Global value chains and the transmission of price shocks

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Abstract

The build-up of global production networks during the past decades has increased the interaction among sectors across countries. The growth of GVCs reflects the international integration of geographically fragmented global production processes, made possible by new technologies and lower trade barriers.

In this paper, we document the role of global input-output linkages in transmitting productivity and price shocks in the international economy. More specifically, we study the role of global input-output linkages in transmitting oil prices shocks across economies.

We build on two sectoral datasets, the World Input Output Database (WIOD) and the OECD- ICIO database and take advantage of the temporal dimension of the dataset to document the extent to which the growth in GVCs has changed inflation dynamics over time.

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1. Introduction and literature review
2. Methodology

2.1 The Input-Output model applied to a shock on production costs.

Leontief's production model (or I-O model) breaks down the impact of a demand shock (Leontief 1951). The trade in value-added analysis reconciles international trade statistics with national I-O tables, which allows Leontief's analysis to be extended to an international context. A number of studies (Hummels, Ishii, and Yi 2001; Daudin et al. 2006; Daudin, Rifflart, and Schweisguth 2011; De Backer and Yamano 2012; Johnson and Noguera 2012; Koopman, Wang, and Wei 2014; Amador, Cappariello, and Stehrer 2015; Los et al. 2016) analyze the value added content of world trade. Some authors focus on Asia (Sato and Shrestha 2014) or to the euro area (Cappariello and Felettigh 2015). Bems and Johnson (2015) focus on competitiveness and compute real effective exchange rates weighted by the value-added trade structure to measure the impact of a change in relative prices on each country's value added.

Leontief's production model has a dual: the price model. Some studies focus on the consequences of a change in production prices based on an I-O model or a SAM (Social Accounting Matrix) model in developing countries. To the best of our knowledge, the dual production model of Leontief has only been adapted in an international context in Cochard et al. (2017).

Leontief's price model is broadly used in multi-sector, single-country macroeconomic models, for example, to measure the effect of a change in energy prices (Bournay and Piriou 2015; Sharify 2013). This approach to the effect of costs on prices is purely accounting ("cost-push inflation"). Firms’ margins are assumed to be fixed. Prices only adjust to absorb cost changes, production techniques are fixed during successive production cycles and inputs substitution (for instance, between countries producing the same goods) is not accounted for, despite variations in relative price. The limitations of this approach are well known (Folloni and Miglierina 1994). In particular, and although the division of global value chains largely takes place within multinational firms, we consider here a unique pricing system based on market prices and independent of firm strategies. This method provides a measure of the vulnerability of each sector to price or productivity shocks (Acemoglu et al. 2012; Carvalho 2014). Though unrealistic, this approach is useful in identifying which countries and sectors are under pressure to adjust their prices when subject to exogenous cost shocks. For instance, it highlights which euro area countries benefit most from an appreciation of the euro or whether adopting the euro has increased interdependence between member countries.

2.2 Applying the I-O model to a price model

The standard I-O model relies on the input-output tables, which represent transactions of goods and services (domestic or imported) at current prices. I-O tables describe the sale and purchase relationships between producers and consumers within an economy. The columns describe, for each industry , the intermediate consumption of goods and services from the various sectors as well as the consumption of primary factors (capital and labor) necessary for producing a product . Each column indicates the total expenditure incurred by each industry during its production process, i.e. the payment of intermediate consumption and the remuneration of production factors (the remuneration of production factors equals the value added). By construction, the I-O tables are balanced: the sum of resources equals the sum of expenditures for the whole economy. The rows of the table contain information on the distribution of the output of industries over user categories.

Define the vector of production of dimension (1,n), A the matrix of input coefficients of dimension (n,n), and the vector of factor incomes of dimension (1,n).

Assuming that there is no possible substitution between the inputs (i.e. that technical coefficients are fixed), we can derive a price equation.

Define , with the price and the quantity of product and normalize quantity such as .

Define the structural matrix of the technical coefficients of dimension (n, n), the vector of production prices of dimension (1, n) and V the vector of factor income of dimension (1, n). Then .

When an exogenous input price shock occurs, firms face a change in their costs, which is passed on directly to production prices. This exogenous shock is assumed not to affect the return on capital and labor. Therefore, there is no adjustment to margins. Under these conditions, for each industry i, the shock can be written as the absolute difference between the initial price and the new price invoiced following the shock (“shocked price” hereafter).

Define the shock vector of dimension (1,n) computed as the difference between the original price and the vector of shocked prices. Then , with the shock vector of dimension (1,n), which contains the direct effect of the shock on output prices.

The price increase is passed on to the industries that use shocked products as intermediate consumptions. The higher is the reliance on shocked inputs, the higher the increase in production prices.

In a first step, the direct impact of the shock on each industry's output prices amounts to .

In a second step, the shock is passed on all industries using these shocked inputs in their production processes. For n production cycles, the increase in production prices amount to .

As the technical coefficients are smaller than 1, the effect of the initial shock on input prices eventually wears out. Finally, the overall effect of the shock is equal to the sum of the initial shock and all the increases that occurred during the successive production cycles. The total effect of the shock on prices, S, is equal to:

With the inverse of Leontief’s matrix, is a vector (1, n) composed of the elements measuring the total effect of the shock on the output price of country i's sector j and the vector of an exogenous input price shock.

To analyze which countries are most affected by a production cost shock through value-added and vertical trade flows in international trade, we need a large structural matrix that integrates input flows between sectors within each country and between countries. This matrix traces the sectoral and geographical origin of inputs produced worldwide. On the diagonal are the country blocks with flows of domestic transactions of intermediate goods and services between industries. The country blocks outside the diagonal represent international flows of intermediate goods and services via bilateral sectoral exports and imports.

* 1. Data and measurement issues

We use two sectoral datasets for international intput-output tables: the World Input Output Database (WIOD) and the OECD- ICIO database.

The World Input Output Database (WIOD) contains time series of inter-country input-output tables from 2000 to 2014. Input-output tables are designed to measure the interrelationships between the producers of goods and services (including imports) within an economy and the users of these same goods and services (including exports). World Input-Output tables (WIOT) connects national table with international trade flows. WIOD uses supply-use tables (SUT) from individual country’s national accounts as the starting point to integrate with bilateral trade statistics and derive the final symmetric world Input-Output table (WIOT). The WIOTs cover 43 countries, of which a majority belongs to the European Union, as well as the rest of the world, constructed as one economy. These global Input-Output (I-O thereafter) tables cover around 85% of world GDP and contain annual information for 56 industries, comprising primary, manufacturing goods and services sectors. Therefore, for each year a full country-sector input-output matrix allows to trace the importance of a supplying industry in one country for an industry in another country. The values in WIOTs are expressed in millions of U.S. dollars; market exchange rates were used for currency conversion (Timmer et al., 2015). All transactions values are in basic prices, reflecting all costs borne by the producer. These tables are accompanied by Socio-Economic Accounts which contain country sector panel data on employment (number of workers, compensation and share of labor in high, medium and low skilled occupations), capital stocks, gross output and value added).

The OECD ICIO database comes close to WIOD in terms of coverage. It builds on the OECD harmonized individual country I-O tables to provide matrices of inter-industrial flows of goods and services in current prices (USD million), for 64 economies and 34 industries, covering the years 1995 to 2011.

The WIOT and OECD-ICIO databases have a number of distinguishing characteristics (see Timmer et al. 2015 for details). The difference most relevant for our analysis relates to the treatment of imports by use category. From national input–output statistics one can derive the use of products by industries and final consumers, but the country of origin of these products is unknown. Therefore, one has to breakdown product import statistics by category of use in the construction of WIOTs.

The ICIO database relies on the so-called import proportionality assumption. The I-O tables show transactions between domestic industries. As a complement to these tables, supplementary tables break down total imports by user (industry and category of final demand). Some countries provide these import tables in conjunction with their I-O tables, but in other cases they are derived by the OECD. The main assumption used in creating these import matrices is the proportionality assumption, which assumes that the share of imports in any product consumed directly as intermediate consumption or final demand (except exports) is the same for all users. Various studies have found that this assumption can be misleading, as import shares vary significantly across use category. Feenstra and Jensen (2012) find that shares of imported materials may differ substantially across US industries. Based on Asian I-O tables, Puzzello (2012) finds that the use of the standard proportionality assumption understates the use of foreign intermediate inputs. Hence, the import proportionality assumption is likely to be particularly binding for developing countries, as the import content of exports is usually higher than the import content of products destined for domestic consumption. To address this issue, the WIOD database starts with imports as given in the supply tables and uses bilateral trade statistics to derive import shares for three end-use categories (intermediate use, ﬁnal consumption and investment) by mapping detailed six-digit products based on extensive product description (see Dietzenbacher et al. 2013).

* 1. Nominal exchange rate shock

We implement an exchange rate shock on the WIOT databases described above. The appreciation of a currency against other currencies leads, for the shock-stricken country, to a fall in the price of its domestic currency imports and an increase in the price of its foreign currency exports. We measure the disinflationary impact of this shock on the country that suffers the shock and, conversely, its inflationary impact on countries that directly and indirectly consume, through third countries linkages, inputs from the shock-stricken country.

Suppose a world with two countries A and B, each having its own national currency, and a currency for international transactions, the dollar. Assuming a 100% appreciation of the currency of country A against the other two currencies, the production prices of country A expressed in dollars would double compared to those of country B expressed in dollars. Country B pays more for its imports of inputs, in dollars as well as in national currency, since the exchange rate of the currency of Country B against the dollar has not changed. Conversely, the input prices imported by country A remain constant in dollar terms, since production prices of country B have not changed and fall by half once expressed in national currency.

We assume that producers have no margin behavior and pass the exchange rate shock fully on to their production prices. The change in the prices of imported goods is therefore transmitted to all domestic prices during the production process through interindustry trade. These upward (downward) movements for country B (country A), affect all input prices in each of the countries.

The effects of the shock spread over multiple production cycles. At the end of this process, the overall impact of the shock is equal in dollar terms, for hte shocked country A, to the rise in production prices due to the exchange rate shock, minus direct and indirect gains (via interindustrial linkages in the country) resulting from declines, in national currency and then converted back into dollar terms, in the prices of inputs imported from B and disseminated to all branches. The overall impact on production prices in dollar terms in country A is therefore lower than the initial exchange rate shock. For country B, the final impact corresponds to the cumulative direct and indirect effects of higher prices of inputs imported from country A and disseminated to all industries.

In a global economy composed of P countries, each with n sectors, the appreciation of a country's currency against all other currencies translates into a rise in the common currency, the dollar for example, in its relative prices vis-à-vis the rest of the world.

The production prices of each sector will vary in dollar terms from in the shock-stricken country and 0 in other countries.

Hence, for each sector in country :

And for any country different from , 

To simplify, output prices for each sector are normalized to 1 and exchange rates to 1:1. A 100% appreciation in the exchange rate of a currency against other currencies therefore corresponds to an absolute shock of +1, with production prices in the shock-stricken country rising from 1 to 2 dollars. The appreciation affects producers through changes in relative prices between countries and, therefore, through changes in input prices traded between the shock-stricken country and other countries.

Consider first the direct impact (in absolute terms) on other countries of the rise in import input prices from shocked country . For any sector l of a country (, the increase in the producer price depends directly on the quantity of inputs imported from the shock-stricken country , weighted by the variation in level of their prices in dollars (i. e. the exchange rate shock):

|  |
| --- |
| (2.1) |

With the quantity of inputs from the country's sector needed to develop a production unit for the country's sector .

For the shocked country, the shock has a disinflationary effect on domestic production prices. In national currency, the production prices of imported inputs fall by , or by 0.5 with .

This decline is spread to all sectors during the production cycle. In sector of the shocked country , this fall will be equal in national currency to:

This level shock can be converted into dollars:

(2.2)

We therefore know the direct impact of the dollar shock on all input prices of all countries in our world economy.

In matrix notation, we create two matrices that build on the large matrix A. These two matrices retain only the direct effects of the exchange rate shock on the price of goods imported by the shocked country and the direct effects of the exchange rate shock on the price of goods imported by the rest of the world from the shocked country. To formalize the initial impact of the shock on the price of traded goods, we neutralize the impact of an input price shock on the price of domestic inputs as well as on the price of inputs traded between countries that are not shocked.

Let us first look at the shock from the perspective of countries which import inputs from country .

Let be the vector of change in production prices in dollars following the 100% appreciation of the currency of country against all other currencies, corresponding to an absolute shock of +1 dollar for all sectors in country . Hence, with for all sectors and in the shocked country .

Building on equation (2.1), we write the direct impact of the exchange rate shock on the other countries as the product of the shock vector and a matrix B. B builds on the large matrix A of technical coefficient, of which only the country blocks of each country's sectoral inputs imported from the shocked country have been kept. The other coefficients are replaced by 0, including those of the block of country concerning the domestic input purchases of the shocked country . The direct impact of the appreciation of the exchange rate of a currency against the dollar on the price of inputs is equal to, with

(2.3)

where each element of the line block represents the technical coefficient related to imports of inputs by sector in country (with ) from sector in country .

Let us now consider the shock from the perspective of the shocked country .

Define the vector of change in input prices imported by country i, in dollars, ).

From equation (2.2), we can write the direct impact for country of the fall in input prices from the rest of the world. The direct impact corresponds to the product of the shock vector and a matrix . builds on the large matrix A of which only the country blocks of the inputs imported by country from other countries have been retained. The other coefficients are replaced by 0, including those of the block of the shocked country located on the diagonal of the technical coefficients, and which concern the domestic input purchases of the shocked country. The direct impact of the appreciation in the exchange rate of the shocked country on the price of its inputs is equal, in dollars at ,, with:

(2.4)

where each element in the column block represents imports of inputs by sector in country from sector in country .

The direct effect on the world is therefore the sum of these vectors from equations (2.3) and (2.4), i. e.

An input price shock then spreads to all sectors in all countries via the global intersectoral exchanges transcribed by the matrix of technical coefficients of the large matrix A. This process will be repeated several times, until the effects are completely exhausted.

In the end, the total effect of the dollar shock is equal to the shock itself, incremented by changes in input prices due to changes in imported input prices, and by all marginal changes in output prices during the various production processes until exhaustion, i. e.: - the total effect of the dollar shock is equal to the shock itself.

 (2.5)

With the total impact vector composed of the elements showing the total impact of the shock on country 's sector .

Equation (2.5) gives the absolute evolution of input prices in international currency. To obtain the absolute evolution of the input prices of the shocked country in national currency, it is enough to remove the exchange rate shock and multiply this balance by the scalar of conversion equal to (0.5 since according to our hypotheses =1):

With S a vector in shocked currency for all countries of the world.

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