LABORATORY OF INDUSTRIAL & ENERGY ECONOMICS
National Technical University of Athens

Global Value Chains and Industrial Innovation in Europe

Petros Dimas, Dimitrios Stamopoulos, Alexandra Kontolaimou and Aimilia Protogerou

Laboratory of Industrial and Energy Economics (LIEE), National Technical University of Athens (NTUA)

Centre of Planning and Economic Research (KEPE), Athens, Greece

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The scope of this study

- This study aims to empirically investigate the contribution of **global value chain (GVC) participation** to the development of **manufacturing (technological) innovation** in European countries

- *Why is this important*?
  - ➢ **Innovation in GVCs** is gaining momentum (Ambos et al. 2021; Buciuni and Pisano 2021) → **but empirical evidence is still rather scarce**; especially at higher aggregation levels
  - ➢ GVC participation at the sector and country level has focused on backward and forward participation components → **little is known about the level of fragmentation included in each type of participation**

- *How do we aim to address this*?
  - ➢ Focus on the sector level, in a sample comprising EU and UK manufacturing sectors
  - ➢ Apply the Wang et al. (2022) factor decomposition framework that enables to differentiate between **simple** and **complex** GVC activities
  - ➢ Apply the Lybbert and Zolas (2014) Algorithmic Links with Probabilities (ALP) crosswalk approach to develop sector level (NACE Rev.2/ISIC Rev.4) patent application metrics to measure industrial innovation
  - ➢ Develop a GVC-adjusted version of the knowledge production function (KPF) (Crépon et al. 1998; Pakes and Griliches 1984)

GVCs and innovation development

- The relationship between **GVC participation** and **innovation** has been a **much-debated** subject – yet studies that have investigated their direct link are rather **scant** (Ambos et al. 2021; Lema et al. 2021; Morrison et al., 2008)
- Participation in GVCs entails a **learning-by-interacting** process
  - ➢ **A linkage-induced innovation paradigm** where horizontal and vertical production linkages induce innovation either on lead firms (MNEs) or their suppliers and clients (sometimes both) (Ambos et al., 2021; De Marchi et al. 2018; Lema et al. 2019)
- From a different view, GVC transactions entail **learning-by-importing** and **learning-by-exporting** effects
  - ➢ Innovation can be enhanced through a **variety of channels**, e.g., knowledge dissemination, spillovers, technology transfer, competition effects in international markets (Castellani and Fassio 2019; Montalbano et al. 2018; De Loecker 2013)
  - ➢ Especially for **industrial** (and predominantly manufacturing) sectors → **prone to the GVC trade** of intermediates and the innovation-propelling effects from:
    - ❖ Access to foreign inputs not available in the domestic market (Colantone and Crinó 2014; Goldberg et al. 2010)
    - ❖ Access to product-embodied knowledge acquired through imported intermediates from competent and knowledge-intensive suppliers (Castellani and Fassio 2019; Ciriaci et al. 2015)

Producer-user interactions, direct and indirect channels for innovation enhancement

- Production linkages between manufacturing sectors and their suppliers and clients correspond to **bi-directional producer-user interactions**
  - ➢Learning-by-interacting knowledge diffusion mechanism of Innovation Systems (Binz and Truffer 2017; Lundvall 1992, 1988)
  - ➢Co-evolution of GVCs and Innovation Systems and joint contribution to innovation capacity (Lema et al. 2019; 2021)
  - ➢Sector specific characteristics are important → technological performance and innovation depend on sectoral patterns of innovation (Malerba 2002; Breschi et al. 2000; Castellacci, 2008) – GVC participation is also related with sector specificities (Timmer et al., 2015)
- GVC participation can enhance innovation *per se* (Tajoli and Felice 2018) but also act as an *enabler for upgrading* into higher value-added activities (Brancati et al., 2017; Ito et al., 2023)
- GVC participation for manufacturing sectors is bi-directional → they act both as suppliers to downstream clients (forward – learning-by-exporting) and users of upstream products (backward – learning-by-importing)

A basic research hypothesis regarding GVCs

- Summing up the key theoretical remarks, we formulate the following main research hypothesis:

HP: Participation in GVCs can stimulate sectoral innovation performance

- Given that GVC participation for manufacturing sectors is bi-directional, our HP can be disaggregated into:

HPa: Forward participation in GVCs can contribute to sectoral innovation performance

HPb: Backward participation in GVCs can contribute to sectoral innovation performance

The intricacies of GVC participation

- GVC participation is not uniform, even if we account for its direction (type)

- Backward and forward GVC participation can be disaggregated in different subcomponents
  - ➢The degree of backward and/or forward fragmentation of the value chain varies according to the number of times VA crosses borders for production purpose
  - ➢The more the stages backward and forward the higher the fragmentation
  - ➢Higher fragmentation can be associated with more complex activities

- **Is innovation performance affected by the degree of GVC participation fragmentation/complexity?**

Methodological overview

- We investigate the link between GVC participation and manufacturing innovation through an extended version of the knowledge generation function (KGF) framework (Crépon et al. 1998; Antonelli et al., 2022)
  - GVC participation is considered as an external innovation antecedent
    - GVC participation direction → **type**
    - GVC participation "complexity" → **mode**
  - Internal innovation inputs (R&D and capital investments) are also accounted
  - We measure technological innovation with patent applications to the EPO retrieved from OECD's Patent Database
- Data sources:
  - OECD's TiVA database (2023)
  - OECD's Patent Database
  - EU-KLEMS and INTANProd database (Bontadini et al., 2023)
- Time period: 1995-2020

Country-sector coverage

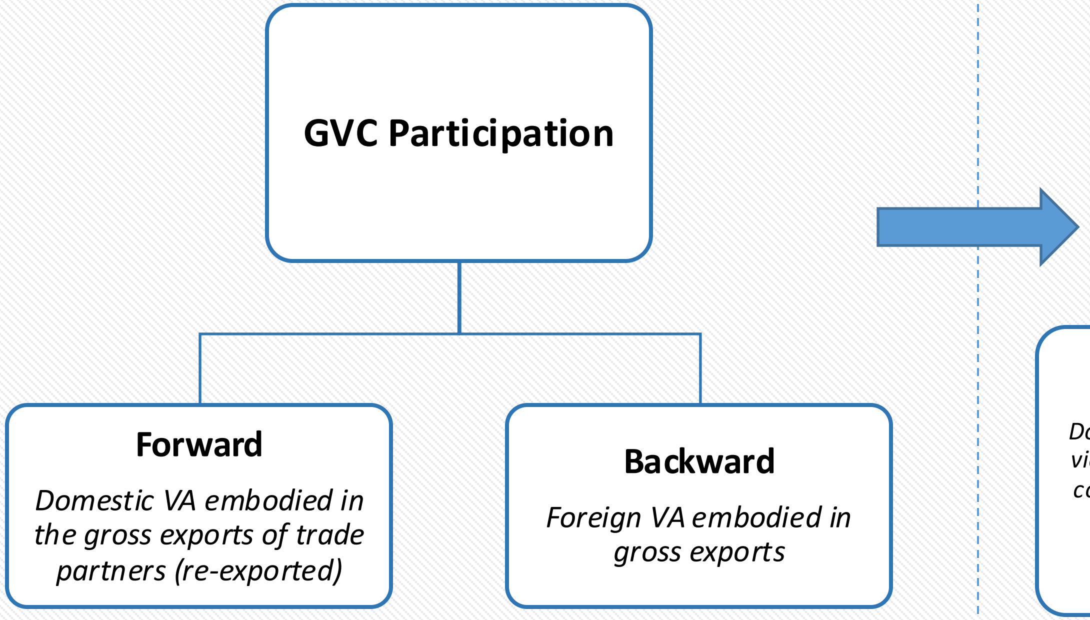
Country_code	Country_name
AT	Austria
BE	Belgium
CZ	Czechia
DK	Denmark
FI	Finland
FR	France
DE	Germany
EL	Greece
IT	Italy
NL	Netherlands
SK	Slovakia
ES	Spain
SE	Sweden
UK	United Kingdom

Sector_code*	Sector_activity
B	Mining and quarrying
C10-T12	Food products, beverages and tobacco
C13-T15	Textiles, wearing apparel, leather and related products
C16-T18	Wood and paper products; printing and reproduction of recorded media
C19	Coke and refined petroleum products
C20	Chemicals and chemical products
C21	Basic pharmaceutical products and pharmaceutical preparations
C22T23	Rubber and plastics products, and other non-metallic mineral products
C24T25	Basic metals and fabricated metal products, except machinery and equipment
C26	Computer, electronic and optical products
C27	Machinery and equipment n.e.c.
C28	Spain
C29T30	Transport equipment
C21T33	Other manufacturing; repair and installation of machinery and equipment
D	Electricity, gas, steam and air conditioning supply
E	Water supply; sewerage; waste management and remediation activities

*NACE Rev.2/ISIC Rev.4 Classification
Sector coverage consistent with that of the EU-KLEMS INTANProd database

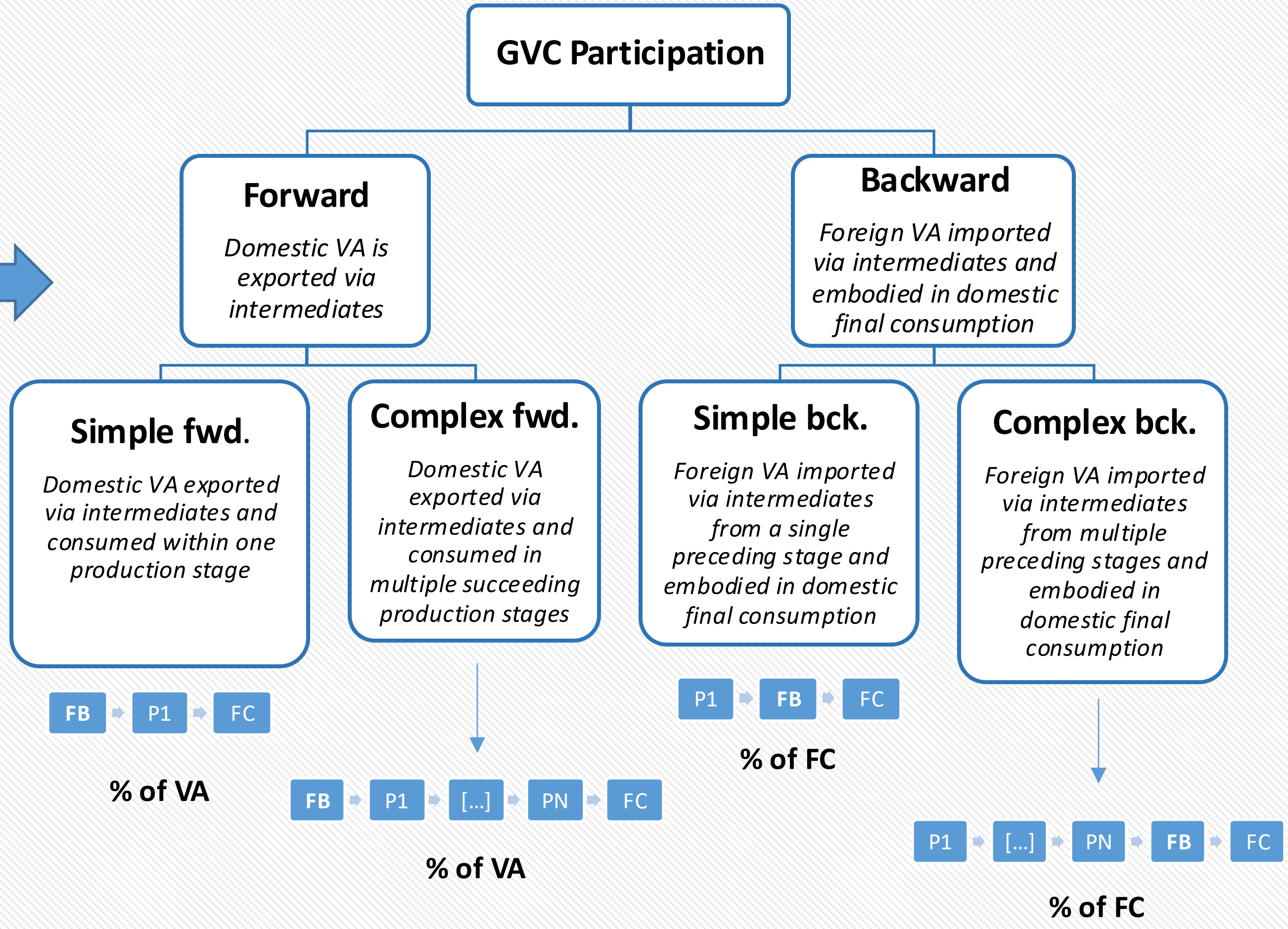
A decomposition framework for different types and modes of GVC participation

Metrics based on VA content of exports (Koopman et al. 2014)



The original approach

New production-based decomposition framework by Wang et al. 2022



P: Partner sector/country (for production)
VA: Value added
FC: Final consumption

A novel perspective

Econometric model

- The adjusted version of the KGF (log-linearized):

$$\ln(\mathrm{INNO})_{i,t} = \alpha + b_1 \ln(\mathrm{GVC})_{i,t-1} + b_2 \ln(\mathrm{K\_Tang\_e})_{i,t-1} + b_3 \ln(\mathrm{K\_RD\_e})_{i,t-1} + \lambda_i + \varepsilon_{i,t}$$

- GVC corresponds to our GVC participation proxies (forward and backward)
  - Including both simple and complex components
  - Estimated as shares to avoid multicollinearity in the model
- $\mathrm{K\_Tang\_e}$ and $\mathrm{K\_RD\_e}$ correspond to fixed (tangible) and R&D (intangible) capital stock per employee,
  - Data retrieved from the EU-KLEMS and INTANProd database
- INNO is proxied through the stock of patent applications to EPO (inventor's country of residence) per employee
  - We apply the Algorithmic Links with Probabilities (ALP) crosswalk approach of Lybbert and Zolas (2014) to link International Patent Classes (IPC) with economic activities (ISIC Rev.4)
  - Patent stock is calculated through the perpetual inventory method using patent flows dating to 1984 (15% depreciation rate)
- The determinants follow a one-period time-lag, as innovation inputs undergo a transformation process which is unlikely to be instantaneous
- The model is estimated with fixed effects estimators* and robust (clustered at the industry level) standard errors

*Random effects were also tested with consistent results, but we select the fixed effects based on the Hausman test results

Variables and sources

Variables	Data source
Patent applications (no.)	OECD Patent Database/Own calculations
GVC participation per **type** and **mode** (%)	OECD ICIOTs/Own calculations based on Wang et al. (2022)
Fixed and R&D capital stock (in mil. of national currency, current prices)*	EU-KLEMS and INTAN-Prod
Labor (no. of employees, in thousands)	EU-KLEMS and INTAN-Prod

* Prices are deflated with VA price indexes (2020 constant prices) retrieved from the EU-KLEMS and INTANProd database

Some descriptives: High-tech manufacturing and innovation leaders lead in terms of patent stock per employee

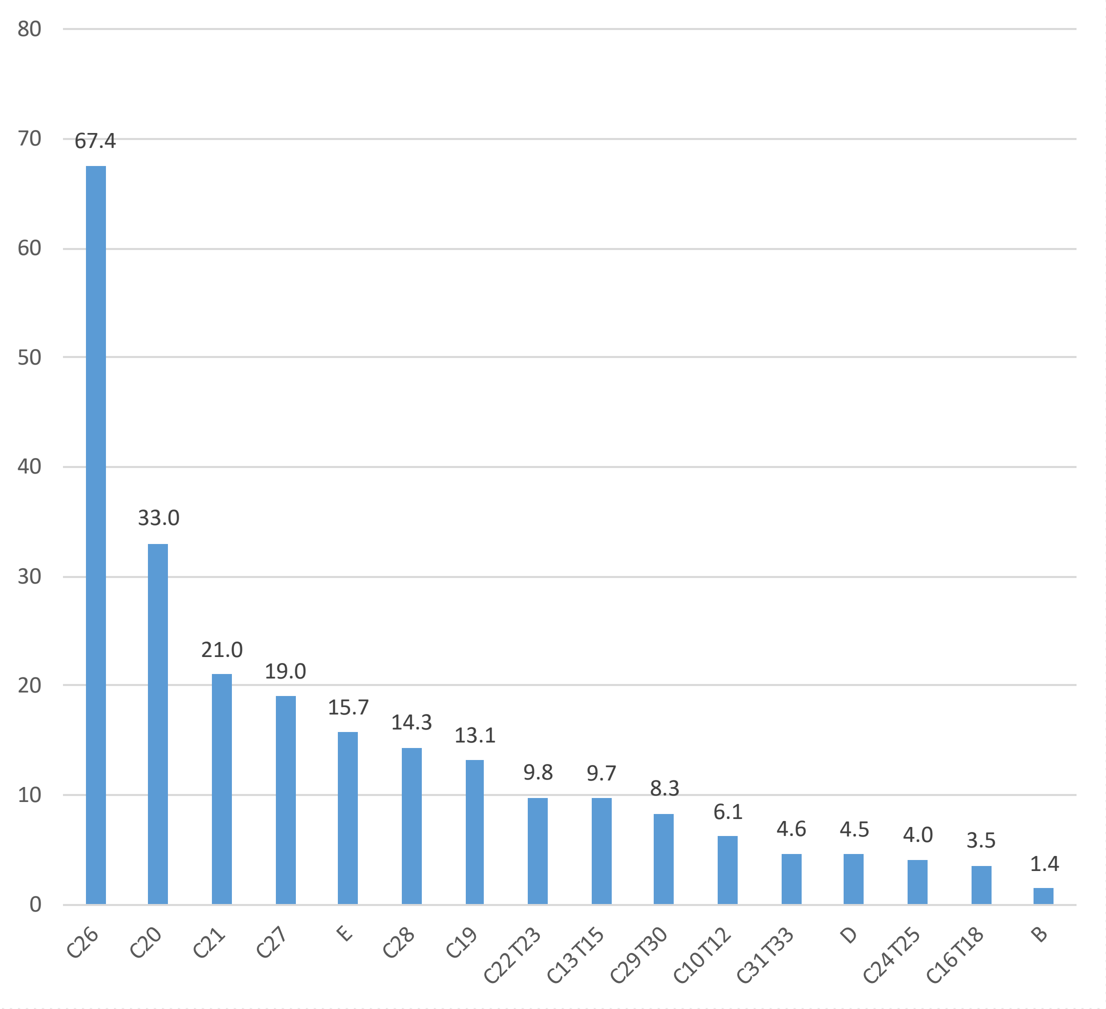


Fig. 1: Patent stock per employee for **European industrial sectors**, 1995-2020 (series average)

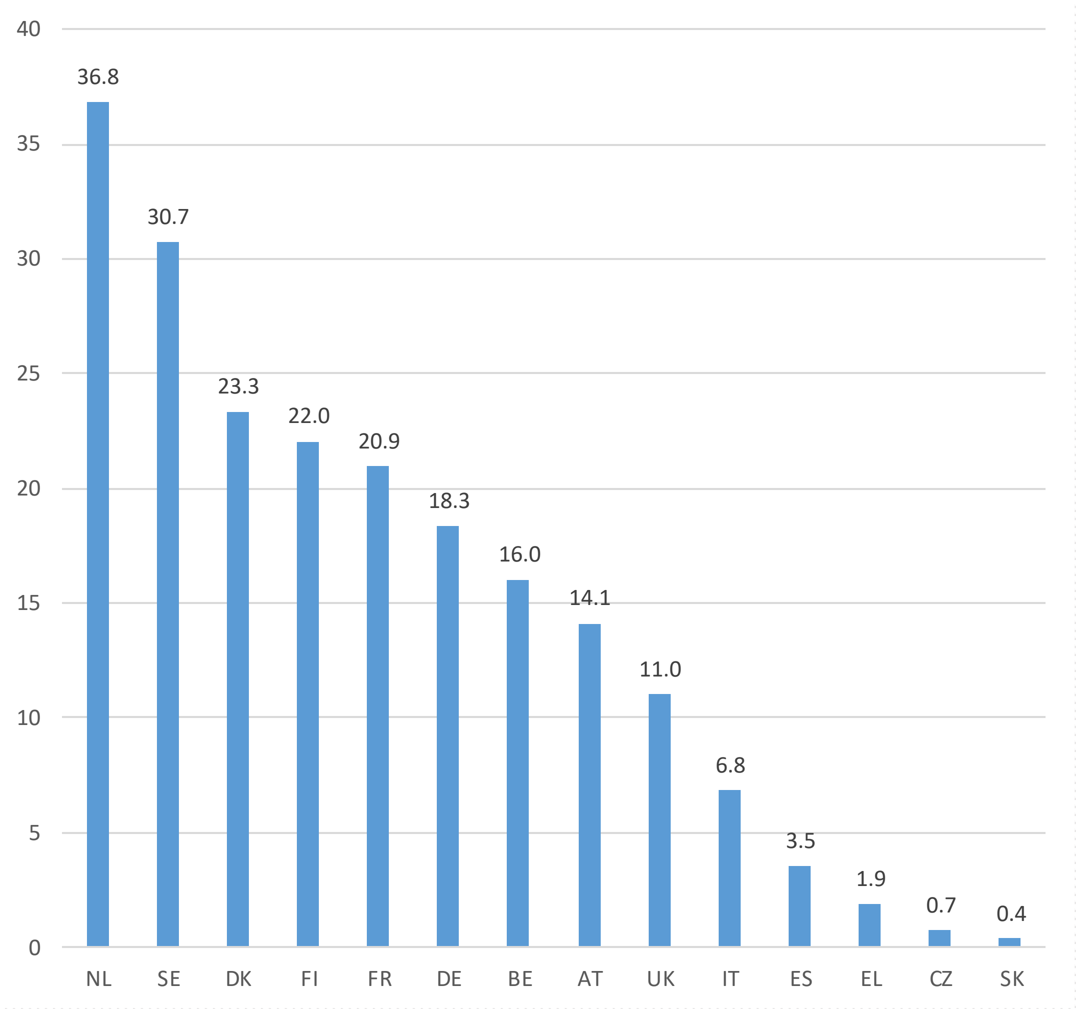


Fig. 2: Patent stock per employee for **countries**, 1995-2020 (series average)

Growth for both forward and backward participation between 1995-2020 in our sample…

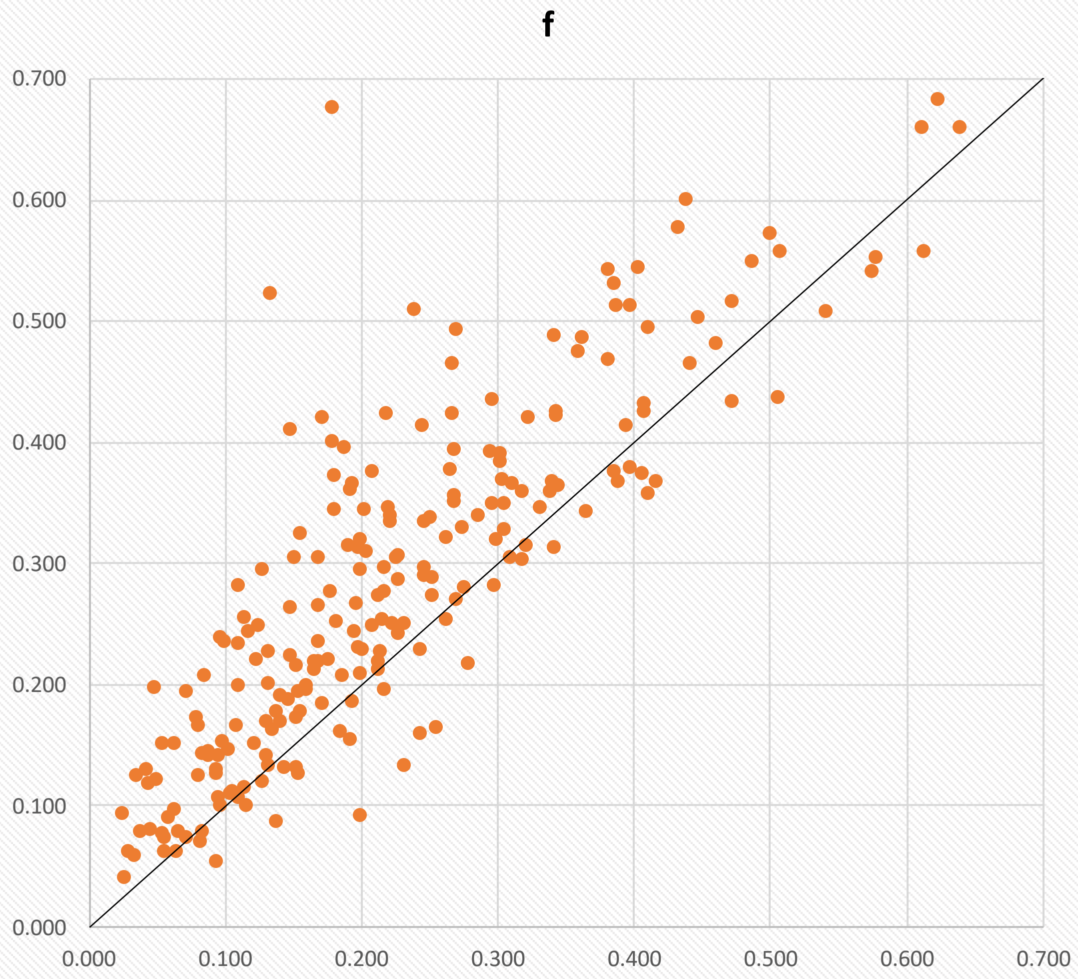


Fig. 3: Total forward GVC participation contrast for all country-sectors for **1995 (x) and 2020 (y).**

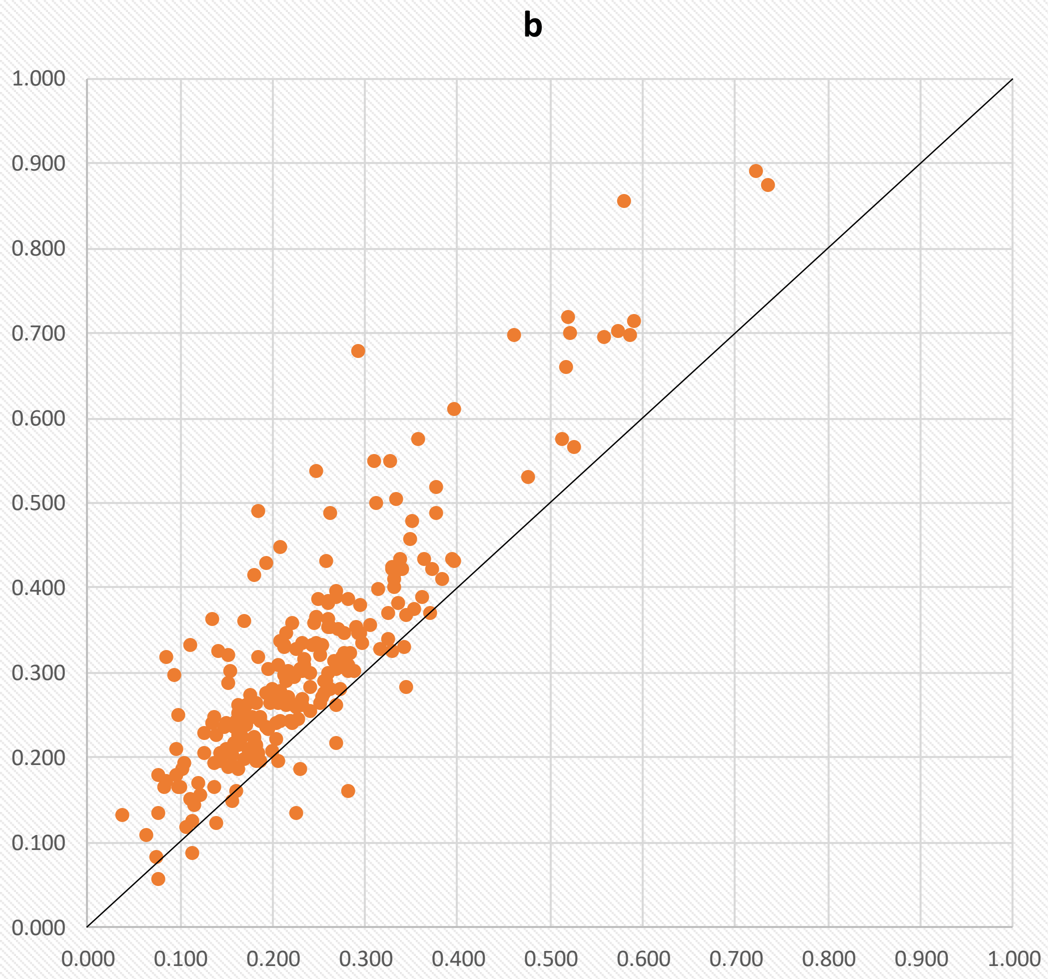


Fig. 4: Total backward GVC participation contrast for all country-sectors for **1995 (x) and 2020 (y)**.

…for forward participation it is mainly drive by its complex component…

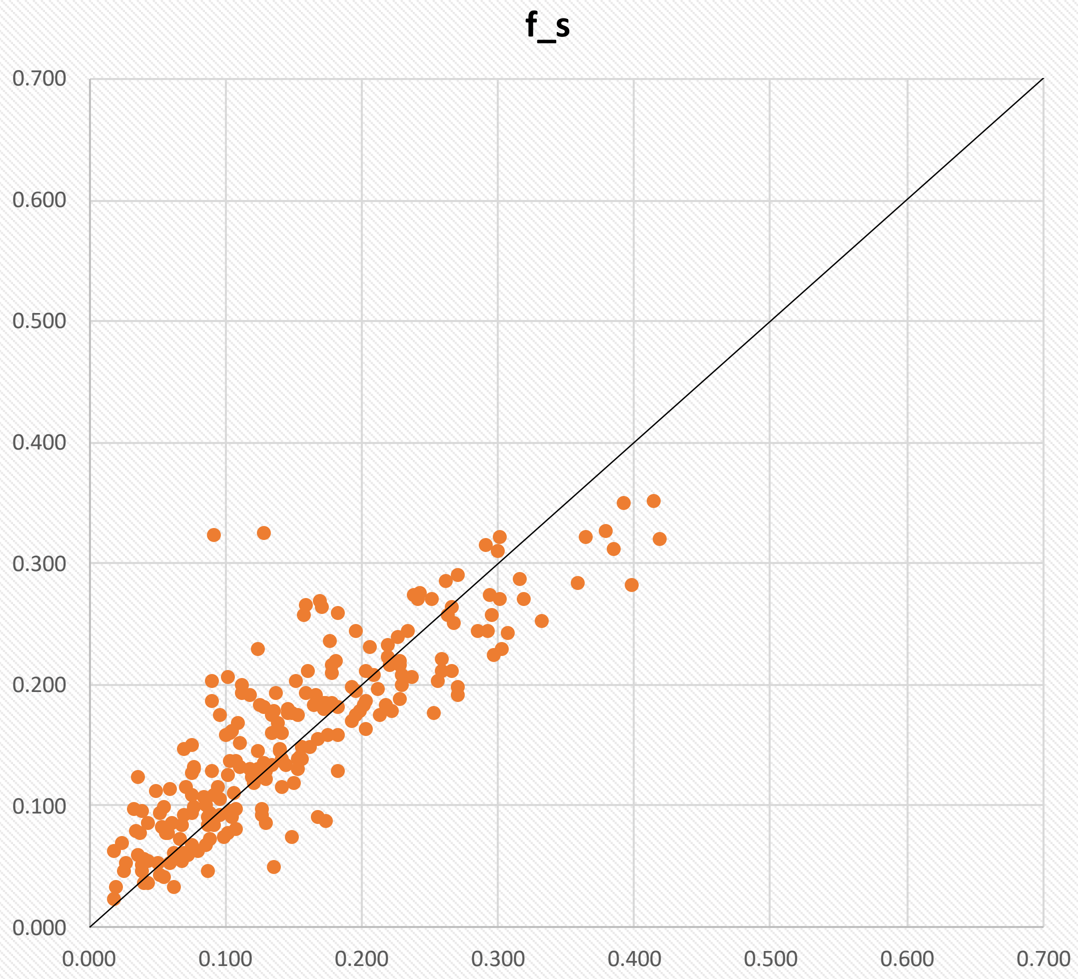


Fig. 5: Simple forward GVC participation contrast for all country-sectors for **1995 (x) and 2020 (y)**.

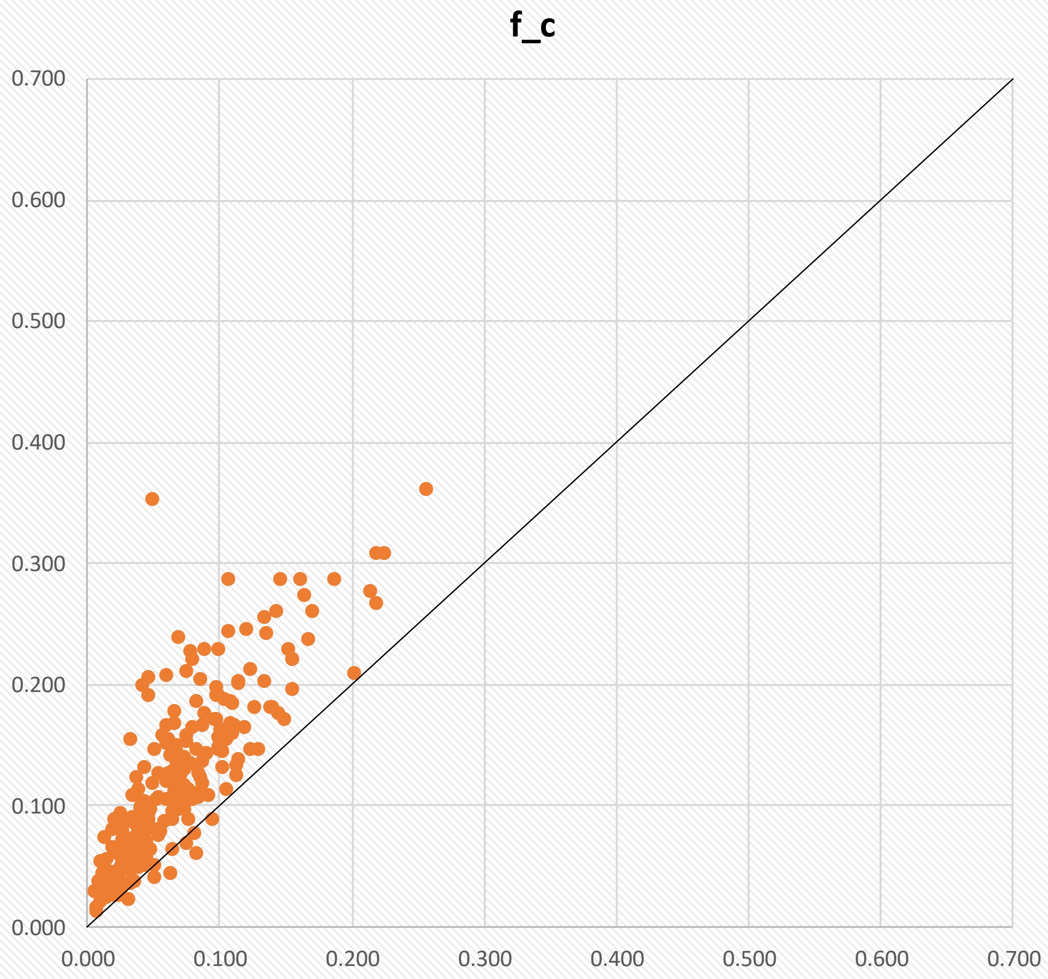


Fig. 6: Complex forward GVC participation contrast for all country-sectors for **1995 (x) and 2020 (y)**.

…and the same also applies for complex backward participation

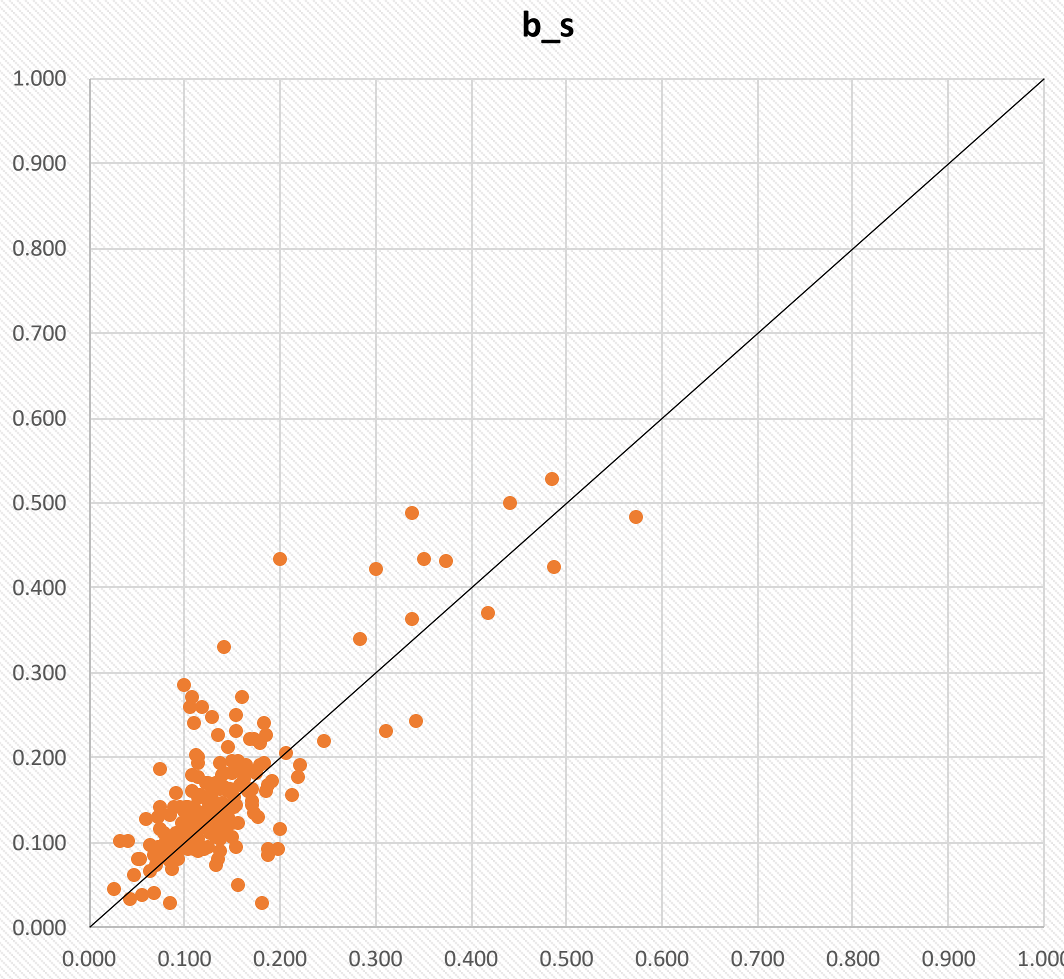


Fig. 7: Simple backward GVC participation contrast for all country-sectors for **1995 (x) and 2020 (y)**.

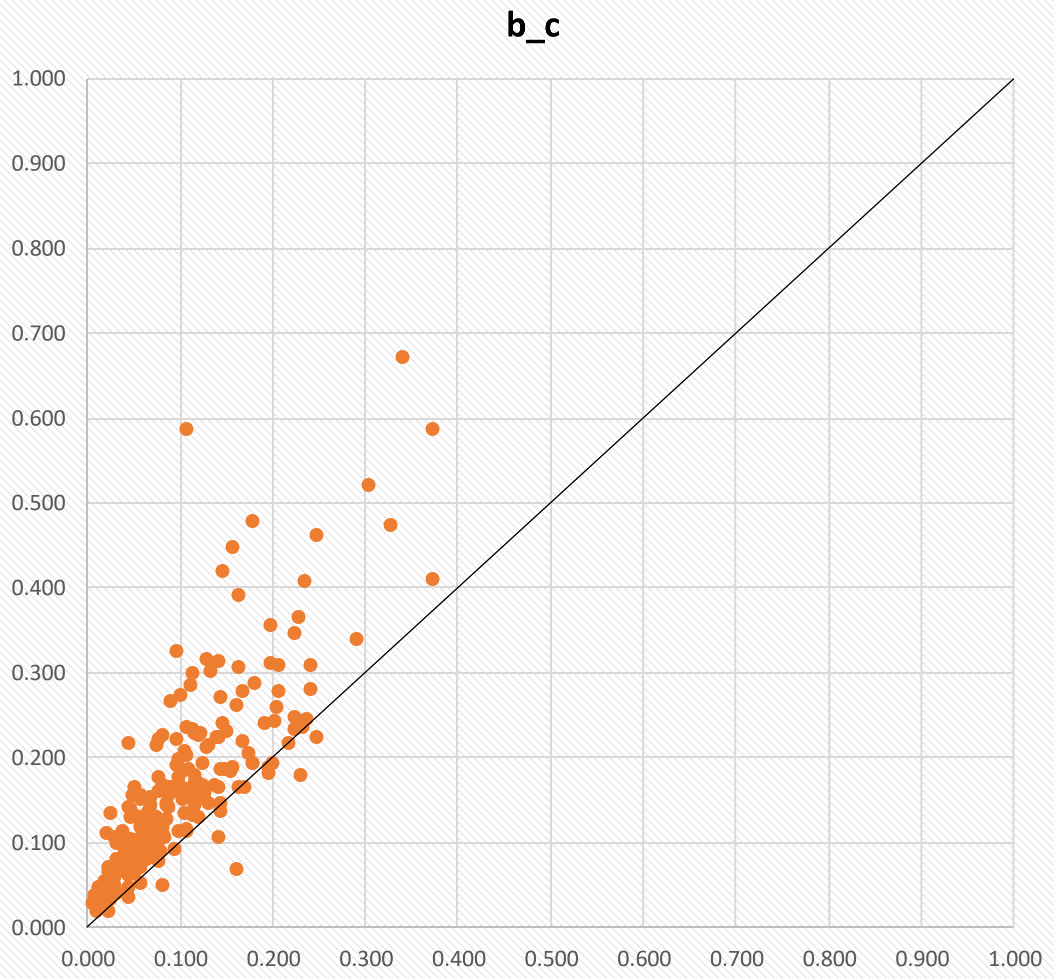


Fig. 8: Complex backward GVC participation contrast for all country-sectors for **1995 (x) and 2020 (y)**.

Econometric results

Table 1: Aggregate results

inno	(1)	(2)	(3)
GVC_f_L1	0.808***		0.476***
	(0.087)		(0.080)
GVC_b_L1		1.033***	0.794***
		(0.090)	(0.085)
K_Tang_L1	0.279***	0.209***	0.243***
	(0.084)	(0.077)	(0.078)
K_RD_L1	0.276***	0.300***	0.254***
	(0.058)	(0.052)	(0.053)
constant	0.744**	1.208***	1.531***
	(0.358)	(0.346)	(0.350)
Country-sector FE	yes	yes	yes
Observations	5303	5303	5303
R2	0.268	0.329	0.253
No. of groups	217	217	217

Table 2: Results for simple GVC activities

inno	(1)	(2)	(3)
GVC_f_s_L1	0.371***		0.426***
	(0.091)		(0.086)
GVC_b_s_L1		0.381***	0.424***
		(0.084)	(0.082)
K_Tang_L1	0.252***	0.245***	0.273***
	(0.091)	(0.089)	(0.089)
K_RD_L1	0.361***	0.382***	0.347***
	(0.059)	(0.056)	(0.056)
constant	0.225	0.235	1.102***
	(0.401)	(0.370)	(0.395)
Country-sector FE	yes	yes	yes
Observations	5303	5303	5303
R2	0.415	0.468	0.391
No. of groups	217	217	217

Table 2: Results for complex GVC activities

inno	(1)	(2)	(3)
GVC_f_c_L1	0.827**		0.631***
	(0.061)		(0.072)
GVC_b_c_L1		0.715***	0.255***
		(0.057)	(0.066)
K_Tang_L1	0.289***	0.213***	0.269***
	(0.074)	(0.076)	(0.074)
K_RD_L1	0.182***	0.261***	0.185***
	(0.053)	(0.052)	(0.052)
constant	1.731***	1.473***	1.904***
	(0.332)	(0.346)	(0.337)
Country-sector FE	yes	yes	yes
Observations	5303	5303	5303
R2	0.172	0.294	0.190
No. of groups	217	217	217

- Results are organized in different tables based on different modes of GVC participation to avoid multicollinearity issues
- We introduce backward and forward participation indicators (and their different modes) both separately and jointly in the specifications → **we interpret the results when they are jointly considered**
- **Controls are always present in the models**
- Robustness test: A model of patent flows (applications) with adjusted investment (i.e., capital formation) variables for the controls

Discussion

- GVC participation **is positively associated to industrial innovation performance** in our sample
  - ✓Our **HP is supported**
- The positive and statistically significant sign is persistent in **both backward and forward participation**
  - ✓**Both HP subcomponents are supported**
  - ✓Reflects **bi-directional learning channels** from both suppliers (learning-by-importing) and clients (learning-by-exporting)
  - ✓Adds macro-level evidence to what Ambos et al. (2021) coin a **"linkage-induced paradigm" of innovation development** in GVCs
  - ✓Link between backward participation (*i.e., a proxy of knowledge flow/input acquisition from abroad*) and innovation performance is higher than that of forward participation
- When we account for **different modes of GVC participation** the results differ only in terms of **magnitude**
  - ✓Simple components present approximately the same link with innovation performance
  - ✓**Complex forward participation presents a stronger correlation with innovation performance compared to complex backward**
- Fixed (tangible) and R&D capital stock are positively associated to innovation performance (as expected)
- Robustness test results support the main findings

Key take away points

- In this study we empirically investigated the effects of GVC participation to industrial innovation in Europe
  - We used a GVC-adjusted version of the KPF
  - We accounted for different types (forward vs. backward) and modes (simple vs. complex) GVC participation
- Our findings are summarized in the following remarks
  - ➢ **GVC participation is positively associated to industrial innovation in Europe**
  - ➢ This finding applies **for all types and modes** of GVC participation
  - ➢ Reflects learning effects accrued by international trade and particularly its GVC subcomponent (i.e., production-related trade)
  - ➢ Provide evidence of the Ambos et al. (2021) “linkage-induced innovation” paradigm at the sector level
  - ➢ Association is stronger for backward participation and, when disaggregated, for complex forward participation

Future work in the making

- Examine the link between innovation and GVC participation in European manufacturing
  - ✓Control for the technology level of different manufacturing sectors
  - ✓Create a typology of different sectoral regimes of GVC participation and innovation

- Another disaggregation for GVC participation types and modes
  - ✓Intra-EU vs. extra-EU GVC flows
  - ✓Relevant for EU strategic autonomy policies
  - ✓Relevant in times of tariff wars by the US government

- Expand the analysis to cover service sectors
  - ✓Significant issue: How to measure innovation (arguably softer that tech) in services?
  - ✓Are patents a reliable proxy? (probably not..)

Thank you for your attention

Contact info:

petrdimas@chemeng.ntua.gr