Title

Assessing vulnerabilities in the European Union: A Territorial and Industrial Analysis of EU Trade Exposure using FIGARO-REG and CARMEN

Authors:

Jorge M. Lopez-Alvarez – Jorge.LOPEZ-ALVAREZ@ec.europa.eu

Jose M. Rueda-Cantuche - Josem.RCANTUCHE@ec.europa.eu

Luis Pedauga - Luis.PEDAUGA@ec.europa.eu

Alba Catalan-Piera – Alba.CATALAN-PIERA@ec.europa.eu

Affiliation:

JRC - European Commission (all authors)

1. Introduction

The integration of a regional perspective is crucial for understanding the structural complexity of the European Union (EU), whose economic fabric is characterised by marked heterogeneity in industrial specialisation, productivity, and participation in global markets. Analyses conducted at the national level often obscure these differences, reducing the ability to identify spatially uneven vulnerabilities and the territorial propagation of economic shocks.

Advances in multi-regional input-output (MRIO) modelling have significantly improved the capacity to address these challenges. In particular, the emergence of detailed interregional databases such as FIGARO-REG has enabled a more precise mapping of economic linkages at the regional scale. By providing a consistent and harmonised representation of production networks across European regions, FIGARO-REG allows for a deeper exploration of spatial economic integration beyond national aggregates.

Developed in support of the RHOMOLO modelling framework, FIGARO-REG is fully aligned with national input-output accounts and offers extensive regional coverage, encompassing 288 NUTS2 regions within the EU, including the United Kingdom and Norway, as well as key external partners. Its detailed sectoral structure—covering more than 300 sectors and 55 product groups for the benchmark year 2017—ensures both coherence with official statistics and a high level of territorial granularity.

Figure 1: Structure of FIGARO-REG

<table>
<tr><td colspan="3" rowspan="3">FIGARO-REG</td><td colspan="9">Intermediate use</td><td colspan="4" rowspan="2">Final Use</td><td rowspan="3">Output</td></tr>
<tr><td colspan="3">Region1</td><td colspan="3">...</td><td colspan="3">Region 305</td></tr>
<tr><td>Industry 1</td><td>...</td><td>Industry 56</td><td>Industry 1</td><td>...</td><td>Industry 56</td><td>Industry 1</td><td>...</td><td>Industry 56</td><td>Government consumption</td><td>Households consumption</td><td>Gross Capital Formation</td><td>Changes in inventories</td></tr>
<tr><td rowspan="9">Intermediate Inputs</td><td rowspan="3">Region 1</td><td>Industry 1</td><td colspan="3" rowspan="3">$DOMESTIC_{1,1}$</td><td colspan="3" rowspan="3">$TRADE_{1,...}$</td><td colspan="3" rowspan="3">$TRADE_{1,305}$</td><td rowspan="3">G_1</td><td rowspan="3">H_1</td><td rowspan="3">$GFCF_1$</td><td rowspan="3">CI_1</td><td rowspan="3">X_1</td></tr>
<tr><td>...</td></tr>
<tr><td>Industry 56</td></tr>
<tr><td rowspan="3">...</td><td>Industry 1</td><td colspan="3" rowspan="3">$TRADE_{...,1}$</td><td colspan="3" rowspan="3">$DOMESTIC_{...,...}$</td><td colspan="3" rowspan="3">$TRADE_{...,305}$</td><td rowspan="3">$G_{...}$</td><td rowspan="3">$H_{...}$</td><td rowspan="3">$GFCF_{...}$</td><td rowspan="3">$CI_{...}$</td><td rowspan="3">$X_{...}$</td></tr>
<tr><td>...</td></tr>
<tr><td>Industry 56</td></tr>
<tr><td rowspan="3">Region 1</td><td>Industry 1</td><td colspan="3" rowspan="3">$TRADE_{305,1}$</td><td colspan="3" rowspan="3">$TRADE_{305,...}$</td><td colspan="3" rowspan="3">$DOMESTIC_{305,305}$</td><td rowspan="3">G_{305}</td><td rowspan="3">H_{305}</td><td rowspan="3">$GFCF_{305}$</td><td rowspan="3">CI_{305}</td><td rowspan="3">X_{305}</td></tr>
<tr><td>...</td></tr>
<tr><td>Industry 56</td></tr>
<tr><td colspan="2"></td><td>Tax Less Subsidies on Products</td><td colspan="9"></td><td>TLS_G</td><td>TLS_H</td><td>TLS_{GFCF}</td><td>TLS_{CI}</td><td></td></tr>
<tr><td colspan="2" rowspan="3">Value Added</td><td>Gross Operating Surplus</td><td colspan="3">GOS_1</td><td colspan="3">$GOS_{...}$</td><td colspan="3">GOS_{305}</td><td colspan="5" rowspan="4"></td></tr>
<tr><td>Compensation of Employees</td><td colspan="3">D_1</td><td colspan="3">$D_{...}$</td><td colspan="3">D_{305}</td></tr>
<tr><td>Othet Net taxes on Production</td><td colspan="3">$ONTP_1$</td><td colspan="3">$ONTP_{...}$</td><td colspan="3">$ONTP_{305}$</td></tr>
<tr><td colspan="3">Output</td><td colspan="3">X_1</td><td colspan="3">$X_{...}$</td><td colspan="3">X_{305}</td></tr>
</table>

Source: Own elaboration

The availability of such granular data has fostered an expanding literature on regional integration into global value chains (GVCs). Empirical evidence points to the persistence of strong intra-European linkages, with a substantial share of value added generated by exports remaining within EU regions. Complementary contributions using models such as CARMEN highlight the role of regional production systems in shaping sectoral interdependencies, particularly in strategic industries like automotive manufacturing. Moreover, applications of the hypothetical extraction method reveal pronounced regional disparities in structural dependencies, including those associated with the energy transition and decarbonisation processes.

Building on this body of work, this paper examines regional interdependencies within global value chains in the context of escalating trade tensions between the United States (US) and

China. The analysis focuses on foreign value added embedded in EU exports to the US as a key transmission channel of external shocks. Employing a multi-level framework—spanning EU, national, and NUTS2 regional scales—and a detailed sectoral breakdown, the study explores the uneven distribution of Chinese value added across territories and industries. This approach provides new insights into the geography of trade-related vulnerabilities and contributes to the development of targeted policy responses aimed at strengthening economic resilience under increasing geopolitical uncertainty.

2. Methodology and data

The empirical approach adopted in this paper is based on a multi-regional input-output (MRIO) framework implemented through the CARMEN model, developed by the Joint Research Centre of the European Commission. CARMEN provides a versatile and modular platform for analysing economic interdependencies, allowing for detailed policy-oriented assessments across both sectors and territories.

Within this framework, the model is applied to decompose bilateral trade flows into their domestic and foreign value-added components. Particular attention is given to quantifying the Chinese value added embodied in European Union (EU) exports to the United States (US). The analysis is conducted at multiple spatial scales—EU, national, and regional (NUTS2)—thereby enabling a comprehensive assessment of territorial heterogeneity and differences in exposure.

The empirical implementation relies on the FIGARO-REG database, which offers a harmonised and internally consistent representation of production systems and trade relationships. This dataset covers approximately 240 EU regions, along with additional European economies such as the United Kingdom and Norway, and includes major global trading partners. With a sectoral breakdown of 56 industries and full alignment with the FIGARO inter-country input-output tables for the benchmark year 2017, the database ensures both statistical coherence and a high level of analytical detail.

To trace the origin of value added embodied in exports, we follow the TiVA decomposition framework (Arto et al., 2019) over the Leontief's model, which allows distinguishing between domestic and foreign contributions.

In this framework, exports from an EU region r to the US can be decomposed into:

- Domestic value added (DVA), generated within the exporting region or country,
- Foreign value added (FVA), generated outside the exporting region,
- and, within FVA, the specific contribution of China (CVA).

Formally, the foreign value added embedded in exports from region r to the US can be written as:

$$FVA_{r\to US} = \sum_{s\neq r} v_s (I - A)^{-1} y_{r\to US}$$

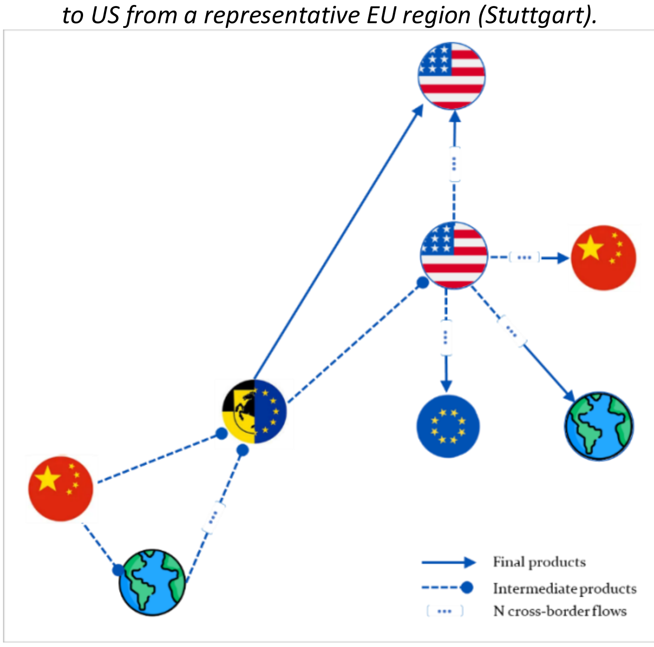
Where s indexes all foreign regions, and $yr \to US$ represents exports from region r to the US. A is the technical coefficients matrix and I the identity matrix.

The Chinese value added content is then obtained by restricting this sum to Chinese regions:

$$CVA_{r\to US} = \sum_{c\in China} v_c (I - A)^{-1} y_{r\to US}$$

In an example of the trade captured in figure 2, an EU region such as Stuttgart can export goods to the US either for final consumption or as intermediate inputs used in further production processes. In both cases, these exports may embody Chinese value added through the use of imported intermediate goods (e.g. semiconductors or batteries), either directly sourced from China or indirectly through third countries.

Figure 2. Flow of Chinese value added content in the exports to US from a representative EU region (Stuttgart).



Source: Own elaboration

3. Results

Following Arto et al. (2019), the analysis relies on three complementary indicators designed to capture different aspects of the Chinese value added embodied in EU exports to the United States.

3.1 EU-Level Results

At the aggregate level, the European Union (EU) displays a meaningful reliance on Chinese inputs within its exports to the United States. In 2017, foreign value added embodied in EU exports to the US reached €57,460 million, with China contributing 12.4% of this total (I3). In absolute terms, this corresponds to €7,122 million (I1), representing 1.7% of total EU exports to the US (I2). Overall, Chinese value added accounts for roughly 13.8% of the value embedded in EU exports to the US.

A sectoral breakdown reveals that this dependence is concentrated in a limited set of industries. As reported in Table 1, the share of Chinese value added within total foreign inputs (I3) exceeds 25% in sectors such as textiles and apparel, computer and electronic products, and electrical equipment, while remaining slightly above 20% in the motor vehicles industry. These sectors also tend to exhibit relatively high export dependence (I2), with the exception of machinery and equipment, where the lower relative share suggests a more diversified sourcing of foreign inputs.

In terms of absolute magnitude (I1), machinery and equipment together with motor vehicle manufacturing account for the largest share of Chinese value added embedded in EU exports to the US. Combined, these sectors represent approximately one-third of the total, corresponding to around €2,409 million. This positions them as the most relevant industries in terms of overall exposure to Chinese upstream inputs.

Table 1. Top-ten EU industries exporting to US with highest share of value added content (sorted 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.

3.2 National-Level Heterogeneity

In particular, small and medium-sized economies in Central and Eastern Europe exhibit notably high levels of supplier dependence at national level. Estonia and Hungary stand out, with I3 values of 27.2% and 25.9%, respectively—more than twice the EU average. Poland and Czechia also display elevated dependence, with shares approaching 20%.

A similar pattern is observed when considering export dependence (I2). Hungary (4.7%) and Estonia (4.5%) record the highest proportions of Chinese value added embedded in their exports to the United States, further underlining the structural nature of their exposure.

Table 2. Top-ten EU countries exporting to US with highest share of value added content (sorted by 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 based on CARMEN and FIGARO-REG.

In contrast, the largest EU economies—Germany and France—account for the highest volumes of Chinese value added in absolute terms (I1), together representing more than half of the EU aggregate. Despite this, their relative exposure remains limited, as Chinese inputs constitute only around 2.1% of their exports to the United States. This pattern reflects the scale, diversification, and greater resilience of their economic structures.

A more detailed sectoral perspective underscores the prominence of the computer and electronics industry. As indicated in Table 3, this sector records the highest shares of Chinese value added across six Member States—Poland, Estonia, France, Hungary, Czechia, and Finland—where China accounts for over 34% of total foreign value added embodied in exports.

These results point to a systematic reliance of the EU electronics sector on Chinese inputs. This dependence is largely driven by China's dominant role in the supply of critical raw materials and intermediate goods. Moreover, it extends beyond the electronics sector itself, permeating a range of upstream industries—including fabricated metals, chemicals, plastics, and glass—thereby reinforcing China's central position within global production networks.

Table 3. Top-ten industries by EU country exporting to US with highest share of value added content (sorted by 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 based on CARMEN and FIGARO-REG.

3.3 Regional-Level Heterogeneity

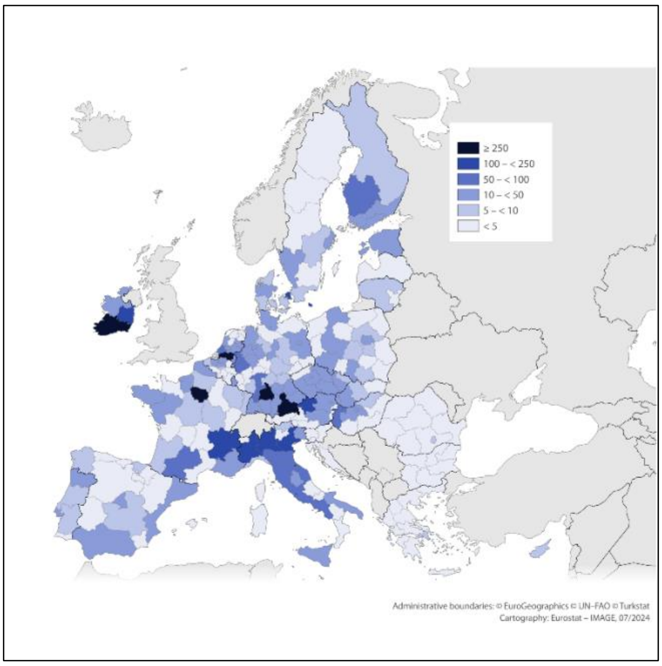
The regional analysis sheds light on how exposure is distributed unevenly across EU territories. As illustrated in Figure 3, Chinese value added embodied in exports to the United States is highly concentrated in a limited number of regions.

The highest absolute levels are found mainly in core industrial areas in countries such as Germany, France, and Ireland, followed by regions in Italy, the Netherlands, Austria, and Denmark. Among them, a few key regions (particularly Stuttgart, Upper Bavaria, and Île-de-France) account for a substantial share of total exposure.

Ireland also emerges as a relevant case, with relatively high levels of Chinese value added linked to its export structure, largely influenced by multinational activity. However, this does not necessarily translate into strong dependence, as the sourcing of inputs remains relatively diversified.

Overall, the pattern suggests that exposure in absolute terms is largely concentrated in major industrial and export-oriented regions, while a broader group of regions contributes more modestly to the total.

Figure 3. Map of Chinese value added content of EU region's exports to US (in million euros – I1)



Source: JRC based on CARMEN and FIGARO-REG.

4. Conclusions

The combination of the granular detail offered by the FIGARO-REG database and the flexibility of the CARMEN model enables a comprehensive examination of regional economic structures. In this paper, these tools are used to decompose value added within global value chains, allowing for the identification of how external inputs are embedded in European export performance.

The results reveal a marked sectoral concentration in the EU's exposure to Chinese value added embodied in exports to the United States. In particular, manufacturing industries such as motor vehicles, machinery and equipment, and computer and electronic products emerge as the most exposed. In these sectors, Chinese inputs account for approximately 18–27% of total foreign value added, pointing to a significant degree of upstream reliance and vulnerability to trade measures targeting goods with high Chinese content.

At the national level, the analysis uncovers a dual pattern of exposure combining scale effects and structural dependence. In absolute terms, large economies—most notably Germany and France—account for more than half of the total Chinese value added embedded in EU exports to the US. However, their relative reliance on Chinese inputs remains comparatively limited. In contrast, smaller economies in Central and Eastern Europe, including Estonia, Hungary, Poland, and Czechia, display significantly higher dependency ratios, with between one-fifth and one-quarter of their export value linked to

Chinese inputs. This dependence is particularly pronounced in the computer and electronics sector, where the contribution of Chinese value added can exceed 40% in some countries.

The regional dimension further highlights the uneven geography of exposure. A relatively small number of regions concentrate a large share of total Chinese value added, including Stuttgart and Upper Bavaria in Germany, Île-de-France in France, North Brabant in the Netherlands, and the Southern and Eastern and Midland regions in Ireland. These areas are characterised by strong industrial specialisation in manufacturing activities—particularly automotive, machinery, and electronics—as well as, in some cases, knowledge-intensive services.

When shifting the focus to relative dependence, a different set of regions emerges as most vulnerable. Regions such as Budapest and Pest in Hungary, Southeast Czechia, Estonia, and the Warsaw metropolitan area exhibit some of the highest shares of Chinese value added in their exports to the US. These findings point to the coexistence of two distinct forms of exposure: one driven by the economic weight of large industrial regions, and another rooted in structural reliance on specific foreign suppliers.

Overall, the analysis provides a multi-level characterisation of EU trade dependencies, showing how global value chain linkages translate into differentiated exposure to external trade policies. By integrating EU-wide, national, and regional perspectives with detailed sectoral evidence, the paper offers a more refined understanding of the territorial dimension of trade vulnerabilities in a context of increasing geopolitical fragmentation.

5. References

Almazán-Gómez, M. A., Llano, C., Pérez, J., & Mandras, G. (2023). The European regions in the global value chains: New results with new data. *Papers in Regional Science, 102*(6), 1097-1127. doi:https://doi.org/10.1111/pirs.12760

Arto, I., Dietzenbacher, E. and Rueda-Cantuche, J.M., Measuring bilateral trade in value added terms, EUR 29751 EN, Publications Office of the European Union, Luxembourg, 2019, ISBN 978-92-76-03846- 7, doi:10.2760/639612, JRC116694.

Dietzenbacher, E. (2002). Interregional Multipliers: Looking Backward, Looking Forward. *Regional Studies, 36*, 125-136.

European Commission. (2024, 02 10). *Automotive Industry*. Retrieved from European Commission: https://single-market-economy.ec.europa.eu/sectors/automotive-industry_en

European Commission. (2024, 1 10). *Automotive Regional Alliance*. Retrieved from Comittee of the Regions: https://cor.europa.eu/en/engage/pages/automotive-regions-alliance.aspx

European Commission. (2024, 10 03). *European Union*. Retrieved from European Commission: https://joint-research-centre.ec.europa.eu/tedam/rhomolo-model_en

European Commission, Joint Research Centre, Rueda Cantuche, J. M., López Alvarez, J. M., Pedauga, L., Catalán Piera, A. and Marques Santos, A. The employment impact of the coal transition in EU regions, Publications Office of the European Union, Luxembourg, 2025, https://data.europa.eu/doi/10.2760/4898550, JRC139404

García-Rodríguez, A., Lazarou, A., Mandras, G., Salotti, S., Thissen, M., & Kalvelagen, E. (2023). A NUTS-2 European Union interreiongal system of Socail Accounting Matrices for the year 2017: The RHOMOLO V4 dataset. *JRC Working Papers on Territorial Modelling and Analysis. 01/2023, European Commission, JRC132883*(1). Retrieved from https://publications.jrc.ec.europa.eu/repository/handle/JRC132883

Hu, J., Wang, S., Huang, K., Wei, Q., & Chen, H. (2022). Sipllover-feedback effects of social, economic, and environmental footprints based on the "Belt and Road Initiative". *Journal of Environmental Management, 305*. doi:https://doi.org/10.1016/j.jenvman.2021.114414

López-Álvarez, J., Rueda-Cantuche, J., Pedauga, L., Banacloche, S., & Piñero, P. (2023). The FIGARO-regio database and a Single Exposure Indicator to measure EU regional vulnerabilities to global value chains. *European Regional Science Association.* Alicante: European Regional Science Association.

Miller, R., & Blair, P. (2009). *Input-Ouput Analysis Foundations and Extensions* (2nd Edition ed.). Cambridge: Cambridge University Press.

Round, J. (2001). Decomposing Multipliers for Economic Systems Involving Regional and World Trade. *Economic Journal, 89*, 850-873.

Rueda-Cantuche, J., & Rémond-Tiedrez, I. (2019). *EU inter-country supply, use and input-output tables : full international and global accounts for research in input-output analysis (FIGARO).* Luxembourg: Publications Office of the European Union.

Rueda-Cantuche J. M., Lopez-Alvarez, J., Pedauga, L., & Catalan-Piera, A., 2025. Unravelling the territorial weave of trade: Assessing EU's vulnerability to US trade policy shifts towards China, Publications Office of the European Union, Luxembourg, 2025, JRC139823, https://data.europa.europa.eu/doi/10.2760/1146761.

Rueda-Cantuche, J., & Rémond-Tiedrez, I. (2019). EU inter-country supply, use and input-output tables : full international and global accounts for research in input-output analysis (FIGARO). Luxembourg: Publications Office of the European Union.

Sonis, M., & Hewings, J. (1988). Superposition and Decomposition Principeles in Hierarchical Social Accounting and Input-Ouput Analysis. In F. Harrigan, & P. McGregor (eds.), *Recent Advances in Regional Economic Modelling* (pp. 46-65). London: Pion.

Stone, R. (1985). The Disaggregation of the Household Sector in the National Accounts. In G. Pyatt, & J. Roud (eds.), *Social Accounting Matrices. A Basis for Planning* (pp. 145-185). Washington, DC: The World Bank.

Zhang, Y., & Zao, K. (2005). The Spillover and Feedback Effects between Coastal and Non-coastal Regions. In N. Okamoto, & T. Ihara (eds.), *Spatial Structure and Regional Development in China.* London: IDE-JETRO Series. Palgrave Macmillan.