DANUBE • 16(3) • pp. 292–303
DOI: 10.2478/danb-2025-0015

sciendo Danube

Specialization Trajectory: Slovakia Within the EU

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Abstract

While the beginning of the new millennium offered hope for accelerated economic performance and a rapid narrowing of the performance gap compared to the EU average, the last almost fifteen years have brought a slowdown in the process of real convergence for Slovakia, as well as a gradual deterioration of its position in international rankings that assess the qualitative aspects of economic development. This paper investigates the trajectory of Slovakia's trade specialization with a focus on technological and R&D intensity, using intra-EU export data and revealed comparative advantage (RCA) indicators for the period 2002–2024. The analysis tracks the evolution of four export categories classified by R&D intensity and examines the stability of specialization patterns through Galtonian regression. The results point to persistent medium-tech specialization and signs of β-de-specialization in several sectors, particularly in high-tech exports. These findings suggest that Slovakia's current export structure, while technologically more sophisticated in appearance, may lack depth in value-added and innovation content. The paper concludes that catching-up economies like Slovakia face limited growth opportunities from static specialization patterns and that long-term convergence prospects depend on structural transformation toward knowledge-intensive and innovation-driven sectors.

Keywords

Slovakia, Trade Specialization, R&D Intensity, Galtonian Regression

I. Introduction

Slovakia's integration into the European Union marked a significant turning point in its economic development, trade orientation, and structural transformation. From the early 2000s, the country pursued a strategy of open markets, institutional reforms, and deep integration with Western Europe, culminating in EU accession in 2004 and euro

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adoption in 2009. These milestones facilitated not only an expansion of trade flows but also a profound reorientation of Slovakia's production structure toward industries where it holds a comparative advantage.

Trade openness has been a defining feature of Slovakia's post-accession trajectory. As a small, export-oriented economy, Slovakia rapidly deepened its participation in European value chains, particularly in manufacturing sectors such as automotive and electronics. The intensity of intra-EU trade grew significantly, while the structure of exports gradually shifted from labor-intensive to more capital- and technology-intensive goods.

This increasing openness has been accompanied by a process of specialization, driven both by market forces and policy incentives. Specialization patterns reflect Slovakia's position in the regional division of labor, its relative factor endowments, and its adaptation to evolving EU-wide economic dynamics. Over time, certain sectors – especially automotive manufacturing – have come to dominate the country's export profile, raising important questions about resilience, dependency, and long-term growth potential. The importance of convergence, both real and nominal, has also characterized Slovakia's economic path. GDP per capita has steadily caught up with the EU average, while inflation and interest rate differentials narrowed in the run-up to euro adoption. However, this convergence has been uneven across regions and sectors, and it remains closely tied to Slovakia's ability to sustain competitiveness within the EU's single market. Building on the discussion of convergence and competitiveness, the analysis that follows focuses on trade specialisation. Laursen (2000) shows that while trade and technological specialisation may co-evolve, they do so with differing levels of stability and clarity. Trade specialisation patterns tend to be more persistent and readily observable, especially in small open economies where export performance plays a central role in structural adjustment. This makes trade a practical entry point for exploring how countries adapt their production structures and competitive positions over time.

The dynamics of trade specialisation over time reflect two interrelated but distinct processes: the persistence of existing specialisation patterns and structural change. These processes are central to understanding how countries, particularly small open economies, adapt to evolving global demand and technological progress.

Persistence in specialisation patterns – also referred to as "stickiness" or path dependency – suggests that countries tend to maintain their comparative advantages over time. This idea is supported by both evolutionary and neoclassical economic theories. From an evolutionary perspective, technologies are often firm-specific, tacit, and embedded in routines, institutions, and cumulative learning processes (Dosi, Pavitt and Soete, 1990). As a result, firms and sectors build on their historical capabilities, leading to continuity in production and export profiles. Similarly, the neoclassical argument by Krugman (1987) emphasizes the role of economies of scale and learning-by-doing, which reinforce existing specialisation patterns. Once a country becomes specialised in a sector, increasing returns and accumulated experience tend to lock in that pattern, limiting the scope for radical shifts. Empirical evidence from Laursen (2000) confirms this: trade specialisation patterns across OECD countries exhibited considerable stability over the period 1971–1991, more so than technological specialisation, which was comparatively more volatile.

However, this persistence does not preclude structural change, which refers to shifts in the sectoral composition of exports over time. Structural change is particularly relevant for catching-up economies that aim to converge with more advanced countries. According to Beelen and Verspagen (1994), such countries are expected to experience the most rapid structural shifts as they reallocate resources toward sectors that allow for higher productivity and technological spillovers. This view reverses the logic of Pasinetti (1981), who argued that the more similar a country's production structure is to that of the technological frontier, the easier it is to catch up. Beelen and Verspagen suggest instead that convergence requires transformation – specifically, aligning domestic structures with high-tech, high-value-added sectors to better absorb external knowledge.

The process of structural change is driven by both supply-side and demand-side forces. On the supply side, models of monopolistic competition and product variety (Dixit and Stiglitz, 1977; Krugman, 1989) suggest that growing economies expand their range of production, gradually shifting toward more sophisticated outputs. From the demand side, rising per capita incomes change consumption patterns, increasing demand for luxury and technology-intensive goods (Pasinetti, 1981). For small open economies, this necessitates domestic production adjustments to match evolving internal and EU-wide demand structures, particularly when integration into the single market reduces trade barriers.

Importantly, not all sectors adjust at the same pace. Laursen (2000) finds that trade specialisation is more persistent in sectors tied to natural resources or mature technologies, whereas high-tech sectors may exhibit more flexibility and dynamism. Moreover, the level of persistence varies across countries depending on institutional capacity, innovation systems, and industrial policy.

In summary, while specialisation patterns tend to persist due to cumulative processes and increasing returns, structural change remains a crucial mechanism – especially for smaller, less advanced economies – to enhance competitiveness and foster convergence. The interplay between these forces shapes long-term trade trajectories and determines a country's adaptability in an integrated economic environment.

In the following, Section II describes the data used and the methodology. We zoom in on Slovak exports and its technological intensity with EU as a comparative structure. In Section III, the paper proceeds to the empirical investigation providing demonstration of both raw and transformed Revealed Comparative Advantage indicators. The latter enter regression analysis investigating the stability of trade patterns. Section IV concludes and outlines further avenues for research.

II. Methodology and Data

Data description

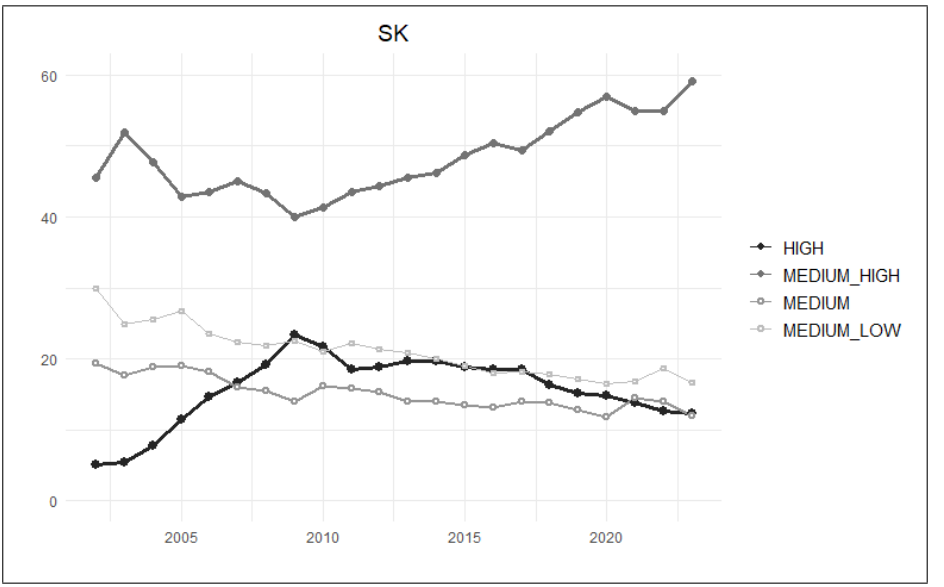
In trade specialization analysis, the focus is placed on exports that serve as a common proxy for revealed comparative advantage, reflecting sectors in which a country demonstrates sustained international competitiveness. Export data are generally more robust, detailed, and consistent across countries, enabling more accurate assessments of structural specialization patterns. Moreover, export performance is closely linked to productive capabilities,

innovation dynamics, and participation in global value chains, all of which are critical for long-term economic growth. In contrast, import structures may be influenced by domestic demand, policy distortions, or short-term supply constraints, making them less informative for identifying productive specialization. For small open economies such as Slovakia, exports also play a central role in external balance and convergence processes within the EU, further justifying their use as the primary basis for specialization analysis.

We utilize International trade in goods statistics (ITGS) published by Eurostat that measure the value and quantity of goods traded between the EU Member States (intra-EU trade) and goods traded by the EU Member States with non-EU countries (extra-EU trade). Specifically, we use CPA 2.1 product nomenclature (Classification of Products by Activity) by 3-digit product code, collecting Intra-EU exports for Slovakia as well as totals for the whole EU. Thus, the dataset is aimed to describe *within-the-EU* competitiveness.

Following Galindo-Rueda and Verger (2016), we concentrate on four export categories featuring different RD intensity labelled HIGH, MEDIUM_HIGH, MEDIUM, and MEDIUM_LOW, filtering out the classes A and B (products of agriculture and mining) spanning product codes 01–09. For attributing the export categories to individual codes, we stick to OECD classification scheme. The comparison with other classifications is provided in Appendix Table A1. Evolution of the categories' shares on total exports for Slovakia is exhibited in Figure 1.

Figure 1: Slovakia export shares across R&D intensity categories



Source: Fifeková et al. (2024)

Shares from Figure 1 capture the structure of exports with respect to R&D (technological) intensity of production activities. In the case of Slovakia, the degree of high-tech intensity in exports serves as a clear indicator of its innovation capacity. One positive trend is the rise in the share of technologically highly intensive commodities, which grew by more than 7 percentage points over the observed period. The most notable increase occurred by 2009, when technologically highly intensive exports made up nearly one-fourth of total exports; however, since that peak, their share has steadily declined to the current level of about 12%. Slovakia's high-tech exports are primarily concentrated in computers, electronics, and optical products. This strong focus on information and communication technology suggests that other potentially important high-tech sectors remain underdeveloped within both the production and export structures.

Specialization indicators and regression analysis

Measuring the specialization is carried out employing Revealed Comparative Advantage index (Balassa, 1965) that contains a comparison of national export structure with that of the EU. The conventional interpretation posits that an RCA value (1) of one for a specific sector signifies that the sector's share in the analyzed country's exports is equivalent to the corresponding average share within the European Union. An RCA value exceeding one denotes a relative specialization of the country in that sector, reflecting an export share higher than the EU average, whereas an RCA value below one indicates a comparatively lower export intensity in that sector relative to the EU benchmark.

$$RCA_j = \frac{X_j / \sum_j X_j}{X_j^{EU} / \sum_j X_j^{EU}}, \tag{1}$$

where X_j stands for exports of sector j. By use of (1), we calculate Slovakia's RCA by relating its export composition to the aggregate exports of all EU Member States, rather than to global trade flows. This approach allows us to evaluate Slovakia's trade specialisation and competitiveness relative to its European peers within the single market. Using the EU as a reference provides a more consistent and comparable benchmark, as Member States operate under similar regulatory frameworks, trade policies, and economic conditions. It also reflects the reality that the EU is Slovakia's main trading partner and the primary arena where its firms face competition. Moreover, this method helps to minimize distortions arising from structural differences that would arise if comparing to global trade, such as the dominance of resource-rich or low-cost manufacturing countries outside the EU.

Given the typically right-skewed distribution of RCA values, the Revealed Symmetric Comparative Advantage (RSCA) index is computed as shown in equation (2). This transformation rescales the values to a range between −1 and 1, thereby enhancing their suitability for regression analysis.

$$RSCA_j = (RCA_j - 1)/(RCA_j + 1) \tag{2}$$

Regression analysis will be used to demonstrate the importance of institutional quality within the economic development framework. A simplistic version empirically links the level of economic development with a number of key determinants as adopted from the growth literature via a linear regression model. To account for nonlinearities, a transformation of the variables entering the model may be conducted. Since we use the regression for mere qualitative statement not aiming at the precise value of estimated coefficients, we resort to using a cross-sectional model across sectors j:

$$RSCA_j^{t_2} = \alpha_j + \beta_j RSCA_j^{t_1} + \varepsilon_j \,, \tag{3}$$

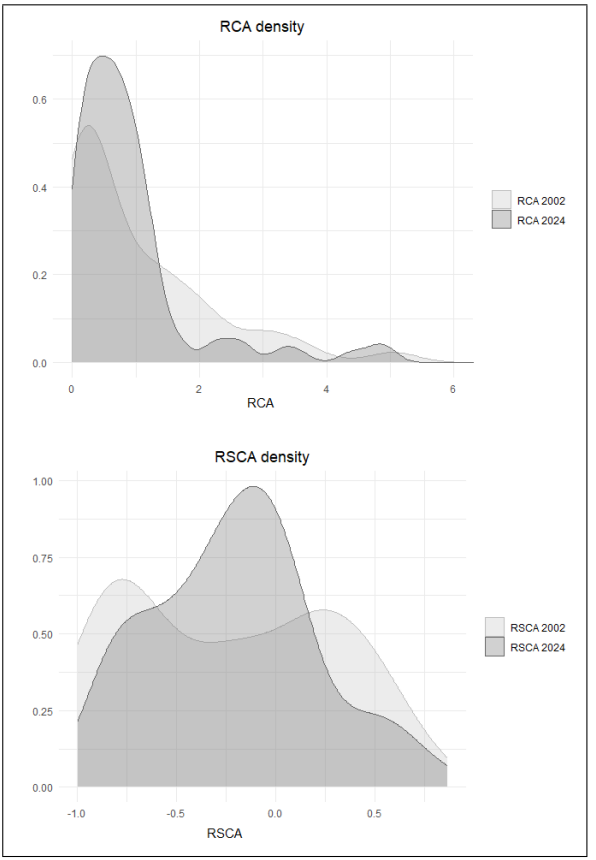
where $RSCA_j$ from the period t_2 is regressed on $RSCA_j$ from the lagged period t_1.

The regression framework interprets the coefficient β as an indicator of how trade specialisation patterns evolve over time. A value of $\beta = 1$ suggests that the pattern remains unchanged between the two periods, t_1 and t_2. If $\beta > 1$, it indicates increasing specialisation – countries tend to reinforce existing strengths by becoming more specialised in sectors where they were already strong and less so in weaker sectors. This can be viewed as *β-specialisation*, analogous to divergence in convergence studies. Conversely, if $0 < \beta < 1$, the pattern reflects *β-de-specialisation*: sectors with initially low specialisation improve, while initially strong sectors lose ground. The degree of this adjustment is captured by the "regression effect", defined as $(1 - \beta)$. In the rare case where $\beta < 0$, the entire ranking of sectors is reversed. The concept of path dependency or "stickiness" is supported when the estimated β is significantly greater than zero; if not, the pattern may be considered reversed or random. Additionally, the regression can indicate whether the overall degree of specialisation has changed. As noted by Cantwell (1989), an increase in national specialisation does not require $\beta > 1$ – dispersion can rise even when β is below unity, depending on the variance structure of the data.
The pattern observed in Fig. 1 helps explain the declining RCA in high-tech exports: as Slovakia's export structure shifts increasingly toward medium-tech products, its relative specialization in high-tech sectors weakens compared to the EU. This internal reorientation contributes to beta-de-specialization, particularly in high-tech, by diluting the weight of more advanced segments in the overall export basket. In this sense, Fig. 1 illustrates a structural evolution that underlies the RCA-based evidence of reduced high-tech competitiveness.

III. Results and Discussion

In the first step we calculated RCA indicators (1) for each of the 3-digit product code from the restricted dataset of products as described above. Subsequently, the symmetric RSCA quantity is determined using (2). In Figure 2 we demonstrate how the left-skewed RCA is rendered centred tending to normal distribution. After this treatment, data are ready to enter the regressions of the type (3).

Figure 2: RCA and RSCA densities (2002, 2024)



Source: Eurostat, authors' calculation

Table 1: Specialization regressions summary

	(HIGH)	(MEDIUM HIGH)	(MEDIUM)	(MEDIUM LOW)
const	✓	✓	✓	✓
β	0.829**	0.666***	0.763***	0.271**
	(0.365)	(0.122)	(0.144)	(0.099)
R^2	0.364	0.576	0.596	0.193
β/R	1.37	0.88	0.99	0.62

Source: Eurostat, authors' calculation

We run four separate Galtonian regressions, each for one category of export products. The results of OLS estimation are displayed in Table 1. The regression results across R&D intensity categories indicate varying degrees of persistence in trade specialisation. Medium and medium-high R&D sectors exhibit the strongest stability, with significant β coefficients (0.763 and 0.666, respectively) and relatively high explanatory power ($R^2 = 0.596$ and 0.576).

High R&D sectors also show moderate path dependence ($\beta = 0.829$), though with a larger standard error, suggesting greater variability. In contrast, medium-low R&D sectors display weak persistence ($\beta = 0.271$) and low explanatory power ($R^2 = 0.193$), pointing to higher volatility and more pronounced structural change. These patterns align with expectations that more knowledge-intensive sectors exhibit stronger cumulative dynamics. As in many small open European economies, technologically based exports in Slovakia are dominated by medium-technology-intensive commodities – with Slovakia registering the highest share of medium-tech exports among its peers. However, countries differ significantly in how their medium-tech exports are structurally diversified. In most cases, motor vehicles, trailers, and semi-trailers form the largest component, with the notable exceptions of Denmark and Austria. In Slovakia's case, medium-tech exports are particularly concentrated in this segment, which alone accounts for up to 40% of total exports. Additional key medium-tech export categories from Slovakia include machinery and equipment, electrical equipment, and chemical and chemical products (Fifeková et al., 2024).

Another statistical aspect of specialization stems from the fact that, with reference to equation (3), the ratio of β and the correlation R between the *RSCA*s in two periods, is equal to the ratio of RSCA dispersions (Hart, 1976):

$$\sigma_j^{t_2} / \sigma_j^{t_1} = \left| \beta_j / R_j \right| \tag{4}$$

The absolute values from the right-hand side of (4) are calculated for four export categories in Table 1. For $\beta > R$ (equivalent to an increase in the dispersion) as in case of HIGH category, the degree of specialisation has increased. Thus, the high-tech exports show the signs of σ-*specialisation*. Conversely, $\beta < R$ for HIGH_MEDIUM and MEDIUM_LOW indicate σ-*de-specialisation*. MEDIUM category appears to be stable over the analyzed period of time. However, consistent with the discussion in the "new growth" literature on β- and σ-convergence (Barro and Sala-i-Martin, 1991), the combination of ($\beta > R$) and ($\beta < 1$) is approached with caution, as the observed increase in the variance of *RSCA* values over time may, to some extent, be driven by the variance of the error term ε in equation (3). The apparent rise in the technological sophistication of Slovak exports may, however, obscure underlying issues such as limited R&D intensity and inadequately represents the predominantly assembly-based nature of its manufacturing processes. For instance, within the country's most export-intensive sector – motor vehicles, trailers, and semi-trailers – the value-added ratio (measured as the proportion of gross value added in the final product) is approximately threefold lower than that of Germany and nearly one-and-a-half times lower than Austria. Consequently, Slovakia's position within the global value chain considerably moderates the assessment of the technological intensity of its export commodities.

Beyond R&D intensity, structural aspects of competitiveness can also be captured through dimensions such as factor intensity and product sophistication, notably using indicators like REVELAST developed by Aiginger (1998). Factor intensity distinguishes sectors based on their reliance on inputs such as labour, capital, or natural resources, enabling an analysis of whether a country's export profile is biased toward low-skill, labour-intensive activities or higher-value capital- and knowledge-intensive production. This distinction is particularly important for small open economies striving to move up the value chain. Meanwhile, REVELAST (Revealed Sectoral Advantage by Technology) focuses on the quality and income elasticity of export products, classifying sectors by their competitive performance relative to structural characteristics like innovation, design, and branding (Aiginger, 1998). Unlike traditional measures of revealed comparative advantage, REVELAST incorporates a structural perspective by assessing whether a country exports more in industries associated with dynamic global demand and high income elasticity. Together, these dimensions complement R&D-based classifications by offering a broader view of export competitiveness – highlighting not only innovation capabilities but also the underlying production factors and demand-side attributes that shape a country's position in global trade.

IV. Conclusion and Further Research

In this study, we investigated specialization patterns in Slovak exports within the EU, with an emphasis on technological intensity and the evolution of comparative advantage. While the analysis involving σ-specialisation may be potentially polluted by the error-term variance, the results confirmed β-de-specialization across the export structure. It may be considered good news for Slovakia as a catching-up economy, whose long-term growth cannot rely solely on deepening its current specialisation in sectors like automotive and assembly manufacturing, which offer diminishing returns over time. Instead, sustainable progress requires structural transformation – shifting towards higher value-added, innovation-driven activities such as knowledge-intensive services and advanced manufacturing. This transition should be supported by targeted policies, including investment in education and skills, fostering research and development, and creating a supportive environment for entrepreneurship and technological upgrading. Such changes are essential for Slovakia to move beyond static gains and achieve dynamic, inclusive growth.

It should be noted that the study frequently uses the terms "technological intensity" and "R&D intensity" interchangeably, primarily due to the underlying OECD classification scheme based on R&D expenditure by sector. However, while closely related, these concepts are not identical. R&D intensity reflects the formal input side of innovation (R&D spending), whereas technological intensity encompasses broader elements such as product complexity, process innovation, and skill requirements. As such, R&D intensity may not fully capture the value-added or innovation capabilities embedded in a country's export structure – especially in cases where production is dominated by assembly functions with limited domestic knowledge content.

Furthermore, RCA indicators used in the analysis are constructed with the aim of capturing within-EU competitiveness. While this enhances comparability among Member States, it

does not necessarily reflect Slovakia's position in global trade. Additional dimensions – such as factor intensity and product sophistication – may help enrich the understanding of competitiveness in future work.

An investigation of the stability of specialization patterns across a broader set of countries can be conducted within the dynamic framework pioneered by Magnier and Toujas-Bernate (1994) and subsequently applied by, for example, Amable and Verspagen (1995). In this approach, RSCAs from consecutive periods are paired, and the estimated coefficient β is decomposed into an average component, a sector-specific component, and a country-specific component. Applying such a methodology would allow a more detailed understanding of how country-specific factors interact with sectoral trends in shaping specialisation outcomes over time.

Slovakia's shift from high-tech to medium-tech exports reduces its competitive pressure in high-tech sectors within the EU, allowing other member states to strengthen their positions in advanced industries. This structural change may lead to a reallocation of market shares, with Slovakia intensifying competition in medium-tech products instead. Overall, it signals a realignment of specialization patterns among EU countries, affecting innovation dynamics and trade competition across different technology segments.

Acknowledgements

The authors acknowledge financial support from project VEGA 2/0001/22 "Slovakia 2030".

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Appendix

Table A1: R&D Intensity Classifications

ISIC Rev. 4	OECD R&D Intensity Classification	Eurostat Technology Classification (NACE Rev. 2)	OECD Technology Classification (ISIC Rev. 3)
303: Air and spacecraft and related machinery	High	High	High
21: Pharmaceuticals	High	High	High
26: Computer, electronic and optical products	High	High	High
252: Weapons and ammunition	Medium-High	Medium-High	Medium-High
29: Motor vehicles, trailers and semi-trailers	Medium-High	Medium-High	Medium-High
325: Medical and dental instruments	Medium-High	Medium-High	High
28: Machinery and equipment n.e.c.	Medium-High	Medium-High	Medium-High
20: Chemicals and chemical products	Medium-High	Medium-High	Medium-High
27: Electrical equipment	Medium-High	Medium-High	Medium-High
30X: Railroad, military vehicles, and transport n.e.c. (ISIC 302, 304, and 309)	Medium-High	Medium-High	Medium-High
22: Rubber and plastic products	Medium	Medium-Low	Medium-Low
301: Building of ships and boats	Medium	Medium-Low	Medium-Low
32X: Other manufacturing except medical and dental instruments (ISIC 32 less 325)	Medium	Low	Low
23: Other non-metallic mineral products	Medium	Medium-Low	Medium-Low
24: Basic metals	Medium	Medium-Low	Medium-Low
33: Repair and installation of machinery and equipment	Medium	Medium-Low	
13: Textiles	Medium-Low	Low	Low
15: Leather and related products	Medium-Low	Low	Low
17: Paper and paper products	Medium-Low	Low	Low
10-12: Food products, beverages and tobacco	Medium-Low	Low	Low
14: Wearing apparel	Medium-Low	Low	Low
25X: Fabricated metal products except weapons and ammunition (ISIC 25 less 252)	Medium-Low	Medium-Low	Medium-Low
19: Coke and refined petroleum products	Medium-Low	Medium-Low	Medium-Low
31: Furniture	Medium-Low	Low	Low
16: Wood and products of wood and cork	Medium-Low	Low	Low
18: Printing and reproduction of recorded media	Medium-Low	Low	Low

Source: Galindo-Rueda andVerger (2016)