Estimating the elasticity of consumer prices to the exchange rate: an accounting approach

Online Appendix *

Hadrien Camatte[†]   Guillaume Daudin[‡]   Violaine Faubert[§]   Antoine Lalliard[¶]

Christine Rifflart[‖]

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Appendix 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 1: **WIOD sectors**

Appendix B: Defining the impact of a change in prices using an I-O model

In this appendix we compute the well-know effect of the impact of a change in prices using an I-O model. 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 in the main text. Hence, the price change is transmitted to country-specific industries that are using domestic input through the change in input prices. The higher the country-specific industries' reliance on those inputs, the higher the change in their production 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 kth 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:

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

with $(I - \mathcal{A})^{-1}$ the Leontieff inverse matrix. If the change in the input prices is small enough, the elements of S correspond to the elasticity of sectoral prices to a change in input prices.

Appendix C: Comparing the impact of a change in prices with that of an exchange rate variation

In this appendix, we use the two-country and one-good case to illustrate the difference between a change in prices and an exchange rate variation.

Effect of a change in prices based of value added 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 change c occurs in the prices of country 2, we have the following initial 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 change in prices S is:

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

To measure the impact on the household consumption expenditure deflator, we compute a weighted sum of these effects:

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

4

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

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

Impact of an exchange rate variation

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:

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

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

$$= (0, c) + (u.c.a_{2,1} - w.c.a_{1,2}, v.c.a_{2,1} - x.c.a_{1,2})$$

$$= (u.c.a_{2,1} - w.c.a_{1,2}, c + v.c.a_{2,1} - x.c.a_{1,2})$$

and

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

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

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

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

This confirms that the impact of an exchange rate variation differs from that of a change in prices.

Appendix D: MRIO data quality issues

Figure 1 shows that the HCE deflator's elasticity extrapolated from WIOD, World Bank and BACI data for the period 2015-2019 is close to the elasticity obtained with MRIO in 2016-2017. By contrast, the elasticity estimated using MRIO is much higher in 2018 and 2019. This discrepancy likely reflects data quality issues in MRIO. Figure 2 shows that the HCE deflator's elasticity estimated using MRIO increased by more than 20% for India and China between 2017 and 2018. For China, the increase reaches 100%, which is not plausible. Such a sharp increase was not observed between 2016 and 2017. Computations with WIOD confirm that such sharp increases were not observed in the past and are thus unlikely (see Figure 3). Looking more closely at MRIO, we observe large shifts in the consumption of services in China in 2018. Chinese households' consumption of Chinese education services increased by 43% between 2017 and 2018, whereas the consumption of Chinese transport services decreased by 43% over the same period. Such large and unlikely shifts suggest data quality issues in MRIO for 2018.
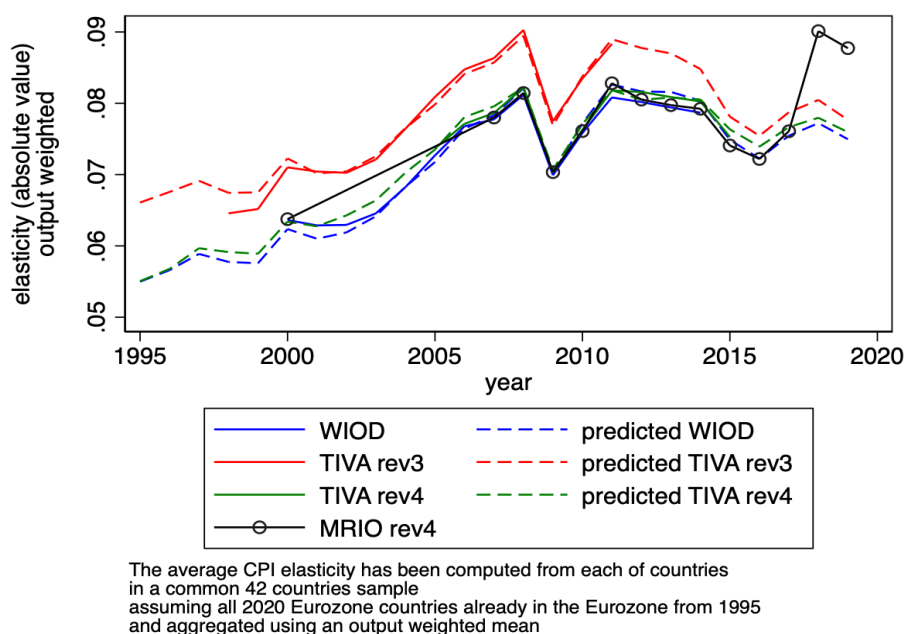

The average CPI elasticity has been computed from each of countries
in a common 42 countries sample
assuming all 2020 Eurozone countries already in the Eurozone from 1995
and aggregated using an output weighted mean

Figure 1: **Comparing the output-weighed HCE deflator's elasticity to predictions based on World Bank and BACI data.**

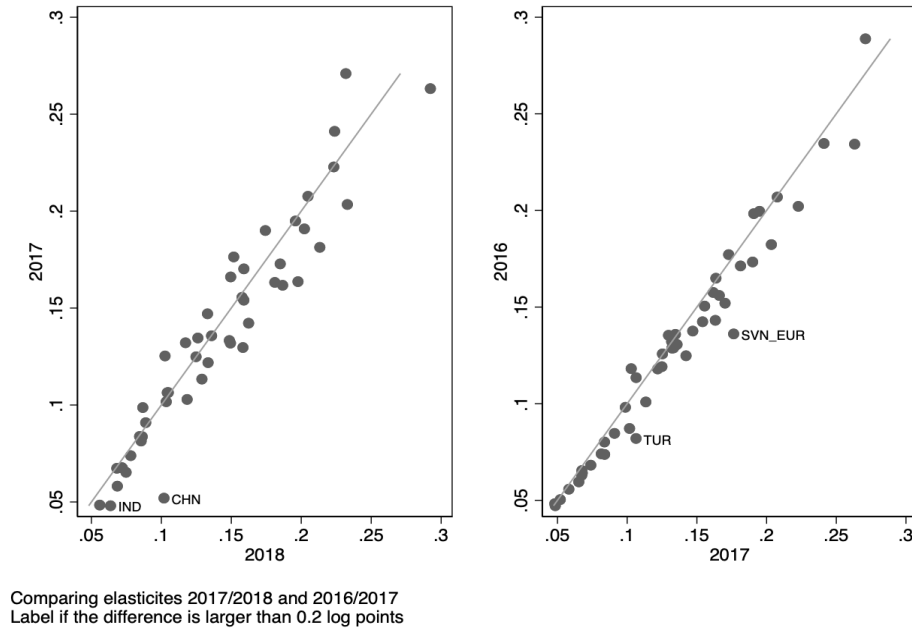Sources: WIOD, TIVA, MRIO, World Bank, BACI and authors' calculations

Comparing elasticites 2017/2018 and 2016/2017
Label if the difference is larger than 0.2 log points

Figure 2: **Comparing country-specific HCE deflator's elasticities computed using MRIO in 2016, 2017 and 2018.**

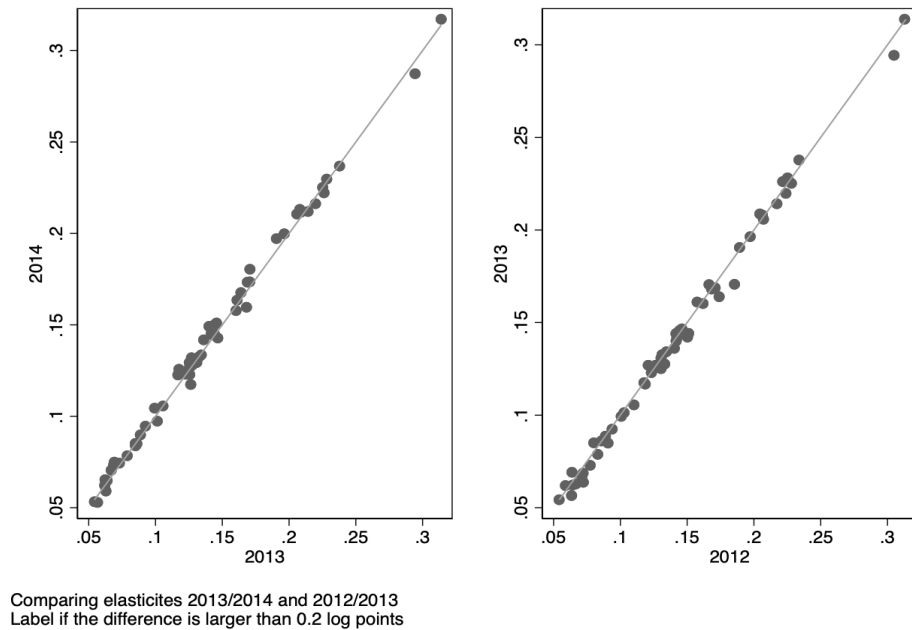Sources: MRIO and authors' calculations

Comparing elasticites 2013/2014 and 2012/2013
Label if the difference is larger than 0.2 log points

Figure 3: **Comparing country-specific HCE deflator's elasticities computed using WIOD in 2012, 2013 and 2014.**

Sources: WIOD and authors' calculations

Appendix E: Estimating the HCE deflator's elasticity using the shares of imported consumption and imported intermediates in domestic consumption

As a complement to section 4.2, Figures 4 and 5 for TIVA rev. 3 and Figures 6 and 7 for TIVA rev. 4 show that using the share of imported final consumer goods and services and the share of imported intermediate goods in domestic final consumption provides a good prediction of the elasticity of the HCE deflator to the exchange rate.
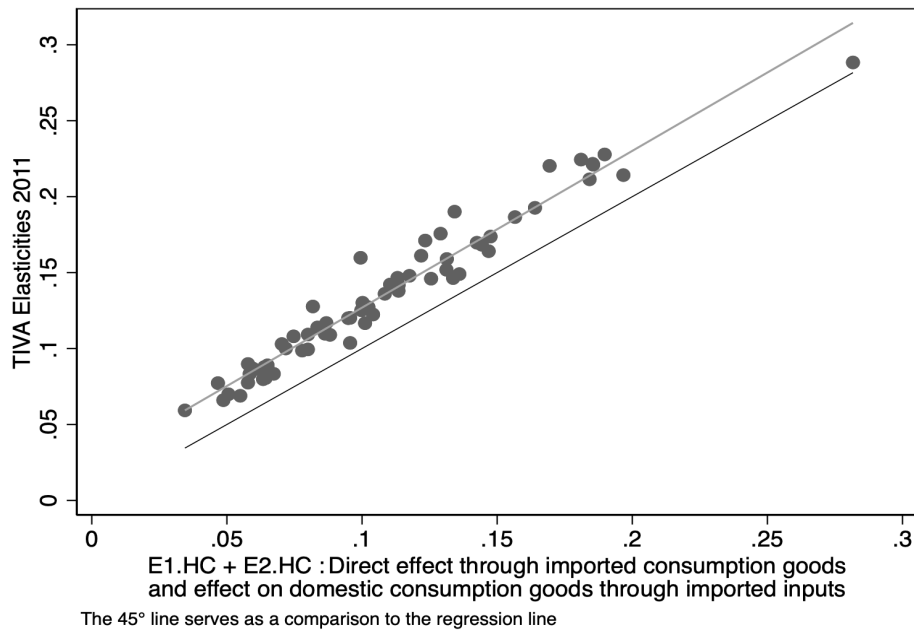

Figure 4: **Comparing** $\overline{s}_i^{i,HC}$ **and** $E1.HC^{i,imp} + E2.HC^{i,dom}$ **(TIVA rev. 3)**
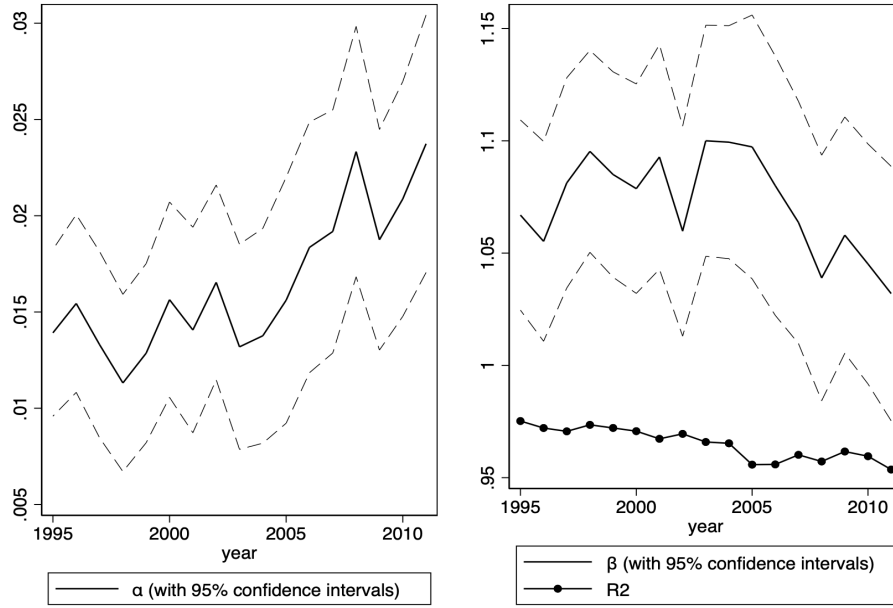
Sources: TIVA rev. 3 and authors' calculations

Figure 5: **Evolution of α, β and $R2$ (TIVA rev. 3)**

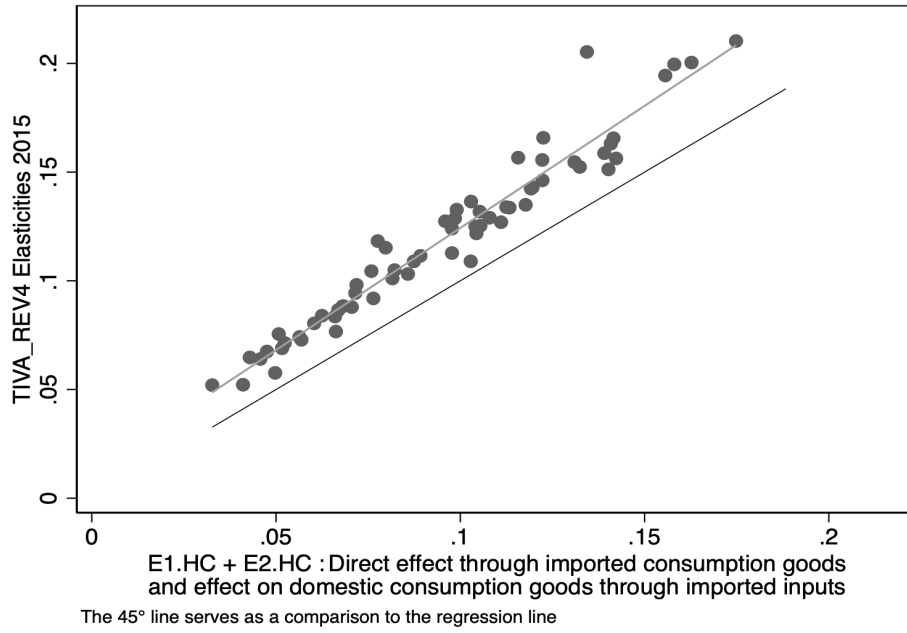Sources: TIVA rev. 3 and authors' calculations

Figure 6: **Comparison between $\bar{s}_i^{i,HC}$ and $E1.HC^{i,imp} + E2.HC^{i,dom}$ (TIVA rev. 4)**

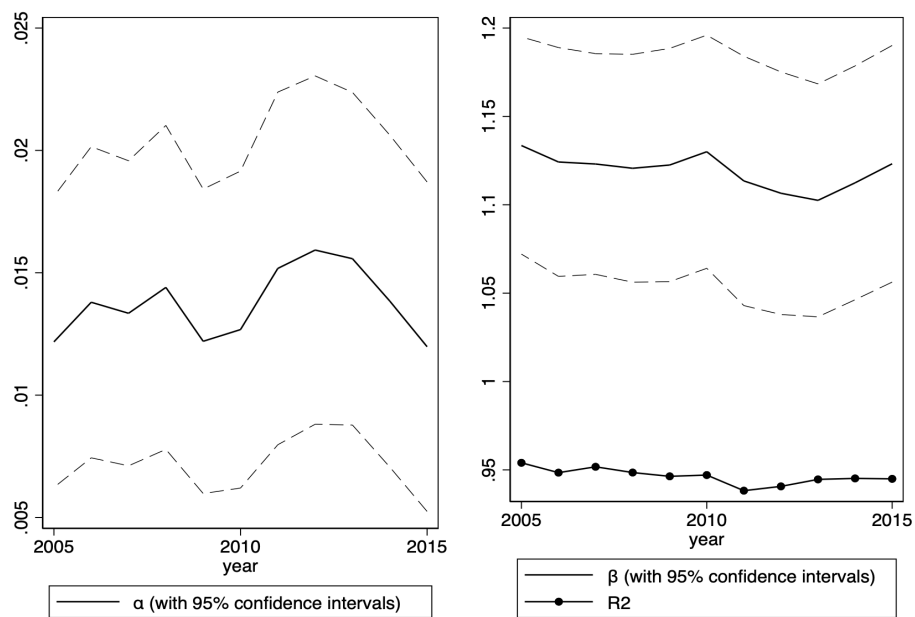Sources: TIVA rev. 4 and authors' calculations

Figure 7: **Evolution of α, β and $R2$ (TIVA rev. 4)**

Sources: TIVA rev. 4 and authors' calculations

Appendix F: Transmission channels of an exchange rate variation in the two-country, one-sector case

As a reminder from the paper, where $\overline{s}_i^{i,HC}$ corresponds to the impact of an exchange rate variation on consumer prices:

$$
\begin{aligned}
\overline{s}_i^{i,HC} &= S^i.HC^i = E1.HC^i + E2.HC^i + E3.HC^i + E4.HC^i \\
&= E1.HC^{i,imp} + E2.HC^{i,dom} + E3.HC^{i,imp} + E4.HC^i
\end{aligned}
\tag{3}
$$

and

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

$$
S^i = \underbrace{C^i}_{\substack{\text{(E1) direct effect through} \\ \text{imported consumer goods}}} + \underbrace{C^i \tilde{\mathcal{B}}^i}_{\substack{\text{(E2) effect on} \\ \textit{domestic} \text{ consumer goods} \\ \text{through } \textit{imported} \text{ inputs}}} + \underbrace{\hat{C}_\$^i.\mathcal{B}^i}_{\substack{\text{(E3) effect on} \\ \textit{imported} \text{ consumer goods} \\ \text{through } \textit{domestic} \text{ inputs}}}
$$

$$
+ \underbrace{\left(\hat{C}_\$^i.\mathcal{B}^i + C^i \tilde{\mathcal{B}}^i \right) * (I - \mathcal{A})^{-1} * \mathcal{A}}_{\text{(E4) residual}}
$$

$$
\tag{4}
$$

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

Unexpectedly, $E3.HC + E4.HC$ does not vary much with the openness rate of the economy (see Figure 12 of the main text).

Let us focus on the two-country, one-sector economy:

$$
E1 = C = (0, -c)
$$

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

$$
E3 = (c, 0). \begin{pmatrix} 0 & a_{1,2} \\ 0 & 0 \end{pmatrix} = (0, c.a_{1,2})
$$

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

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

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

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

And :

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

$$(5)$$

We assume that: $\frac{a_{1,1}}{a_{2,1}} = \frac{1-f}{f}$ and $a_{1,1} + a_{2,1} = a$.

So $a_{1,1} = (1 - f)a$ and $a_{2,1} = fa$.

Then:

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

$$(6)$$

The derivative of this according to f is:

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

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

Based on WIOD 2014, we compute the ratio between value added and production, which corresponds to: egen total=rowtotal(vAUS1-vROW) and then (161-74)/161=0.54.

To simplify, we assume that the ratio is equal to 0.5.

$$a_{1,1} + a_{1,2} = a_{2,1} + a_{2,2} = 0.5$$

$$\frac{a_{1,2}}{a_{1,1} + a_{1,2}} = f$$

$$a_{2,1} = 0.48$$

$$a_{2,2} = 0.02$$

In that case:

$$\bar{s} - E1.HC - E2.HC = \frac{-0.125\,f^3 + 0.245\,f^2 - 0.11\,f}{-0.25\,f - 0.26}$$
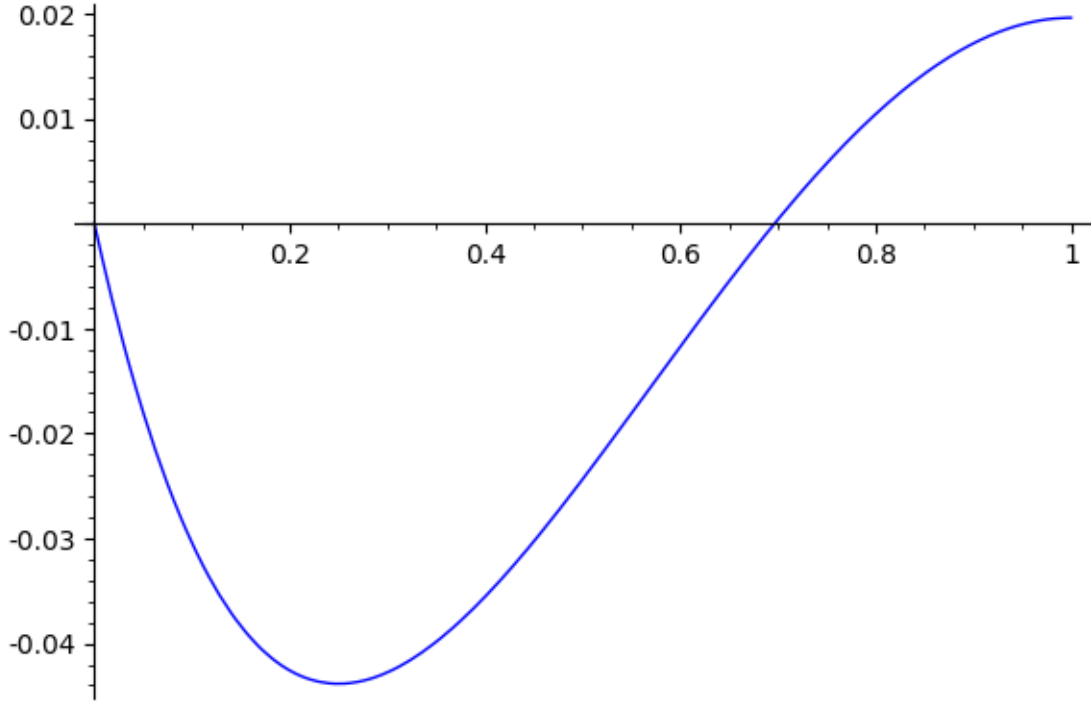
Which yields Figures 8 and 9.

Figure 8: $\bar{s} - E1.HC - E2.HC$ as a function of the openness rate

Actual openness rates in the sample vary between 0.15 and 0.50. In that range, the relationship between the openness rate and the residual is not monotonous (see Figure 8).

Figure 9 confirms that, in that numerical exercise, the total effect is dominated by the direct effect through imported consumer goods and, to a lesser extent, the effect on domestic consumer

goods through imported inputs. The other effects are approximately additive if the openness rate ranges from 0.15 to 0.50.
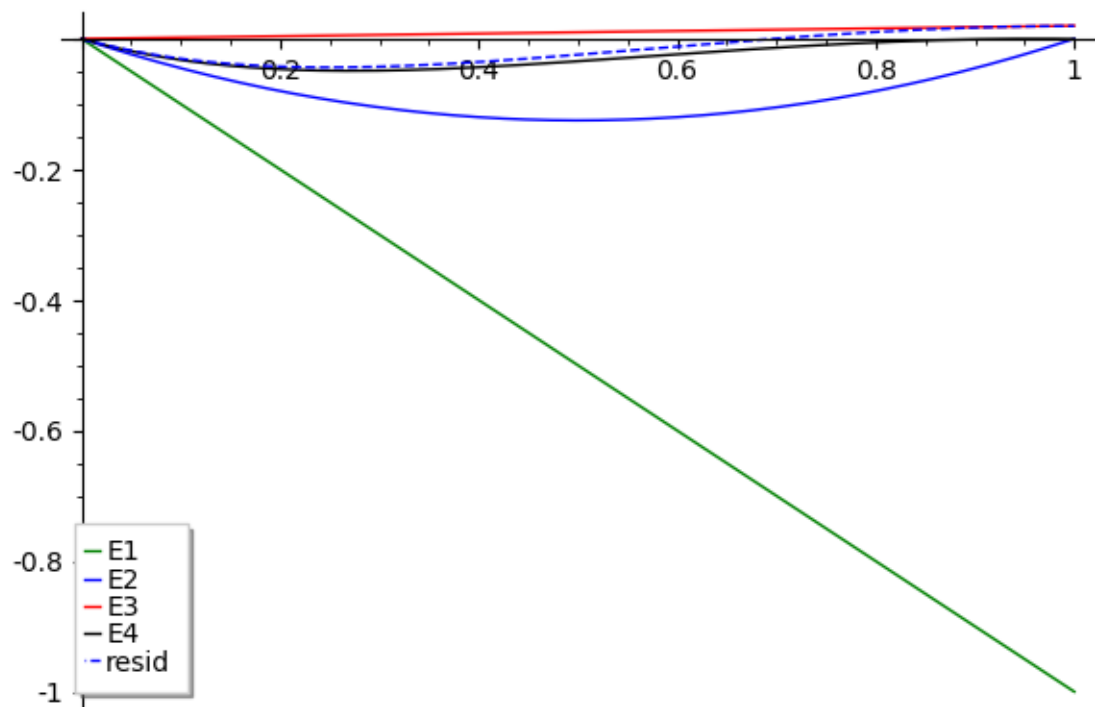

Figure 9: E1.HC, E2.HC, E3.HC, E4.HC and the "residual" $(\bar{s} - E1.HC - E2.HC)$ as a function of the openness rate

Appendix G: Extrapolating the HCE deflator's elasticity using household consumption, intermediate consumption and trade statistics

Section 4.2 shows that the sum of the share of imported goods in household consumption and the share of imported inputs in household consumption of domestic goods ($E1.HC + E2.HC$) is a good predictor of the HCE deflator's elasticity to the exchange rate. 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. Section 4.3 shows that trade and GDP data are a good predictor of the HCE deflator's elasticity. In this appendix, we perform an intermediate exercise. As in section 4.3, we identify consumption and intermediary goods imports using the CEPII BACI database and the BEC classification. In contrast to section 4.3, we relate these imports to household consumption and intermediate consumption instead of the GDP. While the World Bank provides regular estimates for household consumption, estimates for intermediate consumptions are lacking. Eurostat provides estimates for intermediate consumption for European countries. Combining these three data sources (BACI, World Bank and Eurostat), we compute the share of imported consumer goods in household consumption and the share of imported inputs in all inputs.

We then run a panel regression with country fixed-effects, assuming that the coefficients are constant over time and explain within-country variations. To take into account year-specific effects, we add two year-specific variables, i.e. the GDP-weighted mean of each variable of interest (see equation 7).

$$
\begin{aligned}
\bar{s}_{i,t}^{i,t,HC} = \ & \beta_1 \frac{\text{imported consumer goods}_{i,t}}{\text{household consumption}_{i,t}} \\
& + \beta_2 \left[\frac{\text{imported intermediate goods}_{i,t}}{\text{intermediate consumption}_{i,t}} * \frac{\text{domestic consumer goods}_{i,t}}{\text{houshold consumption}_{i,t}} \right] \\
& + \beta_3 \frac{\text{Total imported consumer goods}_t}{\text{Total household consumption}_t} \\
& + \beta_4 \left[\frac{\text{Total imported intermediate goods}_t}{\text{Total intermediate consumption}_t} * \frac{\text{Total domestic consumer goods}_t}{\text{Total household consumption}_t} \right] \\
& + fe_i + \varepsilon_{i,t}
\end{aligned}
\tag{7}
$$

We run the panel regressions for the period 2000 to 2008 and estimate out-of-sample elasticities for each country i for 2014. The outcome is close to the elasticity computed with WIOD for 2014, despite a slight downward bias (see Figure 10).

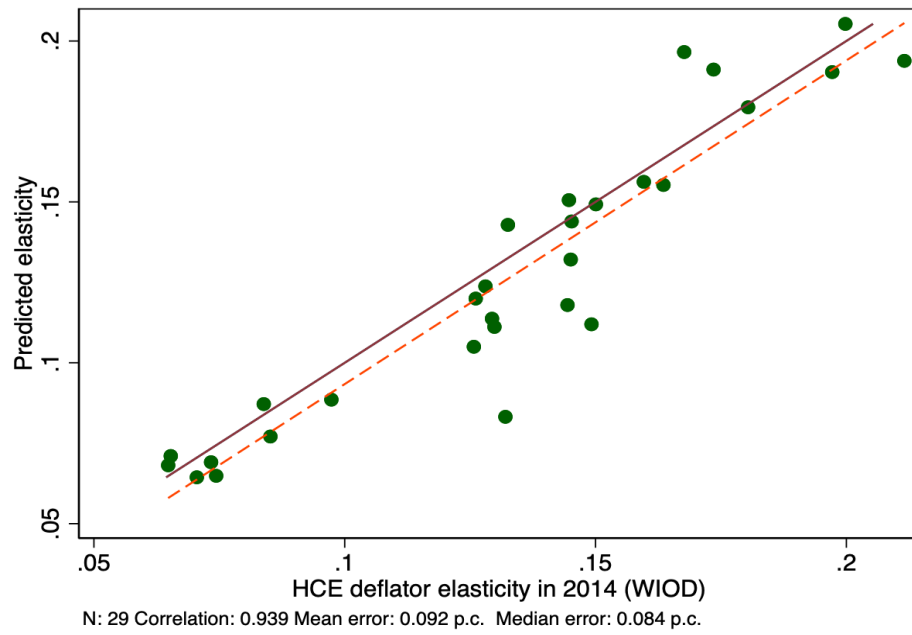N: 29 Correlation: 0.939 Mean error: 0.092 p.c. Median error: 0.084 p.c.

Figure 10: **Comparing the HCE deflator's elasticity in 2014 (WIOD) and the prediction from a panel regression on the 2000-2008 period with fixed effects**