No 18 – November 2017

Policy Brief

CEPII

Why Trade, and what Would Be the Consequences of Protectionism?

Sébastien Jean & Ariell Reshef

Technical Appendix

RESEARCH AND EXPERTISE
ON THE WORLD ECONOMY

A. Openness and Income Per Capita

We use data downloaded from the World Bank's World Development Indicators (WDI). We regress log of GDP per capita (in PPP terms) on the trade share (T = (Exports+Imports)/GDP) and on log GDP (in PPP terms). We restrict the sample to 138 countries with population of at least 1 million (to avoid small and economically insignificant countries and islands) and exclude Singapore, which is a trade outlier due to its role as an entrepot. We estimate the following linear model:

$$\log\left(\frac{GDP}{POP}\right)_c = -4.1 + 1.35 \cdot T_c + 0.47 \cdot \log(GDP)_c \,,$$

where all coefficients are highly statistically significant (p-values of less than 1%). The R2 is 0.54. Figure A1 displays the partial correlation of $\log\left(\frac{\mathrm{GDP}}{\mathrm{POP}}\right)$ with T, after controlling for $\log(\mathrm{GDP})$. In addition, we display the partial regression line (this is an application of the Frisch-Waugh theorem).

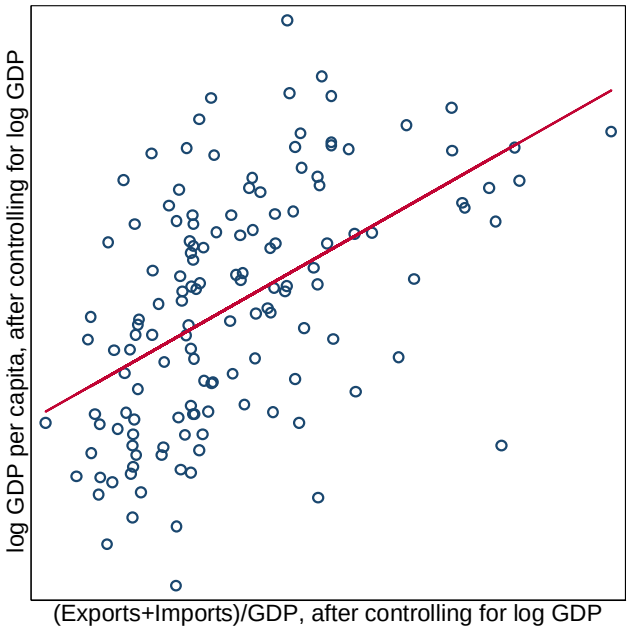

Figure A1: Openness and Income Per Capita

B. Computation of Indices

All calculations of indices in section 1 are based on data from the World Input-Output database (WIOD) using the software "R". The WIOD provides input-output tables for intermediates as well as for final goods. It comprises 56 sectors and 43 countries plus a rest of the world region for the time period from 2000 to 2014. Figure A2 depicts a schematic outline for the exemplary case of 3 countries and 2 sectors.

		A						Y			
Country	Industry	S		R		T		S	R	T	X
		1	2	1	2	1	2				
S	1	A_{11}^{ss}	A_{12}^{ss}	A_{11}^{sr}	A_{12}^{sr}	A_{11}^{st}	A_{12}^{st}	Y_1^{ss}	Y_1^{sr}	Y_1^{st}	$X_1^s = \sum_{c\in\{s,r,t\}}\sum_{i\in\{1,2\}} A_{1i}^{sc} + \sum_{c\in\{s,r,t\}} Y_1^{sc}$
	2	A_{21}^{ss}	A_{22}^{ss}	A_{21}^{sr}	A_{22}^{sr}	A_{21}^{st}	A_{22}^{st}	Y_2^{ss}	Y_2^{sr}	Y_2^{st}	$X_2^s = \sum_{c\in\{s,r,t\}}\sum_{i\in\{1,2\}} A_{2i}^{sc} + \sum_{c\in\{s,r,t\}} Y_2^{sc}$
R	1	A_{11}^{rs}	A_{12}^{rs}	A_{11}^{rr}	A_{12}^{rr}	A_{11}^{rt}	A_{12}^{rt}	Y_1^{rs}	Y_1^{rr}	Y_1^{rt}	$X_1^r = \sum_{c\in\{s,r,t\}}\sum_{i\in\{1,2\}} A_{1i}^{rc} + \sum_{c\in\{s,r,t\}} Y_1^{rc}$
	2	A_{21}^{rs}	A_{22}^{rs}	A_{21}^{rr}	A_{22}^{rr}	A_{21}^{rt}	A_{22}^{rt}	Y_2^{rs}	Y_2^{rr}	Y_2^{rt}	$X_2^r = \sum_{c\in\{s,r,t\}}\sum_{i\in\{1,2\}} A_{2i}^{rc} + \sum_{c\in\{s,r,t\}} Y_2^{rc}$
T	1	A_{11}^{ts}	A_{12}^{ts}	A_{11}^{tr}	A_{12}^{tr}	A_{11}^{tt}	A_{12}^{tt}	Y_1^{ts}	Y_1^{tr}	Y_1^{tt}	$X_1^t = \sum_{c\in\{s,r,t\}}\sum_{i\in\{1,2\}} A_{1i}^{tc} + \sum_{c\in\{s,r,t\}} Y_1^{tc}$
	2	A_{21}^{ts}	A_{22}^{ts}	A_{21}^{tr}	A_{22}^{tr}	A_{21}^{tt}	A_{22}^{tt}	Y_2^{ts}	Y_2^{tr}	Y_2^{tt}	$X_2^t = \sum_{c\in\{s,r,t\}}\sum_{i\in\{1,2\}} A_{2i}^{tc} + \sum_{c\in\{s,r,t\}} Y_2^{tc}$
Total intermediate consumption, A_i^c		ΣA_{i1}^s	ΣA_{i2}^s	ΣA_{i1}^r	ΣA_{i2}^r	ΣA_{i1}^t	ΣA_{i2}^t				
Direct V_i^c		$X_1^s - \Sigma A_{i1}^s$	$X_2^s - \Sigma A_{i2}^s$	$X_1^r - \Sigma A_{i1}^r$	$X_2^r - \Sigma A_{i2}^r$	$X_1^t - \Sigma A_{i1}^t$	$X_2^t - \Sigma A_{i2}^t$				

Figure A2: Schematic Outline of a World Input-Output Table

In Figure A2 the area shaded in light grey includes intermediate value flows, A, among industries (indexed by $i \in \{1,2\}$) of countries (indexed by $c \in \{s,r,t\}$). The area shaded in dark grey indicates information on the production of final goods, Y, and their final consumption. Furthermore, the World Input-Output Tables contain information on total gross output, X, and direct value added, V, of a country-industry. Entries of the tables in the shaded areas can be read as follows:
For example, A_{12}^{sr} describes the intermediate use of industry 2 in country *r* (indicated by the column) provided by industry 1 in country *s* (indicated by the row). Similarly, the entry, Y_2^{rt}, in the shaded Y-area can be interpreted as the value of final goods produced by industry 2 in country *r* which are absorbed by country *t*.[1]

[1] It should be noted that the WIOD distinguishes in total five use-categories of final goods. For reasons of space, these five categories are not displayed in figure A2. The use categories are*: final consumption expenditure by households, final consumption expenditure by non-profit organizations, final consumption expenditure by government, gross fixed capital formation and changes in inventories and valuables.*

1. Import and export shares

1.1 Import shares

Import shares describe the share of intermediates used by a destination country-industry which is sourced from a foreign supplier.

$$IMshare_i^{sd} = \frac{\sum_{p \in P_{di}} A_{pi}^{sd}}{\sum_{c \in C} \sum_{p \in P_{di}} A_{pi}^{cd}}$$

The denominator is computed by calculating the column sums for a destination country-industry across all countries (supplier and the destination country itself).

1.2 Imported consumption

Imported consumption is calculated based on values of the final consumption submatrix of the WIOD, Y.

$$IMconsumption = \frac{Y_p^{sd}}{\sum_{c \in C} Y_p^{cd}}$$

More precisely, computations use the column which is called "final consumption expenditure by households". To obtain the required share, "final consumption expenditure by households" for a given product of a foreign supplier, $\mathrm{Y_p^{sd}}$, is divided by the sum of "final consumption expenditure by households" across all countries (foreign suppliers and the destination country itself) as well as across all product categories, $\sum_{\mathrm{c \in C}} \mathrm{Y_p^{cd}}$.

1.3 Export shares

Export shares are computed based on both intermediate good flows and final goods consumption.

$$EXshares_p^{sd} = \frac{\sum_{i \epsilon I} A_{pi}^{sd} + \sum_{i \in I} Y_{pi}^{sd}}{X_p^s} = \frac{EX_p^{sd}}{X_p^s}$$

Firstly, it is necessary to compute the sum of intermediate and final goods exports, $\sum_{i \epsilon I} A_{pi}^{sd} + \sum_{i \in I} Y_{pi}^{sd}$. To do so, exports of intermediates and final goods to a certain destination are summed across industries along a row. Dividing the resulting sum of exports by total output of the supplier country in a given product category, X_p^s, gives the required export shares.

2. Value added computations

Value added computations are based on the paper of Timmer et al. (2013), "Fragmentation, Incomes and Jobs: An Analysis of European Competitiveness", *Economic Policy* 28, pp. 613– 661, which is rooted in the seminal work of Wassily Leontief (1936), Quantitative input and output relations in the economic system of the united states. *The Review of Economics and Statistics*, 18(3): 105–125.

The basic idea is to decompose the value of final goods production according to the country where the value added originated. Technically, the computation relies on the usage of a vector of final goods, Y, which are absorbed either domestically or abroad, the Leontief inverse matrix, B, as well as a vector of direct value added coefficients per sector, V.

The vector of final goods, Y, is obtained by a row-wise summation of the "Y-area" in figure A across all countries and use categories. The vector of direct value added *coefficients*, V, is obtained by subtracting the entire intermediate consumption of a sector (column sum in the input-output matrix) from the sectoral gross output and dividing this newly computed number by the gross output of the sector.

$$V_i^c = \frac{(X_i^c - \sum_{p \in P} A_{ip}^c)}{X_i^c}$$

The Leontief inverse matrix, B, can be expressed mathematically in the following way.

$B = (I - a)^{-1}$, where *a* is the matrix containing all sub-elements $a_{pi}^{cd} = \frac{A_{pi}^{cd}}{X_i^d}$

The B matrix is obtained in two steps. Firstly, it is necessary to derive the input-output *coefficients*, a_{pi}^{cd}. These coefficients can be obtained by dividing each cell along a column by the gross output of the respective column sector. Secondly, an auxiliary matrix is computed by subtracting the newly computed matrix of input-output coefficients from an identity matrix. Finally, the auxiliary matrix is inverted to obtain the required Leontief inverse matrix, B, whereby a single element of the matrix indicates the amount of the source country's output (indicated by the row) which is needed to sustain the production of one unit of final demand in the destination country (indicated by the column).

In order to decompose the value of final goods production, the vectors V and Y are combined with the matrix B by a matrix-vector multiplication. The result is a VBY matrix of the following form. For ease of presentation, the matrix is depicted for the exemplary case of two countries and two industries.

$$\hat{V}B\hat{Y} = \begin{bmatrix} v_1^s & 0 & 0 & 0 \\ 0 & v_2^s & 0 & 0 \\ 0 & 0 & v_1^r & 0 \\ 0 & 0 & 0 & v_2^r \end{bmatrix} \begin{bmatrix} b_{11}^{ss} & b_{12}^{ss} & b_{11}^{sr} & b_{12}^{sr} \\ b_{21}^{ss} & b_{22}^{ss} & b_{21}^{sr} & b_{22}^{sr} \\ b_{11}^{rs} & b_{12}^{rs} & b_{11}^{rr} & b_{12}^{rr} \\ b_{21}^{rs} & b_{22}^{rs} & b_{21}^{rr} & b_{22}^{rr} \end{bmatrix} \begin{bmatrix} y_1^s & 0 & 0 & 0 \\ 0 & y_2^s & 0 & 0 \\ 0 & 0 & y_1^r & 0 \\ 0 & 0 & 0 & y_2^r \end{bmatrix}$$

$$= \begin{bmatrix} v_1^s b_{11}^{ss} y_1^s & v_1^s b_{12}^{ss} y_2^s & v_1^s b_{11}^{sr} y_1^r & v_1^s b_{12}^{sr} y_2^r \\ v_2^s b_{21}^{ss} y_1^s & v_2^s b_{22}^{ss} y_2^s & v_2^s b_{21}^{sr} y_1^r & v_2^s b_{22}^{sr} y_2^r \\ v_1^r b_{11}^{rs} y_1^s & v_1^r b_{12}^{rs} y_2^s & v_1^r b_{11}^{rr} y_1^r & v_1^r b_{12}^{rr} y_2^r \\ v_2^r b_{21}^{rs} y_1^s & v_2^r b_{22}^{rs} y_2^s & v_2^r b_{21}^{rr} y_1^r & v_2^r b_{22}^{rr} y_2^r \end{bmatrix}$$

In order to correctly read the resulting VBY matrix, it is necessary to notice that values of the matrix can be interpreted in two different ways.[2]

Firstly, regarding the values of the matrix along a *column* indicates the *backward* linkages of production. This perspective reveals the value contribution of country-sectors (given by the row) to the production of another country-sector (given by the column). For example, $v_1^r b_{11}^{rs} y_2^s$ indicates the foreign value added of sector 1 in country r included in the production process of sector 2 in country s. Consequently, by summing across all rows along the column, one obtains the total value of final goods production, y_1^s.

Secondly, regarding the values of the VBY matrix along a *row* indicates the *forward* linkages of production. Hence, values indicate how the value added produced by a country-sector (given by the row) is absorbed in the production process of other sectors in a certain country (given by the column). Thus, in the context of forward linkages, $v_1^r \; b_{11}^{rs} y_2^s$ is interpreted as a part of GDP produced by sector 1 in country r, which is entering the production of sector 2 in country s. The sum across all columns along a row is thus equal to the country-sector's GDP of the considered row.

[2] The explication is following Wang et al. (2013): "Quantifying international production sharing at the bilateral and sectoral levels", *NBER Working Paper No. 19677.*

2.1 Foreign value added in final goods production

The *foreign value added share in final goods production* is hence computed based on the backward perspective. More precisely, the foreign value added is calculated by summing column entries across all rows of foreign country-sectors.

$$FVA_i^c = \frac{\sum_{s \in S} \sum_{p \in P} v_p^s b_{pi}^{sc} y_i^c}{y_i^c}$$

Thus, if one intends to compute the foreign value added in production of sector 1 in country s, it is necessary to sum $v_1^r \; b_{11}^{rs} y_1^s$ and $v_2^r \; b_{11}^{rs} y_1^s$ and eventually divide it by the final good's value.

The underlying data for the computation of foreign value added is taken from the WIOD 2014 release, which provides data on 56 sectors (18 manufacturing industries) in 41 countries from 2000 to 2014.[3]

2.2 Decomposing value added according to production factors

As described in Timmer et al. (2014), "Slicing up Global Value Chains", *Journal of Economic Perspectives*, 28(2), pp. 99–118, the methodology described above can also be applied to decompose the value of final goods production according to capital and labor. The only difference to the computation described in section 4.1 consists in the use of a different vector of coefficients. While calculations on foreign value added are based on a vector of direct value added coefficients, V, the computation of value added by factors requires a vector of factor use per unit of output. In order to derive these vectors it is necessary to divide sector level data on capital and labor compensation by sectoral output.

$$f_i^c = \frac{F_i^c}{X_i^c}$$

By multiplying this vector with the Leontief inverse matrix and a vector of final demand results in a matrix of factor shares in production, fBY, which can be read like the VBY matrix above. The decomposition of the final goods' value according to capital, high- and less-skilled labor requires to derive three different vectors thus resulting in three matrices. Similar to the computation of foreign value added, elements are interpreted based on the backward perspective. Finally, dividing the elements along the row by a sector's value of final goods production gives the required factor shares.

It should be noted that the underlying data for this computation comes from the WIOD 2013 release. This is due to the fact that data on capital and labor compensation which is required for the computation of factor share vectors, is only available from Socio Economic Accounts which match World Input-Output Tables of the 2013 release. Hence the classification of industries is based on ISIC 3 and distinguishes 14 manufacturing sectors in 40 countries between 1995 and 2008. Due to the availability of socio economic account data, the so called "rest of the world region" is excluded from computations.

[3] See Timmer, M. P., Dietzenbacher, E., Los, B., Stehrer, R. and de Vries, G. J. (2015), "An Illustrated User Guide to the World Input–Output Database: the Case of Global Automotive Production", *Review of International Economics.*, 23: pp. 575–605.

Foreign Value Added Shares in Production of EU 28

industry	2000	2014	change
coke & refined petroleum prod.	0.356	0.442	0.086
computer, electronic & optical prod.	0.167	0.228	0.061
basic metals	0.152	0.223	0.071
chemicals & chemical prod.	0.128	0.209	0.081
Water transport	0.137	0.197	0.060
other transport equipment	0.131	0.196	0.065
Air transport	0.123	0.194	0.071
Electricity, gas, steam & air conditioning supply	0.136	0.177	0.041
electrical equipment	0.111	0.154	0.043
motor vehicles, trailers & semi-trailers	0.108	0.152	0.044
textiles, wearing apparel & leather prod.	0.094	0.151	0.057
pharmaceutical products & preparations	0.096	0.148	0.051
rubber & plastic prod.	0.097	0.147	0.050
other non-metallic mineral prod.	0.099	0.139	0.040
machinery & equipment n.e.c.	0.100	0.137	0.037
paper & paper prod.	0.096	0.131	0.036
food prod., beverages & tobacco prod.	0.088	0.131	0.043
Fishing & aquaculture	0.077	0.128	0.051
fabricated metal prod., except machinery & equipment	0.091	0.125	0.035
furniture; other manufacturing	0.091	0.120	0.028
Repair & installation of machinery	0.094	0.117	0.023
Crop & animal production, hunting	0.067	0.112	0.045
wood & cork	0.094	0.111	0.017
Computer programming, consultancy & related act.	0.056	0.103	0.047
Printing & reprod. of recorded media	0.068	0.101	0.032
Mining & quarrying	0.069	0.099	0.030
Construction	0.071	0.093	0.022
Land transport & via pipelines	0.064	0.092	0.028
Sewerage; waste collection & disposal activities	0.078	0.091	0.013

industry	2000	2014	change
Telecommunications	0.061	0.085	0.024
Publishing activities	0.068	0.082	0.014
Warehousing & support for transportation	0.063	0.077	0.014
Water collection, treatment & supply	0.055	0.077	0.021
Activities auxiliary to financial services & insurance act.	0.049	0.076	0.028
Insurance, reinsurance & pension funding	0.055	0.076	0.021
Wholesale trade, except vehicles/motorcycles	0.055	0.072	0.017
Advertising & market research	0.056	0.070	0.014
Postal & courier activities	0.042	0.070	0.028
Motion picture, video & television progr. production	0.056	0.070	0.014
Forestry & logging	0.050	0.066	0.016
Other professional, scientific & technical activities	0.054	0.066	0.012
Wholesale/retail trade & repair of vehicles/motorcycles	0.054	0.065	0.011
Accommodation & food service	0.049	0.063	0.014
Architectural & engineering act.	0.043	0.063	0.020
Financial service act.	0.048	0.061	0.014
Administrative & support service activities	0.048	0.057	0.010
Scientific research & development	0.042	0.056	0.014
Legal & accounting act.; head offices; mgmt consultancy	0.037	0.055	0.019
Human health & social work activities	0.042	0.053	0.011
Retail trade, except	0.037	0.051	0.014
Other service activities	0.042	0.050	0.008
Public administration & defence	0.039	0.043	0.004
Education	0.018	0.023	0.006
Real estate activities	0.019	0.023	0.004
Activities of households as employers	0.000	0.000	0.000

Source: Authors' calculations based on the WIOD 2016 release. Industries classified according to ISIC rev. 4.

Note: Changes refer to percentage point changes between 2014 and 2000. All values are arranged in descending order of values in 2014.

Import Shares in EU 28

industry	2000	2014	change	industry	2000	2014	change
coke & refined petroleum prod.	0.376	0.426	0.050	Public administration & defence	0.082	0.077	-0.005
computer, electronic & optical prod.	0.211	0.312	0.100	Financial service act.	0.058	0.077	0.019
pharmaceutical products & preparations	0.137	0.216	0.079	Land transport & via pipelines	0.056	0.077	0.021
other transport equipment	0.136	0.193	0.057	paper & paper prod.	0.069	0.076	0.007
Water transport	0.138	0.177	0.039	Printing & reprod. of recorded media	0.058	0.075	0.016
Computer programming, consultancy & related act.	0.089	0.167	0.078	Wholesale trade, except vehicles/motorcycles	0.056	0.073	0.017
chemicals & chemical prod.	0.112	0.161	0.049	Scientific research & development	0.062	0.072	0.010
basic metals	0.126	0.158	0.032	Postal & courier activities	0.059	0.072	0.013
Mining & quarrying	0.128	0.157	0.029	Wholesale/retail trade & repair of vehicles/motorcycles	0.059	0.071	0.012
Electricity, gas, steam & air conditioning supply	0.166	0.153	-0.013	Architectural & engineering act.	0.052	0.071	0.019
Air transport	0.100	0.148	0.047	Water collection, treatment & supply	0.056	0.071	0.015
electrical equipment	0.107	0.142	0.035	Forestry & logging	0.076	0.070	-0.005
textiles, wearing apparel & leather prod.	0.081	0.139	0.058	Sewerage; waste collection & disposal activities	0.069	0.068	-0.001
Fishing & aquaculture	0.089	0.128	0.039	Legal & accounting act.; head offices; mgmt consultancy	0.046	0.068	0.022
furniture; other manufacturing	0.091	0.119	0.029	wood & cork	0.072	0.066	-0.006
machinery & equipment n.e.c.	0.087	0.117	0.030	Insurance, reinsurance & pension funding	0.042	0.063	0.022
Repair & installation of machinery	0.091	0.115	0.024	Administrative & support service activities	0.059	0.063	0.004
rubber & plastic prod.	0.082	0.113	0.032	Construction	0.050	0.062	0.013
other non-metallic mineral prod.	0.094	0.111	0.017	Motion picture, video & television progr. production	0.053	0.060	0.007
motor vehicles, trailers & semi-trailers	0.067	0.101	0.034	Other service activities	0.054	0.060	0.006
fabricated metal prod., except machinery & equipment	0.074	0.097	0.023	Warehousing & support for transportation	0.049	0.057	0.008
Human health & social work activities	0.081	0.096	0.016	Advertising & market research	0.047	0.056	0.008
Activities auxiliary to financial services & insurance act.	0.058	0.089	0.031	Education	0.052	0.055	0.004
Crop & animal production, hunting	0.063	0.087	0.024	Retail trade, except	0.050	0.054	0.003
Telecommunications	0.079	0.086	0.007	Accommodation & food service	0.045	0.048	0.003
Publishing activities	0.066	0.083	0.017	Real estate activities	0.030	0.032	0.002
Other professional, scientific & technical activities	0.070	0.078	0.007	Activities of households as employers	0.000	0.001	0.000
food prod., beverages & tobacco prod.	0.061	0.077	0.017				

Source: Authors' calculations based on the WIOD 2016 release. Industries classified according to ISIC rev. 4.

Note: Changes refer to percentage point changes between 2014 and 2000. All values are arranged in descending order of values in 2014.