korea, and Japan—the indirect component accounts for more than half of the total effect. The size of indirect effects underscores the importance of analyzing the full global network of input trade rather than only bilateral linkages.
This figure displays the proportional impact of an inflationary shock in each source country’s inflation on each destination country’s inflation.

Because the baseline analysis is undertaken primarily using sectors covered by PPI (listed in appendix table A2), figures 1 to 3 plot the responses of PPI sectors to cost shocks in the PPI sectors. However, since these exercises use no actual price data, we could also simulate the cost shocks and price responses of all sectors, both PPI and services, covered by WIOD. Appendix figures A4 to A6 repeat the exercises above on all the WIOD sectors. The magnitudes are quite similar to those in figures 1 to 3.

IV. Input Linkages and Global Inflation Comovement

Table 1 reports the main inflation synchronization 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 $\hat{PPI}_{c,t}$ 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 0.365 at the mean and 0.317 at the median in this sample of countries. The global static factor accounts for 0.463 of the variance of the average country’s inflation at the mean and 0.511 at the median. The dynamic factor delivers very similar averages: 0.447 at the mean and 0.488 at the median.

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 nearly 0.9 correlation with both the static and the dynamic variance shares. The static and dynamic variance shares have a 0.997 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 $\hat{C}_{c,t}$ present the same statistics for 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 0.166 (mean).
This figure displays the impact of an inflationary shock that leads to average 1% inflation in the other countries in the world.

and 0.122 (median). The static global factor explains 0.294 (mean) and 0.281 (median) of the variation in $\hat{C}_{12,c,t}$ for the average country, and the dynamic factor explains 0.252 (mean) and 0.240 (median).

The difference between synchronization metrics for $\hat{C}_{12,c,t}$ and $\hat{PPI}_{12,c,t}$ 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 37% (45%) of observed synchronization at the mean (median). The $R^2$ metric implies the largest contribution, with input linkages responsible for 54% (62%) of observed synchronization at the mean (median). The dynamic factor results lie in between.

A. Understanding the Mechanisms

We now perform a battery of alternative implementations designed to better understand under what conditions input linkages create inflation comovement. Namely, we examine the role of exchange rates, the importance of incomplete pass-through, and the nature of domestic and international linkages. Section V estimates the relative roles of global and sectoral shocks.

Imperfect pass-through and pricing-to-market. We begin by evaluating the role of exchange rates in the baseline results. Examining equation (5), which 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.\footnote{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: exchange rate pass-through is positive...
Table 1.—Synchronization in Actual PPI and Cost Shocks

<table>
<thead>
<tr>
<th>Country</th>
<th>$\text{PPI}<em>{t,c}$ ($\hat{\text{C}}</em>{t,c}$)</th>
<th>$\text{PPI}<em>{t,c}$ ($\hat{\text{C}}</em>{t,c}$)</th>
<th>$\text{PPI}<em>{t,c}$ ($\hat{\text{C}}</em>{t,c}$)</th>
<th>$\text{PPI}<em>{t,c}$ ($\hat{\text{C}}</em>{t,c}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AUS</td>
<td>0.529 0.203</td>
<td>0.596 0.371</td>
<td>0.538 0.188</td>
<td></td>
</tr>
<tr>
<td>AUT</td>
<td>0.261 0.031</td>
<td>0.570 0.140</td>
<td>0.515 0.180</td>
<td></td>
</tr>
<tr>
<td>BEL</td>
<td>0.646 0.427</td>
<td>0.755 0.562</td>
<td>0.745 0.436</td>
<td></td>
</tr>
<tr>
<td>BGR</td>
<td>0.524 0.029</td>
<td>0.461 0.001</td>
<td>0.420 0.012</td>
<td></td>
</tr>
<tr>
<td>CAN</td>
<td>0.560 0.175</td>
<td>0.604 0.510</td>
<td>0.573 0.271</td>
<td></td>
</tr>
<tr>
<td>CHN</td>
<td>0.317 0.094</td>
<td>0.665 0.408</td>
<td>0.651 0.214</td>
<td></td>
</tr>
<tr>
<td>CZE</td>
<td>0.323 0.186</td>
<td>0.264 0.197</td>
<td>0.252 0.328</td>
<td></td>
</tr>
<tr>
<td>DEU</td>
<td>0.729 0.362</td>
<td>0.860 0.404</td>
<td>0.860 0.550</td>
<td></td>
</tr>
<tr>
<td>DNK</td>
<td>0.226 0.330</td>
<td>0.224 0.242</td>
<td>0.223 0.293</td>
<td></td>
</tr>
<tr>
<td>ESP</td>
<td>0.736 0.453</td>
<td>0.931 0.789</td>
<td>0.918 0.795</td>
<td></td>
</tr>
<tr>
<td>FIN</td>
<td>0.318 0.123</td>
<td>0.652 0.470</td>
<td>0.598 0.337</td>
<td></td>
</tr>
<tr>
<td>FRA</td>
<td>0.617 0.489</td>
<td>0.689 0.368</td>
<td>0.699 0.472</td>
<td></td>
</tr>
<tr>
<td>GBR</td>
<td>0.217 0.031</td>
<td>0.524 0.433</td>
<td>0.480 0.277</td>
<td></td>
</tr>
<tr>
<td>GRC</td>
<td>0.118 0.035</td>
<td>0.090 0.000</td>
<td>0.079 0.023</td>
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</tr>
<tr>
<td>HUN</td>
<td>0.277 0.123</td>
<td>0.075 0.000</td>
<td>0.073 0.031</td>
<td></td>
</tr>
<tr>
<td>IRL</td>
<td>0.081 0.048</td>
<td>0.104 0.035</td>
<td>0.096 0.044</td>
<td></td>
</tr>
<tr>
<td>ITA</td>
<td>0.730 0.234</td>
<td>0.826 0.506</td>
<td>0.860 0.617</td>
<td></td>
</tr>
<tr>
<td>JPN</td>
<td>0.439 0.104</td>
<td>0.735 0.388</td>
<td>0.690 0.210</td>
<td></td>
</tr>
<tr>
<td>KOR</td>
<td>0.013 0.000</td>
<td>0.048 0.048</td>
<td>0.027 0.025</td>
<td></td>
</tr>
<tr>
<td>LIT</td>
<td>0.369 0.019</td>
<td>0.678 0.228</td>
<td>0.637 0.266</td>
<td></td>
</tr>
<tr>
<td>MEX</td>
<td>0.054 0.000</td>
<td>0.063 0.018</td>
<td>0.064 0.003</td>
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</tr>
<tr>
<td>NLD</td>
<td>0.716 0.480</td>
<td>0.808 0.671</td>
<td>0.831 0.577</td>
<td></td>
</tr>
<tr>
<td>POL</td>
<td>0.103 0.258</td>
<td>0.184 0.299</td>
<td>0.165 0.298</td>
<td></td>
</tr>
<tr>
<td>PRT</td>
<td>0.524 0.122</td>
<td>0.499 0.196</td>
<td>0.495 0.247</td>
<td></td>
</tr>
<tr>
<td>ROM</td>
<td>0.046 0.073</td>
<td>0.000 0.017</td>
<td>0.002 0.005</td>
<td></td>
</tr>
<tr>
<td>RUS</td>
<td>0.281 0.130</td>
<td>0.215 0.264</td>
<td>0.225 0.144</td>
<td></td>
</tr>
<tr>
<td>SVN</td>
<td>0.104 0.024</td>
<td>0.025 0.006</td>
<td>0.021 0.043</td>
<td></td>
</tr>
<tr>
<td>SWE</td>
<td>0.261 0.024</td>
<td>0.499 0.227</td>
<td>0.473 0.154</td>
<td></td>
</tr>
<tr>
<td>TWN</td>
<td>0.286 0.053</td>
<td>0.492 0.445</td>
<td>0.466 0.233</td>
<td></td>
</tr>
<tr>
<td>USA</td>
<td>0.541 0.308</td>
<td>0.766 0.572</td>
<td>0.737 0.788</td>
<td></td>
</tr>
</tbody>
</table>

Panel A reports the $R^2$s of the regression of the country’s inflation ($\text{PPI}_{t,c}$) on the cost shock ($\hat{\text{C}}_{t,c}$) for each country in the sample. Panel B reports the share of the variance in the country’s inflation ($\text{PPI}_{t,c}$) accounted for by the common static factor $\beta_1$. Panel C reports the results assuming a dynamic factor. Country code definitions are reported in appendix table A2.

According to virtually all available estimates, whereas here we in effect set it to 0 and retain only the PPI changes as cost shocks. Table 2 presents the results. To facilitate comparison across scenarios, the top-left panel of the table reproduces from table 1 the mean and median of the $R^2$s and of the shares of variance accounted for by the static and dynamic factors for actual PPI and the baseline recovered cost shocks. The panel labeled “Alt. Cost Shocks: No $\hat{\text{E}}_{c,e,t}$” 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 rate changes are quite similar to the baseline.

An active literature has explored the role of demand complementarities and pricing-to-market in the determination of international prices and exchange rate pass-through (Dornbusch, 1987; Atkeson & Burstein, 2008). Under some market structures and demand systems, firms set their prices as a function of both their cost shocks and the prices of other firms serving a particular market. In other words, instead of equation (4), prices and costs have the following relationship:

$$\hat{P}_{c,u,e,s,t} = \beta(\hat{W}_{c,e,t} + \hat{E}_{c,e,t}) + (1 - \beta)\hat{P}_{c,u,t},$$

where

$$\hat{P}_{c,u,t} = \sum_{c,e,s} \sigma_{c,u,e,s,t-1}P_{c,u,e,s,t}$$

and $\sigma_{c,u,e,s,t-1} = \gamma_{c,u,e,s,t-1}/(1 - \gamma_{c,u,e,s,t-1})$ is the market share of good $e,s$ in market $c, u$ (Burstein & Gopinath, 2015). Since in this formulation all prices depend on all the other prices, extracting the cost shocks from observed PPI series is more challenging but can still be done in one step. Appendix A sets up a general framework that nests multiple assumptions on pass-through and presents the detailed derivations.

We implement the counterfactuals allowing for price complementarities under three alternative assumptions on $\beta$: 1/3, 2/3, and sector-specific $\beta_s$. The values for $\beta$ of 1/3 to 2/3 reflect the considerable uncertainty in the literature regarding the correct value for the pass-through coefficient. For example, Goldberg & Campa (2010) report an estimate of the exchange rate pass-through rate into import price indices of 0.61 in a sample of nineteen 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–data set underlying the official U.S. import price indices. In the third scenario, we use sector-specific values of $\beta_s$ from Osbat and Wagner (2010). The resulting values of $\beta_s$ have a mean of 2/3 and a range of 0.4 to 0.92.
The three panels labeled “Pricing Complementarity” in table 2 report the results for the three assumptions on \( \beta \). If anything, allowing for pricing-to-market further reduces the amount of synchronization in \( \hat{C} \). According to all three of our metrics, a smaller share of variance in these recovered cost shocks is explained by the common factor than in the baseline, though the magnitudes are similar. The results are also not sensitive to whether we set \( \beta \) to 1/3 or 2/3. Introducing sectoral heterogeneity in \( \hat{\beta}_s \) (bottom panel) leads to very similar conclusions. The results are exceedingly similar to those under \( \beta = 2/3 \), which is not surprising since that is also the average value of the sector-specific \( \hat{\beta}_s \)’s.

We contrast these results with a simpler alternative, in which pass-through is imperfect but there are no demand complementarities. Corsetti and Dedola (2005) provide a microfoundation for such a pass-through formulation in a framework with constant elasticity of substitution CES demand and a competitive distribution sector, which leads to variable elasticity of demand perceived by firms. That is, cost shocks are passed through to prices with elasticity \( \beta^m \) strictly less than 1:

\[
\hat{PPI}_{c,a,t} = \beta^m \hat{W}_{c,a,t}.
\]

and

\[
\hat{\rho}_{c,a,s,t} = \beta^m (\hat{W}_{c,s,t} + \hat{E}_{c,e,s,t}).
\]

We refer to this scenario as “mechanical pass-through” and report the results in the three bottom-right panels of table 2, for the same three assumptions on \( \beta^m \) as in the price complementarity exercises: 1/3, 2/3, and sector specific. Under mechanical incomplete pass-through, the results are sensitive to \( \beta^m \) and imply a smaller contribution of input linkages to synchronization when \( \beta^m \) is substantially less than 1. This is sensible: a lower \( \beta^m \) by construction reduces the difference between \( \hat{PPI}_{c,a,t} \) and \( \hat{C}_{c,a,t} \). Because under lower pass-through the two series become more similar, the share of variance explained by the global factor also becomes more similar. Once again, the sector-specific results in the bottom panel look quite similar to those under \( \beta^m = 2/3 \).

The difference between these results and the ones with demand complementarities is stark. Whereas lower mechanical pass-through rates imply a smaller impact of input linkages on inflation synchronization, that is not the case once we use a realistic pricing-to-market framework taking into account that more limited pass-through also means a higher degree of price complementarities. Imperfect cost pass-through and price complementarities interact in such a way that allowing for pricing-to-market does not change the magnitude of the contribution of input linkages to inflation comovement. As \( \beta \) decreases, the higher price complementarities thus seem to offset the reduced impact of direct cross-border spillovers.

**Heterogeneity in international input linkages.** An active recent literature has argued that the extent of heterogeneity in the input-output linkages matters for the propagation of idiosyncratic shocks to the aggregate economy through the input-output network (see Acemoglu et al., 2012; Acemoglu, Ozdaglar, & Tahbaz-Salehi, 2017). We thus evaluate the role of heterogeneity in input usage across countries and sectors for synchronizing national inflation rates. To this end, we construct two counterfactual scenarios for PPI under “balanced” input-output linkages. The first scenario preserves

---

**Table 2—Alternative Implementations: Imperfect Pass-Through and Pricing-to-Market**

<table>
<thead>
<tr>
<th></th>
<th>( R^2 )</th>
<th>Static Factor</th>
<th>Dynamic Factor</th>
<th>( \hat{R}^2 )</th>
<th>Static Factor</th>
<th>Dynamic Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \hat{PP}_{12,c,a,t} )</td>
<td></td>
<td></td>
<td></td>
<td>( \hat{C}_{12,c,a,t} )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>0.365</td>
<td>0.463</td>
<td>0.447</td>
<td>Mean</td>
<td>0.171</td>
<td>0.327</td>
</tr>
<tr>
<td>Median</td>
<td>0.317</td>
<td>0.511</td>
<td>0.488</td>
<td>Median</td>
<td>0.091</td>
<td>0.313</td>
</tr>
<tr>
<td>( \hat{C}_{12,c,a,t} )</td>
<td></td>
<td></td>
<td></td>
<td>( \hat{C}_{12,c,a,t} )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>0.166</td>
<td>0.294</td>
<td>0.252</td>
<td>Mean</td>
<td>0.258</td>
<td>0.379</td>
</tr>
<tr>
<td>Median</td>
<td>0.122</td>
<td>0.281</td>
<td>0.240</td>
<td>Median</td>
<td>0.231</td>
<td>0.378</td>
</tr>
<tr>
<td>( \hat{C}_{12,c,a,t} )</td>
<td></td>
<td></td>
<td></td>
<td>( \hat{C}_{12,c,a,t} )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>0.106</td>
<td>0.200</td>
<td>0.165</td>
<td>Mean</td>
<td>0.277</td>
<td>0.416</td>
</tr>
<tr>
<td>Median</td>
<td>0.051</td>
<td>0.187</td>
<td>0.085</td>
<td>Median</td>
<td>0.259</td>
<td>0.469</td>
</tr>
<tr>
<td>( \hat{C}_{12,c,a,t} )</td>
<td></td>
<td></td>
<td></td>
<td>( \hat{C}_{12,c,a,t} )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>0.085</td>
<td>0.214</td>
<td>0.159</td>
<td>Mean</td>
<td>0.266</td>
<td>0.387</td>
</tr>
<tr>
<td>Median</td>
<td>0.040</td>
<td>0.141</td>
<td>0.143</td>
<td>Median</td>
<td>0.243</td>
<td>0.402</td>
</tr>
</tbody>
</table>

This table reports the mean and median of the \( R^2 \) (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.
the cross-country heterogeneity in input linkages but assumes that within each pair of importer-exporter countries, there are no differences across sectors. That is, we assume a counterfactual input-output matrix $\Gamma_{b_1}$ with the following elements:

$$\gamma_{b_1}^{u_1} = \frac{1}{S^2} \sum_{k \in S, l \in S} \gamma_{c,k,e,l}.$$ \hfill (16)

This counterfactual labeled “$b_1$” suppresses sectoral heterogeneity within each 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 $\Gamma_{b_2}$ is assumed to have the elements

$$\gamma_{b_2}^{u_2} = \begin{cases} 
\frac{1}{S^2} \sum_{k \in S, l \in S} \gamma_{c,k,e,l} & \text{if } c = e \\
\frac{1}{(N-1)S^2} \sum_{k \in S, l \in S, e \in N \setminus \{c\}} \gamma_{c,k,e,l} & \text{if } c \neq e
\end{cases}. $$

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 $\gamma$ values are rescaled such that the total share of non-materials inputs in output in each sector and country $\gamma_{c,u}^{b_2}$ 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

$$\tilde{PPI}_{counter} = (I - \tilde{\Gamma}_{counter})^{-1} \left( D\hat{C} + \tilde{\Gamma}_{counter} \hat{E} \right). \hfill (16)$$

for $counter = \{b_1, b_2\}$, where $\tilde{\Gamma}_{counter}$ is the counterfactual version of equation (7), which uses the elements of the counterfactual $\Gamma$ matrix instead of the actual values. Just as in the baseline analysis, equation (16) assumes complete pass-through of cost shocks to prices.

The panels “Balanced 1” and “Balanced 2” of Table 3 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 33% lower than in the data in the Balanced 1 scenario and 16% lower in the Balanced 2 scenario. The factor models imply smaller differences—only approximately 20% for Balanced 1 and less than 10% for Balanced 2. Indeed, comparing medians in the Balanced 2 scenario, there is actually a small increase in the common component relative to the baseline. This suggests there may be some role for the input linkage heterogeneity in generating the observed comovement, but that the average overall linkages per se represents the single most important mechanism.

**B. Direct Measurement of Cost Shock Synchronization**

Our cost shocks are recovered from the PPI data and capture all of the shocks to the cost of primary factors (labor and capital), as well as nontradeable inputs. We adopt this approach because precise measures of the primitive cost shocks are not available. To provide additional evidence on the synchronization of cost shocks, we collected data on unit labor costs (ULC) from Eurostat, OECD, and national sources. The ULCs are defined as the nominal unit labor costs in the total economy. This data series is available for only 26 countries in our sample, over the period 1996 to 2011. The ULC data are also quarterly and thus cannot be combined with our baseline analysis, which is at monthly frequency. Most important, the ULC data are just for labor costs, and thus do not correspond directly to our $\hat{C}$, which is an encompassing cost variable.\(^{10}\)

Table 4 reports the results of implementing our analysis on ULCs. Because the sample of countries is different and the ULC data are quarterly, the top two panels report our baseline results for $\tilde{PPI}$ and $\hat{C}$ for this subsample of countries and converted to quarterly frequency. The qualitative and quantitative outcomes are very similar to the baseline analysis. The bottom panel implements the factor models on the ULCs. The extent of synchronization in ULCs is lower than for $\hat{C}$ and much closer to $\hat{C}$ than to $\tilde{PPI}$. Thus, evidence based on direct measurement accords quite well with our finding that the cost shocks are less synchronized than actual inflation.

---

\(^{10}\)Unit labor costs changes coincide with $\hat{C}$ when the production function is Cobb-Douglas and markups are either 0 or constant.
Appendix B presents a battery of additional robustness checks on the results, including accounting for domestic input linkages; accounting for higher-order and non-PPI linkages; excluding energy prices; and performing the analysis on PPI data converted to a common currency.

V. 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 model (10). 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. 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 (10) to (12) and is implemented directly on sector-level data. Specifically, we estimate the following model:

\[ X_{c,u,t} = \alpha_{c,u} + \lambda_{c,u}^{w} F_{t}^{w} + \lambda_{c,u}^{c} F_{t}^{c} + \lambda_{c,u}^{u} F_{t}^{u} + \epsilon_{c,u,t}, \]

where \( X_{c,u,t} \) is the twelve-month inflation rate in country \( c \), sector \( u \), which can be either the actual \( PPI_{12,c,u,t} \) or the recovered cost shock \( \hat{C}_{12,c,u,t} \). It is assumed to comprise a global factor \( F_{t}^{w} \) common to all countries and sectors in the sample, the country factor \( F_{t}^{c} \) common to all \( u \) in country \( c \), a sectoral factor \( F_{t}^{u} \) common to all sector \( u \) prices worldwide, and an idiosyncratic error term. Each of the factor series and the error term in the sector-level model (17) in turn are assumed to follow an AR process parallel to equation (11). Additional details on the factor model structure and estimation are collected in appendix D.

Because we are ultimately interested in the comovement of aggregate inflation, we aggregate the sector-level model (17) to the country level in the same manner as in the baseline analysis. To decompose the aggregate country inflation into the global, sectoral, and idiosyncratic components, we combine equation (17) with equation (8):

\[ X_{c,t} = \sum_{u \in S} \omega_{c,u} X_{c,u,t} \]

\[ = \sum_{u \in S} \omega_{c,u} \lambda_{c,u}^{w} F_{t}^{w} + \sum_{u \in S} \omega_{c,u} \lambda_{c,u}^{c} F_{t}^{c} + \sum_{u \in S} \omega_{c,u} \lambda_{c,u}^{u} F_{t}^{u} + \sum_{u \in S} \omega_{c,u} \epsilon_{c,u,t}. \]

Denoting \( \Lambda^{w} = \sum_{u \in S} \omega_{c,u} \lambda_{c,u}^{w}, \Lambda^{c} = \sum_{u \in S} \omega_{c,u} \lambda_{c,u}^{c}, \Lambda^{u} = \sum_{u \in S} \omega_{c,u} \lambda_{c,u}^{u}, \) and \( G^{w} = \sum_{u \in S} \omega_{c,u} \lambda_{c,u}^{w} F_{t}^{w}, \) we obtain

\[ X_{c,t} = \Lambda^{w} F_{t}^{w} + \Lambda^{c} F_{t}^{c} + G^{w} + \sum_{u \in S} \omega_{c,u} \epsilon_{c,u,t}. \]

Equation (18) is the aggregation of the sector-level factor model (17). It states that the 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 factors, and an idiosyncratic component. We can then compute the variance share of the global and country factors as

\[ share_{c,k} = \frac{(\Lambda_{k})^{2} \text{Var}(F_{t}^{k})}{\text{Var}(X_{c,t})} \quad k = w, c, \]

and the share of the variance attributable to sector factors as

\[ share_{c,u} = \frac{\text{Var}(G^{w})}{\text{Var}(X_{c,t})}. \]

We are 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.

We estimate a factor model directly on sector-level price data, extracting global, country, and sector shocks following equation (17), and then decompose aggregate inflation into the contribution of those components as in equation (18). Table 5 reports the summary statistics for shares of variance of overall country-level \( PPI_{12,c,t} \) and \( \hat{C}_{12,c,t} \) accounted for...
by the different shocks, calculated as in equations (19) and (20). Appendix table A5 reports the results for each country.

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 0.070 (0.027) of the variance of country PPI for the mean (median) country. Sectoral shocks, by contrast, account for 0.426 (0.481) at the mean (median). The combined share of variance of actual $PPI_{c,t}$ accounted for by the global and sectoral shocks (0.070 + 0.426 at the mean, 0.027 + 0.481 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 $CI_{c,t}$ compared to actual $PPI_{c,t}$ 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 $CI_{c,t}$ on average than of $PPI_{c,t}$. 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 synchronize price shocks along the sectoral dimension.

VI. Conclusion

Inflation rates are highly synchronized across countries. In a data set of PPI for thirty countries, the single common factor explains nearly half of the fluctuations in PPI inflation in the average economy. It is important to understand the reasons for this internationalization of inflation. This paper evaluates a particular hypothesis: international input linkages are synchronizing inflation rates.

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 rate of exchange rate pass-through or to the extent of pricing to market with demand complementarities. 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.

REFERENCES


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