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A framework for tracing embodied knowledge in Global Value Chains

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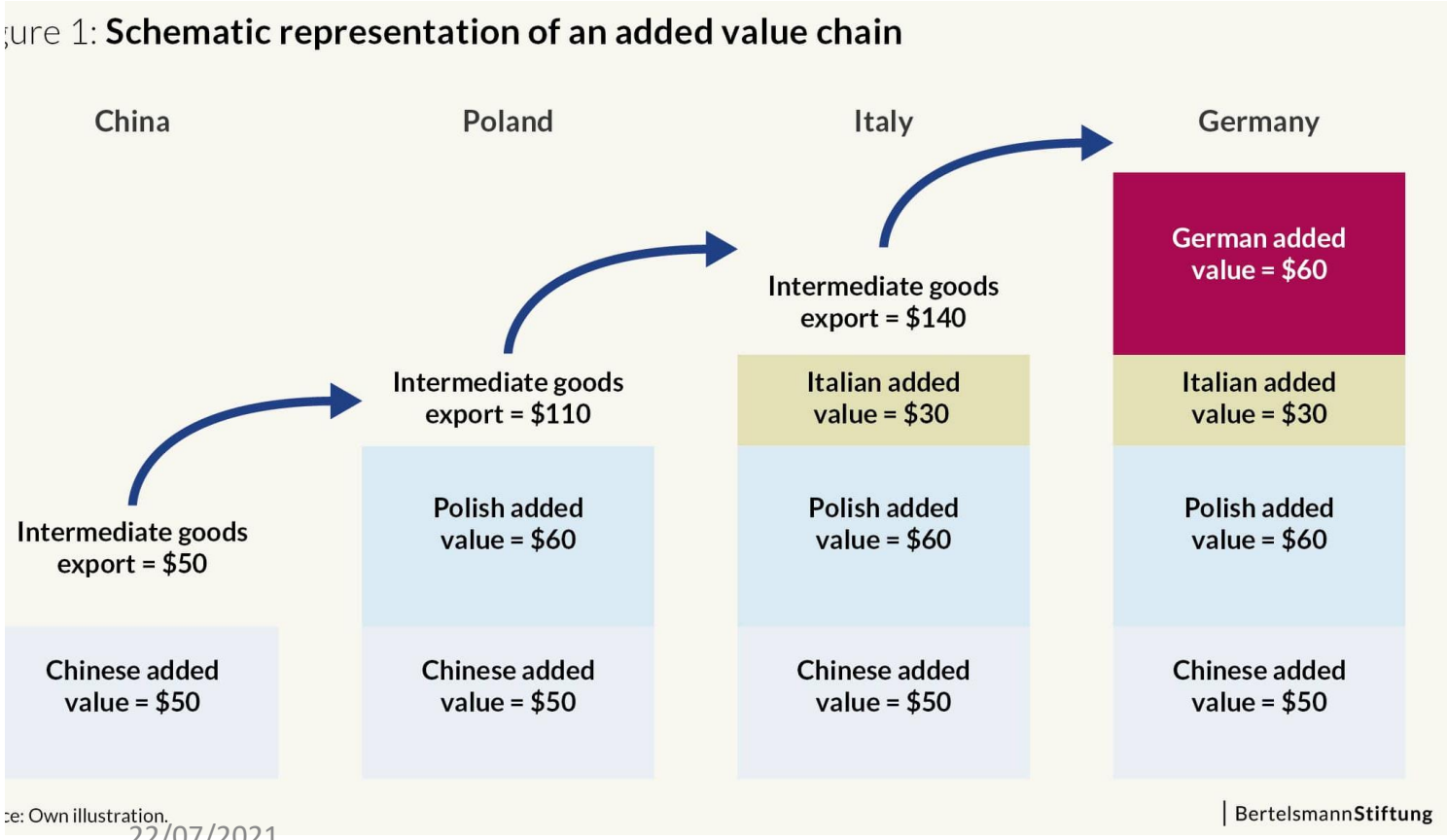
Distributed manufacturing and value chains

The nature and characteristics of global trade have undergone significant structural changes in the recent decades

- Catalysts: accelerating technological innovation, increases in manufacturing complexity and opening of more economies to international trade
- **Countries no longer exchange "*cloth for wine*".** Instead, they are becoming more engaged in diverse and complicated production activities with different tasks and modes that are disintegrated at a global scale.
- Each production stage has its own **discreet requirements in inputs** and **adds its own value** to its production output.
- These **distributed production** activities form the global production networks which have come to be known as ***global value chains*** (GVCs).

A value chain illustration



ɡure 1: **Schematic representation of an added value chain**

ce: Own illustration.

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- 4-country ‘complex’ GVC activity
- Final consumption in Germany includes value added from all contributing upstream countries

Value-Added and Knowledge Contents of Production

- To this point, the **main focus of the economic empirical literature on GV**Cs revolves around the different approaches for the **mapping of participation** in GVCs and the related gains at the firm and the country level based on each stage's **added value** to the final product.
- As **the final goods that are delivered to consumers tend to incorporate increasingly complex technological and knowledge-based components**, GVCs are also evolving in nature to become more knowledge and technology intensive (Baldwin & Evenett, 2015).
- As a result, another critical element that arises in the evolving GVC and trade literature is the **integration of the diffusion of knowledge and innovation** within the globally fragmented production network.
- This dimension has remained **rather underexplored**, especially at the aggregate country and country-industry level, as the transactions involving knowledge do not correspond to a coherent existing framework that could bridge them with aspects of the traditional trade theory (Fu and Gauri, 2021).

Therefore, our overall aim is…

- To provide a coherent framework that integrates knowledge-based capital (KBC) in sectoral linkages
- To enable the tracing of product-embodied knowledge diffusion in global value chains (GVCs)

A note on knowledge-based capital (KBC)

- The selection of KBC is particularly relevant within the contextual framework of GVCs.
- **KBC is alternatively known as intangible capital** (Corrado et al., 2005; 2009, Haskel and Westlake, 2018) and is widely recognized as a significant element in the coordination and the maximization of gains within the global production network (Gereffi et al., 2005; Mudambi, 2008; Fu and Ghauri, 2020).
- Durand and Millberg (2020) developed a conceptual and data-driven argument that **multinational enterprises become "intellectual monopolies" in GVCs** through the accumulation and control of significant intangible assets.
- From a different perspective, Baldwin and Evenett (2015) argue that **the nature of GVCs is transitioning to become knowledge-intensive, with the accumulation of value-added shifting away from traditional manufacturing** and assembly activities towards upstream and downstream knowledge-intensive, innovative activities that include conception, R&D, product design (for the upstream part) and marketing and branding (for the downstream part).

Methodology: Stages

We follow a **two-stage** methodological procedure.

- At the first stage, we **integrate input-output data with knowledge-based capital** (henceforth, KBC) stock data into a framework where intermediate transactions and sectoral linkages act as carriers of product-embodied knowledge and innovation that is disseminated in the global production network.
- Then, in order to capture the ramifications in terms of embodied knowledge for different possible types of GVC participation, **we apply a production-oriented decomposition of the traded KBC** that separates the embodied knowledge flows into different categories that correspond to different types of KBC trade in GVCs.

Methodology: Combining and expanding previous approaches

- Our framework draws elements from the works of Papaconstantinou et al. (1998) and Hauknes and Knell (2009) where **embodied knowledge and innovation in sectoral linkages** was empirically investigated **using R&D expenditure** and input-output data from selected economies and their national input-output tables.
- **We expand their approach and cover the full range of KBC**, considering that the formation of knowledge capital is not limited to R&D, but also covers expenditures on other innovation activities as well (Haskel and Westlake, 2018; OECD, 2018).
- We then further **embed this framework within the context of GVCs** by expanding the geographical scope and appropriately utilizing inter-country input-output tables and specifically the 2016 release of the World Input-Output Database (WIOD) (Timmer et al., 2015) to deploy data and study sectoral knowledge linkages at a regional and global scale.
- Another novel element of this study is the **further expansion of this integrated framework within the context of traditional GVC participation metrics to account for different types of knowledge trade** within the production network. To this end, we decompose the traded component of product-embodied knowledge in analogy with the production-based decomposition of value added proposed in the work of Wang et al. (2017). This decomposition enables us to identify different types of knowledge trade within GVCs and track the participation of countries and sectors in GVCs in terms of knowledge production, dissemination, and absorption.

Methodology: Data

Data regarding KBC investment and capital stock are drawn from the latest edition of the EU-KLEMS database (Stehrer et al., 2019) and cover a range of EU-27 economies, Japan, the UK, and USA.

Inter-country input-output tables are drawn from the 2016 release of the World Input-Output Database (WIOD) (Timmer et al., 2015)

Simplified illustration of KBC embodiment in GVCs

(2)….which is utilised as input by its domestic industries…

(3)….which is then exported as intermediate input for C_2…

(4)….which is then exported as final goods and consumed in C_N

	Intermediate Consumption					Final Uses			Total Output
	Country	C_1	C_2	[…]	C_N	C_1	[…]	C_N	
Intermediates Supply	C_1	$X_{1,1}$	$X_{1,2}$	[…]	$X_{1,N}$	$F_{1,1}$	[…]	$F_{1,N}$	Y_1
	C_2	$X_{2,1}$	$X_{2,2}$	[…]	$X_{2,N}$	$F_{2,1}$	[…]	$F_{2,N}$	[…]
	[…]	[…]	[…]	[…]	[…]	[…]	[…]	[…]	[…]
	C_N	$X_{N,1}$	$X_{N,2}$	[…]	$X_{N,N}$	$F_{N,1}$	[…]	$F_{N,N}$	Y_N
Value Added		VA_1	[…]	[…]	VA_N				
Total Input		I_1	I_2		I_N				

(1) C_1 invests t amount in KBC component i in order to achieve its production levels..

This production activity is distributed across 3 countries (2 manufacturing stages and 1 consumption stage)

This specific activity would be characterised as "complex GVC participation" with a complexity rank of 1.

- Generalisable for industry-level and other KBC components
- Also generalisable for other production related aspects and GVC activity types

Methodology: GVC stages decomposition

The total KBC stock for all intangible investment types originating from for a specific country-sector (n,k) pair...

$$KBC_{tot,tot}^{n,k}$$

...can be distinguished into flows that are bound for domestic use (1) or final (2) or intermediate (3) exports...

$$(1)\sum_{i=1}^{V} KBC_{d\to d,i}^{cons}$$

$$(2)\sum_{i=1}^{V} KBC_{d\to f,i}^{cons}$$

$$(3)\sum_{i=1}^{V} KBC_{d\to d,i}^{int}$$

...the latter of which contain intermediate exports that are used for the production of final products abroad (4), or for products which are re-exported as intermediates (5).

$$(4)\sum_{i=1}^{V} KBC_{d\to f,i}^{smpl}$$

$$(5)\sum_{i=1}^{V} KBC_{d\to f,i}^{cplx}$$

Adaptation from Wang et al. (2017)

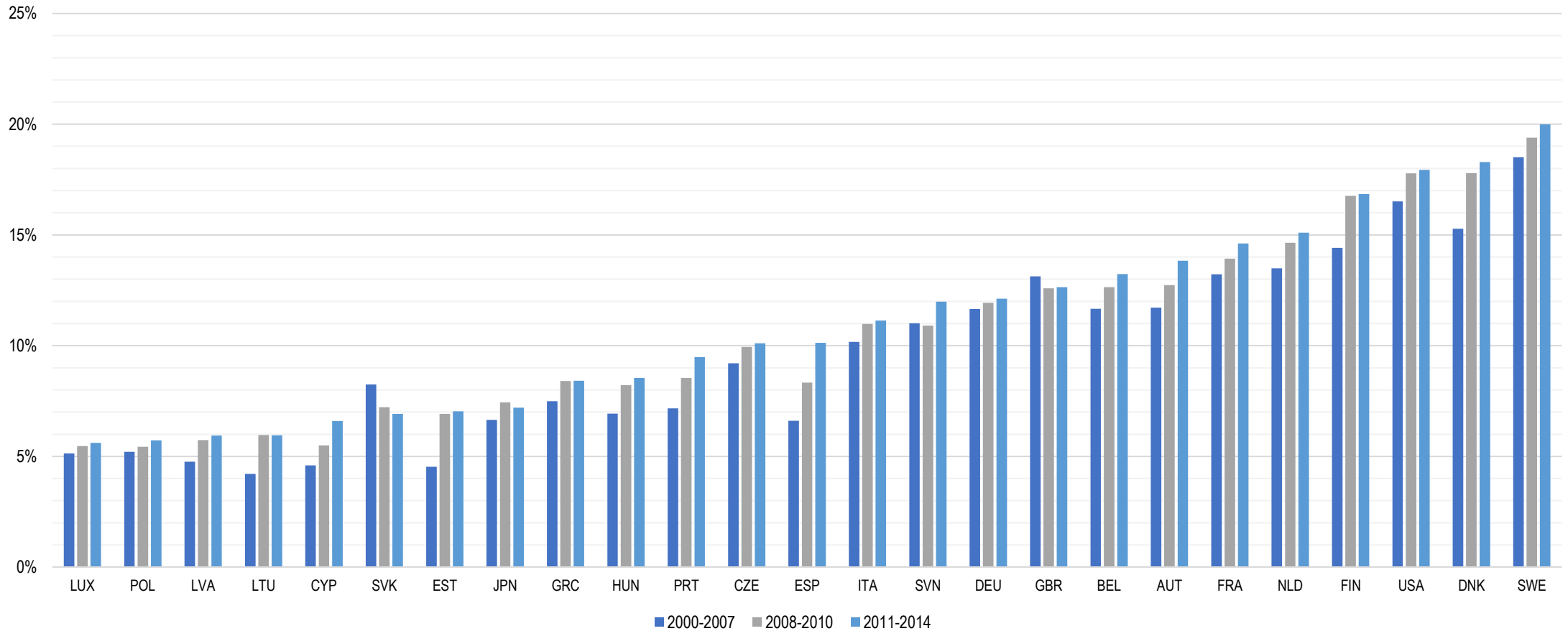
Dimensions of resulting Dataset

- Country-Industry pair of origin or destination (n, k)
- Intangible investment type of capitalised knowledge (v)
- Participation type of trade/GVC production activity (g)
- Year (t)

Overall resulting dimensions: $(\boldsymbol{N} \times \boldsymbol{K})^{\boldsymbol{2}} \times \boldsymbol{V} \times \boldsymbol{G} \times \boldsymbol{T}$

In our case, the dataset contains flows for 26 economies with 56 sectors each, for 15 years, 7 types of KBC stock and 4 types of trade/GVC participation (domestic, traditional trade, simple and complex GVC participation).

Some Results and Illustrations: Average national KBC Intensities



Average national KBC intensity for selected EU countries, Japan, the UK, and USA across all sectors, 2000-2007, 2008-2010 and 2011-2014.
Source: Authors' calculations based on WIOD and EU-KLEMS data

Some Results and Illustrations: Temporal changes in KBC intensities

	$KBC^{n,k}_{int,tot}$ (Total intensity)			$KBC^{cons}_{d\to f,tot}(\widehat{Y^{n,k}})^{-1}$ ('Traditional trade' intensity)			$(KBC^{smpl}_{d\to f,tot} + KBC^{cplx}_{d\to f,tot})(\widehat{Y^{n,k}})^{-1}$ ('GVC participation' intensity)		
Country /Timeframe	2000-2007	2008-2010	2011-2014	2000-2007	2008-2010	2011-2014	2000-2007	2008-2010	2011-2014
CYP	25.7%	8.7%	27.6%	17.8%	-3.0%	49.9%	46.1%	14.6%	52.4%
SVK	-18.9%	9.4%	19.8%	67.1%	8.9%	34.3%	28.8%	1.9%	28.3%
NLD	8.6%	6.7%	6.3%	18.0%	15.4%	-12.0%	13.4%	9.2%	26.7%
PRT	12.5%	14.2%	1.5%	21.2%	7.5%	15.5%	86.3%	10.0%	20.8%
ESP	9.2%	22.9%	12.9%	-5.1%	35.3%	31.1%	6.1%	24.9%	20.3%
POL	12.0%	4.5%	9.7%	44.8%	13.5%	23.4%	57.3%	13.1%	17.8%
SVN	-16.3%	16.7%	3.8%	13.0%	11.1%	8.9%	36.8%	14.2%	14.1%
ITA	3.6%	8.5%	4.6%	3.0%	6.0%	17.6%	18.0%	1.6%	13.5%
JPN	10.1%	7.0%	-2.0%	60.8%	-8.6%	17.7%	76.4%	-3.1%	12.1%
HUN	15.4%	15.5%	3.6%	27.0%	20.7%	-1.6%	42.9%	18.6%	11.9%
FRA	1.8%	6.2%	9.0%	-5.0%	-1.8%	12.5%	0.8%	3.7%	11.8%
CZE	-10.6%	11.2%	0.8%	26.6%	14.9%	12.8%	7.8%	14.9%	10.9%
IRL	39.3%	30.5%	10.0%	22.1%	51.1%	11.3%	41.3%	50.5%	10.9%
DEU	0.7%	4.4%	6.3%	33.7%	-1.5%	6.9%	36.5%	1.6%	9.6%
EST	25.2%	23.6%	9.2%	58.0%	37.9%	1.4%	86.8%	34.5%	9.6%
LTU	32.3%	29.2%	4.4%	56.0%	50.4%	20.2%	109.7%	45.5%	7.4%
LUX	-3.8%	14.4%	1.6%	7.4%	21.4%	4.0%	4.1%	10.7%	4.2%
LVA	-3.0%	33.1%	1.1%	27.0%	66.0%	6.7%	17.0%	71.5%	3.4%
GRC	4.7%	6.6%	-12.3%	45.1%	-10.5%	13.0%	33.9%	3.4%	3.3%
SWE	1.8%	5.7%	6.7%	1.8%	-8.3%	3.3%	14.1%	3.6%	2.9%
FIN	15.2%	12.8%	2.6%	12.9%	-13.7%	-2.7%	19.1%	7.8%	2.6%
DNK	12.3%	14.3%	1.0%	7.4%	12.7%	1.2%	34.1%	6.8%	2.4%
USA	-0.6%	8.9%	0.3%	4.4%	4.8%	-0.6%	9.4%	7.7%	-2.6%
GBR	-10.7%	2.5%	-0.7%	-19.1%	4.1%	-13.4%	-7.4%	3.4%	-8.5%

On section 2, we observe diversified patterns of embodied knowledge capital in traditional trade transactions.

- In the pre-crisis period, **most economies increased their respective intensity with significant growth patterns** observable in Slovakia, Japan, the Baltic economies, Greece, and Poland.
- **Most of the countries appear to rebound in the stagnation period that follows** although some notable exceptions are still present as we observe decreasing growth rates for the UK, Netherlands, Finland and marginally USA.

The patterns observed in section 2 become particularly intriguing when jointly elaborated with corresponding elements regarding knowledge trade in GVCs from section 3.

- For example, the Netherlands record a decrease in the embodied knowledge content of their gross exports during 2011-2014 but at the same time present an increase in the exported knowledge content towards production activities abroad. In fact, we document that most countries present patterns of growing shares of GVC traded KBC stock that relate with the arguments of Baldwin and Evenett (2015) regarding the increased knowledge content of GVCs.
- **This trend was in full force during the 2000-2007 period** and is in-line with the remarkable rise in GVC participation that was recorded by numerous studies during the same period (Johnson and Noguera, 2017; Borin and Mancini, 2019; World Bank, 2020).
- Accordingly, **this growing pattern receded in the following years** but remained positive for most of the economies covered in this study.

Shares of total KBC stock, KBC traded in traditional exporting activity and KBC traded for GVCs activity relative to national total production output for selected EU countries, Japan, the UK, and USA across all sectors for 2000-2007, 2008-2010, and 2011-2014. **Source**: Authors' calculations based on WIOD and EU-KLEMS data

Some Results and Illustrations: A *producer-receiver* classification

We implement this taxonomy based on the ratio of forward KBC participation in GVCs relative to the corresponding backward KBC/VA participation for each country.

$$k_{c,t} = \frac{KBC^{oc}_{GVC,\,FOR}}{KBC^{oc}_{GVC,\,BCK}}$$

$$w_{c,t} = \frac{VA^{oc}_{GVC,\,FOR}}{VA^{oc}_{GVC,\,BCK}}$$

Typology	In terms of Trade-in KBC stock	In terms of Trade-in VA
Consistently classified as **producers**	AUT, BEL, CZE, DEU, DNK, FIN, FRA, GBR, ITA, JPN, NLD, SVN, SWE, USA	AUT, DEU, GBR, NLD, SWE
Consistently classified as **receivers**	HUN, LUX, POL, SVK	CZE, DNK, ESP, FRA, GRC, HUN, IRL, ITA, PRT, SVK, USA
Transition from producers to receivers	-	BEL, FIN, JPN, LUX,
Transition from receivers to producers	CYP, ESP, EST, GRC, IRL, LTU, LVA, PRT	CYP, EST, LTU, LVA, POL, SVN

Classification of countries based on their KBC and VA-based GVC participation indices for the entire timeframe. Typology of countries based on their classification between 2000 and 2014.

Source: Authors' calculations based on WIOD and EU-KLEMS data

Some Results and Illustrations: Divergence of KBC and VA trade

- There is a pronounced inconsistency between the two classifications.
- The observable volatility using VA data indicates that traditional GVC indicators may lead to significant misconceptions regarding participation in GVCs.
- As the introduction of KBC-based GVC indicators monitors the control and deployment of intangible assets, our classification of knowledge *producers* and knowledge *receivers* provides a more informative taxonomy regarding the positioning and the role of each country in the global production network compared to relative classifications based on traditional VA indices.

Ranking aspect (VA-KBC)/Timeframe	2000-2008	2008-2014	2000-2014
$k_{c,t}$ GVC participation indices	0.945	0.898	0.822
$w_{c,t}$ GVC participation indices	0.720	0.722	0.276
	$k_{c,t}$ ranks cor. with $w_{c,t}$ ranks		
2000	**0.762**		
2008	**0.530**		
2014	**0.266**		

Spearman's rank-order correlation coefficients for the relative ranks of countries between selected years and forward to backward (F/B) GVC participation indices

Source: Authors' calculations based on WIOD and EU-KLEMS data

Some conclusions and take-away points

- Overall, **our findings invite a reconsideration of participation in GVCs** through the diffusion of knowledge rather than strictly through the exchange of value added.

- **We document a notable divergence** between patterns of value added-based and knowledge-based participation in GVCs that lead to salient facts regarding the knowledge-oriented restructuring of global trade and provide insights that challenge established perceptions towards evaluating GVC participation.

- Furthermore, **our indicators provide a more refined set of tools to identify and monitor intellectual monopolies in GVCs**, as we are able to go beyond the arguments posed by simple intangible investment claims and add evidence regarding the dissemination and accumulation of these assets.

- **We provide an informative classification of countries between knowledge *producers* and knowledge *receivers*** based on their type of participation in GVCs and by monitoring their trade-in-knowledge capital. The formulated sector linkages between these two groups correspond to user-producer interactions, which in turn constitute critical elements of an international innovation system (Binz and Truffer, 2017; Haukness and Knell, 2009) and set forth a relevant evidence-driven policy discussion that touches upon an intersection of industrial, trade and innovation policy implications.

Still, this is (barely) the tip of the iceberg…

Our framework and the resulting datasets can be used for further specific country/industry/KBC type case studies, deeper examination of bilateral knowledge flows, exploration of the time-dimension of knowledge aspects, construction and examination of trade clusters, regional trade analysis…

Thank you for your time!

Questions