Online supplementary material for Global Production Sharing and the New Demands for Deep Preferential Trade Agreements

ByungKoo Kim

Contents

List of Figures

List of Tables

Appendix A. Construction of Independent Variable

The structure of MRIO table

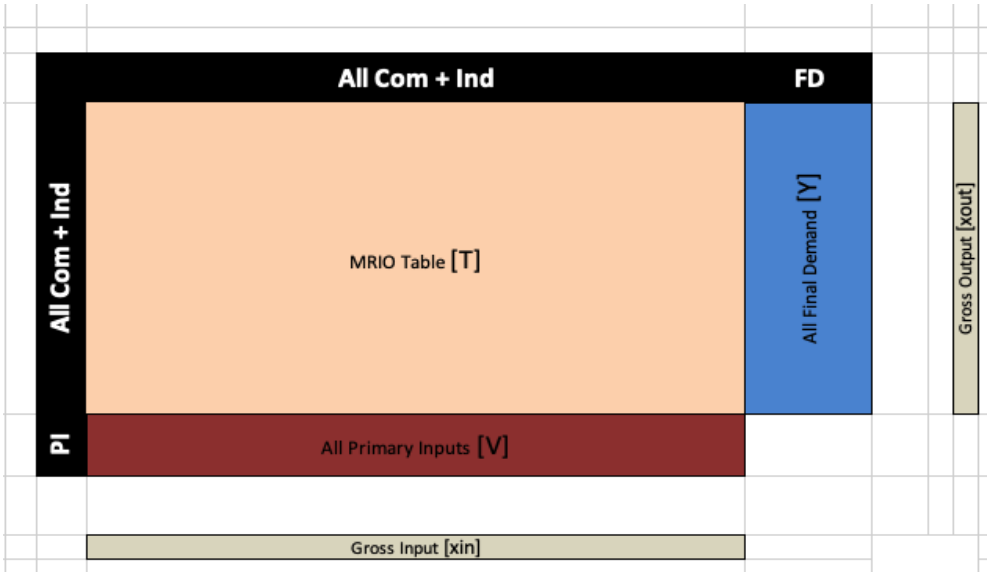


Figure A1: The structure of IO table in MRIO dataset. Source: Eora project

Let N denote the total number of countries and K denote the total number of industries. NK then is the total number of unique country-industry dyads. $\mathbf{T}$ is a NK by NK matrix of intermediate transactions, $\mathbf{Y}$ is a NK by N matrix that represents final consumption, and $\mathbf{V}$ is 6 by NK matrix of production factor inputs such as labor (measured as total wages paid) and capital (subsidies, taxes, investments, and etc.).

There is an important equality constraint for input-output tables. The summation along the columns of $\mathbf{T}$ and $\mathbf{Y}$ is the total output vector $\mathbf{x}$ from demand perspective. Similarly, the summation along the rows of $\mathbf{T}$ and $\mathbf{V}$ is the total output from the supply perspective, and it should match the total output from the demand perspective. That is,

$$\mathbf{T}\hat{\mathbf{i}}_{NK} + \mathbf{Y}\hat{\mathbf{i}}_{N} = \mathbf{x} \text{ and } \hat{\mathbf{i}}_{NK}^{T}\mathbf{T} + \hat{\mathbf{i}}_{N}^{T}\mathbf{V} = \mathbf{x}^{T}$$

where $\hat{\mathbf{i}}$ is a unit vector of 1s.

Many GVC measures rely on $\mathbf{A}$ rather than $\mathbf{T}$. $\mathbf{A}$ is a normalized intermediate transactions matrix constructed by dividing each column of the intermediate value-added transactions matrix $\mathbf{T}$ by the corresponding element of the total output $\mathbf{x}$ such that

$$a_{ij} = t_{ij}/x_j$$

An element in $\mathbf{A}$ denotes the intensity of linkage from one country-industry dyad to another through the supply of intermediate inputs. The Leontief insight employs $\mathbf{A}$ to compute all direct and indirect linkages using the power series. Specifically, graph theory suggests that the adjacency matrix $\mathbf{A}$ represents the direct connection between country-industry pairs and $\mathbf{A}^2$ represents the total indirect connection between the units that could be reached in two steps. Similarly, $\mathbf{A}^3$ shows the total intensity of connections between units that could be reached in three walks. We can continue these to obtain a power series (Miller and Blair, 2009).

$$1 + \mathbf{A} + \mathbf{A}^2 + \mathbf{A}^3 + ... + \mathbf{A}^n + ... = (\mathbf{I} - \mathbf{A})^{-1}$$

Let $\mathbf{B}$ denote this series $\mathbf{B} = (\mathbf{I} - \mathbf{A})^{-1}$. Then $\mathbf{B}$ describes the intensity of all direct and indirect production linkages between country-sector dyads.

Define $\hat{\mathbf{V}}$ as the diagonal matrix where diagonal entries are length NK vector as a result of the column-wise sum of $\mathbf{V}$. Likewise, $\hat{\mathbf{Y}}$ is a diagonal matrix where entries are length NK vector as a result of row-wise summation of $\mathbf{Y}$. Koopman et al. (2014) suggests that $\hat{\mathbf{V}}\mathbf{B}$ records the value-added traveling globally through all direct and indirect linkages such that it reveals the underlying structure of the global production. By multiplying $\hat{\mathbf{V}}\mathbf{B}$ with the final consumption $\hat{\mathbf{Y}}$, one obtains an expression of *the total value-added from a source country-industry directly or indirectly used to produce final goods and services in other country-industry.*

Pre-processing MRIO for $\hat{\mathbf{V}}\mathbf{B}\hat{\mathbf{Y}}$ decomposition

The MRIO table from the Eora global supply chain database originally includes 188 countries and 26 industries. The MRIO table is constructed by combining input-output data from multiple different sources. After putting together data from multiple sources while harmonizing different classification rules of trade information, entries in MRIO inevitably entails varying degrees of measurement errors (Lenzen et al., 2013). The Eora project explains that measurement errors are more pronounced for a set of small countries such as Belarus, Benin, Burkina Faso, Congo and Zimbabwe. Following their recommendation, I remove these countries before computing $\hat{\mathbf{V}}\mathbf{B}\hat{\mathbf{Y}}$. I also remove two redundant industry categories – Others and Re-export & Re-import. Additionally, Recycling and Private Households sectors are also dropped because they reported 0 entries in all time periods of the data for some countries. This results in a total of 155 countries and 22 industries. The full list of industries are reported here.

	Industry Label
1	Agriculture
2	Fishing
3	Mining and Quarrying
4	Food & Beverages
5	Textiles and Wearing Apparel
6	Wood and Paper
7	Petroleum, Chemical and Non-Metallic Mineral Products
8	Metal Products
9	Electrical and Machinery
10	Transport Equipment
11	Other Manufacturing
12	Electricity, Gas and Water
13	Construction
14	Maintenance and Repair
15	Wholesale Trade
16	Retail Trade
17	Hotels and Restraurants
18	Transport
19	Post and Telecommunications
20	Finacial Intermediation and Business Activities
21	Public Administration
22	Education, Health and Other Services

Table A1: Full List of Industries Used to Construct Value-added Production Measure.

$\hat{\mathbf{V}}\mathbf{B}\hat{\mathbf{Y}}$ Decomposition Illustration

$$\hat{\mathbf{V}}\mathbf{B}\hat{\mathbf{Y}} = \underbrace{\hat{\mathbf{V}}\mathbf{L}\hat{\mathbf{Y}}^{\mathrm{D}}}_{\text{Purely Domestic}} + \underbrace{\hat{\mathbf{V}}\mathbf{L}\hat{\mathbf{Y}}^{\mathrm{F}}}_{\text{Autonomous Export}} + \underbrace{\hat{\mathbf{V}}\mathbf{L}\mathbf{A}^{\mathrm{F}}\mathbf{B}\hat{\mathbf{Y}}}_{\text{GVC integrated}} \tag{1}$$

2-Country 2-Sector Illustration

Superscript denotes countries, subscript denotes sectors. $\hat{\mathbf{Y}}^{\mathrm{D}}$ is the diagonal matrix of domestic final consumption and $\hat{\mathbf{Y}}^{\mathrm{F}}$ is the diagonal matrix of foreign final consumption such that $\hat{\mathbf{Y}} = \hat{\mathbf{Y}}^{\mathrm{D}} + \hat{\mathbf{Y}}^{\mathrm{F}}$. Likewise, $\mathbf{A}^{\mathrm{D}}$ is the block-diagonal matrix of domestic intermediate goods linkage coefficient, and $\mathbf{A}^{\mathrm{F}}$ is the off-block-diagonal matrix of foreign intermediate goods linkage coefficient such that $\mathbf{A} = \mathbf{A}^{\mathrm{D}} + \mathbf{A}^{\mathrm{F}}$.

Purely Domestic

The first segment of the decomposition represents a total value-added contribution that is domestically produced and consumed. Specifically,

$$\hat{\mathbf{V}}\mathbf{L}\hat{\mathbf{Y}}^{\mathrm{D}} = \begin{pmatrix} v_1^1 l_{11}^1 y_1^{1d} & v_1^1 l_{12}^1 y_2^{1d} & 0 & 0 \\ v_2^1 l_{21}^1 y_1^{1d} & v_2^1 l_{12}^1 y_2^{1d} & 0 & 0 \\ 0 & 0 & v_1^2 l_{11}^2 y_1^{2d} & v_1^2 l_{12}^2 y_2^{2d} \\ 0 & 0 & v_2^2 l_{21}^2 y_1^{2d} & v_2^2 l_{12}^2 y_2^{2d} \end{pmatrix} \tag{2}$$

The entry in the first row and second column ($v_1^1 l_{12}^1 y_2^{1d}$), for instance, is interpreted as follows. The value-added created in country 1 and sector 1 (v_1^1) moves back and forth as intermediate input between domestic sectors 1 and 2 and then sold to sector 2 (l_{12}^1) where it is used to produce final good that is consumed domestically (y_2^{1d}).

Autonomous Export

$$\hat{\mathbf{V}}\mathbf{L}\hat{\mathbf{Y}}^{\mathrm{F}} = \begin{pmatrix} v_1^1 l_{11}^1 y_{1f}^1 & v_1^1 l_{12}^1 y_2^{1f} & 0 & 0 \\ v_2^1 l_{21}^1 y_1^{1f} & v_2^1 l_{12}^1 y_2^{1f} & 0 & 0 \\ 0 & 0 & v_1^2 l_{11}^2 y_1^{2f} & v_1^2 l_{12}^2 y_2^{2f} \\ 0 & 0 & v_2^2 l_{21}^2 y_1^{2f} & v_2^2 l_{12}^2 y_2^{2f} \end{pmatrix} \tag{3}$$

The entry in the first row and second column ($v_1^1 l_{12}^1 y_2^{1f}$), for instance, is interpreted as follows. The value-added created in country 1 and sector 1 (v_1^1) moves back and forth as intermediate input between domestic sectors 1 and 2 and then sold to sector 2 (l_{12}^1) where it is used to produce final good that is exported for final consumption (y_2^{1f}).

GVC-integrated

$\hat{\mathbf{V}}\mathbf{L}\mathbf{A}^{\mathrm{F}}\mathbf{B}\hat{\mathbf{Y}}$

$$\hat{\mathbf{V}}\mathbf{L}\mathbf{A}^{\mathrm{F}} = \begin{pmatrix} 0 & 0 & v_1^1 l_{11}^1 a_{11}^{1\to 2} + v_1^1 l_{12}^1 a_{21}^{1\to 2} & v_1^1 l_{11}^1 a_{12}^{1\to 2} + v_1^1 l_{12}^1 a_{22}^{1\to 2} \\ 0 & 0 & v_2^1 l_{21}^1 a_{11}^{1\to 2} + v_2^1 l_{22}^1 a_{21}^{1\to 2} & v_2^1 l_{21}^1 a_{12}^{1\to 2} + v_2^1 l_{22}^1 a_{22}^{1\to 2} \\ v_1^2 l_{11}^2 a_{11}^{2\to 1} + v_1^2 l_{12}^2 a_{21}^{2\to 1} & v_1^2 l_{11}^2 a_{12}^{2\to 1} + v_1^2 l_{12}^2 a_{22}^{2\to 1} & 0 & 0 \\ v_2^2 l_{21}^2 a_{11}^{2\to 1} + v_2^2 l_{22}^2 a_{21}^{2\to 1} & v_2^2 l_{21}^2 a_{12}^{2\to 1} + v_2^2 l_{22}^2 a_{22}^{2\to 1} & 0 & 0 \end{pmatrix} \tag{4}$$

Entries of $\hat{\mathbf{V}}\mathbf{L}\mathbf{A}^{F}$ represent a domestic value-added production exported as intermediate inputs to foreign country-sectors. For example, row 1 and col 3 ($v_1^1 l_{11}^1 a_{11}^{1\to 2} + v_1^1 l_{12}^1 a_{21}^{1\to 2}$) indicates domestic value-added in country 1 for both sectors being exported for intermediate use. Each entry then is multiplied by corresponding entries in $\mathbf{B}$ which is a matrix that measures the global intensity of linkage for intermediate use. Multiplying with $\hat{\mathbf{Y}}$, entries of $\hat{\mathbf{V}}\mathbf{L}\mathbf{A}^{\mathrm{F}}\mathbf{B}\hat{\mathbf{Y}}$ then represent a value-added from a country-sector that is embedded in an intermediate input that is exported for intermediate use until eventually consumed in the domestic market or foreign market.

Appendix B: WTO-X Summary Statistics

	Total Count	Mean	Std
Anti Corruption	39	0.12	0.33
Competition Policy	233	0.74	0.44
Environmental Laws	132	0.42	0.49
IPR	160	0.50	0.50
Investment	178	0.56	0.50
Labour Market Regulation	84	0.26	0.44
Movement of Capital	172	0.54	0.50
Consumer Protection	60	0.19	0.39
Data Protection	45	0.14	0.35
Agriculture	100	0.32	0.47
Approximation of Legislation	40	0.13	0.33
Audio Visual	28	0.09	0.28
Civil Protection	4	0.01	0.11
InnovationPolicies	34	0.11	0.31
CulturalCooperation	50	0.16	0.37
EconomicPolicyDialogue	76	0.24	0.43
Education and Training	58	0.18	0.39
Energy	64	0.20	0.40
Financial Assistance	43	0.14	0.34
Health	40	0.13	0.33
HumanRights	25	0.08	0.27
Illegal Immigration	20	0.06	0.24
Illicit Drugs	27	0.09	0.28
Industrial Cooperation	65	0.21	0.40
Information Society	117	0.37	0.48
Mining	24	0.08	0.26
Money Laundering	21	0.07	0.25
Nuclear Safety	15	0.05	0.21
Political Dialogue	43	0.14	0.34
Public Administration	76	0.24	0.43
Regional Cooperation	100	0.32	0.47
Research and Technology	81	0.26	0.44
SME	56	0.18	0.38
Social Matters	54	0.17	0.38
Statistics	59	0.19	0.39
Taxation	41	0.13	0.34
Terrorism	17	0.05	0.23
Visa and Asylum	94	0.30	0.46

Table B1: Summary Statistics of WTO-X Provisions in PTA Data.

Appendix C: Additional Results

Heckman Selection Model

Table B2: Results of Heckman Selection Model

	Dependent variable:		
	Maximum Depth of PTA as Fraction (DESTA)		
	(1)	(2)	(3)
Purely Domestic	-0.213^{***}		
	(0.029)		
Autonomous Exporters		0.702^{***}	
		(0.101)	
GVC-integrated			0.246^{***}
			(0.034)
logGDP	-0.183	-0.197	-0.149
	(0.255)	(0.233)	(0.255)
logGDPc	0.210	0.230	0.174
	(0.255)	(0.233)	(0.255)
logPop	0.167	0.184	0.132
	(0.256)	(0.234)	(0.256)
logFDIin	0.063	0.050	0.067
	(0.069)	(0.063)	(0.069)
Arable Land	-0.025^{***}	-0.025^{***}	-0.026^{***}
	(0.005)	(0.007)	(0.005)
Economic Complexity	0.011^{**}	0.002	0.014^{***}
	(0.005)	(0.005)	(0.005)
Polity2	0.014^{***}	0.012^{***}	0.014^{***}
	(0.002)	(0.002)	(0.002)
BIT Signed	-0.00001	0.00003	0.00001
	(0.0001)	(0.0001)	(0.0001)
Capital open	0.027^{***}	0.027^{***}	0.027^{***}
	(0.003)	(0.003)	(0.003)
Landlocked	-0.148^{***}	-0.132^{***}	-0.150^{***}
	(0.028)	(0.026)	(0.028)
Islands	-0.057^{**}	-0.056^{***}	-0.054^{**}
	(0.023)	(0.021)	(0.023)
Constant	0.173	-0.085	-0.030
	(0.291)	(0.266)	(0.290)
Observations	2,305	2,305	2,305
ρ	1.699	1.663	1.698
Inverse Mills Ratio	0.542^{***}	0.483^{***}	0.542^{***}
	(0.132)	(0.125)	(0.133)
EU/US	✓	✓	✓
Note:			*p<0.1; **p<0.05; ***p<0.01

Zero-inflated Negative Binomial Regression

Note that for WTO-X dependent variable, random effects are relaxed to continent-level and period-level for a better model convergence. The period random effect consists of 4 levels where each level groups about 5 years. Period 1 groups years from 1995 to 1999, period 2 groups years from 2000 to 2005. period 3 groups years from 2006 to 2010 and period 4 groups years from 2011 to 2015.

Table B3: Results of Zero-inflated Negative Binomial Regression

	Dependent variable:			
	Maximum Depth of WTO-X as Count		Maximum Depth of PTA as Count (DESTA)	
	(1)	(2)	(3)	(4)
Autonomous Exporters	0.563**		0.416	
	(0.236)		(0.389)	
GVC-integrated		0.281***		0.486***
		(0.102)		(0.138)
logGDP	−3.493***	−3.533***	−2.746***	−2.822***
	(0.250)	(0.252)	(1.014)	(1.012)
logGDPc	3.487***	3.522***	2.947***	3.018***
	(0.249)	(0.250)	(1.013)	(1.011)
logPop	3.505***	3.546***	2.761***	2.839***
	(0.253)	(0.254)	(1.015)	(1.013)
logFDIin	−0.070	−0.073	−0.014	−0.011
	(0.061)	(0.061)	(0.031)	(0.031)
Arable Land	−0.176***	−0.178***	−0.083	−0.086
	(0.041)	(0.041)	(0.066)	(0.066)
Economic Complexity	0.044*	0.054***	0.060***	0.065***
	(0.017)	(0.016)	(0.015)	(0.015)
Polity2	0.005**	0.005**	−0.002	−0.002
	(0.002)	(0.002)	(0.002)	(0.002)
BIT Signed	0.001	0.000	0.001***	0.001**
	(0.000)	(0.000)	(0.000)	(0.000)
Capital open	0.070***	0.070***	−0.016***	−0.016***
	(0.075)	(0.007)	(0.005)	(0.005)
Constant	2.851***	2.908***	2.595***	−2.544***
	(0.357)	(0.358)	(0.480)	(0.476)
Observations	2,211	2,211	2,211	2,211
continent random effect	✓	✓		
period random effect	✓	✓		
EU/US			✓	✓
country random effect			✓	✓
year random effect			✓	✓
Note:				*p<0.1; **p<0.05; ***p<0.01

Alternative Dependent Variable: IRT for WTO+ and WTO-X

The following equation denotes the setup of the Bayesian IRT model I used to obtain one-dimensional ideal points for each PTA.

$$
\begin{aligned}
y_{ij} &= \begin{cases} 0 \text{ if } y_{ij}^* < 0 \\ 1 \text{ if } y_{ij}^* \geq 0 \end{cases} \\
y_{ij}^* &= \alpha_j + \beta_j \theta_i + \epsilon_{ij} \\
\epsilon_{ij} &\sim N(0, 1)
\end{aligned} \tag{5}
$$

y_{ij} is the binary outcome variable where i denotes a PTA and j denotes a provision. $y_{ij} = 1$ suggests that ith PTA contains jth provision. y_{ij}^* denotes the 'utility' which is modeled with one PTA level parameter (ideal point) and two provision-specific parameters. The two provision level parameters α_j and β_j respectively address the overall tendency to include jth provision (α_j) and how i tends to contain jth provision (β_j). The ideal point $\boldsymbol{\theta}$, therefore, is the summary of PTA depth accounting for provision-specific characteristics.

Table B4 fits the panel regression testing H2 and H3. Results stay robust. For H2, coefficients for Autonomous Export and GVC-integrated are both positive and statistically significant at the conventional level. For H3, the coefficient for GVC-integrated is positive and statistically significant, which is consistent with the main results. The coefficient for Autonomous Export is positive here, but not statistically significant at the conventional 0.05 confidence level, which is also consistent with the main results.

Table B4: Results with Continuous Dependent Variable

	Dependent variable:			
	θ_{irt} for WTO+		θ_{irt} for WTO-X	
	(1)	(2)	(3)	(4)
Autonomous Export	3.256**		1.835*	
	(1.409)		(1.103)	
GVC-integrated		2.128***		1.447***
		(0.475)		(0.372)
logGDP	3.661	3.722	5.800*	5.811*
	(4.086)	(4.068)	(3.198)	(3.186)
logGDPc	−2.597	−2.664	−5.025	−5.039
	(4.087)	(4.070)	(3.199)	(3.187)
logPop	−3.057	−3.072	−5.692*	−5.671*
	(4.088)	(4.070)	(3.200)	(3.188)
logFDIin	−0.016	−0.024	0.118	0.115
	(0.112)	(0.111)	(0.088)	(0.087)
Arable Land	0.303	0.326	−0.016	−0.003
	(0.261)	(0.260)	(0.204)	(0.204)
Economic Complexity	0.628***	0.634***	0.434***	0.438***
	(0.051)	(0.051)	(0.040)	(0.040)
Polity2	−0.003	−0.004	−0.002	−0.002
	(0.006)	(0.006)	(0.005)	(0.005)
BIT Signed	−0.001	−0.001	0.004***	0.004***
	(0.002)	(0.002)	(0.001)	(0.001)
Capital Open	−0.095***	−0.090***	−0.035**	−0.032**
	(0.018)	(0.018)	(0.014)	(0.014)
Observations	1,947	1,947	1,947	1,947
EU/US	✓	✓	✓	✓
country fixed	✓	✓	✓	✓
year fixed	✓	✓	✓	✓
Note:				*p<0.1; **p<0.05; ***p<0.01

Alternative Dependent Variable:

Non-negative Matrix Factorization of WTO-X

A one-dimensional summary of PTA depth, whether a total count of provisions or a continuous measure from IRT, may seem to be too aggregated. However, focusing on each provision for analysis is too disaggregated such that it may suffer from the lack of variation. A possible remedy is to employ a meso-level dependent variable that is not too aggregated nor disaggregated (Orefice and Rocha, 2014). In the paper, I utilized DESTA hierarchy to aggregate provisions at the chapter level and conducted a chapter-specific analysis. In this section, I propose a similar analysis for WTO-X variable. WTO-X, unlike DESTA, does not provide a chapter hierarchy over individual provisions. I use the non-negative matrix factorization(NMF) to obtain a clustering of provisions based on how they appear together in PTAs. For matrices with only positive entries, the NMF is a more suitable approach than PCA which assumes that entries are normally distributed. The NMF decomposes a matrix of non-negative values into a product of two lower-dimensional matrices.

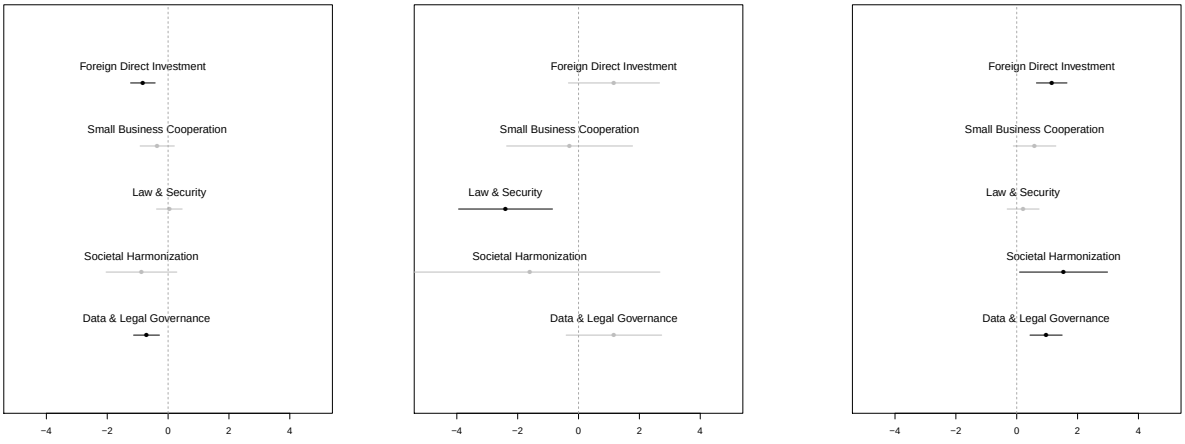
$$\mathbf{Y} \approx \mathbf{WH} \tag{6}$$

$\mathbf{Y}$ is a $N \times K$ matrix where N denotes the total number of PTAs and K denotes the total number of provisions. Then $\mathbf{W}$ is $N \times P$ and $\mathbf{H}$ is $P \times K$ where $P \ll K$. I set $P = 5$ based on the spree plot of its predictive accuracy for $\mathbf{Y}$. The predictive accuracy of $P = 5$ for $\mathbf{Y}$ is 89%. Table B5 gives the summary of the provision clusters.

	Data & Legal Governance	Societal Harmonization	Law & Security	Small Business Cooperation	Foreign Direct Investment
1	AntiCorruption	CulturalCooperation	Terrorism	InnovationPolicies	CompetitionPolicy
2	EnvironmentalLaws	EducationandTraining	SocialMatters	InformationSociety	IPR
3	LabourMarketRegulation	HumanRights	NuclearSafety	PublicAdministration	Investment
4	ConsumerProtection	PoliticalDialogue	MoneyLaundering	RegionalCooperation	MovementofCapital
5	DataProtection	ResearchandTechnology	CivilProtection	SME	Taxation
6	Statistics	Mining	EconomicPolicyDialogue	VisaandAsylum	
7		IllicitDrugs	IllegalImmigration		
8		AudioVisual	IndustrialCooperation		
9			Agriculture		
10			ApproximationofLegislation		
11			Energy		
12			FinancialAssistance		
13			Health		

Table B5: Clusters of provisions in Non-negative matrix factorization

Figure B1 displays coefficients from panel regression analysis for each NMF cluster. The dependent variable y_{it} is the maximum NMF value of PTAs by country i upto year t. Points indicate coefficient values, and horizontal lines are 95% confidence intervals. Coefficients statistically significant at the conventional 0.05 level are colored in black. Coefficients not statistically significant at the conventional 0.05 level are



(a) Purely Domestic (b) Autonomous Exporters (c) GVC-integrated

Figure B1: Panel regression on each NMF cluster of PTA provisions.

colored in gray.

Similar to the results in Figure 2, a greater share of GVC-integrated production is associated with a greater number of provisions, particularly in FDI, societal harmonization, and data & legal governance clusters. FDI cluster includes investment protection and intellectual property rights, which are the chapters in Figure 2 that are positively associated with a greater share of GVC-integrated production. Data & legal governance cluster governs anti-corruption and transparency, addressing primarily *information asymmetry* and *discriminatory treatment*.

References

Koopman, R., Wang, Z., and Wei, S.-J. (2014). Tracing value-added and double counting in gross exports. *American Economic Review*, 104(2):459–494.

Lenzen, M., Moran, D., Kanemoto, K., and Geschke, A. (2013). Building eora: a global multi-region input–output database at high country and sector resolution. *Economic Systems Research*, 25(1):20–49.

Miller, R. E. and Blair, P. D. (2009). *Input-output analysis: foundations and extensions*. Cambridge university press.

Orefice, G. and Rocha, N. (2014). Deep integration and production networks: an empirical analysis. *The World Economy*, 37(1):106–136.