Supplementary Information of Why Your Neighbor Matters: Positions in Preferential Trade Agreement Networks and Export Growth in Global Value Chains

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1 WWZ Decomposition

To measure value-added export data, we use World Input-output Dataset (WIOD) developed by Timmer et al. (2015) and updated by Timmer et al. (2016). Then, we decompose value-added contributions into the country and sector level using Wang, Wei and Zhu (2018) (WWZ hereafter) method.

1.1 World Input-output Data

WIOD encompasses the sector-level input-output trade data of 43 major economies from 2000 to 2014. The dataset covers 56 industrial sectors including fishing, mining, manufacturing of machines, manufacturing of textiles and financial service activities. WIOD is a data matrix of dimension 2472×2690. The number of rows is the product of the number of countries (44) and the number of industries (56) plus 8 auxiliary categories. We removed the 8 auxiliary categories from the list and retain pairs of 43 countries and 56 industries.[1] We removed "Rest of the World (ROW)" from the country list.

There are 5 final goods categories in the columns of WIOD. These 5 columns constitute 2408×5 final demands matrix.[2] The rest of the data is the matrix of intermediate demands with dimension 2408×2408, which the total number of country-industry pair (43×56).

The Leontief decomposition (Leontief, 1936) writes that gross output matrix (X) is the sum of intermediates (AX) and final demand (Y): $X = AX + Y$. Here A denotes input-output coefficient matrix that explains contributions of many intermediate outputs. We can rewrite this as $X = BY$ where $B = (I - A)^{-1}$.

Let V denote direct value-added coefficient vector, then we can represent the process of value-added with infinitely many suppliers as

$$V + VA + VAA + VAAA + ... = V(I + A + A^2 + A^3 + ...) = V(I - A)^{-1} = VB. \quad (1)$$

[1] The 8 auxiliary categories are "total intermediate" "tax", "adjustment", "direct purchase abroad", "purchase by domestic", "value added" ,"international transport margins", and "output at basic prices."

[2] These 5 categories are "`Total intermediate consumption`", "`taxes less subsidies on products`", "`Cif/ fob adjustments on exports`", "`Direct purchases abroad by residents`", and "`Purchases on the domestic territory by non-residents`."

When multiplied by final demands Y, VBY together contains information about sources of value added in each final demand Y. Each row of VBY summarizes how one intermediate input is used both directly and indirectly for the final demands in all countries and sectors. Each column of VBY, on the other hand, represents the source countries and sectors for the final demand in one country and sector. VBY gives the value-added process for the final goods, and Wang, Wei and Zhu (2018) adds here a decomposition of intermediate goods according to where they are finally absorbed.

1.2 2 Country 2 Sector Example

In this note, we report WWZ decomposition of the 2 country 2 sector case as an illustration. Let superscript s and r represent (sender and receiver) countries and superscript 1 and 2 represent sectors. Then, the Leontief insight $X = (I - A)^{-1}Y = BY$ can be expressed as

$$\begin{bmatrix} x_1^s \\ x_2^s \\ x_1^r \\ x_2^r \end{bmatrix} = \begin{bmatrix} b_{11}^{ss} & b_{11}^{ss} & b_{11}^{sr} & b_{12}^{sr} \\ b_{21}^{ss} & b_{22}^{ss} & b_{21}^{sr} & b_{22}^{sr} \\ b_{11}^{rs} & b_{12}^{rs} & b_{11}^{rr} & b_{12}^{rr} \\ b_{21}^{rs} & b_{22}^{rs} & b_{21}^{rr} & b_{22}^{rr} \end{bmatrix} \begin{bmatrix} y_1^{ss} + y_1^{sr} \\ y_2^{rs} + y_2^{rr} \\ y_1^{ss} + y_1^{sr} \\ y_2^{rs} + y_2^{rr} \end{bmatrix} \tag{2}$$

Here, b_{12}^{sr} is the inverse coefficient for goods of sector 1 produced in s that are used in sector 2 in country r. The VBY matrix in 2 country 2 sector example is

$$VBY = \begin{bmatrix} v_1^s & 0 & 0 & 0 \\ 0 & v_2^s & 0 & 0 \\ 0 & 0 & v_1^r & 0 \\ 0 & 0 & 0 & v_2^r \end{bmatrix} \begin{bmatrix} b_{11}^{ss} & b_{12}^{ss} & b_{11}^{sr} & b_{12}^{sr} \\ b_{21}^{ss} & b_{22}^{ss} & b_{21}^{sr} & b_{22}^{sr} \\ b_{11}^{rs} & b_{12}^{rs} & b_{11}^{rr} & b_{12}^{rr} \\ b_{21}^{rs} & b_{22}^{rs} & b_{21}^{rr} & b_{22}^{rr} \end{bmatrix} \begin{bmatrix} y_1^s & 0 & 0 & 0 \\ 0 & y_2^s & 0 & 0 \\ 0 & 0 & y_1^r & 0 \\ 0 & 0 & 0 & y_2^r \end{bmatrix} \tag{3}$$

$$= \begin{bmatrix} v_1^s b_{11}^{ss} y_1^s & v_1^s b_{12}^{ss} y_2^s & v_1^s b_{11}^{sr} y_1^r & v_1^s b_{12}^{sr} y_2^r \\ v_2^s b_{21}^{ss} y_1^s & v_2^s b_{22}^{ss} y_2^s & v_2^s b_{21}^{sr} y_1^r & v_2^s b_{22}^{sr} y_2^r \\ v_1^r b_{11}^{rs} y_1^s & v_1^r b_{12}^{rs} y_2^s & v_1^r b_{11}^{rr} y_1^r & v_1^r b_{12}^{rr} y_2^r \\ v_2^r b_{21}^{rs} y_1^s & v_2^r b_{22}^{rs} y_2^s & v_2^r b_{21}^{rr} y_1^r & v_2^r b_{22}^{rr} y_2^r \end{bmatrix} \tag{4}$$

Note that VB is the value-added multiplier, and each row of VB sums to 1 such that each column of VBY sums to corresponding Y element. For example, $(v_1^s b_{11}^{ss} + v_2^s b_{21}^{ss} + v_1^r b_{11}^{rs} + v_2^r b_{21}^{rs}) y_1^s = y_1^s$.

The total exports of country s consists of two parts: final goods exports and intermediate goods exports.

$$E^{sr} = \begin{bmatrix} e_1^{sr} \\ e_2^{sr} \end{bmatrix} = \begin{bmatrix} y_1^{sr} \\ y_2^{sr} \end{bmatrix} + \begin{bmatrix} a_{11}^{sr} & a_{12}^{sr} \\ a_{21}^{ss} & a_{22}^{sr} \end{bmatrix} \begin{bmatrix} x_1^r \\ x_2^r \end{bmatrix}. \tag{5}$$

Using the Leontief decomposition $X = BY$,

$$\begin{aligned} \begin{bmatrix} x_1^r \\ x_2^r \end{bmatrix} &= \begin{bmatrix} b_{11}^{rs} & b_{12}^{rs} \\ b_{21}^{rs} & b_{22}^{rs} \end{bmatrix} \begin{bmatrix} y_1^{ss} + y_1^{sr} \\ y_2^{ss} + y_2^{sr} \end{bmatrix} + \begin{bmatrix} b_{11}^{rr} & b_{12}^{rr} \\ b_{21}^{rr} & b_{22}^{rr} \end{bmatrix} \begin{bmatrix} y_1^{rr} + y_1^{rs} \\ y_2^{rr} + y_2^{rs} \end{bmatrix} \\ &= \begin{bmatrix} b_{11}^{rs} & b_{12}^{rs} \\ b_{21}^{rs} & b_{22}^{rs} \end{bmatrix} \begin{bmatrix} y_1^{ss} \\ y_2^{ss} \end{bmatrix} + \begin{bmatrix} b_{11}^{rs} & b_{12}^{rs} \\ b_{21}^{rs} & b_{22}^{rs} \end{bmatrix} \begin{bmatrix} y_1^{sr} \\ y_2^{sr} \end{bmatrix} + \begin{bmatrix} b_{11}^{rr} & b_{12}^{rr} \\ b_{21}^{rr} & b_{22}^{rr} \end{bmatrix} \begin{bmatrix} y_1^{rr} \\ y_2^{rr} \end{bmatrix} + \begin{bmatrix} b_{11}^{rr} & b_{12}^{rr} \\ b_{21}^{rr} & b_{22}^{rr} \end{bmatrix} \begin{bmatrix} y_1^{rs} \\ y_2^{rs} \end{bmatrix}. \end{aligned} \tag{6}$$

The gross intermediate goods exports from s to r can be represented as $A^{sr} X^r$. If we multiply Equation (6) with A^{sr} to get $A^{sr}X^r$, then we have

$$A^{sr}X^r = A^{sr}\begin{bmatrix} x_1^r \\ x_2^r \end{bmatrix} = A^{sr}B^{rs}\begin{bmatrix} y_1^{ss} \\ y_2^{ss} \end{bmatrix} + A^{sr}B^{rs}\begin{bmatrix} y_1^{sr} \\ y_2^{sr} \end{bmatrix} + A^{sr}B^{rr}\begin{bmatrix} y_1^{rr} \\ y_2^{rr} \end{bmatrix} + A^{sr}B^{rr}\begin{bmatrix} y_1^{rs} \\ y_2^{rs} \end{bmatrix} \tag{7}$$

where

$$A^{sr} = \begin{bmatrix} a_{11}^{sr} & a_{12}^{sr} \\ a_{21}^{sr} & a_{22}^{sr} \end{bmatrix}, B^{rs} = \begin{bmatrix} b_{11}^{rs} & b_{12}^{rs} \\ b_{21}^{rs} & b_{22}^{rs} \end{bmatrix}, B^{rr} = \begin{bmatrix} b_{11}^{rr} & b_{12}^{rr} \\ b_{21}^{rr} & b_{22}^{rr} \end{bmatrix}.$$

The above result is the decomposition of gross intermediate exports by s into four parts according to where they are absorbed. The first term in the right hand side of Equation (7) ($A^{sr}B^{rs}y^{ss}$) represents the part of s's intermediate goods exports used by r to meet final demands in s.

From the relationship $X = AX + Y$, we can rewrite the gross output produced by r as

$$X^r = A^{rr}X^r + Y^{rr} + A^{rs}X^s + Y^{rs}$$

The latter two parts are exports of intermediate and final goods from r to s. We can use Equation (5) to get

$$X^r = A^{rr}X^r + Y^{rr} + E^{rs} = (I - A^{rr})^{-1}(Y^{rr} + E^{rs}),$$

which can be written as follows:

$$\begin{bmatrix} x_1^r \\ x_2^r \end{bmatrix} = \begin{bmatrix} 1 - a_{11}^{rr} & a_{12}^{rr} \\ a_{21}^{rr} & 1 - a_{22}^{rr} \end{bmatrix}^{-1} \begin{bmatrix} \mathbf{y}_1^{rr} \\ \mathbf{y}_2^{rr} \end{bmatrix} + \begin{bmatrix} 1 - a_{11}^{rr} & a_{12}^{rr} \\ a_{21}^{rr} & 1 - a_{22}^{rr} \end{bmatrix}^{-1} \begin{bmatrix} e_1^{rs} \\ e_2^{rs} \end{bmatrix}. \tag{8}$$

Now, we define the local Leontief inverse L^{rr} as

$$L^{rr} = \begin{bmatrix} l_{11}^{rr} & l_{12}^{rr} \\ l_{21}^{rr} & l_{22}^{rr} \end{bmatrix} = \begin{bmatrix} 1 - a_{11}^{rr} & a_{12}^{rr} \\ a_{21}^{rr} & 1 - a_{22}^{rr} \end{bmatrix}^{-1}$$

and plug it in Equation (8) to obtain

$$\begin{bmatrix} x_1^r \\ x_2^r \end{bmatrix} = \begin{bmatrix} l_{11}^{rr} & l_{12}^{rr} \\ l_{21}^{rr} & l_{22}^{rr} \end{bmatrix} \begin{bmatrix} y_1^{rr} \\ y_2^{rr} \end{bmatrix} + \begin{bmatrix} l_{11}^{rr} & l_{12}^{rr} \\ l_{21}^{rr} & l_{22}^{rr} \end{bmatrix} \begin{bmatrix} e_1^{rs} \\ e_2^{rs} \end{bmatrix}. \tag{9}$$

Then, intermediate goods export from s to r can be decomposed as

$$A^{sr}X^r = \begin{bmatrix} a_{11}^{sr} & a_{12}^{sr} \\ a_{21}^{sr} & a_{22}^{sr} \end{bmatrix} \begin{bmatrix} x_1^r \\ x_2^r \end{bmatrix} = \begin{bmatrix} a_{11}^{sr} & a_{12}^{sr} \\ a_{21}^{sr} & a_{22}^{sr} \end{bmatrix} \begin{bmatrix} l_{11}^{rr} & l_{12}^{rr} \\ l_{21}^{rr} & l_{22}^{rr} \end{bmatrix} \begin{bmatrix} \mathbf{y}_1^{rr} \\ \mathbf{y}_2^{rr} \end{bmatrix} + \begin{bmatrix} a_{11}^{sr} & a_{12}^{sr} \\ a_{21}^{sr} & a_{22}^{sr} \end{bmatrix} \begin{bmatrix} l_{11}^{rr} & l_{12}^{rr} \\ l_{21}^{rr} & l_{22}^{rr} \end{bmatrix} \begin{bmatrix} \mathbf{e}_1^{rs} \\ \mathbf{e}_2^{rs} \end{bmatrix} \tag{10}$$

Recall that each row of VBY summarizes how one intermediate input is used directly and indirectly to produce final goods in corresponding countries and sectors. Then, domestic and foreign value-added multipliers of country s are

$$V^sB^{ss} = [v_1^s b_{11}^{ss} + v_2^s b_{21}^{ss} \quad v_1^s b_{12}^{ss} + v_2^s b_{22}^{ss}] \tag{11}$$

$$V^rB^{rs} = [v_1^r b_{11}^{rs} + v_2^r b_{21}^{rs} \quad v_1^r b_{12}^{rs} + v_2^r b_{22}^{rs}] \tag{12}$$

and $V^sB^{ss} + V^rB^{rs} = [1 \quad 1]$. Domestic value-added multiplier from VB for Country s is

$$V^s(1 - A^{ss})^{-1} = V^sL^{ss} = [v_1^s L_{11}^{ss} + v_2^s L_{21}^{ss} \quad v_1^s l_{12}^{ss} + v_2^s l_{22}^{ss}] \tag{13}$$

Let # denote an element-wise matrix multiplication operator. Then, we can rewrite intermediate export from s to r $A^{sr}X^r$ and final exports y^{sr} as

$$\begin{aligned} A^{sr}X^r = \begin{bmatrix} a_{11}^{sr} & a_{12}^{sr} \\ a_{21}^{sr} & a_{22}^{sr} \end{bmatrix} \begin{bmatrix} x_1^r \\ x_2^r \end{bmatrix} &= \begin{bmatrix} v_1^s l_{11}^{ss} + v_2^s l_{21}^{ss} \\ v_1^s l_{12}^{ss} + v_2^s l_{22}^{ss} \end{bmatrix} \# \left\{ \begin{bmatrix} a_{11}^{sr} & a_{12}^{sr} \\ a_{21}^{sr} & a_{22}^{sr} \end{bmatrix} \begin{bmatrix} x_1^r \\ x_2^r \end{bmatrix} \right\} \\ &+ \left\{ \begin{bmatrix} v_1^s b_{11}^{ss} + v_2^s b_{21}^{ss} \\ v_1^s b_{12}^{ss} + v_2^s b_{22}^{ss} \end{bmatrix} - \begin{bmatrix} v_1^s l_{11}^{ss} + v_2^s l_{21}^{ss} \\ v_1^s l_{12}^{ss} + v_2^s l_{22}^{ss} \end{bmatrix} \right\} \# \begin{bmatrix} a_{11}^{sr} & a_{12}^{sr} \\ a_{21}^{sr} & a_{22}^{sr} \end{bmatrix} \Bigg\} \begin{bmatrix} x_1^r \\ x_2^r \end{bmatrix} \\ &+ \begin{bmatrix} v_1^r b_{11}^{rs} + v_2^r b_{21}^{rs} \\ v_1^r b_{12}^{rs} + v_2^r b_{22}^{rs} \end{bmatrix} \# \left\{ \begin{bmatrix} a_{11}^{sr} & a_{12}^{sr} \\ a_{21}^{sr} & a_{22}^{sr} \end{bmatrix} \begin{bmatrix} x_1^r \\ x_2^r \end{bmatrix} \right\} \end{aligned} \tag{14}$$

and

$$\begin{bmatrix} y_1^{sr} \\ y_2^{sr} \end{bmatrix} = \begin{bmatrix} v_1^s b_{11}^{ss} + v_2^s b_{21}^{ss} \\ v_1^s b_{12}^{ss} + v_2^s b_{22}^{ss} \end{bmatrix} \# \begin{bmatrix} y_1^{sr} \\ y_2^{sr} \end{bmatrix} + \begin{bmatrix} v_1^r b_{11}^{rs} + v_2^r b_{21}^{rs} \\ v_1^r b_{12}^{rs} + v_2^r b_{22}^{rs} \end{bmatrix} \# \begin{bmatrix} y_1^{sr} \\ y_2^{sr} \end{bmatrix}. \tag{15}$$

If we plug Equation (14) and Equation (15) into Equation (5), we get the full decomposition of country s's export:

$$\begin{aligned}
\begin{bmatrix} e_1^{sr} \\ e_2^{sr} \end{bmatrix} = \begin{bmatrix} y_1^{sr} \\ y_2^{sr} \end{bmatrix} + \begin{bmatrix} a_{11}^{sr} & a_{12}^{sr} \\ a_{21}^{ss} & a_{22}^{sr} \end{bmatrix} \begin{bmatrix} x_1^{r} \\ x_2^{r} \end{bmatrix} &= \begin{bmatrix} v_1^s b_{11}^{ss} + v_2^s b_{21}^{ss} \\ v_1^s b_{12}^{ss} + v_2^s b_{22}^{ss} \end{bmatrix} \# \begin{bmatrix} y_1^{sr} \\ y_2^{sr} \end{bmatrix} + \begin{bmatrix} v_1^s l_{11}^{ss} + v_2^s l_{21}^{ss} \\ v_1^s l_{12}^{ss} + v_2^s l_{22}^{ss} \end{bmatrix} \# \left\{ \begin{bmatrix} a_{11}^{sr} & a_{12}^{sr} \\ a_{21}^{ss} & a_{22}^{sr} \end{bmatrix} \begin{bmatrix} b_{11}^{rr} & b_{12}^{rr} \\ b_{21}^{rr} & b_{22}^{rr} \end{bmatrix} \begin{bmatrix} y_1^{rr} \\ y_2^{rr} \end{bmatrix} \right\} \\
&+ \begin{bmatrix} v_1^s l_{11}^{ss} + v_2^s l_{21}^{ss} \\ v_1^s l_{12}^{ss} + v_2^s l_{22}^{ss} \end{bmatrix} \# \left\{ \begin{bmatrix} a_{11}^{sr} & a_{12}^{sr} \\ a_{21}^{ss} & a_{22}^{sr} \end{bmatrix} \begin{bmatrix} b_{11}^{rr} & b_{12}^{rr} \\ b_{21}^{rr} & b_{22}^{rr} \end{bmatrix} \begin{bmatrix} y_1^{rs} \\ y_2^{rs} \end{bmatrix} \right\} + \begin{bmatrix} v_1^s l_{11}^{ss} + v_2^s l_{21}^{ss} \\ v_1^s l_{12}^{ss} + v_2^s l_{22}^{ss} \end{bmatrix} \# \left\{ \begin{bmatrix} a_{11}^{sr} & a_{12}^{sr} \\ a_{21}^{ss} & a_{22}^{sr} \end{bmatrix} \begin{bmatrix} b_{11}^{rr} & b_{12}^{rr} \\ b_{21}^{rr} & b_{22}^{rr} \end{bmatrix} \begin{bmatrix} y_1^{ss} \\ y_2^{ss} \end{bmatrix} \right\} \\
&+ \begin{bmatrix} v_1^s l_{11}^{ss} + v_2^s l_{21}^{ss} \\ v_1^s l_{12}^{ss} + v_2^s l_{22}^{ss} \end{bmatrix} \# \left\{ \begin{bmatrix} a_{11}^{sr} & a_{12}^{sr} \\ a_{21}^{ss} & a_{22}^{sr} \end{bmatrix} \begin{bmatrix} b_{11}^{rr} & b_{12}^{rr} \\ b_{21}^{rr} & b_{22}^{rr} \end{bmatrix} \begin{bmatrix} y_1^{sr} \\ y_2^{sr} \end{bmatrix} \right\} \\
&+ \left\{ \begin{bmatrix} v_1^s b_{11}^{ss} + v_2^s b_{21}^{ss} \\ v_1^s b_{12}^{ss} + v_2^s b_{22}^{ss} \end{bmatrix} - \begin{bmatrix} v_1^s l_{11}^{ss} + v_2^s l_{21}^{ss} \\ v_1^s l_{12}^{ss} + v_2^s l_{22}^{ss} \end{bmatrix} \right\} \# \begin{bmatrix} a_{11}^{sr} & a_{12}^{sr} \\ a_{21}^{sr} & a_{22}^{sr} \end{bmatrix} \begin{bmatrix} x_1^{r} \\ x_2^{r} \end{bmatrix} \\
&+ \begin{bmatrix} v_1^r b_{11}^{rs} + v_2^r b_{21}^{rs} \\ v_1^r b_{12}^{rs} + v_2^r b_{22}^{rs} \end{bmatrix} \begin{bmatrix} y_1^{sr} \\ y_2^{sr} \end{bmatrix} + \begin{bmatrix} v_1^r b_{11}^{rs} + v_2^r b_{21}^{rs} \\ v_1^r b_{12}^{rs} + v_2^r b_{22}^{rs} \end{bmatrix} \# \left\{ \begin{bmatrix} a_{11}^{sr} & a_{12}^{sr} \\ a_{21}^{ss} & a_{22}^{sr} \end{bmatrix} \begin{bmatrix} l_{11}^{rr} & l_{12}^{rr} \\ l_{21}^{rr} & l_{22}^{rr} \end{bmatrix} \begin{bmatrix} y_1^{rr} \\ y_2^{rr} \end{bmatrix} \right\} \\
&+ \begin{bmatrix} v_1^r b_{11}^{rs} + v_2^r b_{21}^{rs} \\ v_1^r b_{12}^{rs} + v_2^r b_{22}^{rs} \end{bmatrix} \# \left\{ \begin{bmatrix} a_{11}^{sr} & a_{12}^{sr} \\ a_{21}^{ss} & a_{22}^{sr} \end{bmatrix} \begin{bmatrix} l_{11}^{rr} & l_{12}^{rr} \\ l_{21}^{rr} & l_{22}^{rr} \end{bmatrix} \begin{bmatrix} e_1^{rs} \\ e_2^{rs} \end{bmatrix} \right\}.
\end{aligned}$$

2 Missing Values

We provided detailed information about missing observations here. First, the total number of missing observations in our fully saturated model is 78, which corresponds to 12% of the total observations. Table 1 reports the number of missing observations by country. Note that all the missing observations are from the right-hand side of the regression equation. While many countries have small numbers of missing observations, Luxembourg, Malta, and Taiwan are completely dropped from the analysis in our most saturated model. The main reason is that the World Bank data set and the polity data set have a large number of missing data for these three countries.

Country	Number of Missing Observations
AUS	1
AUT	1
BEL	4
CHE	1
CYP	3
DEU	1
DNK	3
FIN	3
GRC	1
HUN	3
IDN	3
IRL	1
ITA	1
JPN	2
LUX	15
LVA	1
MLT	15
NOR	1
SVK	1
SVN	1
SWE	1
TWN	15

Table 1: The Number of Missing Observations by Country

Imputing missing information for these three countries can be problematic because we have no information about the missing data of these three countries. The second best way is to check the sensitivity of our results using a less saturated model that includes all the three countries in the sample data. Table 5 shows the results of the regression analysis ((3) and (4)) in parallel with the original findings ((1) and (2)). For an easier interpretation, we use a simple linear regression and panel robust standard error. Also, for easy check, data are not scaled.

Table 5 shows the results. Note that we need to drop some control variables to add Luxembourg, Malta, and Taiwan in the sample. Our original findings in (1) and (2) do not change much when we add Luxembourg, Malta, and Taiwan in the sample ((3) and (4)).

3 Control Variables

We report control variables and their sources in this section.

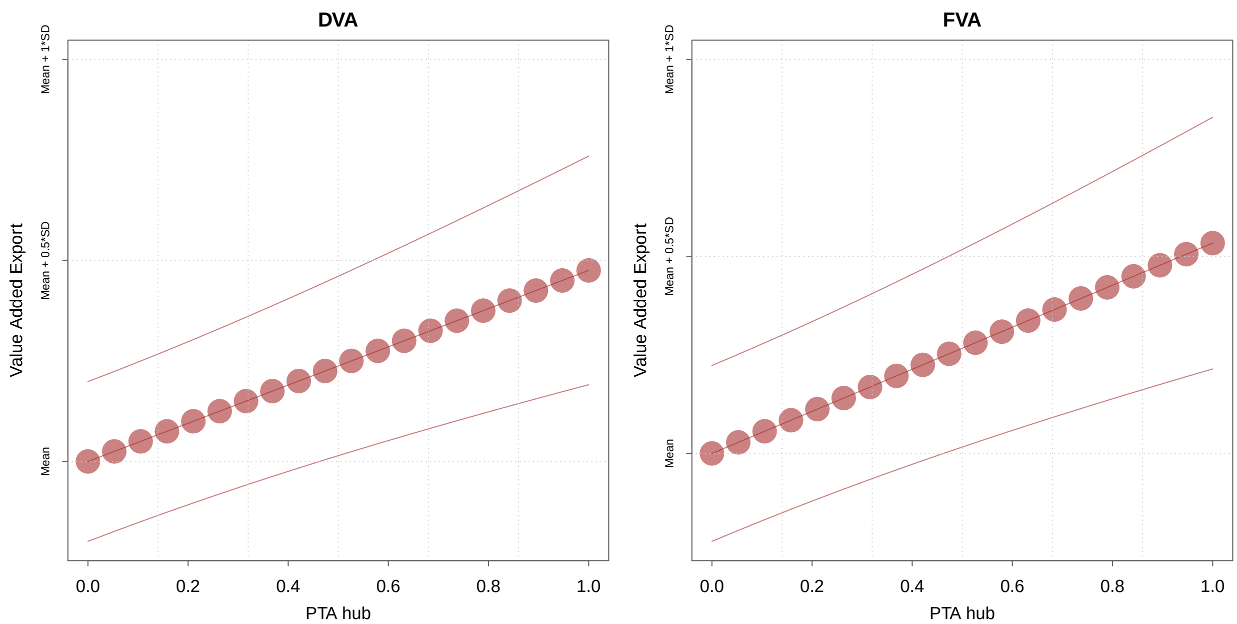

Figure 1: Predicted Effects of PTA Hub Score on Value Added Exports

- `GDP` Log transformed gross domestic product. Source: The World Bank (2018)
- `GDPpercap` Log transformed gross domestic product per capita. Source: The World Bank (2018)
- `population` Log transformed population. Source: The World Bank (2018)
- `land` Log transformed arable land. Source: The World Bank (2018)
- `FDI` Log transformed net inflow of foreign direct investment. Source: The World Bank (2018)
- `Polity` Polity scores. Source: Center for Systemic Peace (2017)
- `MarketOpen` The Chinn-Ito index of degree of capital account openness. Source: Chinn and Ito (2006)
- `PTA Number` The total number of PTAs in the system over time. Source: Author compilation
- `degree` Unweighted degree centrality by country over time. Source: Author compilation

- `betweenness` Betweenness centrality by country over time. Source: Author compilation
- `participation` Participation coefficient centrality by country over time. Source: Author compilation
- `closeness` Closeness centrality by country over time. Source: Author compilation
- `trend` A linear trend. Source: Author compilation
- `Europe` An indicator of European Union members as of 2014. Source: Author compilation

4 List of Countries and Industries

EU countries countries in the data set are Austria, Belgium, Cyprus, Czech Republic, Germany, Denmark, Spain, Estonia, Finland, France, United Kingdom of Great Britain and Northern Ireland, Greece, Hungary, Ireland, Italy, Lithuania, Luxembourg, Latvia, Malta, Netherlands, Poland, Portugal, Slovakia, Slovenia, Sweden. Non-EU countries in the data set are Australia, Bulgaria, Brazil, Canada, Switzerland, China, Croatia, Indonesia, India, Japan, South Korea, Mexico, Norway, Romania, Russian Federation, Turkey, Taiwan, Province of China, the United States.

The included industries and their industry codes are reported in Table 3.

Table 2: Country and Year Fixed-effect Analysis of PTA Hub Effects on Value-added Exports: Variables are unstandardized. The first two models have missing values and the last two models do not have missing values.

	DVA	FVA	DVA	FVA
	(1)	(2)	(3)	(4)
PTA hub	32.01^{***}	31.88^{***}	32.05^{***}	20.50^{***}
	(5.71)	(7.41)	(6.99)	(7.26)
betweenness	0.005^{**}	0.01^{***}	0.01^{**}	0.01^{***}
	(0.002)	(0.003)	(0.003)	(0.003)
participation	-8.41^{***}	-0.64	-2.37	2.12
	(2.94)	(3.82)	(3.85)	(4.00)
closeness	$5,720.50^{***}$	4,413.45	-561.19	-549.07
	(2,173.76)	(2,822.21)	(2,614.47)	(2,715.78)
ego centrality	-0.18^{**}	-0.32^{***}	-0.30^{***}	-0.31^{***}
	(0.07)	(0.09)	(0.09)	(0.10)
ego centrality$_7$	-0.02	0.12	-0.34^{***}	0.12
	(0.09)	(0.12)	(0.11)	(0.11)
ego centrality$_6$	-0.61^{***}	-0.30^{*}	-0.80^{***}	-0.20
	(0.13)	(0.16)	(0.17)	(0.17)
ego centrality$_5$	-0.63^{***}	-0.89^{***}	-1.67^{***}	-1.38^{***}
	(0.21)	(0.28)	(0.28)	(0.29)
ego centrality$_4$	0.30^{***}	0.41^{***}	0.62^{***}	0.64^{***}
	(0.08)	(0.10)	(0.10)	(0.10)
ego centrality$_3$	0.21	0.15	0.50^{***}	0.46^{**}
	(0.14)	(0.18)	(0.18)	(0.19)
ego centrality$_2$	0.64^{***}	1.16^{***}	1.73^{***}	1.73^{***}
	(0.16)	(0.21)	(0.20)	(0.21)
ego centrality$_1$	-0.05	-0.06	-0.003	-0.05
	(0.04)	(0.05)	(0.05)	(0.05)
ego centrality$_0$	-1.30^{***}	0.48	-0.89	0.53
	(0.43)	(0.56)	(0.59)	(0.61)
GDP	-437.50^{***}	-560.85^{***}		
	(91.13)	(118.32)		
land	-17.89^{***}	-18.61^{***}		
	(3.77)	(4.90)		
population	394.82^{***}	511.65^{***}		
	(92.24)	(119.75)		
GDP per capita	460.67^{***}	568.34^{***}		
	(91.10)	(118.27)		
FDI	0.41	0.43		
	(0.27)	(0.35)		
polity	0.38	0.72		
	(0.58)	(0.76)		
MarketOpen	12.42^{***}	8.67^{***}		
	(2.07)	(2.69)		
Number of Countries	40	40	43	43
Observations	567	567	645	645
R^2	0.69	0.45	0.36	0.31
Adjusted R^2	0.68	0.43	0.35	0.29

Note: *p<0.1; **p<0.05; ***p<0.01

	IndustryCode	IndustryLabel
1	A01	Crop and animal production, hunting and related service activities
2	A02	Forestry and logging
3	A03	Fishing and aquaculture
4	B	Mining and quarrying
5	C10-C12	Manufacture of food products, beverages and tobacco products
6	C13-C15	Manufacture of textiles, wearing apparel and leather products
7	C16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials
8	C17	Manufacture of paper and paper products
9	C18	Printing and reproduction of recorded media
10	C19	Manufacture of coke and refined petroleum products
11	C20	Manufacture of chemicals and chemical products
12	C21	Manufacture of basic pharmaceutical products and pharmaceutical preparations
13	C22	Manufacture of rubber and plastic products
14	C23	Manufacture of other non-metallic mineral products
15	C24	Manufacture of basic metals
16	C25	Manufacture of fabricated metal products, except machinery and equipment
17	C26	Manufacture of computer, electronic and optical products
18	C27	Manufacture of electrical equipment
19	C28	Manufacture of machinery and equipment n.e.c.
20	C29	Manufacture of motor vehicles, trailers and semi-trailers
21	C30	Manufacture of other transport equipment
22	C31_C32	Manufacture of furniture; other manufacturing
23	C33	Repair and installation of machinery and equipment
24	D35	Electricity, gas, steam and air conditioning supply
25	E36	Water collection, treatment and supply
26	E37-E39	Sewerage; waste collection, treatment and disposal activities; materials recovery; remediation activities and other waste management services
27	F	Construction
28	G45	Wholesale and retail trade and repair of motor vehicles and motorcycles
29	G46	Wholesale trade, except of motor vehicles and motorcycles
30	G47	Retail trade, except of motor vehicles and motorcycles
31	H49	Land transport and transport via pipelines
32	H50	Water transport
33	H51	Air transport
34	H52	Warehousing and support activities for transportation
35	H53	Postal and courier activities
36	I	Accommodation and food service activities
37	J58	Publishing activities
38	J59_J60	Motion picture, video and television programme production, sound recording and music publishing activities; programming and broadcasting activities
39	J61	Telecommunications
40	J62_J63	Computer programming, consultancy and related activities; information service activities
41	K64	Financial service activities, except insurance and pension funding
42	K65	Insurance, reinsurance and pension funding, except compulsory social security
43	K66	Activities auxiliary to financial services and insurance activities
44	L68	Real estate activities
45	M69_M70	Legal and accounting activities; activities of head offices; management consultancy activities
46	M71	Architectural and engineering activities; technical testing and analysis
47	M72	Scientific research and development
48	M73	Advertising and market research
49	M74_M75	Other professional, scientific and technical activities; veterinary activities
50	N	Administrative and support service activities
51	O84	Public administration and defence; compulsory social security
52	P85	Education
53	Q	Human health and social work activities
54	R_S	Other service activities
55	T	Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use
56	U	Activities of extraterritorial organizations and bodies

Table 3: List of Industries

5 Selection of Regularization Methods

We selected regularization methods by comparing the residual sum of squares (RSS). Three candidate methods are ordinary least squares (OLS), Lasso (Tibshirani, 1996), adaptive Lasso (Zou, 2006). We choose λ for the lasso and the adaptive lasso using 10-fold cross-validation. In the case of the adaptive lasso method, we choose λ within one standard error of the minimum that is known to provide the most regularized model.

Table 4 shows the RSS for different regularization methods. The top panel and the bottom panel show the results from different fixed-effects model specifications. Note that we already detrended data by a linear trend model. Thus, the addition of year fixed-effects term does not make much difference, which is consistent across our various trials. The adaptive lasso method always outperform the other two methods in both equations. Thus, we use the adaptive lass method in the subsequent analysis.

		RSS					
Fixed Effects	Dependent Variable	OLS		Lasso		Adaptive Lasso	
		First stage	Second stage	First stage	Second stage	First stage	Second stage
Country	DVA	392228.52	81094.01	5.59	12.02	1.46	0.63
	FVA	1662449.83	81094.01	12.82	12.02	4.50	0.61
Country and Year	DVA	392228.52	81094.01	5.59	12.02	1.51	0.72
	FVA	1662449.83	81094.01	12.82	12.02	4.05	0.57

Table 4: Residual Sum of Squares

6 Lagged Variable Specifications

We check the sensitivity of our findings against different lag specifications of our causal variable. Table 5 reports the fixed-effects (FE) analysis results using our causal variable ($\texttt{PTA hub}_{t-2}$) as well as its different lag specifications ($\texttt{PTA hub}_{t-1}$ and $\texttt{PTA hub}_{t}$). Now, the coefficients of $\texttt{PTA hub}_{t-2}$ show the marginal effects of the two-year lagged PTA hub status controlling for its contemporaneous and one-year lagged effects.

In the first two model specifications (One-way FE and Two-way FE), our original results do not change much. The two-year lagged PTA hub status has a positive and significant effect on value-added exports. Adding $\texttt{PTA hub}_{t-1}$ and $\texttt{PTA hub}_{t}$ mitigates the effect of PTA hub status between country averages of value-added exports. Note the small sample size in the between model (N = 40, K = 25). The first-differenced model shows a positive and significant effect only in DVA. Interestingly, $\texttt{PTA hub}_{t-1}$ takes a positive and significant effect from $\texttt{PTA hub}_{t-2}$ in FVA. Also, $\texttt{PTA hub}_{t}$ is positive in One-way FE and Two-way FE models.

Although these new findings are somewhat interesting, $\texttt{PTA hub}_{t-2}$ shows larger and more consistent signs than other lag specifications. Also, adding different lag specifications does not change our main findings and conclusions.

7 Additional Regression Results

Table 6 shows the additional regression results of the fixed-effects analysis under different model specifications. In most cases, the statistical significance does not change by dropping some covariates. PTA hub score has a consistent sign on value-added exports across different model specifications.

8 Computation of Participation Coefficient

Participation coefficient is calculated in two steps. First, bloc structure in a network is calculated by optimizing the modularity score. Modularity optimization algorithm is widely employed method for finding stable community structure in a network in various fields of study (Guimera and Amaral, 2005; Newman, 2006; Zhang et al., 2008; Lupu and Traag, 2013). Modularity, which is a "function of the particular division of the network into groups, with larger values indicating stronger community structure" (Newman, 2006, 5), is given by

$$Q = \sum_{s=1}^{B} \left[\frac{t_s}{L} - (\frac{d_s}{2T})^2 \right]$$

where B indicates the number of blocs, T is the total number of ties in the network, and t_s is the number of ties between actors in bloc s and d_s is the sum of the degrees of the actors in bloc s. Here, $\frac{d_s}{2T})^2$ is equivalent to the expected degree of connection between actors within the same bloc. Intuitively, The second step is to identify different roles of actors with respect

Table 5: Lagged Variable Sensitivity Test

Model	One-way FE		Two-way FE		Between		First-differenced	
	DVA	FVA	DVA	FVA	DVA	FVA	DVA	FVA
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
PTA hub$_{t-2}$	0.19***	0.19**	0.16***	0.14**	1.47	−1.89	0.10**	0.08
	(0.06)	(0.09)	(0.05)	(0.07)	(3.36)	(4.66)	(0.04)	(0.07)
PTA hub$_{t-1}$	−0.07	−0.08	−0.09**	−0.10	−8.43	−0.83	0.01	0.06*
	(0.05)	(0.08)	(0.04)	(0.06)	(7.58)	(10.53)	(0.02)	(0.04)
PTA hub$_t$	0.07**	0.14***	0.09***	0.14***	7.70	5.15	−0.02	−0.03
	(0.03)	(0.05)	(0.03)	(0.04)	(4.65)	(6.46)	(0.02)	(0.03)
Europe					0.08	0.59		
					(0.25)	(0.35)		
betweenness	0.02	0.05**	0.02*	0.05***	−0.05	−0.01	0.01	0.01
	(0.01)	(0.02)	(0.01)	(0.02)	(0.07)	(0.10)	(0.01)	(0.02)
participation	−0.01	0.02	−0.04***	−0.01	0.03	0.22	−0.02***	−0.05***
	(0.02)	(0.02)	(0.01)	(0.02)	(0.18)	(0.25)	(0.01)	(0.01)
closeness	−0.01	−0.02	0.05***	0.05**	−0.06	0.01	−0.004	−0.003
	(0.01)	(0.02)	(0.01)	(0.02)	(0.36)	(0.50)	(0.005)	(0.01)
ego centrality	−0.09	−0.18*	−0.10*	−0.20**	−0.42	−1.90	−0.01	0.04
	(0.06)	(0.10)	(0.05)	(0.08)	(1.01)	(1.41)	(0.05)	(0.08)
ego centrality$_7$	−0.02**	0.01	−0.01	0.02	−1.49*	−1.34	0.0000	0.02**
	(0.01)	(0.02)	(0.01)	(0.02)	(0.74)	(1.04)	(0.01)	(0.01)
ego centrality$_6$	−0.03***	−0.02**	−0.02***	−0.01	−0.11	−0.12	−0.01**	−0.01
	(0.01)	(0.01)	(0.01)	(0.01)	(0.34)	(0.48)	(0.01)	(0.01)
ego centrality$_5$	−0.07**	−0.09*	−0.08***	−0.12***	−0.02	−0.32	−0.05**	−0.05
	(0.03)	(0.05)	(0.03)	(0.04)	(0.18)	(0.25)	(0.02)	(0.04)
ego centrality$_4$	−0.03	−0.08***	0.06***	0.09***	0.24	−0.39	−0.06***	−0.15***
	(0.02)	(0.03)	(0.02)	(0.03)	(0.40)	(0.56)	(0.01)	(0.02)
ego centrality$_3$	0.12	0.11	0.05	0.06	−0.08	−0.42	−0.06	−0.34**
	(0.09)	(0.15)	(0.08)	(0.12)	(0.27)	(0.38)	(0.08)	(0.13)
ego centrality$_2$	0.02	0.04	0.12***	0.21***	0.15**	0.10	0.06*	0.10**
	(0.03)	(0.06)	(0.03)	(0.05)	(0.07)	(0.10)	(0.03)	(0.05)
ego centrality$_1$	0.01	0.01	−0.02	−0.03	−0.08	0.58	−0.03	−0.06**
	(0.03)	(0.04)	(0.02)	(0.03)	(0.43)	(0.60)	(0.02)	(0.03)
ego centrality$_0$	−0.55***	−0.21	−0.35***	0.09	0.13	0.43	−0.15	−0.18
	(0.15)	(0.23)	(0.12)	(0.18)	(0.25)	(0.35)	(0.15)	(0.24)
GDP	−9.06***	−14.82***	−9.18***	−14.82***	4.25*	8.67**	−0.84	−1.01
	(3.33)	(5.30)	(2.69)	(4.10)	(2.27)	(3.16)	(3.52)	(5.63)
land	−0.24***	−0.29**	−0.20***	−0.24***	0.06	−0.07	0.02	−0.01
	(0.07)	(0.12)	(0.06)	(0.09)	(0.08)	(0.11)	(0.06)	(0.09)
population	8.02**	13.59**	8.84***	14.55***	−3.21	−7.95**	−0.44	−0.76
	(3.58)	(5.71)	(2.90)	(4.42)	(2.42)	(3.36)	(3.84)	(6.12)
GDP per capita	6.04***	9.45***	5.99***	9.22***	−1.78	−4.54**	1.15	1.26
	(2.04)	(3.25)	(1.65)	(2.52)	(1.37)	(1.91)	(2.16)	(3.46)
FDI	0.02**	0.03**	0.01*	0.01	0.18**	0.34***	0.01**	0.02***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.07)	(0.10)	(0.004)	(0.01)
polity	0.08**	0.17***	0.02	0.07	−0.03	−0.10	−0.01	0.03
	(0.04)	(0.06)	(0.03)	(0.05)	(0.08)	(0.11)	(0.03)	(0.05)
MarketOpen	0.07***	0.05***	0.05***	0.03**	−0.03	0.04	0.02	0.02
	(0.01)	(0.02)	(0.01)	(0.01)	(0.10)	(0.14)	(0.01)	(0.02)
trend	0.04***	0.07***			0.16	0.16	0.02	0.07***
	(0.004)	(0.01)			(0.17)	(0.24)	(0.02)	(0.02)
Observations	497	497	497	497	40	40	457	457
R^2	0.92	0.88	0.70	0.44	0.98	0.96	0.65	0.54
Adjusted R^2	0.91	0.86	0.64	0.34	0.94	0.89	0.64	0.52

Note: *p<0.1; **p<0.05; ***p<0.01

Table 6: Fixed-effect Analysis of PTA Hub Effects on Value-added Exports: The dependent variables are value-added exports measured by DVA and FVA, respectively.

	Dependent Variables											
	DVA			FVA			DVA			FVA		
	Model											
Country Fixed-Effects	*Y*	*Y*	*Y*	*Y*	*Y*	*Y*	*Y*	*Y*	*Y*	*Y*	*Y*	*Y*
First-Differenced	*N*	*N*	*N*	*N*	*N*	*N*	*Y*	*Y*	*Y*	*Y*	*Y*	*Y*
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
PTA hub	0.08***	0.13***	0.19***	0.07**	0.14***	0.23***	0.03*	0.08***	0.11***	0.01	0.09**	0.14**
	(0.02)	(0.03)	(0.04)	(0.03)	(0.04)	(0.06)	(0.02)	(0.03)	(0.04)	(0.03)	(0.04)	(0.06)
betweenness			0.02			0.05**			0.01			0.02
			(0.01)			(0.02)			(0.01)			(0.02)
participation			−0.03*			−0.01			−0.02***			−0.05***
			(0.01)			(0.02)			(0.01)			(0.01)
closeness			−0.01			−0.03*			−0.004			−0.004
			(0.01)			(0.02)			(0.004)			(0.01)
ego centrality			−0.08			−0.18*			−0.02			−0.03
			(0.06)			(0.10)			(0.04)			(0.07)
ego centrality_7		−0.02**	−0.02**		−0.01	−0.004		0.001	−0.003		0.02*	0.01
		(0.01)	(0.01)		(0.01)	(0.01)		(0.01)	(0.01)		(0.01)	(0.01)
ego centrality_6		−0.03***	−0.03***		−0.03***	−0.03***		−0.01**	−0.01**		−0.01	−0.01
		(0.01)	(0.01)		(0.01)	(0.01)		(0.01)	(0.01)		(0.01)	(0.01)
ego centrality_5		−0.05*	−0.04		−0.05	−0.04		−0.04	−0.04*		−0.02	−0.03
		(0.03)	(0.03)		(0.05)	(0.05)		(0.02)	(0.02)		(0.04)	(0.04)
ego centrality_4		0.002	−0.005		−0.02	−0.02		−0.05***	−0.05***		−0.12***	−0.13***
		(0.02)	(0.02)		(0.02)	(0.02)		(0.01)	(0.01)		(0.02)	(0.02)
ego centrality_3		0.19**	0.16*		0.03	0.10		0.01	−0.04		−0.19	−0.29**
		(0.08)	(0.09)		(0.13)	(0.14)		(0.08)	(0.08)		(0.12)	(0.13)
ego centrality_2		−0.01	0.01		0.05	0.06		0.07**	0.07**		0.14***	0.14***
		(0.03)	(0.03)		(0.05)	(0.05)		(0.03)	(0.03)		(0.04)	(0.05)
ego centrality_1		−0.02	0.01		−0.03	0.02		−0.03**	−0.02		−0.05**	−0.04
		(0.02)	(0.03)		(0.03)	(0.04)		(0.01)	(0.02)		(0.02)	(0.03)
ego centrality_0		−0.62***	−0.55***		−0.27	−0.14		−0.13	−0.14		−0.14	−0.13
		(0.14)	(0.15)		(0.22)	(0.23)		(0.14)	(0.15)		(0.24)	(0.24)
trend	0.02***	0.02***	0.03***	0.04***	0.05***	0.05***	−0.001	0.004	0.01	0.04*	0.05**	0.06***
	(0.002)	(0.004)	(0.004)	(0.004)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)	(0.02)	(0.02)
GDP	−9.09***	−12.70***	−12.79***	−15.58***	−18.23***	−18.00***	−1.19	−1.18	−1.66	0.41	1.46	0.42
	(3.23)	(3.20)	(3.19)	(4.88)	(5.02)	(5.00)	(3.04)	(2.97)	(2.96)	(5.19)	(4.87)	(4.82)
land	−0.27***	−0.32***	−0.33***	−0.37***	−0.41***	−0.43***	−0.01	0.01	0.01	−0.08	−0.02	−0.02
	(0.07)	(0.07)	(0.07)	(0.11)	(0.11)	(0.11)	(0.06)	(0.06)	(0.05)	(0.10)	(0.09)	(0.09)
population	7.85**	11.92***	11.93***	14.37***	17.30***	16.94***	−0.01	−0.09	0.39	−1.92	−3.28	−2.26
	(3.45)	(3.43)	(3.41)	(5.20)	(5.38)	(5.35)	(3.29)	(3.23)	(3.21)	(5.62)	(5.28)	(5.23)
GDP per capita	6.15***	8.33***	8.38***	10.05***	11.63***	11.48***	1.42	1.37	1.67	0.50	−0.23	0.40
	(1.99)	(1.97)	(1.96)	(3.00)	(3.08)	(3.07)	(1.87)	(1.83)	(1.82)	(3.19)	(2.99)	(2.96)
FDI	0.02**	0.02***	0.02***	0.03***	0.03***	0.03***	0.01***	0.01**	0.01**	0.02***	0.02***	0.02***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.003)	(0.003)	(0.003)	(0.01)	(0.01)	(0.01)
Pollity	0.08***	0.08**	0.07**	0.13***	0.12**	0.12**	−0.004	−0.01	−0.01	0.02	0.02	0.02
	(0.03)	(0.03)	(0.03)	(0.05)	(0.05)	(0.05)	(0.02)	(0.02)	(0.02)	(0.03)	(0.03)	(0.03)
MarketOpen	0.07***	0.07***	0.07***	0.06***	0.06***	0.06***	0.02*	0.02*	0.02	0.02	0.03*	0.03
	(0.01)	(0.01)	(0.01)	(0.02)	(0.02)	(0.02)	(0.01)	(0.01)	(0.01)	(0.02)	(0.02)	(0.02)
Observations	567	567	567	567	567	567	527	527	527	527	527	527
R^2	0.91	0.91	0.92	0.87	0.87	0.87	0.62	0.64	0.65	0.41	0.50	0.51
Adjusted R^2	0.90	0.91	0.91	0.85	0.85	0.86	0.61	0.63	0.64	0.40	0.48	0.49

Note: *p<0.1; **p<0.05; ***p<0.01

to their blocs. Guimera and Amaral (2005) proposes *z-score* to differentiate roles of actors within a bloc. The z-score is given by

$$z_i = \frac{\kappa_i - \overline{\kappa}_{s_i}}{\sigma_{\kappa_{s_i}}}$$

where κ_i is the number of ties of i to the other actors within the same bloc, $\overline{\kappa}_{s_i}$ is the average number of ties within the bloc that i belongs to, and $\sigma_{\kappa_{s_i}}$ indicates the standard deviation of κ in s_i. What z-score measures is the extent of connectivity of actor i to other actors in the same bloc.

Using the z-score, we can now measure the participation coefficient. The participation coefficient P_i is,

$$P_i = 1 - \sum_{s=1}^{B} (\frac{\kappa_{i,s}}{k_i})^2$$

Here, $\kappa_{i,s}$ is the number of ties from i to actors in bloc s and k_i is the degree of actor i. What the latter term measures is the number of actor i's ties to bloc s divided by the total degree of that actor. In other words,

$$P_i = 1 - \sum_{s=1}^{B} \left(\frac{\text{number of } i\text{'s ties to bloc } s}{\text{total degree of actor } i} \right)^2 .$$

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