Estimating the impact of exchange rate fluctuations on consumer prices: an accounting approach *

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Abstract

We analyse the elasticity of the household consumption expenditure (HCE) deflator to the exchange rate, using world input-output tables (WIOT). In line with the existing literature, we find a modest elasticity of around 0.1. The elasticity is stable over time but heterogeneous across countries. Depending on the country, the elasticity ranges from 0.05 to 0.22. Such heterogeneity reflects different degrees of openness to trade and differences in foreign product content in domestic consumption. Direct effects through imported consumption and intermediates entering domestic production explain most of the transmission of an exchange rate appreciation to domestic prices. By contrast, global value chains participation plays a limited role. Our results are robust to using four different WIOT datasets. As WIOT are not available for the latest years,

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we compute the HCE deflator elasticity from 2016 onwards using trade data and GDP statistics. By doing so, we compute a precise estimate of the elasticity without resorting to WIOT.

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Introduction

This paper focuses on the elasticity of the household consumption expenditure (HCE hereafter) deflator to the exchange rate. We analyse the composition and determinants of the HCE deflator elasticity using world input-output tables (WIOT hereafter) covering twenty years of data, from 1995 to 2018. For the sake of robustness, we use several datasets (WIOD, two distinct releases of the OECD TiVA database and the MRIO database developed by the Asian Development Bank). We perform an accounting exercise based on information contained in WIOTs with large matrices inversion. We make three additional assumptions to simplify our computations. First, we assume a full exchange rate pass-through to import prices. As a result, our estimates provide an upper bound of the HCE deflator elasticity. In addition, we suppose that all pricing occur using the currency of the producing country, despite the well-documented role of dominant-currency pricing (Gopinath et al. [2020]). We also assume that the impact of the exchange rate fluctuation is proportional across sectors. Despite these simplifying assumptions, our estimates provide an accounting-based gauge of how large the exchange rate pass-through could be, considering direct and indirect import content in consumption and global value chain linkages. It helps identifying which countries and sectors are under pressure to adjust their prices when subject to a change in the exchange rate.

Our contribution to the literature is fourfold. First, we analyse the evolution of the elasticity of the HCE deflator to the exchange rate and differences accross countries. We document the heteregeneity observed in the euro area, reflecting different degrees of openness to trade.

Second, building on sectoral data, we examine which sectors experience higher spillovers from an appreciation of the national currency. We focus on the main components of the HCE deflator, i.e. manufacturing goods, services, food and energy. We analyse the contribution of these different products to the HCE deflator elasticity to shed light on the cross-country heterogeneity in the elasticity estimates.

Third, we analyse the determinants of the HCE elasticity and the role of global value chains in the transmission of an exchange rate appreciation to the HCE deflator. We identify four channels through which the exchange rate impacts the HCE deflator when production processes are global: *i)* the prices of imported final goods sold directly to domestic consumers; *ii)* the prices of imported inputs entering domestic production; *iii)* the price of exported inputs feeding through imported foreign production; *iv)*, changes in domestic and foreign production costs in turn pass through to the price of inputs for domestic and foreign goods, causing further changes in production costs through input-output linkages. We find that the first two channels explain three-quarters of the transmission of an exchange rate appreciation to domestic prices. By contrast, the last two channels, which reflect the impact of global value chains, play a more limited role, with marked cross-countries heterogeneity. Hence, only one-fourth of the elasticity of the HCE deflator to the exchange rate is attributable to participation in global value chains. Fourth, we show that a precise assessment of the HCE deflator elasticity to the exchange rate can be estimated without resorting to WIOT. The construction of World Input-Output tables is data-demanding and WIOTs are typically released with a lag of several years. As a result, WIOT are not available for the most recent years. For instance, the latest WIOD dataset dates back to 2015. To address this gap, we estimate the HCE deflator elasticity from 2016 onwards using GDP statistics and trade data on consumption and intermediates. We compare our

The rest of the paper is organised as follows. Section 1 reviews the related literature. Section 2 presents the methodology and the data sources. In section 3, we estimate the elasticity of the HCE deflator to the exchange rate up to 2018 and analyse its determinants. In section 4, we use up-to-date GDP and trade data to estimate the elasticity of the HCE deflator for the most recent years, without resorting to WIOT.

1 Related literature

Exchange rate pass-through to domestic prices A large body of literature documents the exchange rate pass-through (ERPT hereafter) to domestic prices. A regular finding is that the pass-through differs between countries, across sectors and over time. The pass-through depends, among other things, on trade openness, integration in international production chains, firms' pricing strategies and the currency of invoicing for trade.

Campa and Goldberg [2008] have documented a declining ERPT to import and consumer prices since the 1980s, whereas Leigh et al. [2017] find that the ERPT is stable over time. In the euro area, Özyurt [2016] shows that the pass-through is partial and has declined in the 2000s. This decline coincided with the increasing share of emerging economies in world trade and the accession of China to the WTO. The lowest degree of pass-through is found for Germany, most likely reflecting the large size of the country and the high share of local currency pricing. By contrast, Ortega and Osbat [2020] find that the ERPT to euro area import and consumer prices has been stable since the 1990s.

The choice of currency of invoicing determines the extent of the response of prices to an exchange rate movement. An exporter can price its products either in its own currency ('producer currency pricing' paradigm), in the destination's currency ('local currency pricing' paradigm), or in a third 'dominant' currency (see Ortega and Osbat [2020] for a discussion of the literature). The invoicing decision is an active channel through which producers adjust their prices in relation to their own market power and to local competitive pressures. While prices fixed in the local currency are irresponsive to the bilateral exchange rate between the local currency and the currency of the producer, prices in the producer or dominant currency have a higher ERPT. A large body of empirical literature suggests that the vast majority of trade is invoiced in a small number of 'dominant currencies,' with the U.S. dollar playing a major role. The 'dominant currency paradigm' (Gopinath et al. [2020]) implies that for non-U.S. countries, the exchange rate pass-through into import prices (in home currency) should be high and driven by the dollar exchange rate as opposed to the bilateral exchange rate, whereas for the U.S. the pass-through into import prices should be low.

The ERPT also depends on integration in global value chains. Based on Belgian firm-product-level data, Amiti et al. [2012] find that import intensity and market share are key determinants of the ERPT to export prices. According to De Soyres et al. [2018], the ERPT decreases as the foreign value added increases.

Although we do not estimate the ERPT (we rather assume a full exchange rate pass-through to simplify our computations), our approach provides an accounting-based gauge of how large the exchange rate pass-through could be, considering direct and indirect import content in consumption. In this respect, the elasticity of the HCE deflator to the exchange rate can be regarded as an upper bound.

The Input-Output model applied to a change n production costs The Leontief's production model (or Input-Output model, I-O thereafter) analyses the impact of a demand shock in a closed economy [Leontief, 1951]. The trade in value-added analysis reconciles international trade statistics with national I-O tables, thus allowing to extend Leontief's analysis to an international context. Leontief's production model has a dual: the cost-push price model, which helps analysing the consequences of a change in production prices. Leontief's price model is broadly used in multi-sector, single-country macroeconomic models, for example, to measure the effect of changes in energy prices [Bournay and Piriou, 2015, Sharify, 2013]. Cochard et al. [2016] rely on an accounting approach to analyse the effects of costs on prices ("cost-push inflation").

Supply-driven price models have a number of well-documented limitations [Folloni and Miglierina, 1994] and rely on a number of simplifying assumptions. Firms' margins are assumed to be fixed. Prices only adjust to absorb cost changes and production techniques are fixed during successive production cycles. Inputs substitution (for instance, between countries producing the same goods) is not accounted for, despite a change in relative prices. Although the division of global value chains largely takes place within multinational firms, supply-driven price models assume a unique pricing system based on market prices and independent of firms' strategies. Despite these shortcomings, supply-driven price models provide a measure of the vulnerability of each sector to price or productivity shocks [Acemoglu et al., 2012, Carvalho, 2014]. Hence, though unrealistic, using input-output tables is useful for identifying which countries and sectors are under pressure to adjust their prices when subject to exogenous cost shocks.

2 The PIWIM model

Based on initial work from the OFCE (Observatoire Français des Conjonctures Économiques) Cochard et al. [2016], we have developed the PIWIM model (Push-cost Inflation through World Input-output Matrices).

2.1 Defining a price shock in an I-O model

To identify which countries are most affected by a price shock through value-added and vertical international trade flows, 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) describes 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 "bilateral" blocks outside of the diagonal represent international flows of intermediate goods and services via bilateral sectoral exports and imports.

Traditionnaly, WIOTs are interpreted in a Leontief framework of Leontief production functions to analyse the evolution of quantities in the economy. Here, we assume a Cobb-Douglas production function: the technical coefficients correspond to the share of each input in total costs. We derive a price equation, following [De Soyres et al., 2018]).

We define N as the product of the number of countries (I) and the number of sectors (J), $\mathcal{A}$ the matrix of technical input coefficient of dimension (N, N), and Y the gross output vector of dimension $(1, N)$.

In each sector of each country, a representative firm uses domestic production factors (V)

and domestic and imported intermediates m according to a Cobb-Douglas technology:

$$Y_n = V_n^{\gamma_n} \times \prod_{n'=1}^{n'=N} {m_{n,n'}}^{a_{n,n'}} \text{ with } \gamma_n + \sum_{n'=1}^{n'=N} a_{n,n'} = 1$$

Where γ_n is the share of domestic production factors, $a_{n,n'}$ the share of output from (country,sector) n' in the total production of (country,sector) n.

Assuming perfectly competitive firms and prices set at the marginal cost, standard cost minimisation for each country leads to the following pricing system:

$$p_n = x_n \times w_n^{\gamma_k} \times \prod_{n'=1}^{n'=N} p_{n'}^{a_{n,n'}}, \forall n$$

With x the unit income of domestic production factors and x_n a constant depending only on parameters:

$$x_n = \gamma_k^{-\gamma_k} \times \prod_{n'=1}^{n'=N} a_{n,n'}^{-a_{n,n'}}$$

Using logs, we have:

$$log(p_n) = log(x_n) + \gamma_n log(w_n) + \sum_{n'=1}^{n'=N} a_{n,n'}.log(p_{n'}), \forall n$$

Define P the vector of prices , Z a vector of $log(x_n) + \gamma_n.log(w_n)$, all of dimension $(1, N)$:

$$log(P) = Z + log(P)\mathcal{A} \tag{1}$$

Suppose an exogenous change in input prices defined in log points (i.e. approximating percentages for small changes). Define $\Delta^0 log(P)$ the vector of dimension $(1, N)$ computed as the difference between the original price vector $log(P^0)$ and the new vector $log(P^1)$.

Then:

$$\Delta^0 log(P) = log(P^1) - log(P^0) = C,$$

with C the vector of dimension (1,N) that contains the direct effect of the change in prices expressed in log points.

C directly affects the HCE deflator. In addition, firms face a change in their costs, which affects their prices according to equation 1. Hence, the price change is transmitted to country-specific industries that use the products subject to a change in input prices as intermediate consumptions. The higher the country-specific industries'reliance on those inputs, the higher the change in prices.

In a first step, the impact of the change in input prices on each country-specific industry's output prices amounts to $\Delta^1 log(P) = C\mathcal{A}$.

In a second step, the impact of the change in input prices is passed on to all the country-specific industries using these inputs. For the k^{th} step, the increase in production prices amounts to $\Delta^k log(P) = C\mathcal{A}^k$.

As the technical coefficients are smaller than 1, the effect of the change in input prices wears out as k increases. The overall effect of the change in input prices is equal to the sum of the initial change in prices and all the subsequent changes in each step. Let us call S the total effect of the change in input prices (in log points), a vector $(1, N)$ composed of the elements s_{ij} measuring the total effect of the shock on the price of sector j in country i. We have:

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

with $(I - \mathcal{A})^{-1}$ the Leontieff inverse matrix. If the change in the exchange rate is small enough, the elements of S correspond to the elasticity of sectoral prices to a change in input prices. Using consumption shares to perform a weighted average of these elasticities, we compute the household consumption expenditure (HCE) deflator elasticity to a change in input prices [1].

2.2 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 produces a good for a specific final use, 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. First, 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.
This paper uses several multi-year WIOTs for the sake of robustness: the World Input Output Database (WIOD), the multi-regional input-output tables (MRIO) developed by the Asian Development Bank (ADB) and the Trade in Value Added Database (TiVA) from the OECD-ICIO.

The World Input Output Database (WIOD) WIOD is hosted and updated by the University of Groningen (Netherlands) and benefits from the financial support of the European Commission. It 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. WIOD covers 43 countries (of which 28 members of the European Union) accounting for 85% of global GDP (see Table 1). WIOD contains annual information for 56 industries. Therefore, for each year a full country-sector input-

[1] The HCE deflator has different sectoral weights than the headline consumer price index (CPI) as the former also encompasses, for example, the rental equivalent of real estate expenditures.

output matrix traces the importance of a supplying industry in country j for an industry in country i. The values in WIOTs are expressed in U.S. dollars at basic prices. 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

Tab. 1: **Coverage of the WIOD**

The Asian Development Bank's MRIO database The WIOD provides disaggregate information for a limited number of Asian economies. To address the analytical needs related to the Asian and Pacific regions, the Asian Development Bank (ADB) has augmented the WIOD with details for nineteen additional Asian economies[2]. The industrial aggregations and the conceptual framework of the ADB MRIO database (and hence the methods used in the construction of the tables) are similar to those of WIOD.

The Trade in Value Added (TiVA) database The TiVA database is compiled by the OECD. It builds on the OECD harmonised country-level input-output tables to provide matrices of inter-industrial flows of goods and services in current prices (U.S. dollars). We use two versions of TiVA (see OECD [Decembre 2018] on the differences between the two datasets.). The 2016 edition of the TiVA database (third revision) includes 64 economies covering OECD, EU28, G20, most East and South-east Asian economies, a selection of South American countries and the Rest of the world. The industry list includes 34 sectors, among which 16 manufacturing and 14 services sectors. It covers the period 1995-2011 and is based on the 1993 system of national accounts. The fourth revision, released in

[2] The MRIO database includes the following additional economies: Bangladesh, Bhutan, Brunei Darussalam, Cambodia, Fiji, Hong Kong, Kazakhstan, Kyrgyz Republic, Lao People's Democratic Republic, Malaysia, Maldives, Mongolia, Nepal, Pakistan, Philippines, Singapore, Sri Lanka, Thailand and Viet Nam.

2018, includes 65 economies (see Table 2) and 36 sectors and covers the 2005-2015 period. It is based (just like WIOD) on the 2008 system of national accounts.

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

Tab. 2: **Coverage of TiVA revisions 3 (2016) and 4 (2018)**

Comparison of the databases WIOD and the TiVA databases are constructed using similar assumptions (OECD and WTO [2011], Timmer et al. [2015], OECD [Decembre 2018]). For example, both start with the construction of harmonised country-specific supply-use tables (SUTs) that are then transformed into world input-output tables. Both databases use the "import proportionality assumption" to allocate specific bilateral imports to using industries. National input-output statistics provide how much of each product firms use for intermediary consumption and investment. However, the breakdown of these into domestic and imported product is not available. Hence, the construction of world input-output tables requires allocating imports to using industries. The import proportionality assumption assumes that the proportion of intermediates that an industry purchases from abroad is equal to the ratio of imports of intermediates to the total domestic demand of intermediates in that product. 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. WIOD and TiVA databases, however, rely on the BEC (Broad Economic Categories) classification to map detailed six-digit products into intermediate use, final consumption and investment [Dietzenbacher et al., 2013].

One explicit difference between the databases is that WIOD assumes that the input mix is independent from the destination market. The TiVA databases do not rely on this assumption for two countries (Mexico and China). Instead, the TiVA databases use different input-output tables for the exporting, import processing and domestic-market oriented sectors of these countries (or at least two of those, depending on the country and the version of the TiVA database). Despite this difference, we obtain similar results with TiVA and WIOD, which probably reflects the fact that we do not focus on Mexico and China.

Another difference relates to the method for harmonising national data and trade statistics. WIOD relies on the shares of imported inputs provided by national account, contrary to TiVA. As a result, TiVA is closer to international trade statistics than WIOD. This explains why the share of imported inputs is smaller in TiVA for some countries (other than China and the USA).

2.3 Accounting impact of an exchange rate variation on domestic prices

Implementing an exchange rate variation is more complex than implementing a change in production costs. The appreciation of the currency of country A leads to a fall in the national currency price of country A's imports, while the foreign-currency price of its exports increase. We are mainly interested in the impact of an exchange rate appreciation on consumer prices in country A. We also estimate the inflationary impact on countries that directly and indirectly, through third countries linkages, consume inputs from country A.

Suppose a world with two countries A and B, each having its own national currency, and a third currency for international transactions, the dollar. Following a 5% appreciation of the currency of country A against the two other currencies, the prices of country A expressed in dollars increase by 5% 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 price of imported inputs in country A remains constant in dollars, since the prices of country B have not changed, and halves once expressed in country A's national currency. It has an impact on consumer prices (in national currency) in country A.

For the sake of simplicity, producers are assumed to completely pass the exchange rate appreciation on their production prices. Hence, we do not consider other relevant determinants of the exchange rate pass-through. For instance, pricing-to-market strategies of exporters aiming to defend their market shares would imply a lower exchange rate pass-through. Similarly, settlement and invoicing of imports in the domestic currency is another factor likely to weaken the elasticity of domestic prices to exchange rate movements. As a result, our estimates provide an upper bound of the HCE deflator elasticity[3]. 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 change in prices spread over multiple simultaneous production cycles. The overall impact of the exchange rate variation in dollar terms is equal, for the shocked country A, to the rise in prices due to the exchange rate fluctuation, 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 prices in dollar terms in country A is therefore lower than the initial exchange rate variation, as national currency prices are also affected. 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 price of each sector will vary in percentage (approximated as log point assuming that the exchange rate variation is small enough) by: $c_{\$}^{i}$ for sectors in the

[3] Using alternative pricing assumptions would entail lower values. For instance, assuming that only 60% of invoices in the euro area goods trade are denominated in foreign currency (see Ortega and Osbat [2020]) would entail lower elasticity values.

shock-stricken country i and 0 in other countries.

Hence, for each sector j in country i:

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

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

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

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 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, weighed by the variation in level of the price of inputs in dollars (i. e. the exchange rate variation). If $a_{kl,ij}$ is the share of inputs from the country i's sector j needed in the production of country's k sector l, we have :

$$\Delta^1 log(p_{\$kl}) = c^i_\$.a_{kl,i1} + \ldots + c^i_\$.a_{kl,ij} + \ldots + c^i_\$.a_{kl,iJ} = \sum_{j=1}^{J} c^i_\$.a_{kl,ij} = c^i_\$.\sum_{j=1}^{J} a_{kl,ij} \tag{3}$$

For the shocked country, an appreciation of the currency has a disinflationary effect. In national currency, the prices of imported inputs fall in each sector by $c^i = -\frac{c^i_\$}{1+c^i_\$}$, or by $-\frac{10}{11}\%$ with $c^i_\$ = 10\%$.

We approximate these changes by their log point equivalent[4]. 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:

[4] We could have used the log point approximation earlier and write that $c^i = -c^i_\$$ with nearly the same results for small shocks.

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

This shock can be converted into dollars:

$$\Delta^1 log(p_{\$ij}) = \left(1+c^i_\$\right) \cdot \left(-\frac{c^i_\$}{1+c^i_\$}\right) \sum_{\substack{k=1 \\ k \neq i}}^{k=I} \left[\sum_{l=1}^{l=J} a_{ij,kl}\right] \tag{4}$$

This yields the first step impact of the exchange rate variation on all input prices of all countries.

To express this in matrix notation, we define two matrices that build on the world input-output matrix $\mathcal{A}$ defined in 2.1. These two matrices retain only the first-step effects of the exchange rate variation on the price of goods and services imported by the shocked country i and the first-step effects of the exchange rate variation on the price of goods and services imported by the rest of the world from country i. Compared to $\mathcal{A}$, we "close off" the links between a domestic input price shock and the price of goods as well as the link between non-shocked input prices and the price of goods in a non-shocked country.

Let us first consider the impact of the exchange rate variation from the perspective of countries that import inputs from country i.

Let $C^i_\$$ be the vector of log points changes in dollar prices following the appreciation of the currency of country i against all other currencies. Hence,

$$C^i_\$ = (0 \ldots 0 \ldots c_{\$ij} \ldots c_{\$ik} \ldots 0 \ldots 0)$$

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

Building on Equation 3, the direct impact of the exchange rate variation on the other countries corresponds to the product of the shock vector $C^i_\$$ and a matrix $\mathcal{B}^i$. $\mathcal{B}^i$ 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 first-step impact of the appreciation of a currency against the dollar on the price of inputs in countries that are not impacted by the appreciation is equal to $C^i_\$\mathcal{B}^i$ with

$$C^i_\$\mathcal{B}^i = \left(0\ldots c^i_\$\ldots 0\right)\begin{pmatrix} 0 & \cdots & 0 \\ a_{11,ij} & 0 & a_{IJ,ij} \\ 0 & \cdots & 0 \end{pmatrix} \tag{5}$$

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 impact of the exchange rate fluctuation from the perspective of the shocked country i.

Define C^i the vector of change in prices everywhere expressed in country i's currency.

$$C^i = \left(-\frac{c^i_\$}{1+c^i_\$}, \ldots 0 \ldots, -\frac{c^i_\$}{1+c^i_\$}\right)$$

From Equation 4, we write the first-step impact for country i of the fall in input prices from the rest of the world. The first-step impact corresponds to the product of the shock vector C^i and a matrix $\tilde{\mathcal{B}^i}$. $\tilde{\mathcal{B}^i}$ builds on the large matrix $\mathcal{A}$ of which only the country blocks of those 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.

Notation table

- $a_{kl,ij}$: the share of inputs from country i's sector j in the production of country's k sector l.
- $\mathcal{A}$: Matrix of world input-output coefficients.
- $\mathcal{B}^i$: $\mathcal{A}$ including only the coefficients of each country's sectoral inputs imported from country i (excluding domestic inputs in i).
- $\tilde{\mathcal{B}}^i$: $\mathcal{A}$ including only the country blocks of the inputs imported by country i from other countries (excluding domestic inputs in i).
- $c^i_\$$: change in the exchange rate of the currency of country i in dollar. If it appreciates by 10%, $c^i_\$ = 0.1$.
- c^i: impact of the exchange rate variation on the price of non-i goods expressed in the currency of i. $c^i = -\frac{c^i_\$}{1+c^i_\$}$. If $c^i_\$ = 0.1$, $c^i = -0.0909...$
- C^i: vector of log point change in prices everywhere expressed in country i's currency: $C^i = \left(-\frac{c^i_\$}{1+c^i_\$}, \ldots 0 \ldots, -\frac{c^i_\$}{1+c^i_\$}\right) = (c_i, \ldots 0 \ldots, c_i)$
- $C^i_\$$: vector of log points changes in dollar prices following the appreciation of the currency of country i against all other currencies. $C^i_\$ = (0 \ldots 0 \ldots c_{\$ij} \ldots c_{\$ik} \ldots 0 \ldots 0)$ with $c_{\$ij} = c_{\$ik} = c^i_\$$
- $\hat{C}^i_\$$: vector of the log point change in dollar prices of goods and services from country i used as inputs in all other countries. $\hat{C}^i_\$ = \left(0 \ldots \frac{c^i_\$}{1+c^i_\$}, \ldots 0\right)$
- $p_{\$ij}$: price of goods producted by the sector j in country i in dollars (or any international reference currency)

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

$$C^i\tilde{\mathcal{B}}^i = \left(-\frac{c^i_\$}{1+c^i_\$}, \ldots 0 \ldots, -\frac{c^i_\$}{1+c^i_\$}\right)\begin{pmatrix} 0 & \ldots a_{ij,11} \ldots & 0 \\ 0 & 0 & 0 \\ 0 & \ldots a_{ij,IJ} \ldots & 0 \end{pmatrix} \tag{6}$$

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 the direct impact into 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 $\tilde{C}^i_\$\tilde{\mathcal{B}}^i$ with:

$$\tilde{C}^i_\$\tilde{\mathcal{B}}^i = \left(1 + c^i_\$\right).C^i\tilde{\mathcal{B}}^i = \left(-c^i_\$ \ldots 0 \ldots - c^i_\$\right)\begin{pmatrix} 0 & \ldots a_{ij,11} \ldots & 0 \\ 0 & 0 & 0 \\ 0 & \ldots a_{ij,IJ} \ldots & 0 \end{pmatrix} \tag{7}$$

The first-step effect on the world is therefore the sum of these vectors from equations 5 and 7, i. e. $C^i_\$.\mathcal{B}^i + \tilde{C}^i_\$\tilde{\mathcal{B}}^i$.

The change in input prices then spreads to all sectors in all countries via the global intersectoral exchanges transcribed by the matrix of technical coefficients of the large matrix $\mathcal{A}$. This process will be simultaneously repeated several times, until the effects are completely exhausted. In the end, the total price effect of the exchange rate variation is equal to the sectoral shock itself, incremented by changes in input prices due to changes in imported input prices (both in the shocked country and in non-shocked countries), and by all changes in prices during the production processes, i. e.:

$$\begin{aligned} S^i_\$ = \Delta P^i_\$ = C^i_\$ \quad &+ \quad \left(C^i_\$.\mathcal{B}^i + \tilde{C}^i_\$\tilde{\mathcal{B}}^i\right) + \left(C^i_\$.\mathcal{B}^i + \tilde{C}^i_\$\tilde{\mathcal{B}}^i\right)\mathcal{A} + \left(C^i_\$.\mathcal{B}^i + \tilde{C}^i_\$\tilde{\mathcal{B}}^i\right)\mathcal{A}^2 \\ &+ \quad \ldots + \left(C^i_\$.\mathcal{B}^i + \tilde{C}^i_\$\tilde{\mathcal{B}}^i\right)\mathcal{A}^k + \ldots \end{aligned}$$

$$S^i_{\$} = C^i_{\$} + \left(C^i_{\$}.\mathcal{B}^i + \tilde{C}^i_{\$}\tilde{\mathcal{B}}^i\right) * (I - \mathcal{A})^{-1} \tag{8}$$

With $S^i_{\$}$ the total impact vector composed of the elements $s^i_{\$kj}$ showing the total impact of a change in the exchange rate of country i on the price of the country k's sector j in international currency in log points. Equation 8 gives the evolution of sectoral prices in international currency. Analysing this vector is the main objet of Cochard et al. [2016], which focuses on the evolution of price-competitiveness.

By contrast, we focus on the effect of an exchange rate variation on consumer prices. Hence, we are interested in the same impact expressed in national currency. To obtain the evolution of the sectoral prices of the shocked country in national currency, we remove the exchange rate variation in international currency, multiply the balance by the scalar of conversion equal to $\frac{1}{1+c^i_{\$}}$ and add the initial exchange rate fluctuation in national currency.

$$\begin{aligned} S^i &= C^i + \left(\frac{1}{1+c^i_{\$}}\right) * \left(S^i_{\$} - C^i_{\$}\right) \\ &= C^i + \left(\frac{1}{1+c^i_{\$}}\right) * \left(C^i_{\$}.\mathcal{B}^i + \tilde{C}^i_{\$}\tilde{\mathcal{B}}^i\right) * (I - \mathcal{A})^{-1} \\ &= C^i + \left(\hat{C}^i_{\$}.\mathcal{B}^i + C^i\tilde{\mathcal{B}}^i\right) * (I - \mathcal{A})^{-1} \end{aligned} \tag{9}$$

Where $\hat{C}^i_{\$} = \left(0 \ldots \frac{c^i_{\$}}{1+c^i_{\$}}, \ldots 0\right)$ is the increase in dollar prices of goods and services from country i used as inputs in all other countries.

S^i represents the overall impact of an exchange rate variation on prices in each sector of each country expressed in the currency of country i. S^i is expressed in log points. If the variation is small enough, the elements of S^i correspond to the elasticities to the exchange rate of consumer prices in country i. We return to this equation and its interpretation in section 4.

To convert this vector into the HCE deflator elasticity in country i, $\bar{s}^i$, we use the household consumption shares to compute a weighed average of the elements of S^i. Let

HC^i be the vector of sectoral shares in country i's household consumption[5]:

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

Where hc^i_{kj} corresponds to household consumption in country i of goods and services 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 elasticity of the HCE deflator of country i to the exchange rate.

$$\overline{s_i}^{i,HC} = S^i.HC^i = \sum_{\substack{j=1\ldots J\\ k=1\ldots I}} s^i_{kj}.\frac{hc^i_{kj}}{hc^i} \tag{10}$$

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

3 Accounting impact of an exchange rate variation on consumer prices

We use the model presented in 2.3 to analyse the impact of an exchange rate variation on the household consumption expenditure (HCE) deflator. We assume that the variation in the nominal exchange rate is small enough to assimilate log and percentage points and hence consider $\overline{s_i}^{i,HC}$ as the HCE deflator elasticity to the exchange rate. Following an appreciation of the national currency versus all other currencies, imported inputs and imported consumer goods become cheaper and domestic prices expressed in national currency decrease.

[5] Consumption is at market prices, whereas the WIOTs are all at basic prices. This is not an issue as long as we assume that all taxes and subsidies on products are proportional, like the value-added tax.

3.1 Heterogeneity across country

We find that the HCE deflator elasticity is heterogeneous across countries. Using the WIOD database, which covers a sample of 43 countries, we find that the elasticity ranges from 0.05 to 0.35 (see Figure 2). This heterogeneity reflects different degrees of openness to trade and differences in foreign product content in domestic consumption. The elasticity is lower for large advanced and developing countries. For instance, we find an elasticity of 0.06 in 2011 for the US. Accross the euro area, the elasticity of the HCE deflator differs substantially, ranging from 0.07 in Italy to 0.18 in Ireland, a small open economy with a large traded sector and a large share of trade outside the euro area. For larger countries (France, Germany, Italy and Spain) and countries whose trade is concentrated with euro area partners (such as Portugal and Greece), the elasticity is close to 0.10, reflecting a lower degree of openness to trade. It is twice higher in small open economies like Luxembourg, Malta, Slovakia and Ireland.

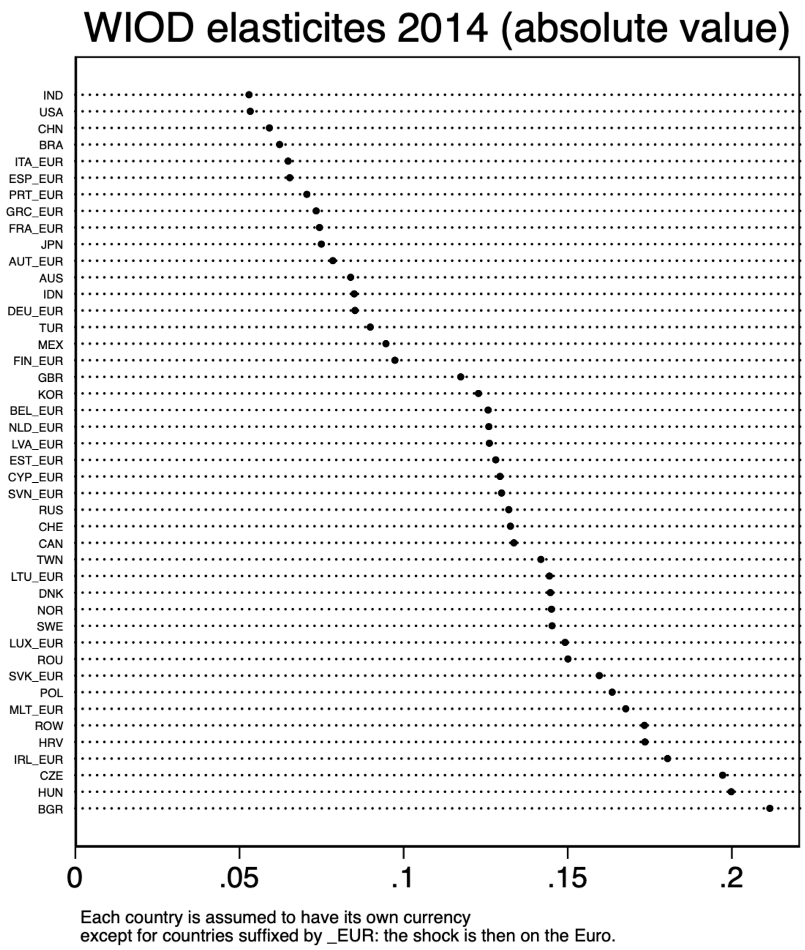

Fig. 1: **Distribution of the HCE deflator elasticity to a chang in the exchange rate (WIOD) - 2014.**

Sources: WIOD and authors' calculations

Using WIOD, we also estimate the impact of an appreciation of the US dollar (USD) on its trading partners, with a focus on the euro area. A large portion of extra-EU imports are denominated in US dollars and hence movements in the dollar also have a significant impact on import prices for countries in the euro area. Unsurprisingly, we obtain the highest elasticities for the US neighbouring countries. The elasticity of the HCE deflator to the USD is close to 0.12 for Canada and 0.09 for Mexico. The elasticity is below 0.06 for most euro area countries except Ireland. Ireland stands out, with an elasticity of 0.09, i.e. close to that of Canada and Mexico. The U.S. is Ireland's major trading partner outside of the EU. The U.S. accounted for 19% of the total current account outflows in

2018 according to the Irish Central Statistics Office, the largest share of any other EU country[6].

Figure 1 shows that we obtain similar country results with the three databases (WIOD and two distinct releases of TiVA), both in 2011 and 2014.

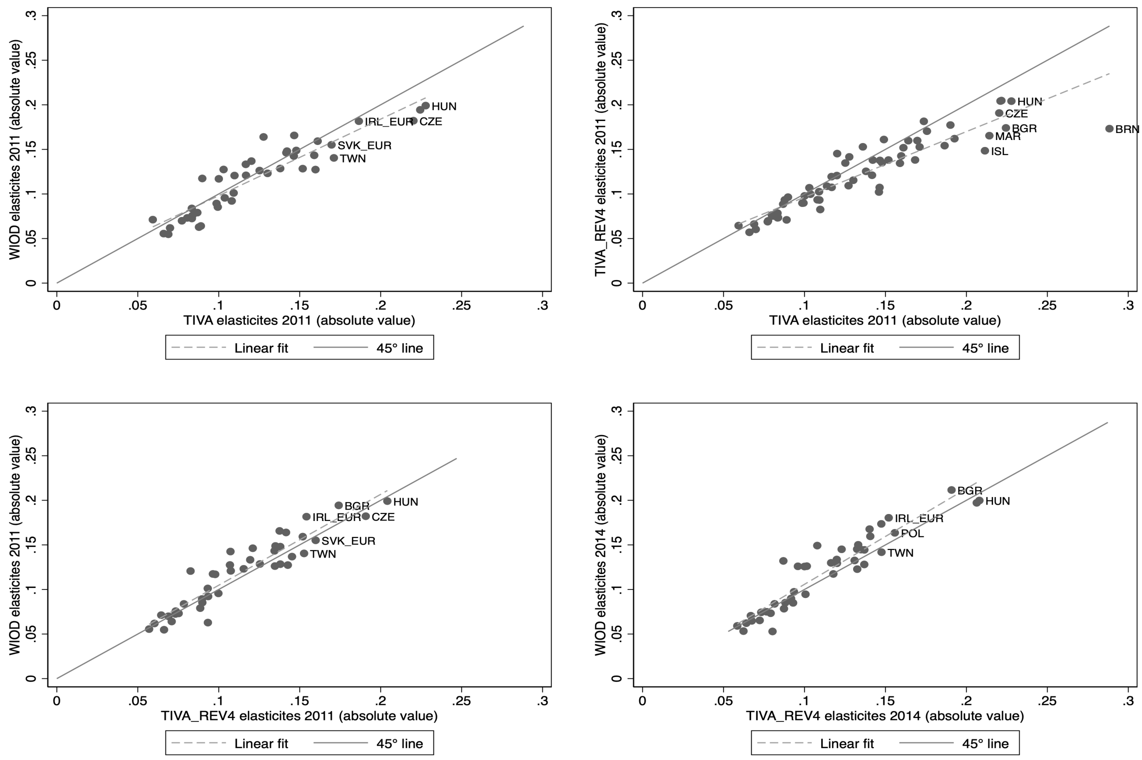

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Fig. 2: **Comparison of the HCE deflator elasticity to the exchange rate for WIOD, TIVA rev. 3 and TIVA rev. 4, 2011 and 2014**

Sources: WIOD, TIVA rev. 3 and TIVA rev. 4, authors' calculations

Heterogeneity in the elasticity is related to differences in foreign product content in domestic consumption. Figure 4 shows that the value of the elasticity is closely related to the share of imported goods and services in household consumption. The higher the country's import share in consumption, the higher the elasticity of the HCE deflator to the exchange rate. Small open economies in the euro area post higher import content of consumption. Our findinngs concur with the literature. For instance,Ortega and Osbat [2020] find that the direct and indirect import content in consumption ranges from 12%

[6] However, a large portion of US imports (pharmaceuticals products and aircraft) are later exported by Irish-based firms without being purchased by Irish consumers (Reddan and Rice [2017]), and therefore have a negligible contribution to domestic consumer goods inflation.

in Italy to 33% in Ireland and Malta, according to calculations based on input-output tables from WIOD.

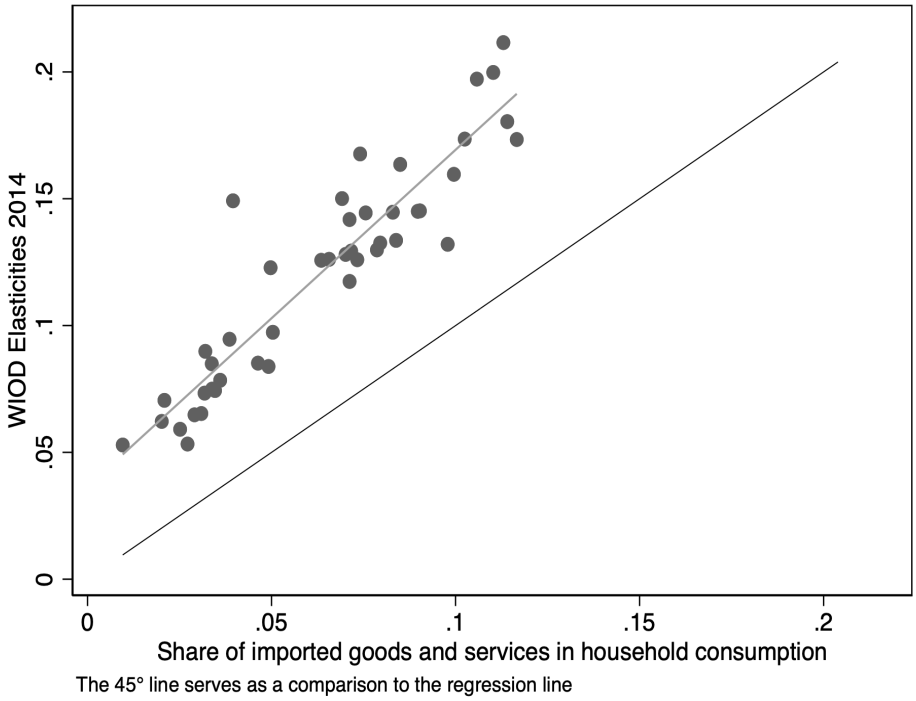

Fig. 3: **HCE deflator elasticity and share of imported consumption in total consumption (WIOD)**

Sources: WIOD and authors' calculations

3.2 Evolution over time

We find that the elasticity of the HCE deflator to the exchange rate has remained broadly stable over the past two decades. Using the WIOD database, we find that the mean output-weighted elasticity of the HCE deflator increased from 0.08 in 2000 to 0.09 in 2008. After peaking in 2008, the elasticity slightly declined between 2009 and 2015. Results from the MRIO database suggest that the elasticity has bounced back from 2016 onwards, reaching 0.13 in 2018. Our results concur with the literature. Using comprehensive measures of global value chain integration, Timmer et al. [2016] find that the expansion of global value chain has slowed since the 2008-2009 Great Recession.

Our results are robust to using different databases. WIOD and MRIO provide similar results. This is unsurprising, given that the main difference between the databases relates to the broader geographic coverage of MRIO. MRIO includes nineteen additional emerging Asian economies. Given these economies' relative small size, using MRIO provides aggregate results similar to those of WIOD.

We obtain similar results with WIOD and TIVA (see Figure 3). Using data from TIVA rev. 3, which covers a sample of 64 countries, yields a higher elasticity. This result likely reflects the different treatment of contract manufacturing in the 2008 system of national accounts compared to the 1993 system, which reduces imported inputs. The small differences observed between WIOD and TiVA rev. 4 likely reflect different ways of reconciling national accounts and international trade statistics. Output-weighted results provide a lower elasticity, reflecting the fact that large countries are relatively closed compared to small economies. Using the third revision of the TiVA database, we find that the output-weighed elasticity has increased by 25% between 1995 and 2008, reaching 0.1 in 2008. The elasticity has slightly declined afterwards.

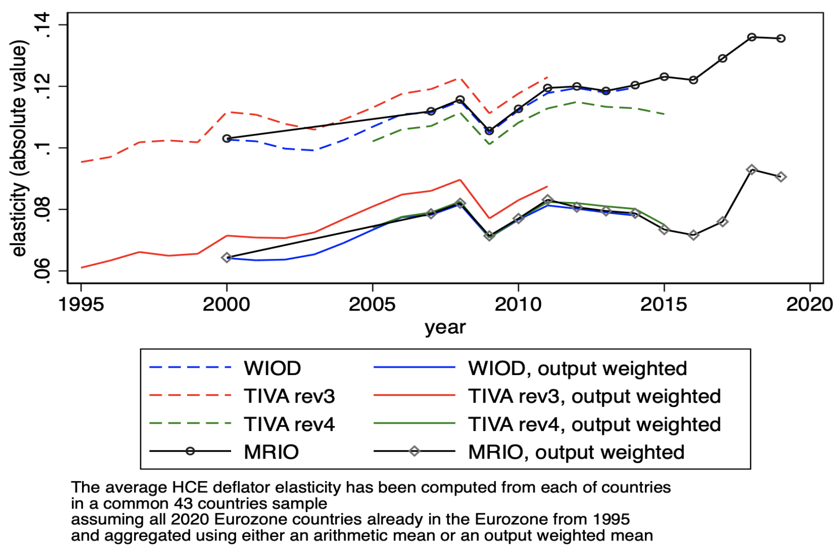

Fig. 4: **Evolution of the output-weighted elasticity of the HCE deflator, 1995-2015**

Sources: WIOD, TIVA rev. 3, TIVA rev. 4 and authors' calculations

3.3 Determinants of the HCE deflator elasticity

We analyse the determinants of the HCE elasticity and the role of global value chains in the transmission of an exchange rate appreciation to the HCE deflator. To do so, we identify four channels through which an exchange rate appreciation impacts the HCE deflator when production processes are global: *i)* the prices of imported final goods sold directly to domestic consumers; *ii)* the prices of imported inputs entering domestic production; *iii)* the price of exported inputs feeding through imported foreign production; *iv)*, changes in domestic and foreign production costs in turn pass through to the price of inputs for domestic and foreign goods and cause further changes in production costs through input-output linkages.

Figure 5 shows the contribution of domestic versus imported goods to the elasticity of the HCE deflator. We define

$$\overline{s}_i^{i,HC} = \overline{s}_{i,imp}^{i,HC} + \overline{s}_{i,dom}^{i,HC} = S^i.HC^{i,dom} + S^i.HC^{i,imp} \tag{11}$$

Where:

$$\begin{aligned} HC^i &= HC^{i,dom} + HC^{i,imp} \\ &= \begin{pmatrix} 0 \\ \\ \ldots \\ \frac{hc^i_{ij}}{hc^i} \\ \ldots \\ \\ 0 \end{pmatrix} + \begin{pmatrix} \frac{hc^i_{11}}{hc^i} \\ \\ \ldots \\ 0 \\ \ldots \\ \\ \frac{hc^i_{IJ}}{hc^i} \end{pmatrix} \end{aligned} \tag{12}$$

For example,

$$\overline{s}_{i,imp}^{i,HC} = \sum_{\substack{j=1\ldots J \\ k=1\ldots I \\ k\neq i}} s^i_{kj}.\frac{hc^i_{kj}}{hc^i} \tag{13}$$

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

Overall, we find that the first two channels explain three-quarters of the transmission of an exchange rate appreciation to domestic prices. By contrast, the last two channels, which reflect the impact of global value chains, play a more limited role, with marked across-countries heterogeneity. Hence, only one-fourth of the HCE elasticity to the exchange rate is attributable to participation in global value chains.

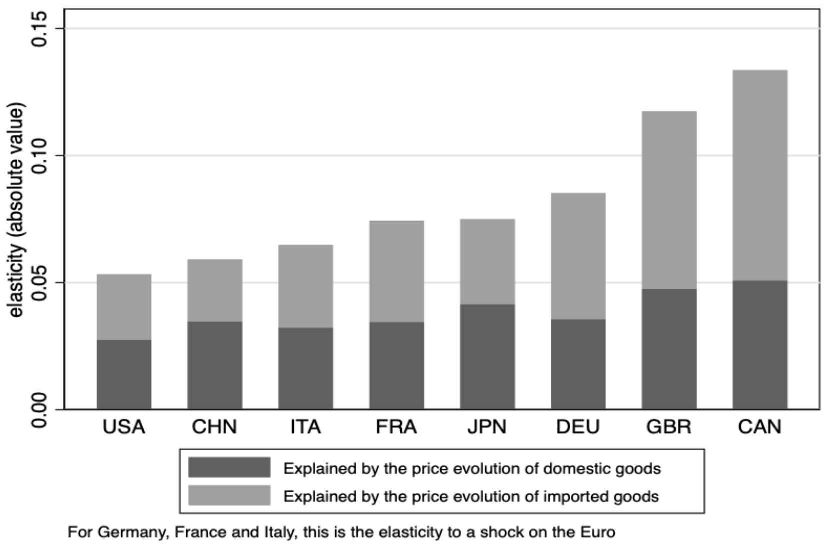

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Fig. 5: **Contribution of imported and domestic final goods and services to the HCE deflator elasticity**

Sources: WIOD and authors' calculations

3.4 Contribution of the main components of the HCE deflator

Building on sectoral data, we examine which sectors experience higher spillovers from an exchange rate appreciation. We focus on the main components of the HCE deflator, i.e. manufacturing goods, services, food and energy. We analyse the contribution of these different products to the HCE deflator elasticity to shed light on the observed heterogeneity in the elasticity estimates. Figure 6 shows the impact of a change in the exchange rate on the main components of the HCE deflator. Non-energy industrial goods explain the bulk of the total impact. 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, services represent a substantial share of total consumption. Similarly, domestic core inflation (i.e. all products except food and energy) 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.

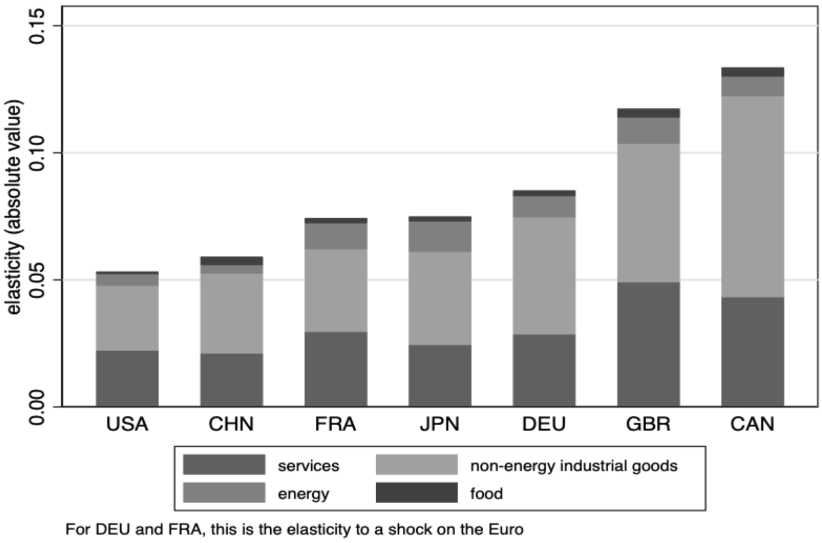

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Fig. 6: **Contribution of different products to the HCE deflator elasticity to the exchange rate**

Sources: WIOD and authors' calculations

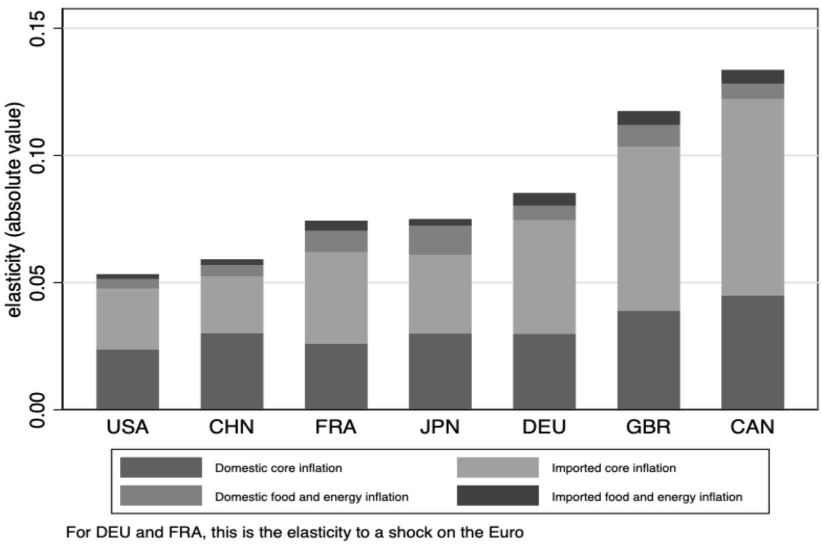

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Fig. 7: **Contribution of domestic and imported components to the HCE deflator elasticity**

Sources: WIOD and authors's calculations

4 Filling the data gap: estimating the HCE deflator elasticity without using WIOT

4.1 Estimating the HCE deflator elasticity without resorting to WIOT

In this section, we show that a precise assessment of the HCE deflator elasticity to the exchange rate can be estimated without resorting to WIOT. The construction of World Input-Output tables is data-demanding and WIOTs are typically released with a lag of several years. As a result, world input-output matrices are not available for the most recent years. The latest years covered by WIOD and TiVA rev. 4 are, respectively, 2014 and 2015. In addition, using WIOTs involves cumbersome computations. Given these difficulties, we look for a simpler way to compute the elasticity of the HCE deflator to the exchange rate. We estimate the HCE deflator elasticity from 2016 onwards using GDP statistics and trade data on consumption and intermediates.

First, we break down $\overline{s_i}^{i,HC}$ into different elements classified by ease of use and computation. Let us start from equation 9. We have:

$$
\begin{aligned}
S^i &= C^i + \left(\hat{C}^i_{\$}.\mathcal{B}^i + C^i\tilde{\mathcal{B}}^i\right) * (I-\mathcal{A})^{-1} \\
S^i &= \underbrace{C^i}_{\substack{\text{(E1) direct effect through}\\ \text{imported consumption goods}}} + \underbrace{C^i\tilde{\mathcal{B}}^i}_{\substack{\text{(E2) effect on}\\ \textit{domestic}\text{ consumption goods}\\ \text{through }\textit{imported}\text{ inputs}}} + \underbrace{\hat{C}^i_{\$}.\mathcal{B}^i}_{\substack{\text{(E3) effect on}\\ \textit{imported}\text{ consumption goods}\\ \text{through }\textit{domestic}\text{ inputs}}} \\
&\quad + \underbrace{\left(\hat{C}^i_{\$}.\mathcal{B}^i + C^i\tilde{\mathcal{B}}^i\right) * (I-\mathcal{A})^{-1} * \mathcal{A}}_{\text{(E4) residual}}
\end{aligned}
\tag{14}
$$

C^i and $\hat{C}^i_{\$}$ have a large number of zeros. Hence, we can write, defining $HC^{i,dom}$ and $HC^{i,imp}$ as the domestic and imported shares of HC^i and adjusting the dimension of $E1$, $E2$ and $E3$:

$$
\begin{aligned}
\overline{s}_i^{i,HC} &= S^i.HC^i = E1.HC^i + E2.HC^i + E3.HC^i + E4.HC^i \\
&= E1.HC^{i,imp} + E2.HC^{i,dom} + E3.HC^{i,imp} + E4.HC^i
\end{aligned}
\tag{15}
$$

When the domestic currency appreciates, $E1.HC^{i,imp}$ ($E1.HC$ hereafter) and $E2.HC^{i,dom}$ ($E2.HC$ hereafter) reduce the consumer prices of the country i whereas $E3.HC^{i,imp}$ ($E3.HC$) increases them.

This decomposition differs from equation 11. Equation 11 focuses on the contribution of domestic versus imported goods to the HCE deflator elasticity to a change in the exchange rate. By contrast, equation 15 highlights the transmission channels of the exchange rate fluctuation.

Figure 8 plots the shares of $E1.HC$, $E2.HC$, $E3.HC$ and $E4.HC$ (shortening $E4.HC^i$) in $\overline{s}_i^{i,HC}$. $E1.HC$ dominates. While $E3.HC$ is negligible, $E4.HC$ accounts for 10% to 30% of $\overline{s}_i^{i,HC}$ for most countries except China. On the whole, as shown by Figure 9, input-output mechanisms (i.e. all shares except $E1.HC$) explain a large share of the elasticity, especially for large countries or euro area countries subject to an appreciation of the euro. This share has increased until 2013-2014, implying an increasing need of data from WIOTs to perform our computations (see Figure 10).

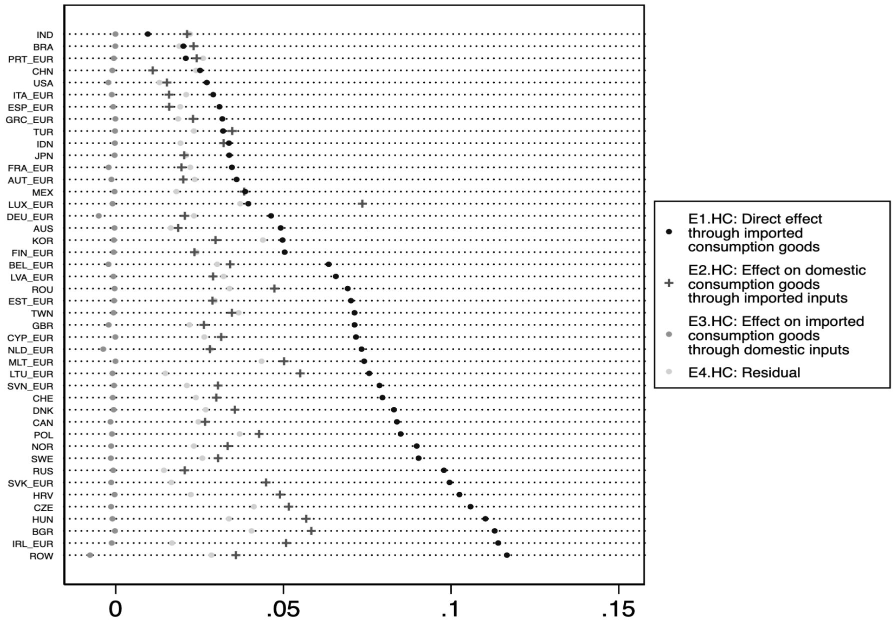

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Fig. 8: **Decomposition of $\bar{s}_i^{i,HC}$ into $E1.HC$, $E2.HC$, $E3.HC$ and $E4.HC$**

Sources: WIOD and authors' calculations

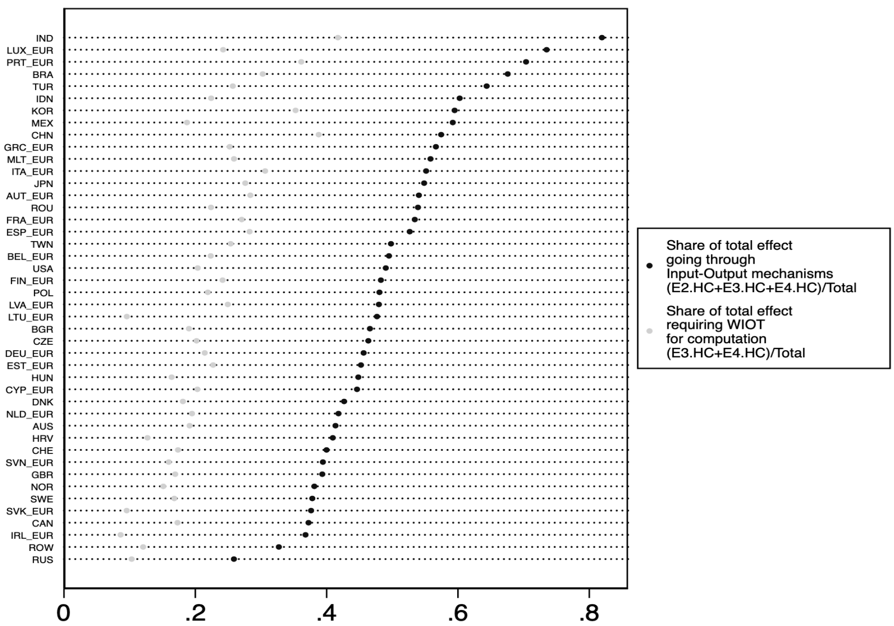

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Fig. 9: **Decomposition of $\bar{s}_i^{i,HC}$**

Sources: WIOD and authors' calculations

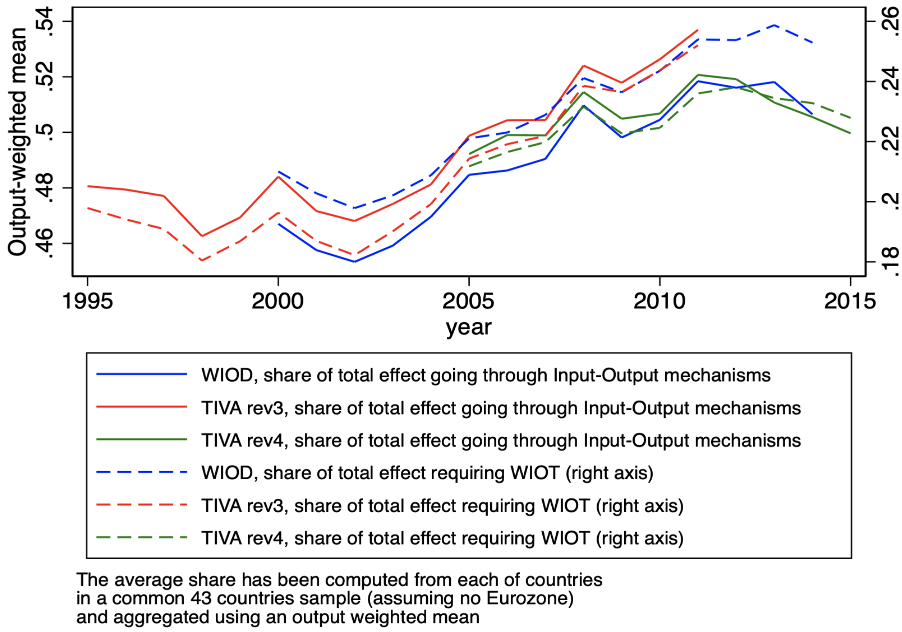

Fig. 10: **Decomposition of $\overline{s}_i^{i,HC}$ through time**

Sources: WIOD, TIVA rev. 3, TIVA rev. 4 and authors' calculations

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

We infer $\overline{s}_i^{i,HC}$ from $E1.HC$ and $E2.HC$. Figure 11 depicts the relationship between $\overline{s}_i^{i,HC}$ and $E1.HC + E2.HC$ according to equation 16. The high R^2 (0.98) suggests that $E1.HC + E2.HC$ is a good predictor of $\overline{s}_i^{i,HC}$.

$$\overline{s}_i^{i,HC} = \alpha + \beta \left(E1.HC^{i,imp} + E2.HC^{i,dom} \right) + \varepsilon_i \tag{16}$$

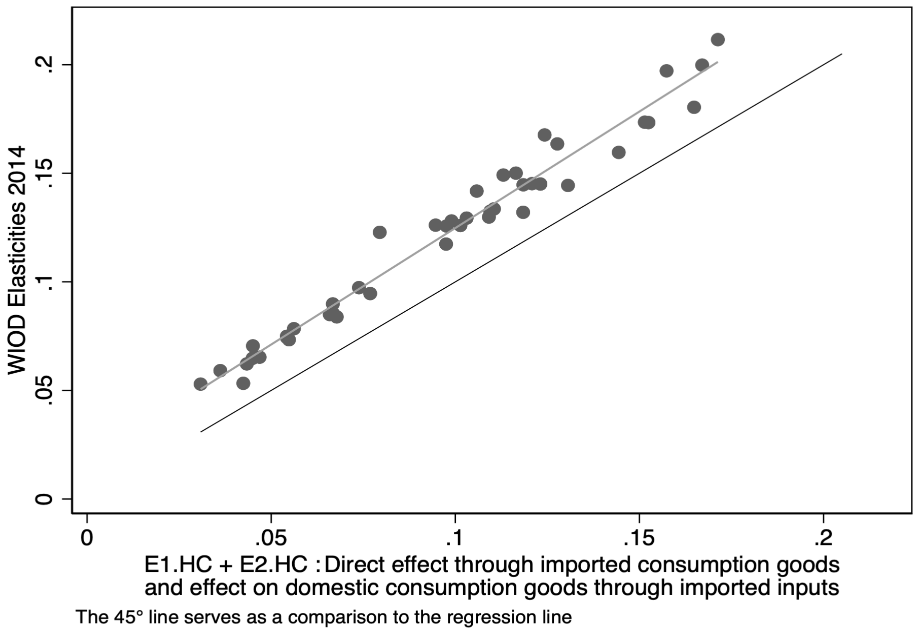

Fig. 11: **Comparison of** $\overline{s}_i^{i,HC}$ **and** $E1.HC^{i,imp} + E2.HC^{i,dom}$

Sources: WIOD and authors' calculations

We check whether the relationship is constant over time by estimating yearly cross-sections of equation 16. With the exception of 2009, the relationship is broadly stable (see Figures 12 and 13).

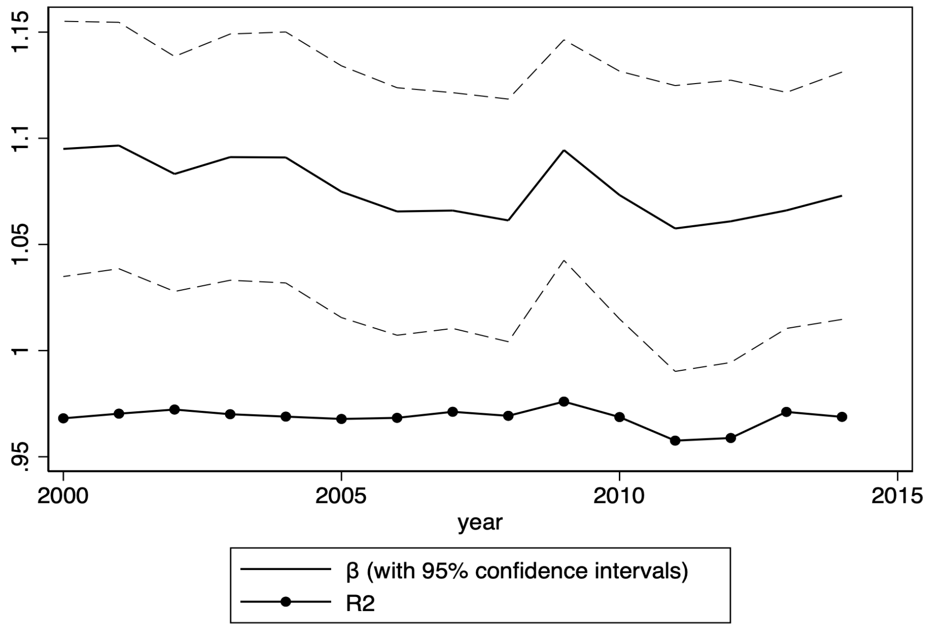

Fig. 12: **Evolution of β (the coefficent of E1.HC+E2.HC) and R^2 over time (WIOD)**

Sources: WIOD and authors' calculations

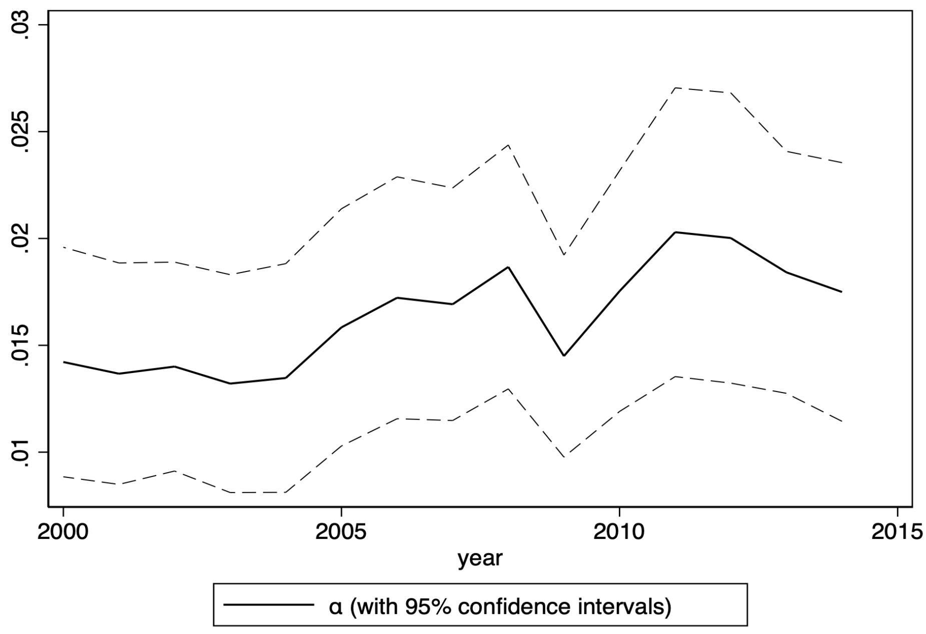

Fig. 13: **Evolution of α (the constant) over time (WIOD)**

Sources: WIOD and authors' calculations

We obtain similar results with TiVA (see Online Appendix B). Our results suggest that we can approximate the HCE deflator elasticity 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. $E1.HC + E2.HC$ is a good predictor of the total effects. Yet, they cannot be extrapolated in a multiplicative way, as the other effects ($E3.HC + E4.HC$) add to them rather than amplifying them. They are of similar size for small open economies and large closed ones. This likely reflects the fact that a small economy compensates for its small size by being more open, and vice versa.[7]

4.2 Estimating the HCE deflator elasticity using GDP and trade statistics

The sum of the share of imported goods in household consumption and the share of imported inputs in household consumption of domestic goods ($E1.HC + E2.HC$) are a good predictor of the effect of exchange rate fluctuations on household consumption prices. However, these data ($E1.HC$ and $E2.HC$) are not up-to-date for a large number of countries, as they are not routinely computed by national statistical institutes. We can rely on a proxy (see Online Appendix C) by identifying consumption and intermediary goods imports using UN Comtrade data and the BEC classification and using a measure for household consumption (from the World Bank) and intermediate consumption (from Eurostat). Intermediate consumption data are not available for all countries. As a result, the regressions provided in Online Appendix C only include a limited number of observations.

To expand our panel, we use in this section an even simpler proxy for $E1.HC{+}E2.HC$. This proxy only requires trade data from Comtrade and GDP data from the World Bank. This data is available until 2018. As a result, we can include more countries in the new

[7] Although this functional form might seem counterintuitive (one might expect that the elasticity is an affine function of openness as summarized by $E1.HC$), the analytical examination of the two-country, one-sector case shows that it is plausible (see Online Appendix E).

panel (see equation 17).

$$\overline{s}_{i,t}^{i,t,HC} = \alpha \quad + \beta_1 \frac{\text{imported consumption goods}_{i,t}}{\text{GDP}_{i,t}} + \beta_2 \frac{\text{imported intermediate goods}_{i,t}}{\text{GDP}_{i,t}} + \beta_3 \frac{\text{Total imported consumption goods}_t}{\text{Total GDP}_t} + \beta_4 \frac{\text{Total imported intermediate goods}_t}{\text{Total GDP}_t} + fe_i + \varepsilon_{i,t} \tag{17}$$

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).[8]

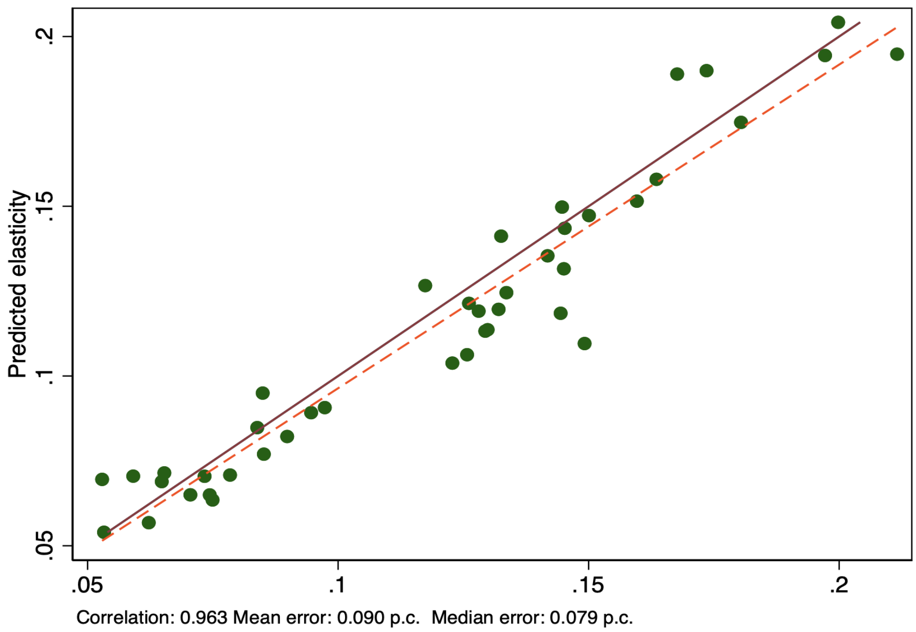

Fig. 14: **Comparing the HCE deflator elasticity in 2014 (WIOD) and the prediction from a panel regression on the 2000-2008 period with fixed effects using only World Bank and Comtrade data.**

Sources: WIOD, World Bank, Comtrade and authors' calculations

Using these equations, we can predict the HCE deflator elasticity from 2016 onwards to make up for the lack of WIOTs. Figure 15 shows that the in-sample predictions are robust, giving confidence in the quality of the out-of-sample predictions.

[8] Results are available upon request

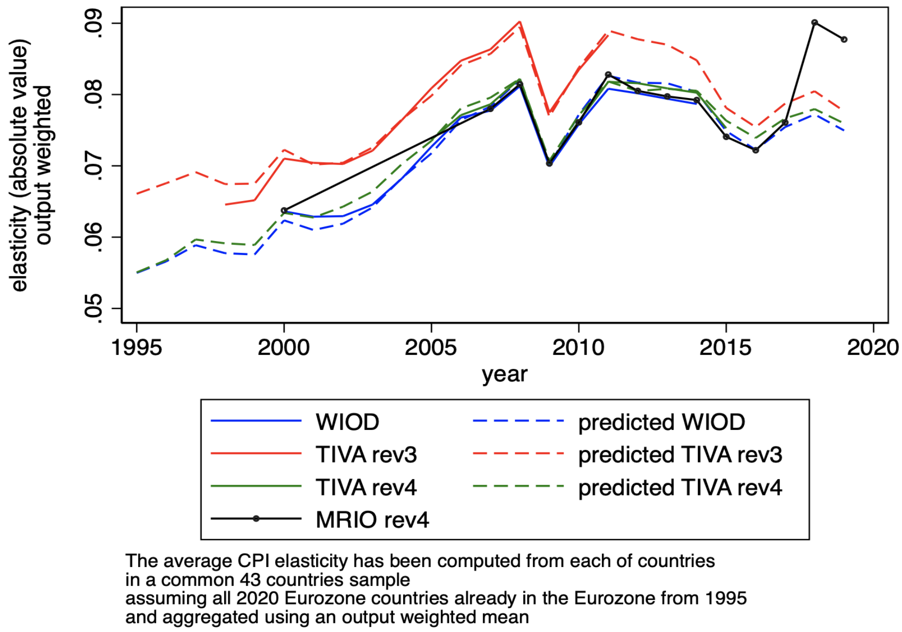

Fig. 15: **Comparing the output-weighed HCE deflator elasticity to predictions based on World Bank and Comtrade data.**

Sources: WIOD, World Bank, Comtrade and authors' calculations

5 Conclusion

This paper focuses on the elasticity of the household consumption expenditure (HCE) deflator to the exchange rate. Our contribution to the literature is fourfold.

First, we analyse the composition and determinants of the HCE deflator elasticity using world input-output tables covering twenty years of data, from 1995 to 2018. We use several datasets to ensure the robustness of our results. In line with the existing literature, we find a rather modest elasticity of the HCE deflator to the exchange rate of around 0.1. The output-weighted elasticity has remained broadly stable over the past two decades. However, results from the MRIO database suggest an upward trend in recent years. Aggregate figures mask substantial cross-country heterogeneity, reflecting different degrees of openness to trade and differences in foreign product content in domestic consumption. The elasticity is larger for small open economies with higher import content of consumption.

Second, we examine which sectors experience higher spillovers from an exchange rate appreciation. To do so, we focus on the main components of the HCE deflator. Non-energy industrial goods explain the bulk of the total HCE deflator elasticity to the exchange rate. Services also play a significant role, especially in advanced economies, as they represent a substantial share of total consumption.

Third, we analyse the determinants of the HCE deflator elasticity and the role of global value chains in the transmission of an exchange rate appreciation to domestic prices. We find that direct effects through imported consumption and intermediates entering domestic production explain three-quarters of the transmission of an exchange rate appreciation to domestic prices. By contrast, global value chains participation plays a limited role, with marked cross-countries heterogeneity.

Fourth, we show that a precise assessment of the HCE deflator elasticity to the exchange rate can be estimated without resorting to WIOT, which are not available for the most recent years. To address this data gap, we estimate the HCE deflator elasticity from 2016 onwards using GDP statistics and trade data on consumption and intermediates.

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