TITLE: ASSESSING VULNERABILITIES IN THE EUROPEAN UNION: A TERRITORIAL AND INDUSTRIAL ANALYSIS OF EU TRADE EXPOSURE USING FIGARO-REG AND CARMEN

Authors and affiliation:

Jorge M. Lopez Alvarez (Jorge.LOPEZ-ALVAREZ@ec.europa.eu) – JRC European Commission

Jose M. Rueda-Cantuche (Josem.RCANTUCHE@ec.europa.eu) – JRC European Commission

Luis Pedauga (Luis.PEDAUGA@ec.europa.eu) – JRC European Commission

Alba Catalan (Alba.CATALAN-PIERA@ec.europa.eu) – JRC European Commission

KEYWORDS

Input Output Models, EU Export Dependencies, Trade in Value Added (TiVA), FIGARO-REG, CARMEN

INTRODUCTION

In recent decades, the interconnectedness facilitated by globalisation and stable geopolitical relations has woven complex networks of dependencies among global economic blocs. Global Value Chains (GVCs) have driven improved efficiencies and significant cost savings, yet they have also exposed nations to vulnerabilities through disruptions from foreign suppliers and markets. These vulnerabilities have become increasingly pronounced amidst shifting geopolitical dynamics. Notably, events such as war conflicts, escalating energy costs, and heightening protectionist measures have considerably altered the global landscape, transforming former advantageous dependencies into notable vulnerabilities for the European Union (EU).

This work endeavours to explore these multifaceted challenges across three integral levels of analysis: EU-wide, national, and regional, with a particular focus on industrial sectors. Specifically, we analyse the variability of Chinese value added within EU exports to the US, offering unique insights into the EU regions and industries most vulnerable to US trade restrictions on goods with high Chinese value added content. By dissecting these elements, this paper seeks to examine the hidden impacts of external decisions in the EU economy.

METHODOLOGY, MODEL AND DATA

This study employs the CARMEN model, a versatile tool developed by the European Commission's Joint Research Centre (JRC), designed for a range of policy-relevant impact analyses at territorial and industrial levels. For the purposes of this research, CARMEN's modular approach facilitates the examination of both domestic and foreign value added content within bilateral exports across three tiers: EU, national, and regional, with detailed industrial breakdown. This methodology primarily relies on TiVA (Trade in Value Added) analysis, focusing particularly on foreign value added.

CARMEN's core input is the FIGARO-REG (García et al., 2023) multi-regional input-output (MRIO) table, a comprehensive economic database encompassing 240 EU regions (NUTS2), 48 non-EU regions including Norway and the United Kingdom, alongside 16 major non-EU trading actors. It provides data

for 56 industries and is fully consistent with Eurostat's 2017 FIGARO inter-country input-output tables (Remond-Tiedrez and Rueda-Cantuche, 201f9).

To assess the foreign value added the Tiva methodology is used. Formally can be formulated as:

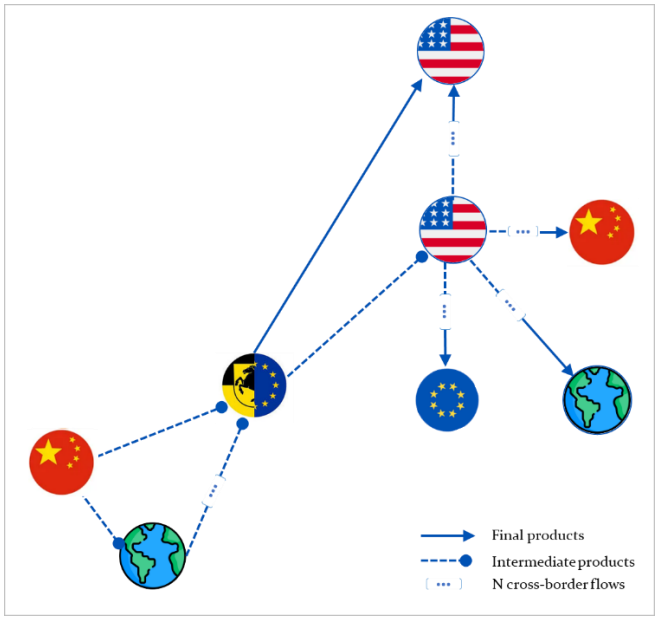
$$FVA^{f}_{r,s,i} = \sum_{j} \left(a^{i,f}_{r,j} \cdot X_{r,s,i} \right)$$

Let $X_{r,s,i}$ be the exports from region r to country s in industry i. The foreign value added content in $X_{r,s,i}$ attributed to a foreign country f is calculated by tracing the input flows from f used in the production process.

Where $a^{i,f}_{r,j}$ represents the technical coefficient indicating the proportion of inputs from industry j in country f utilised for producing exports $X_{r,s,i}$.

For instance, in the case of Stuttgart as an illustrative example (Figure 1), Germany, exports of goods and services to the US involve domestic value added content derived from local production. When Stuttgart exports intermediate goods, these components contribute to the production of final goods abroad, carrying foreign value added content—from inputs originating in countries like China—whether imported directly or indirectly.

Figure 1 – Flow of Chinese value added content in the exports to US from a representative EU region (Stuttgart).



Source: Own elaboration.

MAIN RESULTS

The results are presented to demonstrate the significance of the territorial dimension and the varied economic structures. Following Arto et al. (2019), this study employs three indicators to evaluate the Chinese value-added content embedded within regional exports from the EU to the US. The indicators are as follows:

- I1: Chinese value-added content in each EU region's exports to the US (expressed in million Euros), which quantifies dependence in absolute terms.
- I2: Share of Chinese value-added content relative to each EU region's total exports to the US, reflecting dependence relative to exports.
- I3: Share of Chinese value-added content relative to each EU region's total foreign value-added content in exports to the US, indicating dependence relative to foreign suppliers, specifically China.

At EU level the EU's total foreign value-added in exports to the US was quantified at 57.460 million Euros. Of this, 12.4% was originated from China, amounting to 7.122 million Euros and accounting for 1.7% of the overall EU exports to the US. This Chinese contribution represents 13.8% of the total EU exports to the US. Notably, the Chinese value-added content surpassed 25% in sectors such as textiles and wearing apparel, computers, electronics, and electrical equipment, and slightly exceeded 20% in the manufacture of motor vehicles.

Table 1 – Top-Ten EU Industries Exporting to the US with the Highest Share of Value-Added Content (Ranked by I3)

Industry	I1 (Million €)	I2 (%)	I3 (%)
Textile and wearing apparel	237	4.3	29.3
Computer and electronics	825	5.0	26.7
Electrical equipment	351	3.6	25.7
Motor vehicles	1,311	3.2	20.4
Machinery and equipment	1,098	2.8	18.4
Other transport equipment	683	3.8	17.3
Repair/installation of machinery	42	1.7	16.0
Construction	20	1.4	15.0
Fabricated metal products	124	1.5	14.4
Wood and cork	17	1.1	14.2
...	...	...	...
European Union	**7,122**	**1.7**	**12.4**

Source: JRC based on CARMEN and FIGARO-REG.

At national level, significant heterogeneity is observable according to the dependences shown in Table 2: Estonia and Hungary present more than double the EU average in terms of the proportion of Chinese value-added in their exports to the United States, with figures of 27.2% and 25.9%, respectively, relative to their total foreign value-added. Poland and Czechia follow closely with approximately 20% ratios. A similar pattern is reflected in the shares of Chinese value-added content within total exports for Estonia and Hungary, showing 4.7% for Hungary and 4.5% for Estonia.

Table 2 – Top-Ten EU Countries Exporting to the US with Highest Share of Value-Added Content (Ranked by Indicator I3)

Country	I1 (Million €)	I2 (%)	I3 (%)
Estonia	22	4.5	27.2
Hungary	182	4.7	25.9
Poland	120	1.6	20.8
Czechia	100	2.6	20.6
Germany	2,671	2.1	17.6
Slovenia	8	1.8	17.3
Slovakia	42	2.3	16.8
Austria	228	2.0	16.6
France	1,198	2.1	16.6
Italy	859	1.9	15.9
...	...	...	...
European Union	**7,122**	**1.7**	**12.4**

Source: JRC, utilising CARMEN and FIGARO-REG data.

In absolute terms, Germany and France alone account for more than half of the total Chinese value-added content in EU exports to the United States. Nonetheless, the proportion of Chinese value-added content within their overall exports remains relatively modest, standing at 2.1% for both nations. Six EU member states—namely Poland, Estonia, France, Hungary, Czechia, and Finland—report over 34% of their total foreign value-added content originating from China (Table 2).

Table 3 – Top-Ten Industries by EU Country Exporting to the US with Highest Share of Value-Added Content (Ranked by Indicator I3)

Country	Industry	I1 (Million €)	I2 (%)	I3 (%)
Poland	Computer and electronics	18	9.4	41.4
Estonia	Computer and electronics	14	12.7	40.1
France	Computer and electronics	123	6.6	38.8
Hungary	Computer and electronics	71	11.7	37.6
Czechia	Computer and electronics	18	7.2	36.1
Czechia	Textile and wearing appare	2	5.8	35.9
Czechia	Paper and paper products	1	4.4	34.8
Finland	Computer and electronics	23	4.8	34.1
Poland	Textile and wearing appare	2	4.1	34.0
Estonia	Electrical equipment	2	7.3	33.3
...		...	...	...
European Union		**7,122**	**1.7**	**12.4**

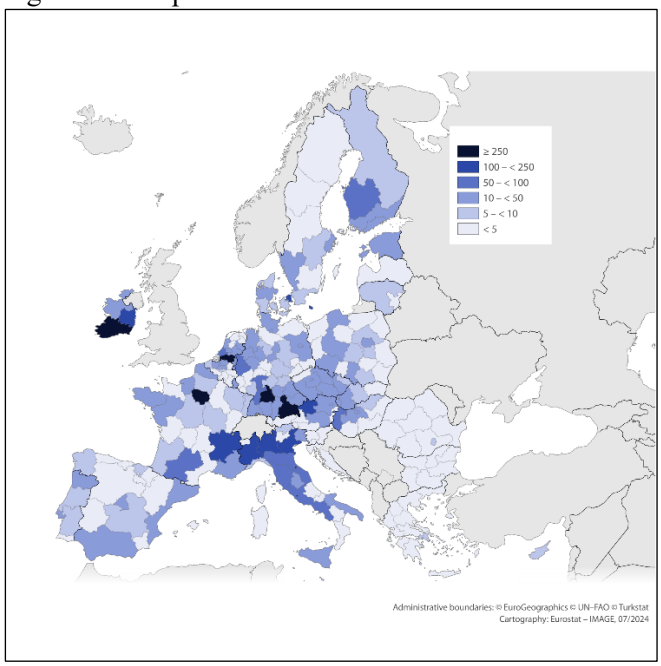
Source: JRC, utilising CARMEN and FIGARO-REG data.

The territorial tier adds a more granular level of heterogeneity. The spatial distribution of Chinese value-added content within regional exports is shown in Figure 2. Regions shaded in dark blue denote the highest levels of Chinese value-added content, predominantly observed in certain regions of Germany, Ireland, and France, followed by regions in Italy, the Netherlands, Austria, and Denmark.

The German regions of Stuttgart and Upper Bavaria, along with the French region of Ile-de-France, collectively account for 40% of the total Chinese value-added content in EU exports to the US, amounting to approximately 2,800 million Euros. Despite their smaller geographic size, the Southern and Eastern and Midland regions of Ireland notably contribute 466 million Euros in Chinese value-

added content in their exports to the US, a phenomenon potentially explained by the concentration of digital companies in these Irish regions.

Figure 2 – Map of Chinese Value-Added Content in EU Regions' Exports to the US (in million Euro)



Source: JRC, utilising CARMEN and FIGARO-REG data.

Table 4 ranks the top ten EU regions exporting to the US with the highest shares of Chinese value-added content, as per Indicator I3. This includes four Hungarian regions—Budapest, Pest, Western Transdanubia, and Central Transdanubia—with shares ranging between 31.6% and 24.3%. Additionally, Estonia, treated as a single region, and Southeast Czechia, exhibit shares close to 30%. Furthermore, three Polish regions—the Warsaw metropolitan area, Lower Silesia, and Lodz—are highlighted for their significant Chinese value-added content in exports to the US.

Table 4 – Top-ten EU regions exporting to US with highest share of Chinese value added content (sorted by I3)

Region	I1 (Million €)	I2 (%)	I3 (%)
Budapest (HU)	47	4.5	31.6
Southeast (CZ)	21	3.5	27.9
Pest (HU)	22	4.9	27.4
Estonia (EE)	22	4.5	27.2
Warsaw metropolitan area (PL)	29	2.2	26.5
Western Transdanubia (HU)	71	5.9	26.5
Central Transdanubia (HU)	33	5.1	24.3
Lower Silesia (PL)	14	1.9	23.8
Piedmont (IT)	146	2.4	23.4
Lodz (PL)	6	1.5	23.0
...	...	...	...
European Union	**7,122**	**1.7**	**12.4**

Source: JRC based on CARMEN and FIGARO-REG.

Table 5 offers insights into the industries with the most substantial Chinese value-added content within exports to the US for each of the regions identified in Table 4. Expectedly, the manufacturing of computers and electronics emerges as the industry with the greatest Chinese value-added content in

regional exports to the US, particularly in areas such as Budapest (Hungary), the Warsaw metropolitan area, Lower Silesia and Lodz (Poland), and Estonia—all with Chinese value-added shares exceeding 40%. In addition, Piedmont in Italy (24%) and Western Transdanubia in Hungary (37%) are noted for their robust automotive export industries, characterised by high Chinese value-added content in motor vehicle exports to the US.

Table 5 – Industries with High Chinese Value-Added Content in Exports to the US, Top Ten EU Regions (sorted by Indicator I3).

Region - Industry	I1 (Million €)	I2 (%)	I3 (%)
Budapest (HU) - Computer and electronics	31	16.8	45.9
Southeast (CZ) - Machinery and equipment	6	4.6	31.2
Pest (HU) - Computer and electronics	17	10.9	36.4
Estonia (EE) - Computer and electronics	14	12.7	40.1
Warsaw metr. (PL) - Computer and electronics	5	13.1	50.8
Western Transdanubia (HU) - Motor vehicles	5	11.4	37.7
Ctl. Transdanubia (HU) - Computer and electronics	16	12.0	38.4
Lower Silesia (PL) - Computer and electronics	3	9.6	41.1
Piedmont (IT) - Motor vehicles	72	2.4	24.1
Lodz (PL) - Computer and electronics	2	8.1	41.2
...	...	...	...
European Union	**7,122**	**1.7**	**12.4**

Source: JRC, utilising CARMEN and FIGARO-REG data.

CONCLUSIONS

Trade barriers and tariffs between main partners for the EU could penalise strongly imports with significant value-added content. Specifically in this analysis for US and China: motor vehicles, machinery and equipment, and computers and electronics are the main industries affected. Within these sectors, China contributes approximately 18-27% of the foreign value-added incorporated into EU exports to the US. In absolute terms, Germany and France account for more than half of the total Chinese value-added content in EU exports to the US. However, smaller Eastern European countries such as Estonia, Hungary, Poland, and Czechia present higher relative dependence levels, with 21-27% of their export value derived from Chinese inputs. Notably, Polish exports in computers and electronics to the US can contain up to 41% Chinese value added, with Estonia at 40%.

From a territorial perspective, six regions concentrate 50% of the EU's Chinese value-added content in exports to the US: Stuttgart and Upper Bavaria in Germany, Ile-de-France in France, North Brabant in the Netherlands, and the Southern and Eastern and Midland regions in Ireland. Other regions, including Budapest and Pest in Hungary, Southeast Czechia, Estonia, and the Warsaw metropolitan area in Poland, are identified as particularly vulnerable to potential export reductions.

The results highlight a significant dependency of the EU's computer and electronics manufacturing sector on the Chinese market, irrespective of the individual country’s scale or economic framework. Notably, the manufacturing of computer and electronic products is heavily reliant on critical raw materials, with China being the global leader in the production of many such materials that has a relevant impact in EU sectors like fabricated metals, chemicals, stone and glass, or plastic and rubber manufacturing.

This is a case of use of CARMEN utilising a robust datasets MRIO underlined such as FIGARO-REG, the findings obtained provide an unprecedented snapshot of the EU economy's exposure and

vulnerabilities across EU-wide, national, and regional levels, enhanced by detailed industry coverage. The complex net of trade interdependencies can be disentangled by CARMEN at detailed levels.

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