Global value chains and the transmission of price shocks *

First draft version

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April 27, 2020

Abstract

Firms' participation in global value chains strengthens cross-country transmission of price shocks through cost-push inflation. We study the impact of exchange rate shocks on consumer prices by using three sectoral world input-output datasets. We find that the first-round effects (through imported inputs and final goods) explain three-quarters of the propagation of global shocks to domestic prices. By contrast, we find a limited role for the second-round effect, i.e. the additional transmission of lower domestic input prices to other sectors of the domestic economy and other countries occurring during subsequent production cycles. We also show that the first-round effects are a good predictor of the total effects. Our findings are robust to using different world input-output databases. World input-output databases are not available for the last five years. To address this gap, we use up-to-date GDP and trade data to approximate the accounting impact of an exchange rate shock on consumer prices for the most recent years.

JEL Classification: C67, E31, F42, F62
Keywords: input-output linkages, spillovers, global value chains, cost-push inflation, euro area

1 Introduction

Trade liberalization and lower transportation and communication costs facilitate the fragmentation of production across national borders. Participation in global value chains strengthens cross-country linkages via trade in intermediate inputs. When value chains are global, fluctuations in exchange rates affect domestic prices through two distinct price channels: *i)* the prices

*We thank Pavel Diev, Hubert Escaith, Guillaume Gaulier, Yannick Kalantzis, Guy Levy-Rueff and Jean-François Ouvrard for comments and suggestions, as well as participants at Banque de France seminars.

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of imported final goods sold directly to domestic consumers and *ii)* the prices of imported inputs feeding through domestic production of intermediate and final goods. In addition to this first-round effect, a currency appreciation in the domestic country has a second-round impact: because of exported intermediate goods, inputs become more expensive for foreign firms. As a result, production costs increase in the country whose currency depreciates. Changes in domestic and foreign production costs in turn pass through to the price of inputs for domestic and foreign firms and cause further production costs variations. Besides these purely accounting impacts, the pass-through of exchange rate shocks into consumer prices also depends on the intensity of competition in domestic markets: while an exchange rate appreciation lowers the price of imported inputs, a firm with limited competitive pressure may avail of greater profit margins rather than reduce prices in an effort to maintain market share. Despite some shortcomings, the accounting approach illustrates the vulnerability of each sector to price shocks. Hence, though unrealistic, it is useful for identifying which countries and sectors are under pressure to adjust their prices when subject to exogenous cost shocks.

In this paper, we measure the accounting effect of exchange rate fluctuations on consumer prices. We use world input-output tables covering twenty years of data (from 1995 to 2015). Most of the literature on global supply chains has focused on the role of input-output linkages in propagating shocks to production. By contrast, we examine the role of input-output linkages in propagating shocks to consumer prices. We analyse the impact of global inflationary shocks on the main components of consumer prices (manufacturing goods, services, food and energy). We also analyse the impact of global inflationary shocks on the prices of imported and domestic goods. We show that, following an appreciation of the domestic currency, the first-round effects (through imported inputs and imported final goods) explain three-quarters of the propagation of global shocks to domestic consumer prices. By contrast, we find a limited role for secound-round effects, i.e. the additional transmission of lower domestic input prices to other sectors of the domestic economy and to other countries occurring during subsequent production cycles. This limited role is the same in absolute terms for most countries. Our findings are robust to using three different datasets (two different releases of the OECD TiVA database and WIOD).

The construction of World Input-Output tables (WIOT hereafter) is data-demanding and WIOTs are typically released with a lag of several years. As a result, WIOTs are not available for the last five years. To address this gap, we use more up-to-date GDP and trade data to approximate the accounting impact of an exchange rate shock on consumer prices from 2015 onwards. Our proxy is helpful for assessing the impact of global value chains shocks on inflation from 2015 onwards.

The paper is organised as follows. Section 2 reviews the related literature. Section 3 presents the methodology and the data sources. Section 4 computes the accounting impact of an exchange rate shock on consumer prices up to 2015. World input-output databases are not available for the last five years. To address this gap, Section 5 relies on up-to-date GDP and trade data to approximate the accounting impact of an exchange rate shock on consumer prices from 2015 onwards.

2 Related literature

2.1 Trade in intermediate goods and the exchange rate pass-through

Our paper relates to several strands of literature. A first strand of literature has examined the link between global value chain (GVC) participation and the exchange rate pass-through (ERPT) to domestic prices. De Soyres et al. (2018) find that a higher share of foreign value added in exports reduces the ERPT to export prices and export volumes. Georgiadis et al. (2019) estimate that the rise of global value chain (GVC) participation accounts for 50% of the decline in the ERPT to import prices observed since the mid-1990s. Hagemejer (2020) find that a growing GVC participation of the suppliers of imported intermediate consumptions reduces the ERPT to producer prices. The ERPT for countries whose suppliers are strongly involved in GVC is significantly smaller than for economies whose suppliers do not participate in GVC.

Our research also relates to the literature on the cross-border propagation of cost shocks. Auer et al. (2017) document that input-output linkages contribute substantially to synchronising producer price (PPI) inflation across countries. Antoun de Almeida (2016) show that the cross-border sectors pairs which trade more intensively with each other in intermediate inputs display higher PPI inflation correlation, indicating price spillovers along the global supply chain.

Another strand of literature has focused on the link between the ERPT and the share of intermediate consumptions in imports. The empirical literature shows that the pass-through declines across the pricing chain. Ortega et al. (2020) find that the ERPT into import prices is high and fast, whereas the ERPT into final consumer prices is significantly smaller and relatively slower (see also Hahn (2003); Kunovac and Comunale (2017); Ben Cheikh and Rault (2017).

From an input-output accounting perspective, the ERPT to consumer prices is bounded by the direct and indirect import content of consumption. Using WIOD and assuming a full exchange rate pass-through to import prices, Schaeffer (2019) finds that the sum of the direct and indirect import content in consumption was 16% in the HICP and 14% in the HICP excluding energy and food (HICPX) in 2014 in the euro area.

Another strand of literature investigates whether the ERPT is stable over time. Campa and Goldberg (2008) have documented a declining ERPT to import and consumer prices since the 1980s and 1990s. Ozyurt (2016) also shows that the pass-through is partial in the euro area. The decline in the ERPT observed over the past two decades coincided with the increasing share of emerging economies in world trade and the accession of China to the WTO. By contrast, Leigh et al. (2017) find that both the ERPT and the price elasticity of trade volumes are stable over time. In the euro area, Ortega et al. (2020) show that the ERPT into total import prices has been broadly stable over time (at around 20 %), while the ERPT to extra-euro area import prices has declined.

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

The Leontief's production model (or Input-Output model, I-O thereafter) studies the impact of a demand shock in a domestic economy (Leontief, 1951). The trade in value-added analysis reconciles international trade statistics with national I-O tables, and thus allows to extend Leontief's analysis to an international context. A number of studies (Hummels et al., 2001;

Daudin et al., 2006, 2011; De Backer and Yamano, 2012; Johnson and Noguera, 2012; Koopman et al., 2014; Amador et al., 2015; Los et al., 2016) analyse the value added content of world trade. Some authors focus on Asia (Sato and Shrestha, 2014) or on the euro area (Cappariello and Felettigh, 2015).

Leontief's production model has a dual: the price model. It studies the diffusion of cost-push inflation in the economy. Using it, 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. In France, the Insee (Bourgeois and Briand, 2019) has developed the AVIONIC model based on French symmetric input-output tables. It measures the impact of an exogenous variation in the price of inputs on the price of production. 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). Implicitly, Bems and Johnson (2015) use it as they focus on competitiveness and compute real effective exchange rates weighted by the value-added trade structure to measure the impact of a demand change in value added on value added prices and final expenditure levels. Cochard et al. (2016) relies on an accounting approach to analise the effect of costs on prices ("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 prices. 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, it assumes a unique pricing system based on market prices and independent of firms' strategies. Still, this method provides a measure of the vulnerability of each sector to price or productivity shocks (Acemoglu et al., 2012; Carvalho, 2014). Hence, though unrealistic, it is useful for identifying which countries and sectors are under pressure to adjust their prices when subject to exogenous cost shocks. For instance, it can show which euro area countries benefit most from an appreciation of the euro or whether adopting the euro has increased interdependence between member states.

3 The PIWIM model

Based on initial work from the OFCE (Observatoire Français des Conjonctures Économiques) Cochard et al. (2016), we developed a model named «PIWIM» (Push cost Inflation through World Input-output Matrices). This paper makes extensive use of this model.

3.1 Defining a price shock in a I-O model

To identify which countries are most affected by a price shock through value-added and vertical trade flows in international trade, we need a large structural matrix that integrates input flows between sectors, both within each country and between countries. This matrix traces the sectoral and geographical origin of inputs.

The standard I-O model relies on input-output tables registering transactions of goods and services (domestic or imported) at current prices. The I-O tables describe the sale and purchase

relationships between producers and consumers within an economy. Each column describes, for each industry j, the intermediate consumption of goods and services from the various sectors. By extension, a "world" I-O table (WIOT hereafter) describe the sale and purchase relationships between producers and consumers in the whole world, differentiating between sectors in different countries. The WIOT has, on its diagonal, the country blocks with flows of domestic transactions of intermediate goods and services between industries. The country blocks outside of the diagonal represent international flows of intermediate goods and services via bilateral sectoral exports and imports.
Assuming no inputs substitution between industries or countries (i.e. assuming that technical coefficients are fixed), we can derive a price equation under the assumption of complete cost pass-through.
N is equal to the product of the number of countries (I) and the number of sectors (J). Define $\mathcal{A}$ the matrix of technical input coefficient of dimension (N, N), and Y the output vector of dimension $(1, N)$. $Y = (y_1 \dots y_N)$.
Define $y_n = p_n * q_n$, with p_n the price and q_n the quantity of product from country n and normalize quantity such as $q_n = 1$.
Define P the vector of production prices of dimension $(1, N)$ and V the vector of factor income of dimension $(1, N)$ needed to produce one unit of good in each sector. The price of each good is equal to the cost of producing it: $P = P\mathcal{A} + V$.

Suppose an exogenous input price shock. Firms face a change in their costs, which - by hypothesis - they pass on directly to production prices to keep factor incomes constant. Define $\Delta^0 P$ the shock vector of dimension $(1, N)$ computed as the difference between the original price vector P^0 and the new vector P^1. Then:

$$\Delta^0 P = P^1 - P^0 = C,$$

with C the shock vector of dimension (1,N) that contains the direct effect of the shock on output prices.

The price increase is passed on to the country-specific industries that use shocked products as intermediate consumptions. The higher the reliance on shocked inputs, the higher the increase in production prices.
In a first step, the direct impact of the shock on each country-specific industry's output prices amounts to $\Delta^1 P = C\mathcal{A}$.
In a second step, the shock is passed on to all country-specific industries using these shocked inputs in their production processes. For k production cycles, the increase in production prices amounts to $\Delta^k P = C\mathcal{A}^k$.
As the technical coefficients are smaller than 1, the effect of the initial shock on input prices eventually wears out. 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. Let us call S the total effect of the shock on prices, a vector $(1, N)$ composed of the elements s_{ij} measuring the total effect of the shock on the output price of sector j in country i. We have:

$$S = C\Big(I + \mathcal{A} + \mathcal{A}^2 + ... + \mathcal{A}^k + ...\Big) = C(I - \mathcal{A})^{-1} \tag{1}$$

with $(I - \mathcal{A})^{-1}$ the inverse of Leontief's matrix.

3.2 Data

WIOTs are an extension of the national input-output tables. Input-output tables measure the relationships between the producers of goods and services (including imports) within an economy and the users of these goods and services (including exports). The national tables specify, in line, for each industry, the use of the product as intermediate or final use. In a national table, final use includes exports alongside domestic final uses, whereas exports are not a final use in world input-output tables. WIOTs show which foreign industry produced a specific good, and which foreign industry or final user uses the exports of a given country. For example, WIOTs show how much international trade is embedded in the consumption of a particular final product.
Aggregating national input-output tables into world input-output tables is challenging for many reasons. For example, national input-output tables vary widely in terms of detail and scope, and are therefore not fully consistent. Furthermore, the availability of year-specific national input-output tables is limited, especially for developing economies.
Two datasets are available: (i) the World Input Output Database (WIOD) and (ii) the OECD-ICIO database TiVA.

The World Input Output Database (WIOD) WIOD contains time series of inter-country input-output tables from 2000 to 2014. It provides wIOTs that reconcile national input-output tables (or supply-use tables) with bilateral trade statistics to derive the final symmetric world input-output table. The WIOD covers 43 countries (of which 28 members of the European Union) accounting for 85% of global GDP (see Table 1). The WIOD contains annual information for 56 industries, including the primary sector, manufacturing and services. Therefore, for each year a full country-sector input-output matrix traces the importance of a supplying industry in one country for an industry in another country. The values in WIOTs are expressed in U.S. dollars; market exchange rates were used for currency conversion (Timmer et al., 2015).

Europe	Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, United Kingdom
North America	Canada, United States
Latin America	Brazil, Mexico
Asia-Pacific	Australia, China, India, Indonesia, Japan, Korea, Taiwan
Other	Russia, Turkey

Table 1: **Economies included in the World Input-Output Database**

The Trade in Value Added (TiVA) database The TiVA database is compiled by the OECD and the WTO. It builds on the OECD harmonized individual country input-output tables to provide matrices of inter-industrial flows of goods and services in current prices (USD). We use two versions of TiVA (see OECD (Decembre 2018) on the differences between the two datasets). The third revision, released in 2016, includes 64 economies (i.e. 35 OECD Countries, 28 non-OECD economies and the Rest of the world) and 34 industries, and covers the period 1995-2011. The fourth revision, released in 2018, includes 65 economies (see Table 2) and 36 sectors and covers the 2005-2015 period.

Europe	Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, United Kingdom
North America	Canada, United States
Latin America	Argentina, Brazil, Chile, Colombia, Costa Rica, Mexico (differentiating between three (Rev. 3) or two (Rev. 4) Mexico), Peru
Asia-Pacific	Australia, Cambodia, China (differentiating between four (Rev. 3) or three (Rev. 4) China), Hong Kong SAR, India, Indonesia, Japan, Khazakhstan (in Rev. 4), Korea, Malaysia, New Zealand, Philippines, Singapore, Taiwan, Thailand, Viet Nam
Other	Brunei, Israel, Morocco, Russia, Saudi Arabia, South Africa, Tunisia, Turkey

Table 2: **Economies included in TiVA revisions 3 and 4**

Major differences between the WIOD and TiVA databases The WIOD and TiVA databases have distinct characteristics (see Timmer et al. (2015)). The most relevant difference for our analysis relates to the allocation of specific imports to using industries.

National input-output statistics provide the use of products by industries and final consumers. However, the breakdown of the use table into domestic and imported origin is not available. Hence, the construction of world input-output tables requires allocating imports to using industries.

The TiVA database relies on the "import proportionality assumption" to allocate specific imports to using industries: for a given product, one assumes that the proportion of intermediates that an industry purchases from abroad is equal to the ratio of imports to total domestic demand in that product[1]. This assumption can be misleading. Feenstra and Jensen (2012) find that shares of imported materials may differ substantially across U.S. industries. Based on Asian input-output tables, Puzzello (2012) finds that the proportionality assumption understates the use of foreign intermediate inputs. It is likely to be particularly binding for developing countries, as the import content of exports is usually higher than the import content of products used for domestic consumption.

By contrast, the WIOD does not rely on the standard import proportionality assumption. Its imputation method relies on a classification of detailed products in bilateral trade statistics. Imports are allocated across three use categories (intermediate use, final consumption and investment) by mapping detailed six-digit products in the International Trade Statistics (Dietzenbacher et al., 2013).

[1]See OECD and WTO (2011) for details.

To sum up, the WIOD includes information on bilateral industry-specific input use, whereas such information exists only in imputed form in TiVA.

3.3 Nominal exchange rate shock

We implement an exchange rate shock using WIOD. The appreciation of the currency of country A leads to a fall in the domestic-currency price of country A's imports, while the foreign-currency price of its exports increase. We mainly focus on the disinflationary impact of this shock on country A. We also estimate the inflationary impact on countries that directly and indirectly consume, through third countries linkages, inputs from country A.
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 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 its exchange rate against the dollar has not changed. Conversely, the prices of imported inputs in country A remain constant in dollars, since the production prices of country B have not changed, and fall by half once expressed in country A's national currency.
We assume that producers completely pass the exchange rate shock on their production prices. The change in the prices of imported goods is therefore transmitted to all domestic prices, both directly and through inter-industry linkages. These upward (downward) movements for country B (country A) affect all input prices in both countries.
The effects of the shock spread over multiple production cycles. At the end of this process, the overall impact of the shock in dollar terms is equal, for the shocked country A, to the rise in production prices due to the exchange rate shock, minus direct and indirect decreases (via inter-industry linkages in the country), 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 is equal to the cumulative direct and indirect effects of the higher prices of imported inputs.

In a global economy composed of I countries, each with J sectors, the appreciation of a country's currency i against all other currencies translates into a rise in country i's prices in dollars. The production price of each sector will vary in dollar terms by: $c^i_\$$ in the shock-stricken country i and 0 in other countries.
Hence, for each sector j in country i:

$$\Delta^0 p_{\$ij} = p^1_{\$ij} - p^0_{\$ij} = c_{\$ij} = c^i_\$$$

And for each sector j in country $k (k \neq i)$,

$$\Delta^0 p_{\$kj} = p^1_{\$kj} - p^0_{\$kj} = c_{\$kj} = 0$$

To simplify, initial output prices for each sector are normalised 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 i and other countries.

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

$$\Delta^1 p_{\$kl} = c_{\$}^{i} * a_{kl,i1} + \ldots + c_{\$}^{i}.a_{kl,ij} + \ldots + c_{\$}^{i}.a_{kl,iJ} = \sum_{j=1}^{J} c_{\$}^{i}.a_{kl,ij} = c_{\$}^{i}.\sum_{j=1}^{J} a_{kl,ij} \tag{2}$$

With $a_{kl,ij}$ the quantity of inputs from the country i's sector j needed to develop a production unit for the country's k sector l.

For the shocked country, the shock has a disinflationary effect on domestic production prices. In national currency, the production prices of imported inputs fall in each sector by $c^i = -\frac{c_{\$}^{i}}{1+c_{\$}^{i}}$, or by 0.5 with $c_{\$}^{i} = 1$.

This decline then spreads to all domestic-input using sectors. In sector j of the shocked country i, this fall amounts in national currency to:

$$\Delta^1 p_{ij} = \sum_{l=1}^{l=J} c^i.a_{ij,1l} + \ldots + \sum_{l=1}^{l=J} c^i.a_{ij,kl} + \sum_{l=1}^{l=J} c^i.a_{ij,pl} = \left(-\frac{c_{\$}^{i}}{1+c_{\$}^{i}}\right).\sum_{\substack{k=1 \\ k \neq i}}^{k=I} \left[\sum_{l=1}^{l=J} a_{ij,kl}\right]$$

This level shock can be converted into dollars:

$$\Delta^1 p_{\$ij} = \left(1+c_{\$}^{i}\right).\left(-\frac{c_{\$}^{i}}{1+c_{\$}^{i}}\right)\sum_{\substack{k=1 \\ k \neq i}}^{k=I} \left[\sum_{\mathrm{l}=1}^{l=J} a_{ij,kl}\right] \tag{3}$$

We therefore know the direct impact of the shock on all input prices of all countries. In matrix notation, we create two matrices that build on the world input-output matrix A defined in 3.1. These two matrices retain only the direct effects of the exchange rate shock on the price of goods imported by the shocked country i and the direct effects of the exchange rate shock on the price of goods imported by the rest of the world from country i. To formalise 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 that import inputs from country i.

Let $C^i_\$$ be the vector of change in production prices in dollars following the appreciation of the currency of country i against all other currencies. Hence,

$$C^i_\$ = \big(0\dots0\dots c_{\$ij}\dots c_{\$ik}\dots0\dots0\big)$$

with $c_{\$ij} = c_{\$ik} = c^i_\$$ for all sectors j and k in the shocked country i.

Building on Equation 2, the direct impact of the exchange rate shock on the other countries corresponds to the product of the shock vector $C^i_\$$ and a matrix $\mathcal{B}$. $\mathcal{B}$ builds on the large matrix $\mathcal{A}$ of technical coefficients, but only keeps the coefficients of each country's sectoral inputs imported from the shocked country i. The other coefficients are replaced by 0, including those of the block of country i concerning the domestic inputs of country i. The direct impact of the appreciation of a currency against the dollar on the price of inputs in countries that are not shocked is equal to $C^i_\$\mathcal{B}$ with

$$C^i_\$\mathcal{B} = \big(0\dots c^i_\$\dots0\big)\begin{pmatrix} 0 & \cdots & 0 \\ a_{11,ij} & 0 & a_{IJ,ij} \\ 0 & \cdots & 0 \end{pmatrix} \tag{4}$$

where each $a_{kl,ij}$ element of the line block represents the technical coefficient related to imports of inputs by sector l in country k (with $k \neq i$) from sector j of country i.

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

Define C^i the vector of change in production prices everywhere expressed in country i's currency, $\left(-\frac{c^i_\$}{1+c^i_\$},\dots0\dots,-\frac{c^i_\$}{1+c^i_\$}\right)$.

From Equation 3, we can write the direct impact for country i of the fall in input prices from the rest of the world. The direct impact corresponds to the product of the shock vector C^i and a matrix $\tilde{\mathcal{B}}$. $\tilde{\mathcal{B}}$ builds on the large matrix $\mathcal{A}$ of which only the country blocks of the inputs imported by country i from other countries have been retained. The other coefficients are replaced by 0, including those of the block of country i concerning the domestic inputs of country i.

The direct impact of the appreciation of the shocked country i on the price of its inputs corresponds, in national currency, to $C^i\tilde{\mathcal{B}}$ with:

$$C^i\tilde{\mathcal{B}} = \left(-\frac{c^i_\$}{1+c^i_\$},\dots0\dots,-\frac{c^i_\$}{1+c^i_\$}\right)\begin{pmatrix} 0 & \dots a_{ij,11}\dots & 0 \\ 0 & 0 & 0 \\ 0 & \dots a_{ij,IJ}\dots & 0 \end{pmatrix} \tag{5}$$

where each $a_{ij,kl}$ element in the column block represents imports of inputs by sector j in country

i from sector l of country k. We then convert this direct impact in dollars, by multiplying it by the new value of the national currency in dollars, $\left(1 + c_{\$}^{i}\right)$. The direct impact of the appreciation of the shocked country i on the price of its inputs corresponds, in dollars, to $\tilde{C}_{\$}^{i}\tilde{\mathcal{B}}$ with:

$$\tilde{C}_{\$}^{i}\tilde{\mathcal{B}} = \left(1 + c_{\$}^{i}\right).C^{i}\tilde{\mathcal{B}} = \left(-c_{\$}^{i} \dots 0 \dots - c_{\$}^{i}\right) \begin{pmatrix} 0 & \dots a_{ij,11} \dots & 0 \\ 0 & 0 & 0 \\ 0 & \dots a_{ij,IJ} \dots & 0 \end{pmatrix} \tag{6}$$

The direct effect on the world is therefore the sum of these vectors from equations 4 and 6, i. e. $C_{\$}^{i}.\mathcal{B} + \tilde{C}_{\$}^{i}\tilde{\mathcal{B}}$.
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 sectoral effect of the dollar shock is equal to the sectoral 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 production processes, i. e.:

$$S_{\$}^{i} = \Delta P_{\$}^{i} = C_{\$}^{i} + \left(C_{\$}^{i}.\mathcal{B} + \tilde{C}_{\$}^{i}\tilde{\mathcal{B}}\right) + \left(C_{\$}^{i}.\mathcal{B} + \tilde{C}_{\$}^{i}\tilde{\mathcal{B}}\right)\mathcal{A} + \left(C_{\$}^{i}.\mathcal{B} + \tilde{C}_{\$}^{i}\tilde{\mathcal{B}}\right)\mathcal{A}^{2} + \dots + \left(C_{\$}^{i}.\mathcal{B} + \tilde{C}_{\$}^{i}\tilde{\mathcal{B}}\right)\mathcal{A}^{k} + \dots$$

$$S_{\$}^{i} = C_{\$}^{i} + \left(C_{\$}^{i}.\mathcal{B} + \tilde{C}_{\$}^{i}\tilde{\mathcal{B}}\right) * (I - \mathcal{A})^{-1} \tag{7}$$

With $S_{\$}^{i}$ the total impact vector composed of the elements $s_{\$kj}^{i}$ showing the total impact of a shock on country i's exchange rate on country k's sector j. Equation 7 gives the absolute evolution of sectoral prices in international currency. The study of this vector is the main objet of Cochard et al. (2016). //

By contrast, this paper focuses on the internal effect of an exchange rate shock. To obtain the absolute evolution of the sectoral prices of the shocked country in national currency, we remove the exchange rate shock in international currency, multiply the balance by the scalar of conversion equal to $\frac{1}{1+c_{\$}^{i}}$ and add the initial exchange rate shock in national currency.

$$\begin{aligned} S^{i} &= C^{i} + \left(\frac{1}{1 + c_{\$}^{i}}\right) * \left(S_{\$}^{i} - C_{\$}^{i}\right) \\ &= C^{i} + \left(\frac{1}{1 + c_{\$}^{i}}\right) * \left(C_{\$}^{i}.\mathcal{B} + \tilde{C}_{\$}^{i}\tilde{\mathcal{B}}\right) * (I - \mathcal{A})^{-1} \\ &= C^{i} + \left(\hat{C}_{\$}^{i}.\mathcal{B} + C^{i}\tilde{\mathcal{B}}\right) * (I - \mathcal{A})^{-1} \end{aligned} \tag{8}$$

Where $\hat{C}_{\$}^{i} = \left(0 \dots \frac{c_{\$}^{i}}{1+c_{\$}^{i}}, \dots 0\right)$ is the increase in dollar prices of goods from country i used as inputs in all other countries.
S^{i} represents the overall impact of a shock on prices in each sector of each country expressed in the shocked currency. It is quite different from S defined in eq. (1), because in the case of S,

the price shock affects all users, whereas in the case of S^i, the price shock affects only users that do not share a currency with country i. To illustrate the difference, the two-country, one sector case is explored in Appendix 1.

To convert this vector into a price-level shock in country i, $\bar{s}^i$, we compute a weighted average of the sectoral effects of the shock. This paper focuses on the price of household consumption. Let HC^i be the vector of sectoral shares in country i's consumption :

$$HC^i = \begin{pmatrix} \frac{hc^i_{11}}{hc^i} \\ \cdots \\ \frac{hc^i_{kj}}{hc^i} \\ \cdots \\ \frac{hc^i_{IJ}}{hc^i} \end{pmatrix}$$

Where hc^i_{kj} corresponds to household consumption in country i of goods produced by sector j from country k and hc^i represents the total household consumption of country i.
$\overline{s_i}^{i,HC}$ provides the average impact of the shock on the consumer price of country i.

$$\overline{s}_i^{i,HC} = S^i.HC^i = \sum_{\substack{j=1...J \\ k=1...I}} s^i_{kj}.\frac{hc^i_{kj}}{hc^i} \tag{9}$$

with s^i_{kj} is a coefficient of S^i for country i.

4 The impact of exchange rates fluctuations on consumer prices

We use the model presented in 3.3 to analyse the impact of an exchange rate shock on consumer prices. We focus on the absolute value of $\overline{s_i}^{i,HC}$ following a 100% appreciation of the domestic currency versus all other currencies. Following an apreciation of the domestic currency, imported inputs and imported consumer goods become cheaper. Hence, domestic prices expressed in domestic currency decrease. As our model is linear, the exact value of the shock does not matter: choosing 100% allows us to interpret $\overline{s_i}^{i,HC}$ as an elasticity. Using the WIOD database, we find that a 100% appreciation of the dollar reduce the U.S. consumer prices by 5.5%.

Additionaly, for euro-area members, we distinguish between the effect of the appreciation of the euro and the effect of the appreciation of a hypothetical national currency. For France, using WIOD, a 100% appreciation of the euro leads to a 7.6% reduction of domestic prices. A 100% appreciation of the hypothetical French national currency leads to a 12.2% reduction of domestic prices.

Using a sample of 43 countries, we plot the elasticity of consumer prices over time. Figure 1 shows that the evolution is similar, regardless of the database (WIOD or TIVA).

However, using data from TIVA rev3 yields a slightly higher elasticity (see Figure 2).

Using data from WIOD, Figure 3 shows that, in absolute terms, the elasticity lies between 0.05 and 0.15 for most countries. Figure 4 shows that the value of the elasticity is closely related to the share of imported goods and services in household consumption.

We look at the contribution of domestic versus imported goods to the total impact of an

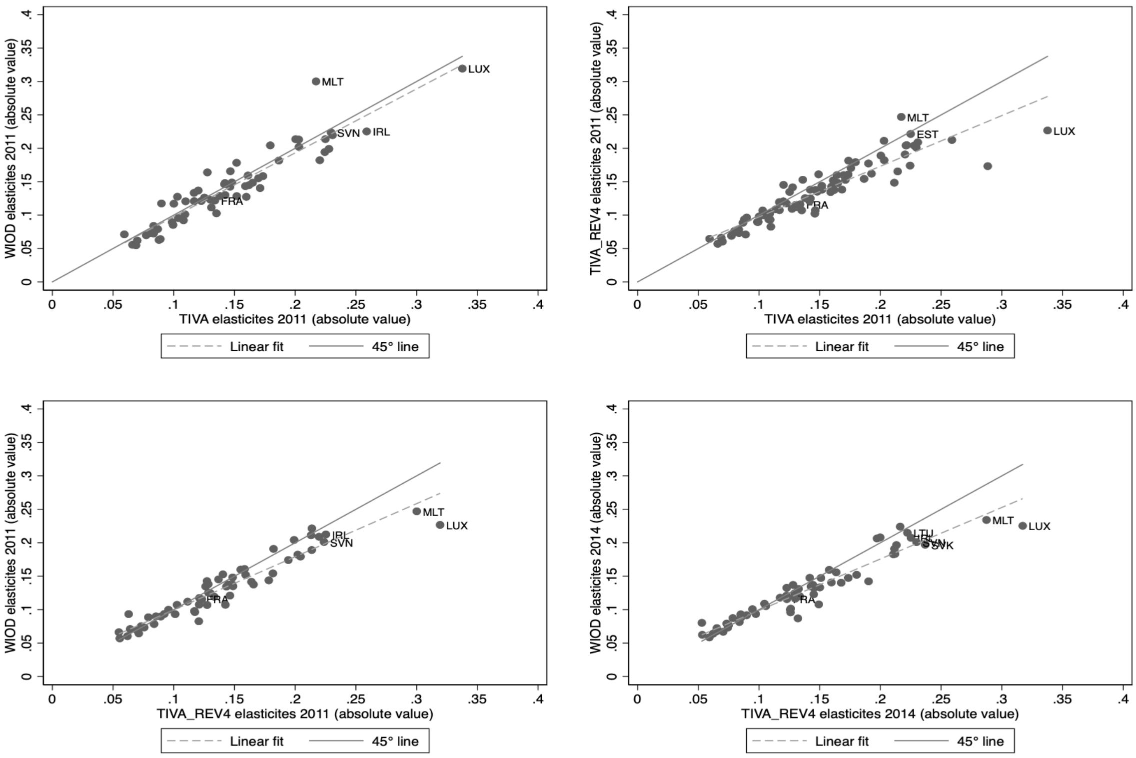

Figure 1: **Comparing consumer price elasticity to an exchange rate appreciation of 100% for WIOD, TIVA and TIVA rev4, 2011 and 2014**

Source: WIOD, TIVA rev3 and TIVA rev4

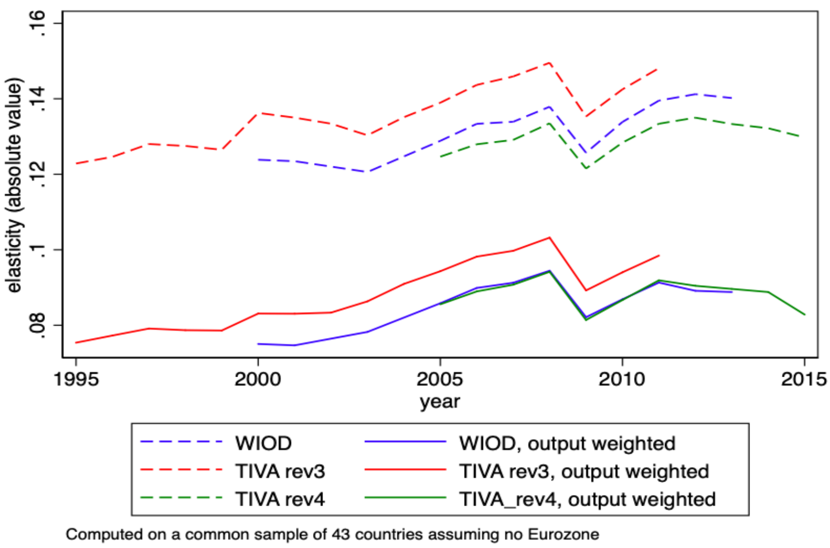

Figure 2: **Comparing the elasticity of consumer prices to an exchange rate appreciation of 100% for WIOD and TIVA, 1995-2014**

Source: WIOD and TIVA

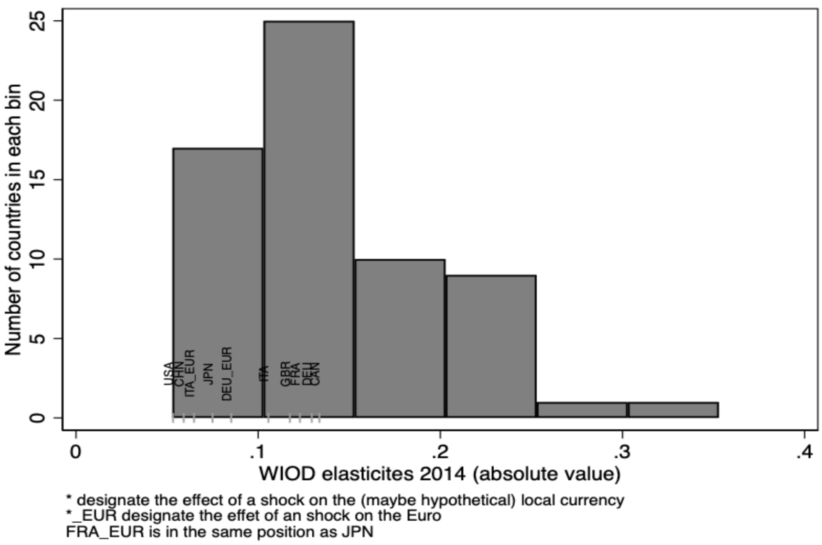

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Figure 3: **Distribution of the elasticity of consumer prices to a 100% exchange rate appreciation (WIOD)**

Source: WIOD

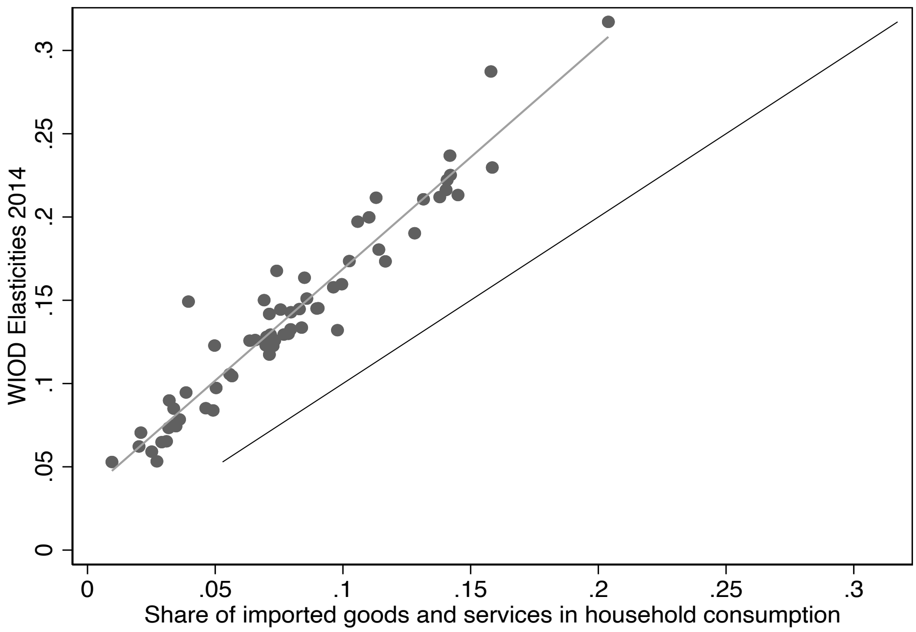

Figure 4: **Elasticity of consumer prices to an exchange rate shock and the share of imported consumption (WIOD)**

exchange rate shock on consumer prices. We define

$$\overline{s}_{i}^{i,HC} = \overline{s}_{i,imp}^{i,HC} + \overline{s}_{i,dom}^{i,HC} = S^{i}.HC^{i,dom} + S^{i}.HC^{i,imp} \tag{10}$$

Where:

$$\begin{array}{ccccc} HC^i & = & HC^{i,dom} & + & HC^{i,imp} \\ & = & \begin{pmatrix} 0 \\ ... \\ \frac{hc^i_{ij}}{hc^i} \\ ... \\ 0 \end{pmatrix} & + & \begin{pmatrix} \frac{hc^i_{11}}{hc^i} \\ ... \\ 0 \\ ... \\ \frac{hc^i_{IJ}}{hc^i} \end{pmatrix} \end{array} \tag{11}$$

For example,

$$\bar{s}^{i,HC}_{i,imp} = \sum_{\substack{j=1...J \\ k=1...I \\ k \neq i}} s^i_{kj} . \frac{hc^i_{kj}}{hc^i} \tag{12}$$

Figure 5 shows that the prices of imported final consumer goods contribute most to the total effect. Although imported final consumer goods account for a smaller share of total consumption than domestic goods, they are the most impacted by the initial exchange rate shock. Imported final consumer goods also explain the differences in price elasticities observed between open and less open economies.

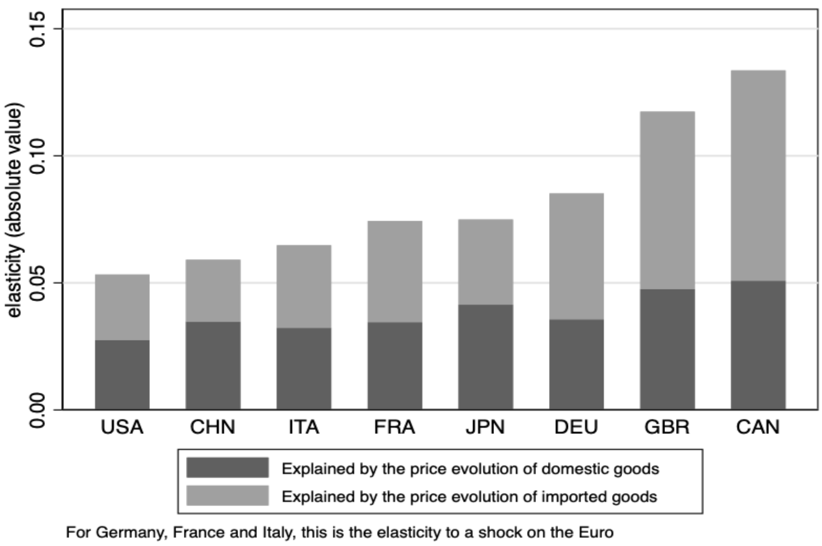

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Figure 5: **Contribution of imported and domestic goods to the elasticity of consumer prices to a 100% exchange rate appreciaton**

Source: WIOD, 2014

We also analyse the impact of global inflationary shocks on the main components of consumer prices (manufacturing goods, services, food and energy). Non-energy industrial goods make the bulk of the total impact (Figure 6). However, services also play a significant role, especially in advanced economies. Although services are mainly produced domestically and do not rely much on imported inputs, they make up a substantial share of total consumption. Similarly, domestic core inflation accounts for a significant share of the total impact (Figure 7), reflecting the weight of domestic services and non-energy industrial goods in total consumption.

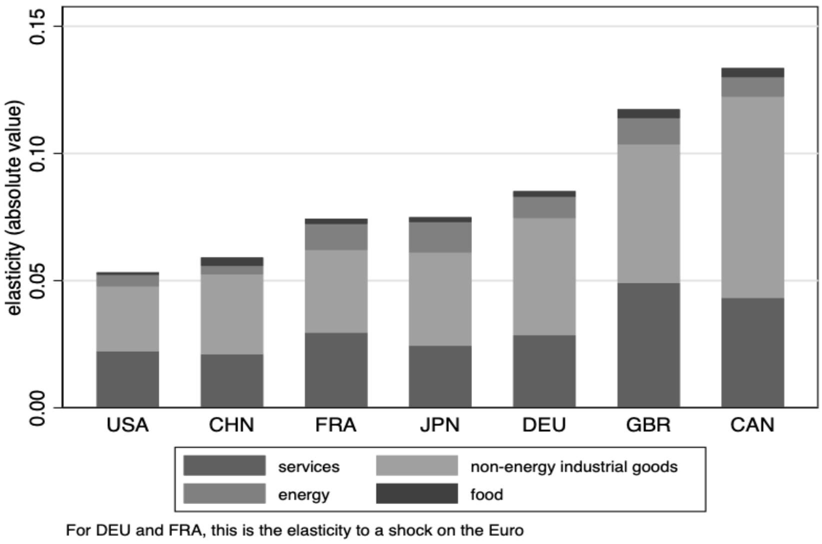

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Figure 6: **Contribution of different products to the elasticity of consumer prices**

Source: WIOD, 2014

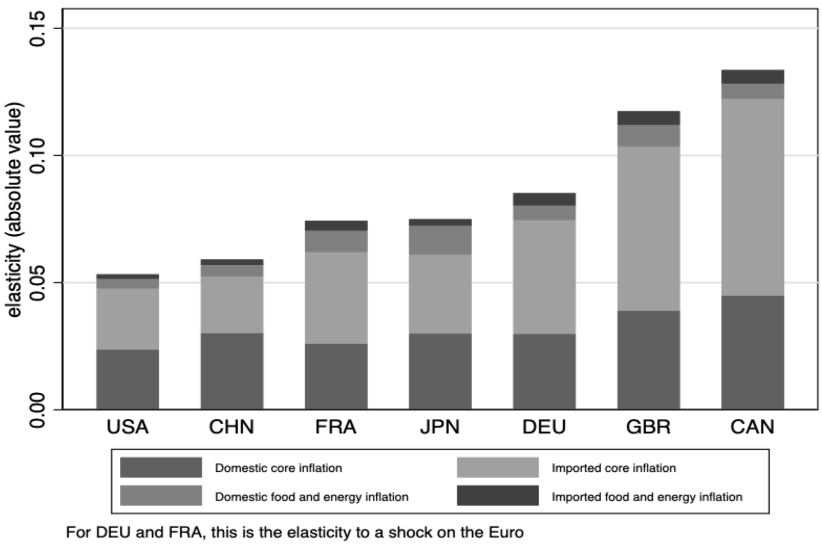

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Figure 7: **Contribution of domestic and imported components to the elasticity of consumer prices**

Source: WIOD, 2014

5 Can we extrapolate the consumer price elasticity?

5.1 Doing without the world input-output matrices

World input-output matrices are not available for the most recent years (the latest years covered by WIOD and TiVA are, respectively, 2014 and 2015). In addition, using WIOTs involves complex computations. Given these difficulties, we look for a simpler way to compute the elasticity of consumer prices to the exchange rate. We break down $\overline{s_i}^{i,HC}$ into different elements classified by ease of use and computation. Let us start from equation 8. We have:

$$
\begin{aligned}
S^i &= C^i + \left(\hat{C}^i_{\$}.\mathcal{B} + C^i\tilde{\mathcal{B}}\right) * (I-\mathcal{A})^{-1} \\
S^i &= \underbrace{C^i}_{\substack{\text{(E1) direct effect through} \\ \text{imported consumption goods}}} + \underbrace{C^i\tilde{\mathcal{B}}}_{\substack{\text{(E2) effect on} \\ \textit{domestic}\text{ consumption goods} \\ \text{through }\textit{imported}\text{ inputs}}} + \underbrace{\hat{C}^i_{\$}.\mathcal{B}}_{\substack{\text{(E3) effect on} \\ \textit{imported}\text{ consumption goods} \\ \text{through }\textit{domestic}\text{ inputs}}} \\
&+ \underbrace{\left(\hat{C}^i_{\$}.\mathcal{B} + C^i\tilde{\mathcal{B}}\right) * (I-\mathcal{A})^{-1} * \mathcal{A}}_{\text{(E4) residual}}
\end{aligned}
\tag{13}
$$

C^i and $\hat{C}^i_{\$}$ have a large number of zeros. So, we have:

$$
\begin{aligned}
\overline{s}_i^{i,HC} &= S^i.HC^i = E1.HC^i + E2.HC^i + E3.HC^i + E4.HC^i \\
&= E1.HC^{i,imp} + E2.HC^{i,dom} + E3.HC^{i,imp} + E4.HC^i
\end{aligned}
\tag{14}
$$

When the domestic currency appreciates, $E1$ and $E2$ reduce country i consumer prices whereas $E3$ increases them.

This decomposition differs from equation 10. Equation 10 focuses on the contribution of domestic versus imported goods to the total impact of an exchange rate shock on consumer prices. By contrast, equation 14 highlights the transmission channels of the shock.

Figure 8 plots the shares of $E1.HC^{i,imp}$, $E2.HC^{i,dom}$, $E3.HC^{i,imp}$ and $E4.HC^i$ in $\overline{s}_i^{i,HC}$. $E1.HC^{i,imp}$ dominates. While $E3.HC^{i,imp}$ is negligible, $E4.HC^i$ accounts for 10% to 30% of $\overline{s}_i^{i,HC}$ for most countries except China.

$E1$ and $E2$ can be computed with national input-output matrices whereas world input-output matrices are needed for computing $E3$ and $E4$. World input-output matrices are not available for the most recent years. Yet $E4.HC^i$ can be inferred from easier-to-compute elements of $\overline{s}_i^{i,HC}$.

We try to infer $\overline{s}_i^{i,HC}$ from $E1.HC^{i,imp}$ and $E2.HC^{i,dom}$. Figure 9 depicts the relationship between $\overline{s}_i^{i,HC}$ and $E1.HC^{i,imp} + E2.HC^{i,dom}$ according to equation 15. The high R^2 (0.98) suggests that $E1.HC^{i,imp} + E2.HC^{i,dom}$ is a good predictor of $\overline{s}_i^{i,HC}$.

$$
\overline{s}_i^{i,HC} = \alpha + \beta\left(E1.HC^{i,imp} + E2.HC^{i,dom}\right) + \varepsilon_i \tag{15}
$$

We check whether the relationship is constant over time by estimating yearly cross-sections of equation 15. With the exception of 2009, the relationship is broadly stable (see Figures 10 and 11).

We obtain similar results with TiVA (see Appendix C). Our results suggest that we can approximate the elasticity of consumer prices for the most recent years, using the share of imported goods in household consumption and the share of imported inputs in household consumption of domestic goods.

5.2 Doing without TiVA and WIOD, but keeping Eurostat

However, these data are not up-to-date for a large number of countries. These shares are not routinely computed by national statistical institutes. We have to use a proxy. It is fairly easy to

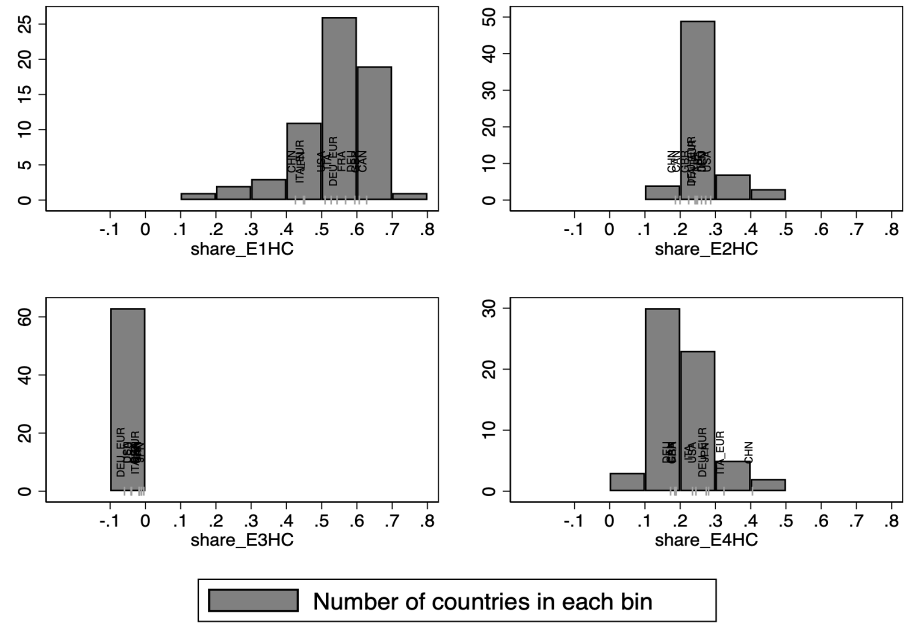

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Figure 8: **Decomposition of** $\bar{s}_i^{i,HC}$

Source: WIOD, 2014

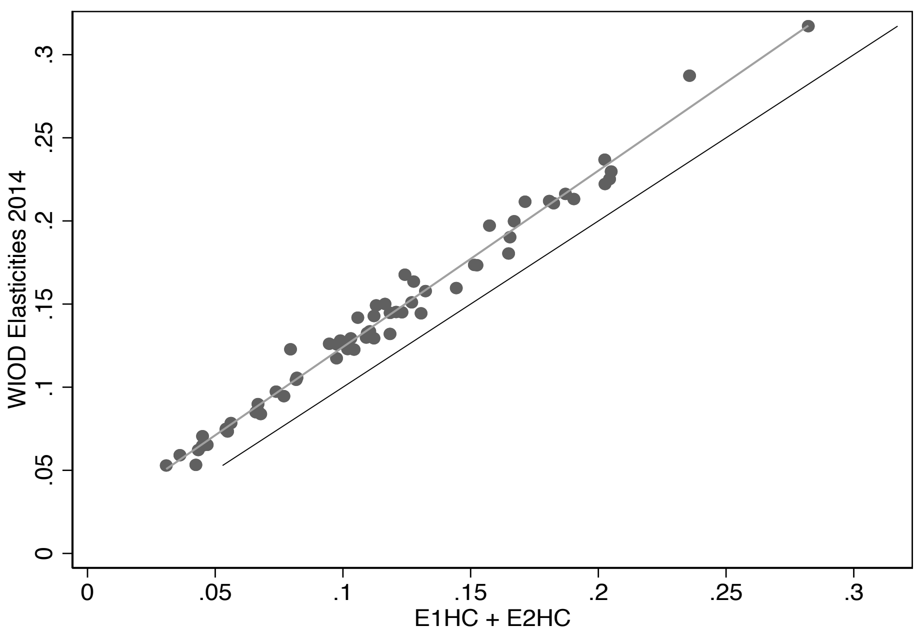

Figure 9: **Comparing** $\bar{s}_i^{i,HC}$ **and** $E1.HC^{i,imp} + E2.HC^{i,dom}$

identify consumption and intermediary goods imports using UN Comtrade data and the BEC classification. The World Bank provides regular estimates of household consumption.It does not provide an estimate for intermediate consumptions. In the case of European countries[2],

[2]And some others for selected years

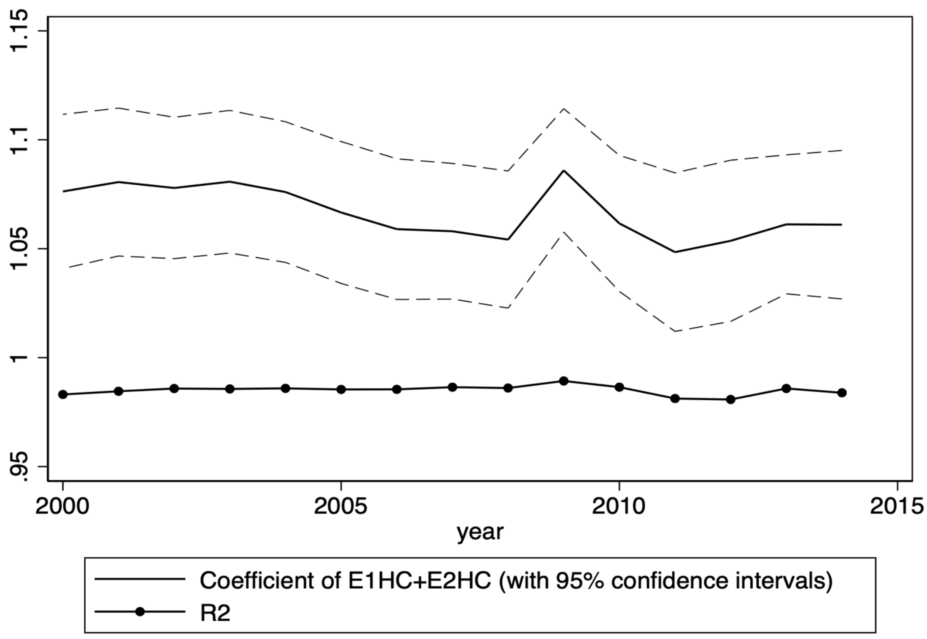

Figure 10: **Evolution of β and $R2$ over time (WIOD)**

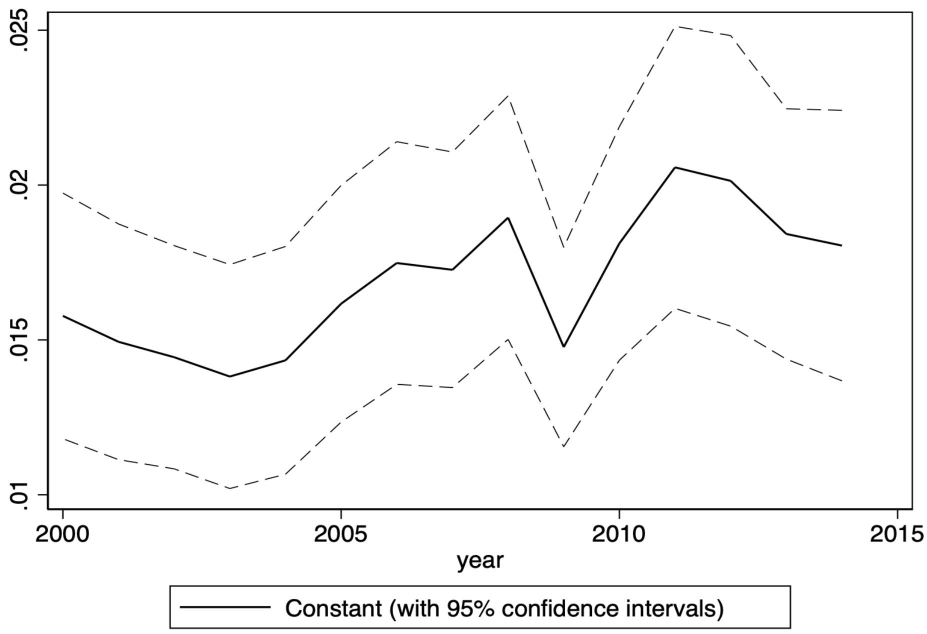

Figure 11: **Evolution of α over time (WIOD)**

Eurostat provides estimates for intermediate consumptions.

Combining these three data sources, we compute the share of imported consumption goods in household consumption and the share of imported inputs in all inputs.

We mimick equation 15 by equation 16. We estimate successive cross-sections of equation 16 to check whether the proxy is satisfactory.

$$\overline{s}_i^{i,HC} = \alpha + \beta[\ \frac{\text{imported consumption goods}_i}{\text{household consumption}_i} + \frac{\text{imported intermediate goods}_i}{\text{intermediate consumption}_i} * \left(1 - \frac{\text{imported consumption goods}_i}{\text{houshold consumption}_i}\right)] + \varepsilon_i \quad (16)$$

In the same way, Figure 12 mimicks Figure 10. The results are less encouraging: the R^2 is smaller and declining over time, and the estimated coefficient is not constant.

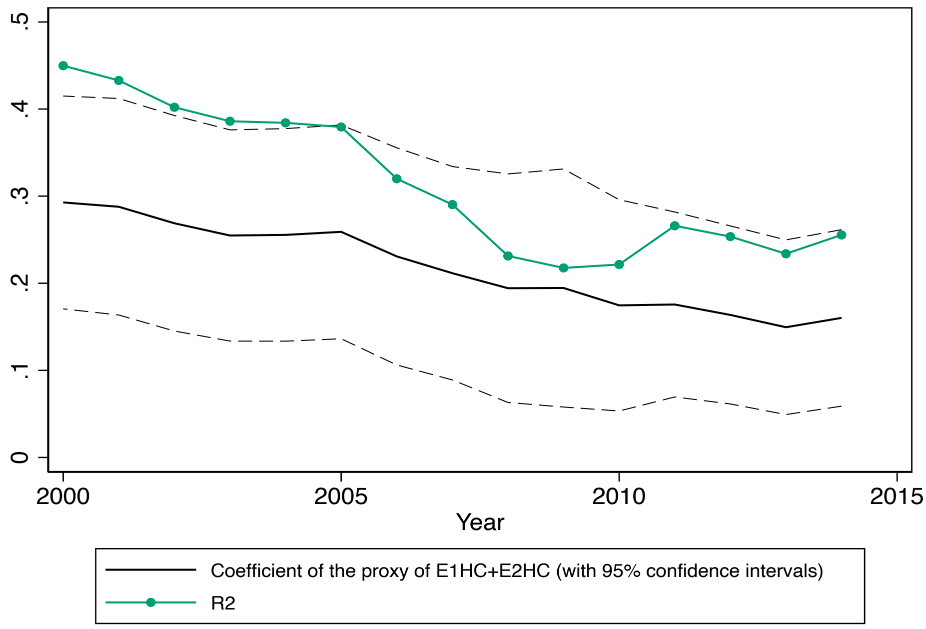

Figure 12: **Evolution of β and $R2$ (WIOD) using Eurostat data to approximate E1HC + E2HC (limited number of countries)**

Estimating successive cross-sections of equation 16 is a demanding test. In addition, cross-sections do not take advantage of country-specific information. To address this caveat, we run a panel regression with country-fixed effects. We assume that β is constant over time for each country i (equation 17).

$$\overline{s}_{i,t}^{i,t,HC} = \alpha + \beta[\ \frac{\text{imported consumption goods}_{i,t}}{\text{household consumption}_{i,t}} + \frac{\text{imported intermediate goods}_{i,t}}{\text{intermediate consumption}_{i,t}} * \left(1 - \frac{\text{imported consumption goods}_{i,t}}{\text{houshold consumption}_{i,t}}\right)] + fe_i + \varepsilon_{i,t} \quad (17)$$

We run the panel regressions for the period 2000 to 2008. We then estimate the out-of-sample elasticity for each country i for 2014. The outcome is close to the elasticity computed with WIOD for 2014 (see Figure 13). Hence, we could use this approach to estimate the elasticity of consumer prices from 2015 onwards.

5.3 Doing without Eurostat

Data on intermediate consumption and household consumption are not available for all countries. As a result, our regressions only include a limited number of observations. To expand our panel,

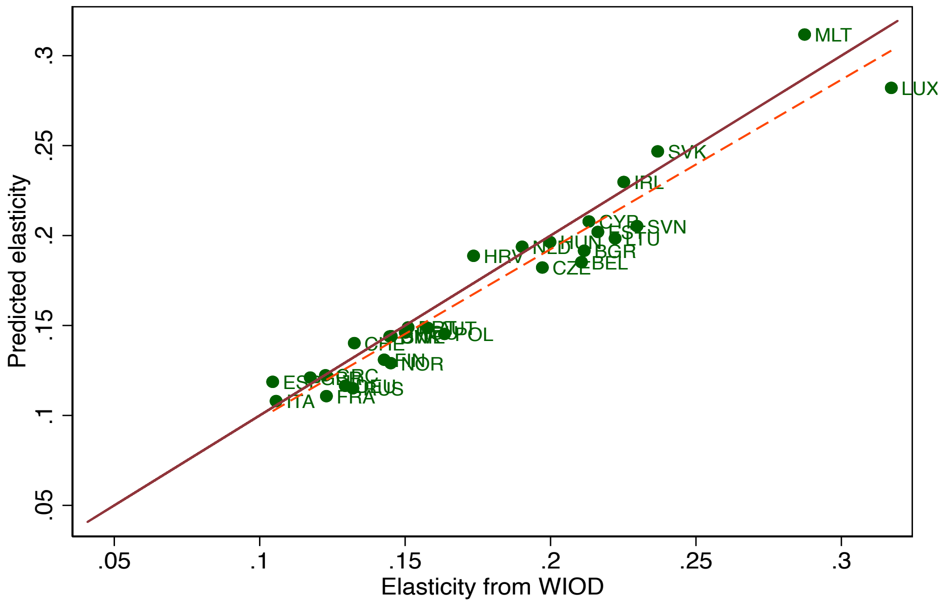

Figure 13: **Comparing the elasticity computed from WIOD in 2014 with the one predicted from a panel regression between 2000 and 2008**

we use an even simpler proxy for E1HC+E2HC that requires only trade data from Comtrade and GDP data from the World Bank. It becomes therefore possible to include many more countries in the new panel (see equation 18).

$$\overline{s}_{i,t}^{i,t,HC} = \alpha + \beta[\frac{\text{imported consumption goods}_{i,t}}{\text{GDP}_{i,t}} + \frac{\text{imported intermediate goods}_{i,t}}{\text{GDP}_{i,t}}] + fe_i + \varepsilon_{i,t} \tag{18}$$

The out-of-sample prediction remains satisfactory, although the mean and median errors are larger (see Figure 14). Our findings are robust to using other databases (revision 3 and revision 4 of TIVA)[3].

6 Conclusion

This paper focuses on the accounting effect of exchange rate fluctuations on consumer prices. We use different world input-ouptut databases that capture the evolution of global value chains over a twenty-year period (from 1995 to 2015). We estimate the elasticity of domestic consumer prices to a shock on the domestic currency. The elasticity varies between 0.05 and 0.35 depending on the country. It is strongly correlated with the openness rate: the more open a country is, the higher its elasticity. Based on the third revision of TiVA database, we find that the output-weighted elasticity has increased by 25% between 1995 and 2008, to 0.1 in 2008. After contracting in 2009, this elasticity has stabilised below its 2008 level, according to WIOD and the fourth revision of the TiVA database. We also analyse the impact of global inflationary shocks on the main components of consumer prices. Domestic core inflation accounts for a significant share of the

[3]Results are available upon request

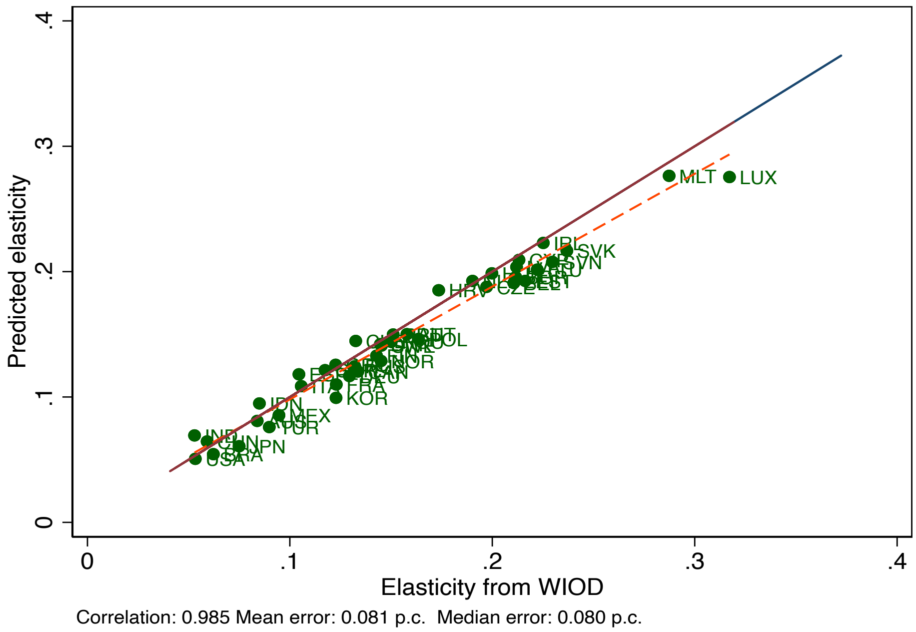

Figure 14: **Comparing the elasticity computed with WIOD for 2014 with the forecast from a panel regression estimated on the period 2000-2008**

total impact, reflecting the weight of domestic services and non-energy industrial goods in total consumption.

Following an exchange rate shock, the first-round effects (through imported inputs and final goods) explain three-quarters of the propagation of global shocks to domestic prices. By contrast, we find a limited role for the secound-round effects, i.e. the additional transmission of lower domestic input prices to other sectors of the domestic economy and other countries occurring during subsequent production cycles. The first-round effects are a good predictor of the total effects.

The construction of World Input-Output tables is data-demanding and WIOTs are typically released with a lag of several years. To address this gap, we use more up-to-date GDP and trade data to approximate the accounting impact of an exchange rate shock on consumer prices from 2015 onwards. Our proxy is helpful for assessing the impact of global value chains shocks on inflation from 2015 onwards.

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A WIOD Sectors

A01	Crop and animal production, hunting and related service activities
A02	Forestry and logging
A03	Fishing and aquaculture
B	Mining and quarrying
C10-C12	Manufacture of food products, beverages and tobacco products
C13-C15	Manufacture of textiles, wearing apparel and leather products
C16	Manufacture of wood and of products of wood and cork, except furniture; articles of straw and plaiting materials
C17	Manufacture of paper and paper products
C18	Printing and reproduction of recorded media
C19	Manufacture of coke and refined petroleum products
C20	Manufacture of chemicals and chemical products
C21	Manufacture of basic pharmaceutical products and pharmaceutical preparations
C22	Manufacture of rubber and plastic products
C23	Manufacture of other non-metallic mineral products
C24	Manufacture of basic metals
C25	Manufacture of fabricated metal products, except machinery and equipment
C26	Manufacture of computer, electronic and optical products
C27	Manufacture of electrical equipment
C28	Manufacture of machinery and equipment n.e.c.
C29	Manufacture of motor vehicles, trailers and semi-trailers
C30	Manufacture of other transport equipment
C31-C32	Manufacture of furniture; other manufacturing
C33	Repair and installation of machinery and equipment
D35	Electricity, gas, steam and air conditioning supply
E36	Water collection, treatment and supply
E37-E39	Sewerage and other waste management services
F	Construction
G45	Wholesale and retail trade and repair of motor vehicles and motorcycles
G46	Wholesale trade, except of motor vehicles and motorcycles
G47	Retail trade, except of motor vehicles and motorcycles
H49	Land transport and transport via pipelines
H50	Water transport
H51	Air transport
H52	Warehousing and support activities for transportation
H53	Postal and courier activities
I	Accommodation and food service activities
J58	Publishing activities
J59-J60	Motion picture, video and television programme production; programming and broadcasting activities
J61	Telecommunications
J62-J63	Computer programming, consultancy; information service activities
K64	Financial service activities, except insurance and pension funding
K65	Insurance, reinsurance and pension funding, except compulsory social security
K66	Activities auxiliary to financial services and insurance activities
L68	Real estate activities
M69-M70	Legal and accounting activities
M71	Architectural and engineering activities; technical testing and analysis
M72	Scientific research and development
M73	Advertising and market research
M74-M75	Other professional, scientific and technical activities; veterinary activities
N	Administrative and support service activities
O84	Public administration and defence; compulsory social security
P85	Education
Q	Human health and social work activities
R-S	Other service activities
T	Activities of households as employers; producing activities of households for own use
U	Activities of extraterritorial organizations and bodies

Table 3: **Industries in WIOD**

B Contrasting S and S^i in the two-country, one sector case

In this appendix, we use the two-country and one-good case to illustrate the difference between a price shock (section 3.1) and an exchange rate shock (section 3.3)

B.1 Effect of a price shock based of VA contents

Using the notations of the paper, we have in the two-country and one good case:

$$\mathcal{A} = \begin{pmatrix} a_{1,1} & a_{1,2} \\ a_{2,1} & a_{2,2} \end{pmatrix}$$

$$I - \mathcal{A} = \begin{pmatrix} 1 - a_{1,1} & -a_{1,2} \\ -a_{2,1} & 1 - a_{2,2} \end{pmatrix}$$

$$(I - \mathcal{A})^{-1} = \frac{1}{(1 - a_{1,1})(1 - a_{2,2}) - a_{2,1}a_{1,2}} \begin{pmatrix} 1 - a_{2,2} & a_{1,2} \\ a_{2,1} & 1 - a_{1,1} \end{pmatrix} = z. \begin{pmatrix} 1 - a_{2,2} & a_{1,2} \\ a_{2,1} & 1 - a_{1,1} \end{pmatrix}$$

$$= \begin{pmatrix} u & v \\ w & x \end{pmatrix}$$

$$\text{Country 1 demand shares} = d = \begin{pmatrix} 1 - f \\ f \end{pmatrix}$$

$$(I - \mathcal{A})^{-1} d = \begin{pmatrix} u - uf + vf \\ w - wf + xf \end{pmatrix}$$

When a shock c occurs on the prices of country 2 (the currency does not matter here), we have the following initial shock vector : $C = (0, c)$. In the first instance, this has an impact on prices $C\mathcal{A}$, and then $C\mathcal{A}^2$, etc. Hence the total effect of the shock S is:

$$S = C + C\mathcal{A} + C\mathcal{A}^2 ... = C(I - \mathcal{A})^{-1} = \begin{pmatrix} cw & cx \end{pmatrix}$$

To measure the effect on French consumption prices, we compute a weighted sum of these effects.

$$\bar{s} = c.\left[(1 - f)w + xf\right] = c.\frac{(1 - f)a_{2,1} + f(1 - a_{1,1})}{(1 - a_{1,1})(1 - a_{2,2}) - a_{2,1}a_{1,2}} \tag{19}$$

If each nation's production only uses national inputs, we have:

$$\bar{s} = c.\frac{f}{1 - a_{2,2}}$$

B.2 Exchange rate shock

Using the notations in the paper, we have:

$$C = \left(0, \frac{-c_\$}{1+c_\$}\right) = (0, -c)$$
$$C_\$ = (c_\$, 0)$$
$$\tilde{C}_\$ = (0, -c_\$)$$
$$\hat{C}_\$ = \left(\frac{c_\$}{1+c_\$}, 0\right) = (c, 0)$$
$$\mathcal{B} = \begin{pmatrix} 0 & a_{1,2} \\ 0 & 0 \end{pmatrix}$$
$$\tilde{\mathcal{B}} = \begin{pmatrix} 0 & 0 \\ a_{2,1} & 0 \end{pmatrix}$$

Hence

$$\begin{aligned} S &= (0, c) + [(0, -c.a_{1,2}) + (c.a_{2,1}, 0)] * \begin{pmatrix} u & v \\ w & x \end{pmatrix} \\ &= (0, c) + (c.a_{2,1}, -c.a_{1,2}) * \begin{pmatrix} u & v \\ w & x \end{pmatrix} \\ &= (0, c) + (u.c.a_{2,1} - w.c.a_{1,2}, v.c.a_{2,1} - x.c.a_{1,2}) \\ &= (u.c.a_{2,1} - w.c.a_{1,2}, c + v.c.a_{2,1} - x.c.a_{1,2}) \end{aligned}$$

and

$$\bar{s} = (u.c.a_{2,1} - w.c.a_{1,2}, c + v.c.a_{2,1} - x.c.a_{1,2}) \,.\begin{pmatrix} 1-f \\ f \end{pmatrix}$$
$$\bar{s} = c\,[f\,(1 + v.a_{2,1} - x.a_{1,2}) + (1-f)\,(u.a_{2,1} - w.a_{1,2})]$$

If each nation's production only uses national inputs, we have a plausible

$$\bar{s} = c.f$$

This confirms that an exchange rate shock differs from a price shock.

C Comparing $\overline{s}_i^{i,HC}$ and $E1.HC^{i,imp} + E2.HC^{i,dom}$ in the TIVA rev. 3 and TIVA rev. 4 databases

Figures 15, 16 and 17 for TIVA rev. 3 and Figures 18, 19 and 20 for TIVA rev. 4 show that we get a good prediction of the accounting effects of an exchange rate shock on consumption prices by using simply the share of imported final consumption goods and services and the share of imported intermediate goods in domestic final consumption goods and services.

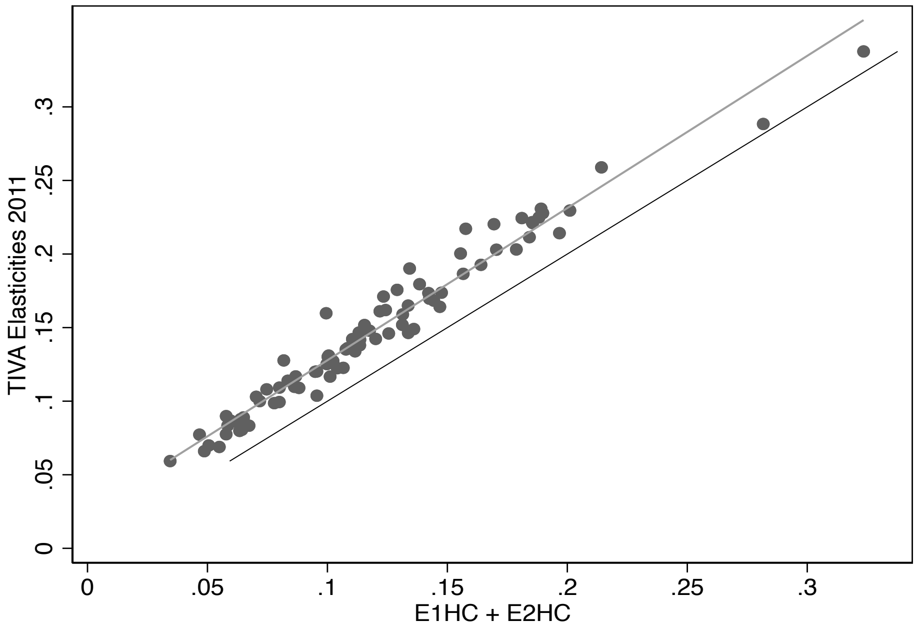

Figure 15: **Comparing $\overline{s}_i^{i,HC}$ and $E1.HC^{i,imp} + E2.HC^{i,dom}$ (TIVA rev. 3)**

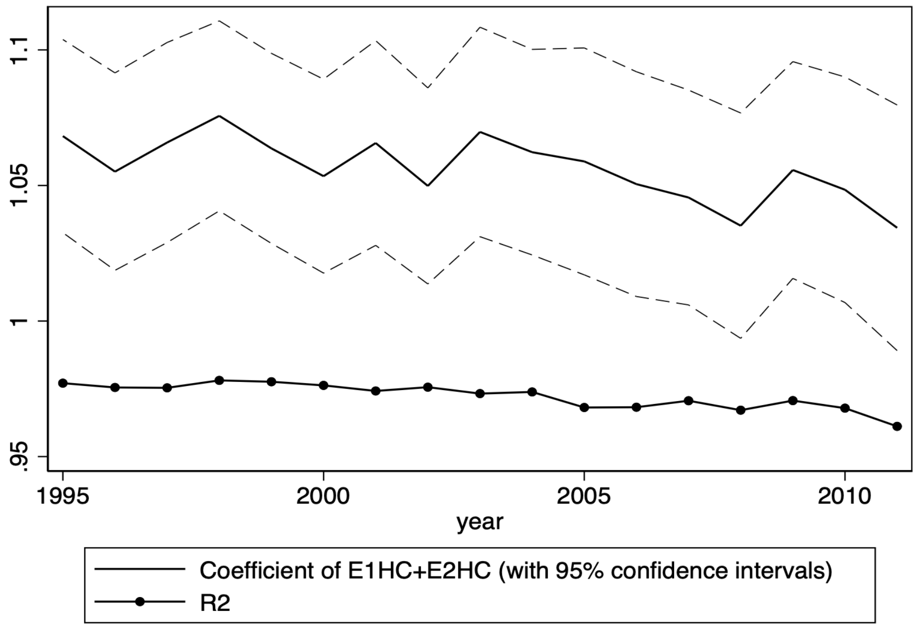

Figure 16: **Evolution of β and $R2$ (TIVA rev. 3)**

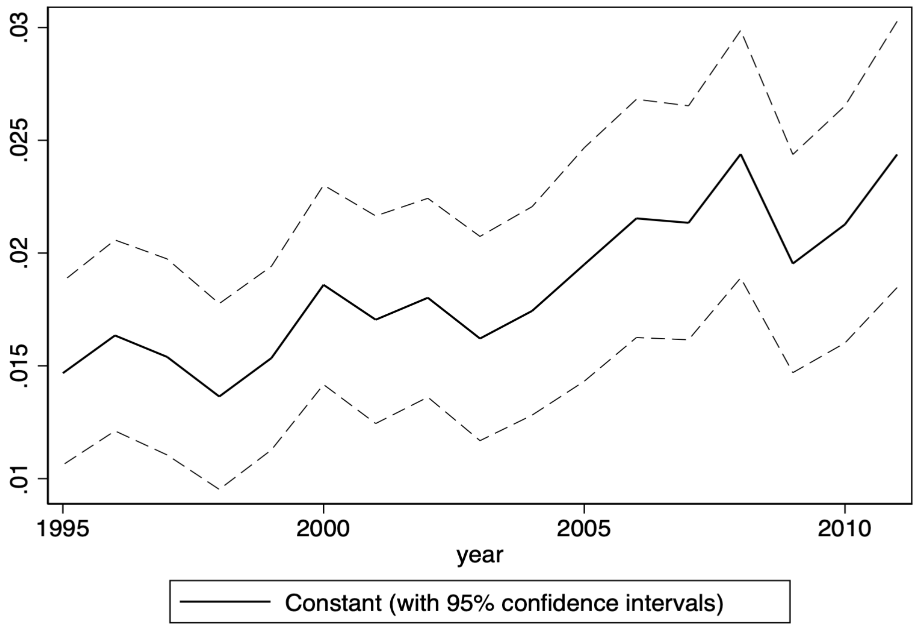

Figure 17: **Evolution of α (TIVA rev. 3)**

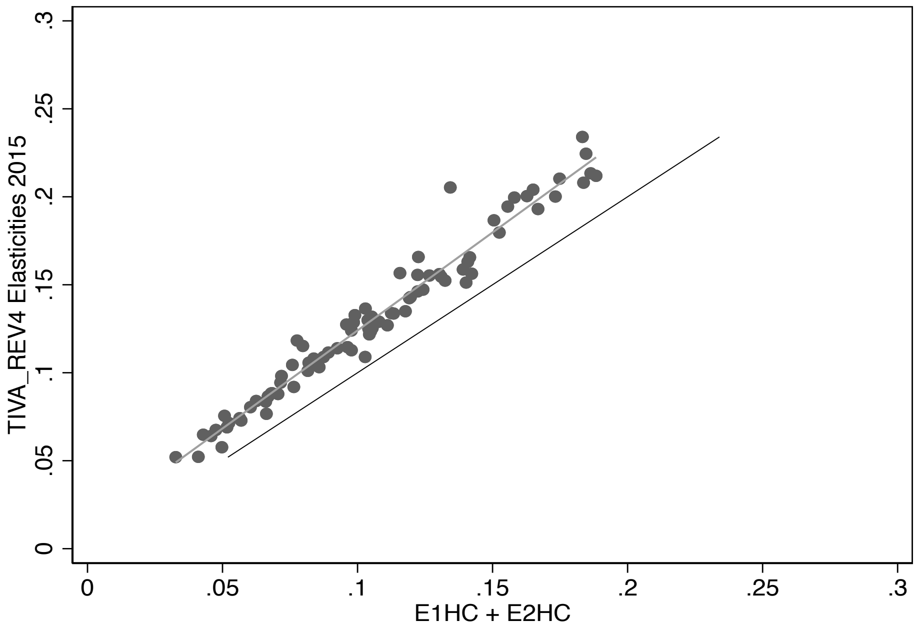

Figure 18: **Comparing $\overline{s}_i^{i,HC}$ and $E1.HC^{i,imp} + E2.HC^{i,dom}$ (TIVA rev. 4)**

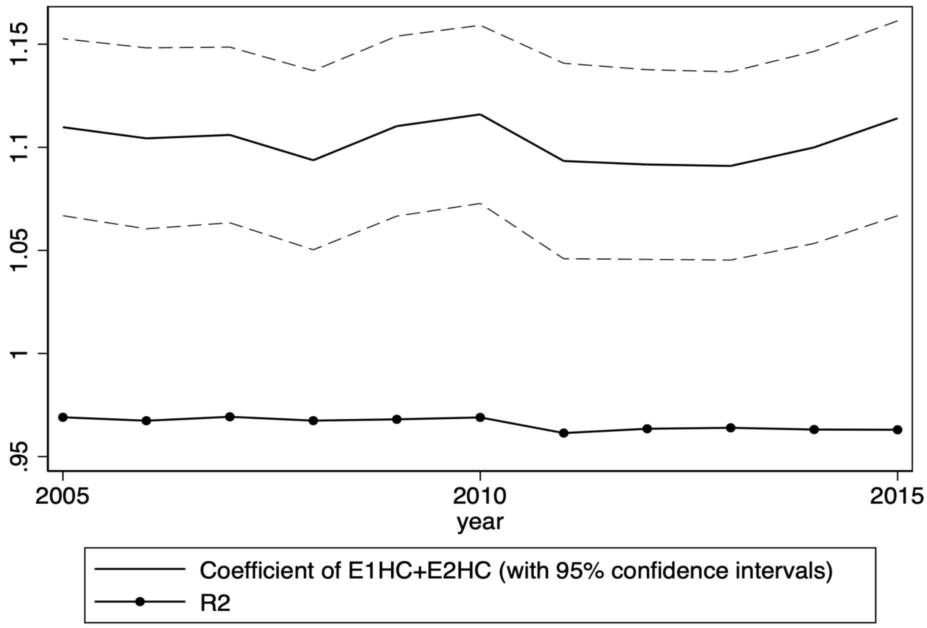

Figure 19: **Evolution of β and $R2$ (TIVA rev. 4)**

D Studying the decomposition of the shock in the two-country, one-sector case

D.1 Presenting the issue

As a reminder from the paper, where $\overline{s}_i^{i,HC}$ is the effect of an exchange rate shock on consumption prices :

$$\begin{aligned} \overline{s}_i^{i,HC} &= S^i.HC^i = E1.HC^i + E2.HC^i + E3.HC^i + E4.HC^i \\ &= E1.HC^{i,imp} + E2.HC^{i,dom} + E3.HC^{i,imp} + E4.HC^i \end{aligned} \tag{20}$$

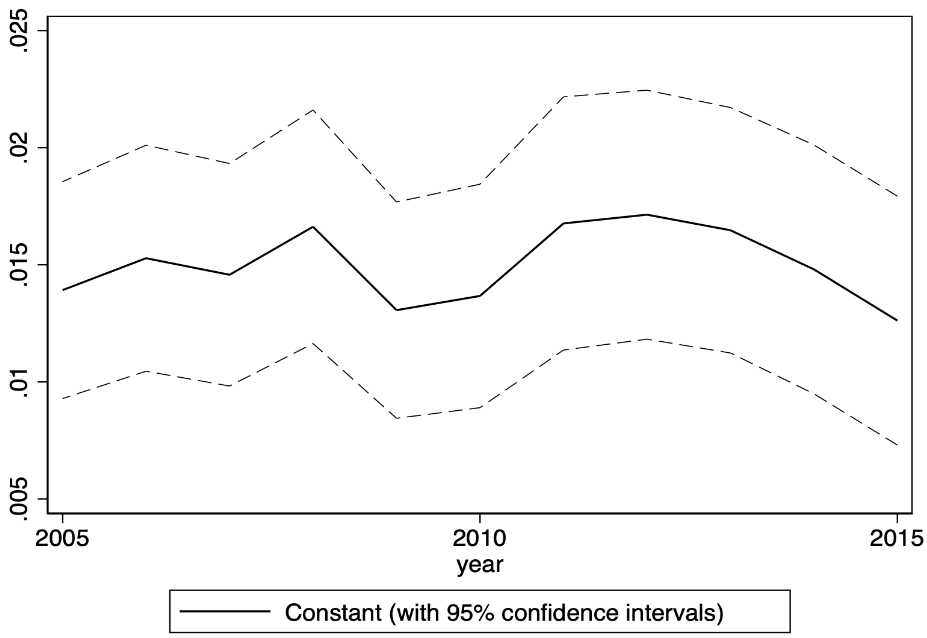

Figure 20: **Time evolution of α (TIVA rev. 4)**

and

$$
\begin{aligned}
S^i &= C^i + \left(\hat{C}^i_{\$}.\mathcal{B} + C^i\tilde{\mathcal{B}}\right) * (I-\mathcal{A})^{-1} \\
S^i &= \underbrace{C^i}_{\substack{\text{(E1) direct effect through} \\ \text{imported consumption goods}}} + \underbrace{C^i\tilde{\mathcal{B}}}_{\substack{\text{(E2) effect on} \\ \textit{domestic} \text{ consumption goods} \\ \text{through } \textit{imported} \text{ inputs}}} + \underbrace{\hat{C}^i_{\$}.\mathcal{B}}_{\substack{\text{(E3) effect on} \\ \textit{imported} \text{ consumption goods} \\ \text{through } \textit{domestic} \text{ inputs}}} \\
&+ \underbrace{\left(\hat{C}^i_{\$}.\mathcal{B} + C^i\tilde{\mathcal{B}}\right) * (I-\mathcal{A})^{-1} * \mathcal{A}}_{\text{(E4) residual}}
\end{aligned}
\tag{21}
$$

When the shock corresponds to an appreciation of the domestic currency, $E1$ and $E2$ reduce country i's consumer prices whereas $E3$ increases it. $E1$ and $E2$ are easy to compute with national input-output matrices, whereas world input-output matrices are needed for computing $E3$ and $E4$.

We have the strange result that $E3 + E4$ seems to be constant, whatever the openness rate of the economy (see Figure 9)

Let us see what happens in a two-country, one-sector economy :

$$
\begin{gathered}
E1 = C = (0, -c) \\
E2 = C.\tilde{\mathcal{B}} = (0, -c) . \begin{pmatrix} 0 & 0 \\ a_{2,1} & 0 \end{pmatrix} = (-c.a_{2,1}, 0) \\
E3 = (c, 0). \begin{pmatrix} 0 & a_{1,2} \\ 0 & 0 \end{pmatrix} = (0, c.a_{1,2})
\end{gathered}
$$

$$E1.HC = (0, -c) \, . \begin{pmatrix} 1-f \\ f \end{pmatrix} = -f.c$$
$$E2.HC = (-c.a_{2,1}, 0) \, . \begin{pmatrix} 1-f \\ f \end{pmatrix} = -c.a_{2,1}. (1-f)$$
$$E3.HC = (0, c.a_{1,2}) \, . \begin{pmatrix} 1-f \\ f \end{pmatrix} = f.c.a_{1,2}$$

We do not lose any generality by normalising the shock c to 1.

And, developped from SAGE :

$$\bar{s} - E1.HC - E2.HC = \left(-\frac{a_{12}a_{21}^2 - a_{11}a_{21}a_{22} + (a_{11}-a_{12})a_{21} - \left(a_{12}a_{21}^2 - a_{11}a_{21}a_{22} - (a_{11}-1)a_{12} + (a_{11}-2\,a_{12})a_{21}\right)f}{a_{12}a_{21} - (a_{11}-1)a_{22} + a_{11} - 1} \right) \tag{22}$$

In order to be able to study the symbolic form, we assume: $\frac{a_{1,1}}{a_{2,1}} = \frac{1-f}{f}$ and $a_{1,1} + a_{2,1} = a$. So $a_{1,1} = (1-f)a$ and $a_{2,1} = fa$.

Then:

$$\bar{s} - E1.HC - E2.HC = \left(-\frac{\left(a^2a_{12} + a^2a_{22} - a^2\right)f^3 - \left(2\,a^2a_{22} - 2\,a^2 + \left(a^2+a\right)a_{12}\right)f^2 + \left(a^2a_{22} - a^2 + a_{12}\right)f}{(a-1)a_{22} - (aa_{12} + aa_{22} - a)f - a + 1} \right) \tag{23}$$

According to SAGE, the derivative of this according to f is:

$$\begin{pmatrix} -\frac{\left(\left(a^2a_{12}+a^2a_{22}-a^2\right)f^3 - \left(2\,a^2a_{22}-2\,a^2+\left(a^2+a\right)a_{12}\right)f^2 + \left(a^2a_{22}-a^2+a_{12}\right)f\right)(aa_{12}+aa_{22}-a)}{((a-1)a_{22}-(aa_{12}+aa_{22}-a)f-a+1)^2} \\ -\frac{a^2a_{22}+3\left(a^2a_{12}+a^2a_{22}-a^2\right)f^2 - a^2 - 2\left(2\,a^2a_{22}-2\,a^2+\left(a^2+a\right)a_{12}\right)f + a_{12}}{(a-1)a_{22}-(aa_{12}+aa_{22}-a)f-a+1} \end{pmatrix}$$

The sign of this expression is difficult to study. We hence move to a numerical application.

D.2 Numerical application

From WIOD2014, we can compute the ration between VA and production. The computation with the WIOD data is : egen total=rowtotal(vAUS1-vROW) and then (161-74)/161=54%.

For simplification, we assume that the ratio is equal to 0.5.

$$a_{1,1} + a_{1,2} = a_{2,1} + a_{2,2} = 50\%$$
$$\frac{a_{1,2}}{a_{1,1} + a_{1,2}} = f$$
$$a_{2,1} = 0.48$$
$$a_{2,2} = 0.02$$

In that case:

$$\bar{s} - E1.HC - E2.HC = \frac{-0.125\,f^3 + 0.245\,f^2 - 0.11\,f}{-0.25\,f - 0.26}$$

Which yields Figures 21 and 22.

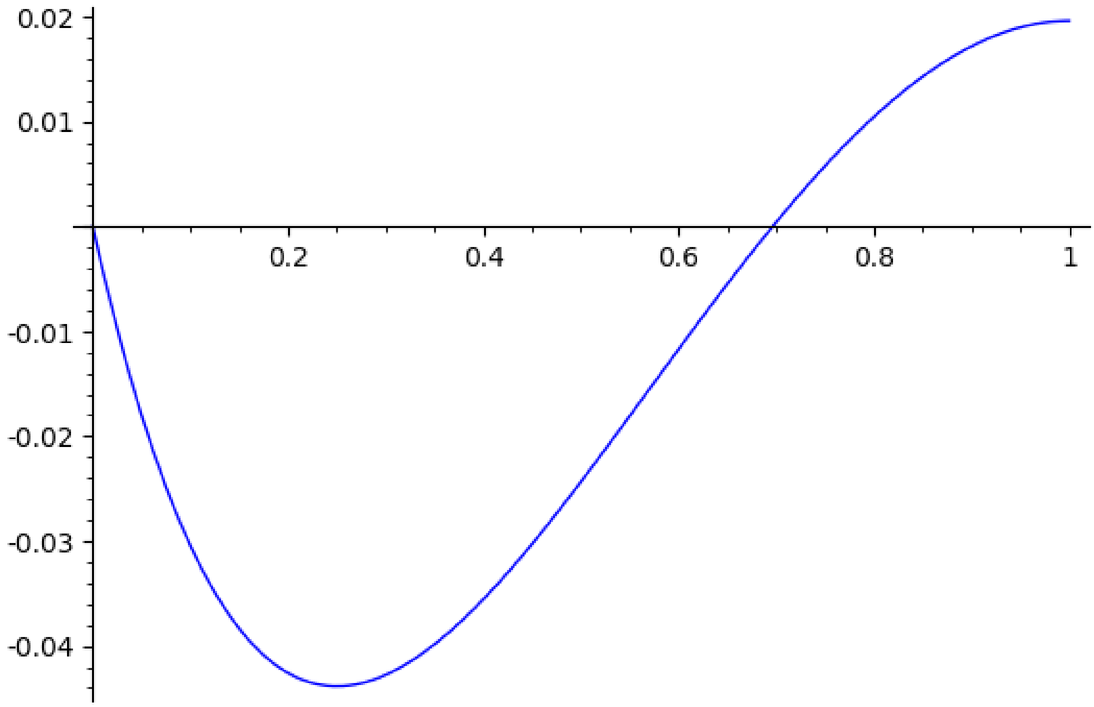

Figure 21: $\bar{s} - E1.HC - E2.HC$ as a function of the openness rate

Actual openness rates in the sample vary between 0.15 and 0.5. In that zone, the relationship between the openness rate and the residual is not monotonous (see Figure 21).

Figure 22 comfirms that, in that numerical exercice, the total effect is dominated by the direct effect through imported consumption goods and, to a lesser extent, the effect on domestic consumption goods through imported inputs. The other effects are approximately additive if the openness rate is betweem 0.15 and 0.5.

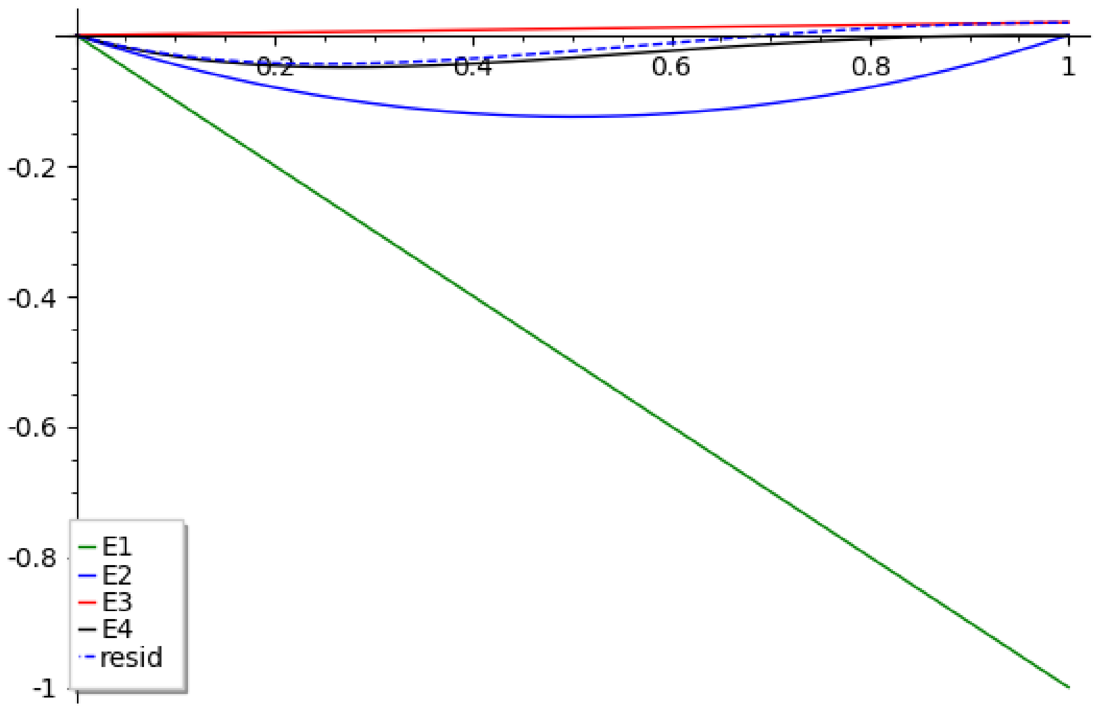

Figure 22: E1.HC, E2.HC, E3.HC, E4.HC and the "residual" ($\bar{s} - E1.HC - E2.HC$) as a function of the openness rate