Supplier Concentration and Strategic Import Dependence: Evidence from Slovakia

Viktória Vörösová
ORCID iD: 0009-0004-2020-653X
viktoria.vorosova@euba.sk
Bratislava University of Economics and Business, Faculty of Commerce, Department of International Trade
Bratislava, Slovakia

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Abstract: This paper analyses Slovakia's strategic import dependence within global value chains, with a focus on the concentration of external suppliers of strategically relevant products. Recent developments in European industrial and trade policy, including debates on strategic autonomy and supply chain resilience, have highlighted the vulnerability of small open economies to disruptions arising from highly concentrated import structures. Using detailed trade data for the period 2019-2023, the study assesses supplier concentration in Slovakia's imports by applying the Herfindahl-Hirschman Index (HHI) and combining it with an economic relevance threshold. The aim of the paper is to quantify strategic import dependence and identify concentration patterns that may increase exposure to external shocks and supply disruptions. The results indicate a temporary increase in supplier concentration in 2022, accompanied by a rise in the number of strategically dependent product categories, followed by partial moderation in 2023. Strategic dependencies are concentrated primarily in energy-related commodities and selected industrial inputs. The findings suggest that Slovakia's import dependence is not systemic across the entire import structure but concentrated within specific economically significant segments.

Keywords: Strategic import dependence, Global value chains, Supplier concentration

JEL Classification codes: F14, F23

INTRODUCTION

Global value chains (GVCs) have significantly increased economic interdependence between countries, enhancing efficiency through specialisation while simultaneously exposing economies to external shocks. Recent geopolitical tensions, including Russia's invasion of Ukraine in 2022, pandemic-related disruptions, and trade policy uncertainty have intensified concerns about excessive reliance on external suppliers, particularly in strategically important sectors (Gereffi et al., 2021; Helwig, 2023). Within the European Union, these concerns have been articulated through the concept of open strategic autonomy, which seeks to reconcile economic openness with resilience and security considerations (Schmitz & Seidl, 2023; Mariotti, 2025).

These issues are particularly relevant for Slovakia as a small open economy strongly integrated into European production networks. Its industrial structure is heavily export-oriented and depends on imported intermediate goods, especially in manufacturing sectors such as automotive, machinery, and electronics. This makes Slovakia relatively more exposed to external supply disruptions and concentrated import relationships.

Recent policy reports at the EU level have identified product categories characterised by high import concentration and limited diversification (European Commission, 2021). However, while EU-wide assessments provide a macro-level overview of strategic dependencies, considerably less empirical attention has been devoted to how supplier concentration evolves dynamically within individual member states. This is especially important in economies such as Slovakia, where external exposure may be shaped not only by trade openness, but also by strong manufacturing specialisation, deep integration into cross-border production systems, and limited substitution capacity in key product categories.

This paper addresses this gap by analysing supplier concentration and strategic import dependence in Slovakia between 2019 and 2023. Using HS4-level trade data from the BACI database, the study measures concentration through the Herfindahl-Hirschman Index (HHI) and combines it with an economic relevance threshold to identify product categories that simultaneously exhibit high concentration and substantial import value.

By providing a product-level assessment of supplier concentration in a small open EU economy, this paper contributes to the literature in three ways. It translates EU-level assessments of strategic dependencies to the national context and documents how concentration evolves over time in Slovakia. It also situates these dynamics in the context of the 2022 shock to European supply chains following Russia's invasion of Ukraine. In doing so, it examines whether concentration patterns intensified and how they subsequently adjusted. Finally, by combining the HHI with an economic relevance criterion, the paper distinguishes between statistically concentrated categories and economically significant dependencies.

1 LITERATURE REVIEW

The expansion of global value chains (GVCs) has fundamentally reshaped international production, increasing efficiency through cross-border specialisation while deepening economic interdependence. Although participation in GVCs is widely associated with gains in competitiveness and productivity, the literature increasingly points to the risks created by concentrated upstream dependencies and limited substitution possibilities (Gereffi et al., 2021). Recent geopolitical tensions and pandemic-related supply shocks have exposed the fragility of such production networks. At the same time, these disruptions have sharpened an important debate in the literature: whether vulnerability stems from global integration itself, or rather from the specific structure and concentration of supplier relationships.

Importantly, vulnerability does not arise merely from trade openness but from the configuration of supplier structures within value chains. High concentration in specific nodes may amplify the transmission of shocks, particularly when substitution possibilities are limited (Coveri et al., 2025). At the firm level, resilience is often linked to diversification and adaptive capabilities (Chatterjee et al., 2024), whereas at the macro level, concentrated sourcing of critical inputs may generate broader systemic exposure (Imbruno et al., 2024). However, the literature is less clear on how vulnerability should be measured, since concentration alone does not necessarily imply strategic risk unless it is combined with economic significance and limited substitutability.

Within the European Union, the debate on economic vulnerability has increasingly been framed through the concept of open strategic autonomy. This framework seeks to reconcile continued integration in global markets with the strengthening of resilience in strategically sensitive sectors (Schmitz & Seidl, 2023; Mariotti, 2025). Strategic autonomy has evolved from a primarily security-oriented concept into a broader economic governance agenda encompassing industrial policy, trade defence instruments, and supply chain diversification (Helwig, 2023; Haroche, 2023). However, the literature remains divided on how this concept should be

operationalised in practice, particularly regarding the boundary between resilience-enhancing diversification and potentially costly or inefficient policy intervention.

The European Commission (2021) identified strategic dependencies in product categories characterised by high concentration and limited diversification, particularly in critical raw materials, energy-related commodities, and advanced manufacturing inputs. However, EU-level assessments provide aggregated insights and do not necessarily capture the heterogeneity of exposure across member states. In particular, aggregation may either understate product-specific vulnerabilities in smaller economies or overstate risks where substitution possibilities exist at lower levels of disaggregation. This limitation makes national-level evidence especially important for identifying vulnerabilities that may remain obscured in EU-wide assessments.

Recent national-level evidence for Slovakia is provided by the Institute for Economic Analysis (IHA) (Steinhauser & Bolčo, 2025), which examines strategic import dependence using concentration indicators derived from the Herfindahl-Hirschman Index (HHI) and complementary risk measures. The study applies both standard and weighted versions of the HHI, drawing on the methodological framework of the European Commission (2021), and evaluates concentration at a more aggregated product level. Its findings highlight elevated concentration in selected energy-related and industrial product groups and underline the importance of monitoring structural vulnerabilities in Slovak imports. At the same time, the study reflects a broader limitation of much of the existing literature: concentration is assessed mainly as a structural snapshot, while detailed product-level dynamics and post-shock adjustments remain less explored.

Assessing strategic dependence therefore requires combining measures of supplier concentration with indicators of economic exposure. The Herfindahl-Hirschman Index (HHI), originally developed in competition economics, has become a standard tool for evaluating concentration in trade structures (European Commission, 2021). By capturing the distribution of supplier shares within a product category, the HHI provides a quantitative indicator of potential external dependence. However, its explanatory power is limited when used in isolation, as concentration does not capture the strategic importance or substitutability of the product.

Recent contributions have addressed this limitation by combining concentration metrics with measures of exposure and substitutability (Magerman & Consonni, 2025). This perspective highlights that economically significant product categories must be distinguished from statistically concentrated but marginal trade flows. However, empirical analyses that systematically track the dynamic evolution of supplier concentration at a detailed product level remain limited. This is particularly relevant for small open economies embedded in European manufacturing networks, where exposure patterns may shift over time in response to external shocks. These limitations motivate a product-level and time-sensitive analysis of supplier concentration, with particular attention to the evolution of strategic import dependence in the Slovak case.

2 METHODOLOGY

Data

The empirical analysis is based on international trade data from the BACI database compiled by CEPII (CEPII, 2023). BACI provides harmonized bilateral trade flows at detailed product levels and is widely used in empirical trade research due to its reconciliation of mirror statistics and consistency across reporting countries.

The analysis covers the period 2019-2023 and focuses on Slovakia as the importing country. Imports are disaggregated at the HS4 level. The HS4 aggregation provides sufficient product granularity to capture structural concentration patterns while avoiding excessive volatility that may arise at more disaggregated levels (e.g., HS6), where small trade flows can artificially inflate concentration measures. At the same time, HS4 ensures comparability across years and statistical stability in concentration calculations.

For each HS4 product category, total imports are calculated as the sum of imports from all partner countries. Trade values in the BACI dataset are expressed in thousand USD. All data processing and statistical computations were conducted using R statistical software (R Core Team, 2024).

Measuring Supplier Concentration

Supplier concentration is measured using the Herfindahl-Hirschman Index (HHI), a standard indicator of market concentration in industrial organization. For each HS4 product category, the HHI is calculated as:

$$HHI = \sum_{i=1}^{n} s_i^2 \quad (1)$$

where s_i represents the share of supplier i in total imports of a given HS4 product and n denotes the number of supplying countries.

The HHI ranges from 0 to 1. Higher values indicate greater concentration of imports among a limited number of suppliers. While the HHI originates in competition policy, its application in trade analysis serves as a proxy for structural exposure to external partners (European Commission, 2021; Magerman & Consonni, 2025). It captures the distribution of supplier shares but does not directly measure substitutability or political risk.

In addition to the HHI, the number of suppliers (n_suppliers) is calculated for each product to provide complementary information on diversification patterns. While recent national evidence for Slovakia (Steinhauser & Bolčo, 2025) applies both standard and weighted versions of the HHI and evaluates concentration at a more aggregated product level, this study employs an unweighted HHI at the HS4 level. The unweighted measure captures structural supplier concentration within individual product categories independently of their overall trade weight. Economic relevance is incorporated separately through a percentile-based threshold, allowing clearer identification of products that are simultaneously concentrated and economically significant. The average HHI reported in the results section is calculated as an unweighted mean across HS4 categories, reflecting structural concentration patterns rather than trade-size effects.

Identifying Strategic Import Dependence

Concentration alone does not necessarily imply strategic vulnerability. A highly concentrated product category may represent only a negligible share of total imports. Therefore, following the framework applied in the European Commission (2021), this study combines concentration measures with an economic relevance criterion. The term *strategic* is used here in a quantitative rather than policy or security sense: the analysis identifies strategic import dependencies within HS4 product groups, not a definitive list of strategically critical goods.

Strategically dependent products are identified based on two conditions:

1. Supplier concentration exceeding a threshold of HHI > 0.25.
2. Total imports of the product exceeding the 75th percentile of the import distribution in a given year.

The concentration threshold of 0.25 corresponds to commonly applied benchmarks in competition analysis and is used here as a heuristic indicator of relatively high supplier concentration. While higher thresholds (e.g., HHI > 0.4) are sometimes used to identify extreme concentration, the chosen level allows detection of structurally relevant concentration patterns at the product level without restricting the analysis to only highly exceptional cases.

The percentile-based economic relevance criterion ensures that only products with comparatively high import value in each year are classified as strategic. Using a relative threshold rather than an absolute value preserves comparability across periods despite fluctuations in aggregate trade levels and reduces sensitivity to macroeconomic shocks.

This dual-threshold approach reduces the risk of overstating vulnerability based solely on statistical concentration and aligns with recent efforts to quantify strategic dependence in a systematic manner (Magerman & Consonni, 2025). By applying these criteria consistently across 2019-2023, the analysis enables both cross-sectional and dynamic assessment of supplier concentration and strategic exposure.

Limitations

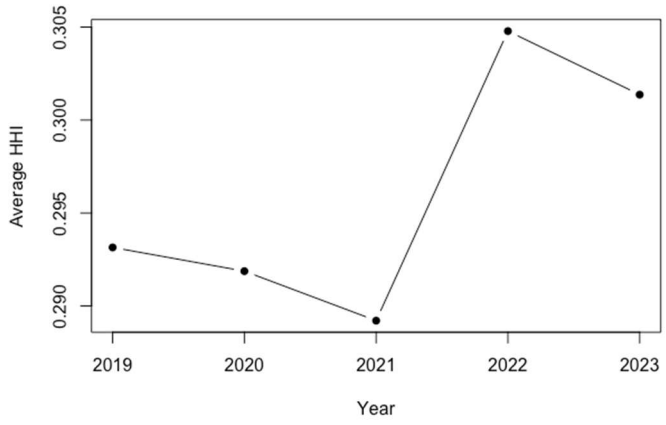
Several limitations should be acknowledged. First, the HHI captures concentration but does not directly account for substitutability between suppliers or geopolitical risk associated with specific partner countries. Second, the analysis is based on gross trade flows rather than value-added measures, which may not fully reflect embedded dependencies within complex value chains. Third, the threshold approach involves normative choices; however, these are grounded in established policy practice (European Commission, 2021) and are applied consistently across years. Alternative concentration thresholds could affect the number of products classified as strategic; however, the qualitative patterns observed remain robust.

3 RESULTS AND DISCUSSION

3.1 Dynamics of Supplier Concentration

Figure 1 presents the evolution of the average HHI for Slovak imports at the HS4 level between 2019 and 2023. During 2019-2021, concentration levels remained broadly stable, with the average HHI declining from 0.293 to 0.289, corresponding to a modest decrease of approximately 1.4%. This pattern indicates that supplier concentration changed only marginally before 2022.

Fig. 1 Average import concentration over time



Source: Author's calculations based on BACI International Trade Database (CEPII) and own processing in R.

In 2022, a distinct shift becomes observable as the average HHI increases to 0.305, representing a rise of approximately 5.5% compared to 2021 and the highest level recorded during the analysed period. Although the absolute increase appears moderate, it is notable because it interrupts the previously stable pattern observed in 2019-2021.

In 2023, the average HHI decreases slightly to 0.301 (-1.3% relative to 2022), yet remains above pre-2022 levels. This suggests that the 2022 increase was not fully reversed, even though concentration did not continue to rise. Overall, the pattern points to a temporary intensification of supplier concentration followed by only partial moderation.

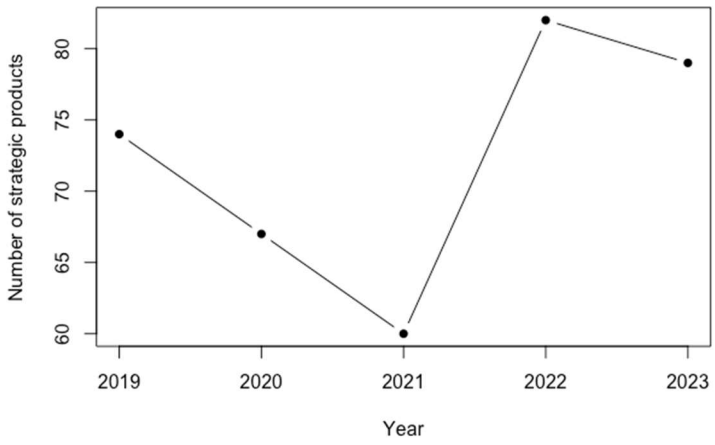
Expansion and Structure of Strategic Import Dependence

Figure 2 illustrates the number of product categories meeting both the concentration threshold (HHI > 0.25) and the economic relevance criterion. Between 2019 and 2021, the number of strategically dependent products declined from 74 to 60, representing a decrease of approximately 18.9%.

In 2022, however, the number increased sharply to 82 categories, corresponding to a rise of nearly 36.7% compared to 2021. This constitutes the most pronounced change observed during the analysed period. In 2023, a slight decline to 79 categories (-3.7%) is recorded; however, the level remains above that observed prior to 2022.

Together with the increase in average HHI shown in Figure 1, this pattern suggests that the change observed in 2022 was not limited to higher concentration within a few product groups, but also involved a broader expansion in the number of economically significant import categories classified as strategic.

Fig. 2 Development of strategic import dependencies (Slovakia)



Source: Author's calculations based on BACI International Trade Database (CEPII) and own processing in R.

While Figures 1 and 2 provide aggregate and count-based evidence of concentration dynamics, they do not reveal how concentration is distributed across product categories. To determine whether the 2022 increase reflects broader changes across the import structure or concentration within specific economically significant segments, a product-level distributional perspective is required. Figures 3 and 4 therefore examine the joint relationship between supplier concentration and total import value.

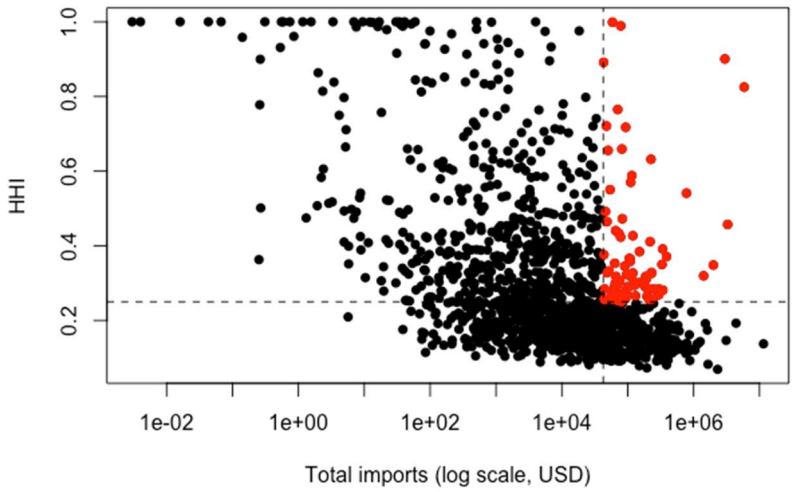
3.2 Distributional Structure of Concentration and Economic Relevance

Figures 3 and 4 show the joint distribution of supplier concentration and total import value at the HS4 level in 2022 and 2023. Import values are presented on a logarithmic scale to account for their skewed distribution.

In Figure 3, each point represents one product category. The horizontal dashed line marks the concentration threshold (HHI = 0.25), while the vertical dashed line indicates the economic relevance threshold (75th percentile of total imports). Product categories meeting both criteria are highlighted in red and are located in the upper-right quadrant. Most product categories remain below the concentration threshold, indicating that elevated concentration is not a general feature of the overall import structure. However, a smaller subset combines relatively high concentration with high import value, suggesting that strategic import exposure is concentrated in a limited number of economically significant categories.

Given that 2022 represents the year with the most pronounced increase in average concentration and strategic product counts, and 2023 captures the subsequent adjustment phase, the product-level and distributional analysis focuses on these two years. Earlier years exhibited comparatively stable patterns and are therefore not presented in detailed product-level form for reasons of parsimony.

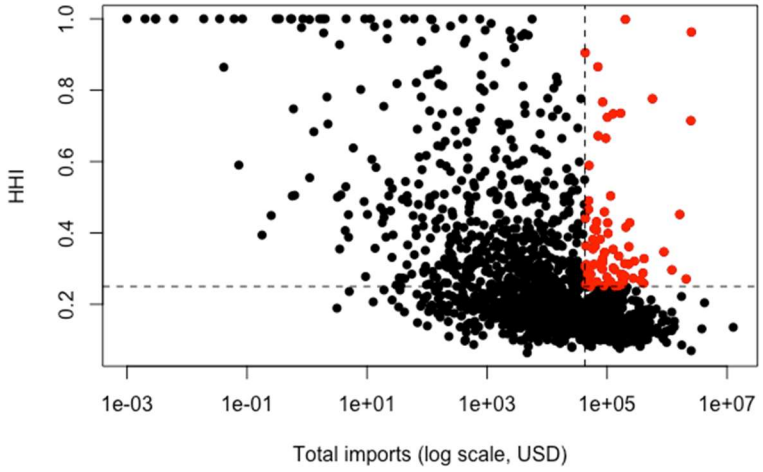
Fig. 3 Import concentration and economic relevance, Slovakia 2022



Source: Author's calculations based on BACI International Trade Database (CEPII) and own processing in R.

Figure 4 presents the relationship between supplier concentration and total import value in 2023. The overall distribution of product categories remains broadly comparable to 2022, with most observations concentrated in the lower part of the concentration spectrum (HHI < 0.25). Product categories exceeding both the concentration and economic relevance thresholds are again located in the upper-right quadrant. Although the number of such categories declines slightly compared to 2022, a distinct cluster of highly concentrated and economically significant imports remains visible, indicating that the partial moderation observed in 2023 did not eliminate the concentration patterns that emerged in the previous year.

Fig. 4 Import concentration and economic relevance, Slovakia 2023



Source: Author's calculations based on BACI International Trade Database (CEPII) and own processing in R.

Taken together, the scatterplots indicate that the increase in concentration in 2022 was not limited to marginal trade flows, but involved economically significant product categories. At the same time, concentration remains selective rather than system-wide.

Although the scatterplots show the overall distribution of concentrated and economically relevant imports, they do not identify the specific product categories behind these patterns. Tables 1 and 2 therefore present the ten most concentrated and economically significant strategic import dependencies in 2022 and 2023.

3.3 Product-Level Composition of Strategic Dependencies

Table 1 reports the ten most concentrated and economically significant strategic import dependencies in 2022 at the HS4 level. The highest concentration levels are observed in nuclear reactors (HS 8401), rail locomotives powered from an external source of electricity (HS 8601), and crude petroleum oils (HS 2709), all with HHI values above 0.9. At the same time, the number of suppliers varies considerably across product categories, from 3 to 31, indicating that high concentration may coexist with both narrow and broader supplier bases. Import values also differ substantially, ranging from USD 43 million (HS 9304) to nearly USD 5.9 billion (HS 2711), showing that concentration is not limited to low-value product groups.

Tab. 1 Top 10 strategic import dependencies in Slovakia, 2022 (HS4 level)

HS4	Product description	HHI	Total imports (thousand USD)	Number of suppliers
8401	Nuclear reactors	0.999	58,736	5
8601	Rail locomotives powered from an external source of electricity.	0.989	78,262	3
2709	Petroleum oils and oils obtained from bituminous minerals, crude.	0.900	2,985,150	9
9304	Other arms (e.g., spring, air or gas guns and pistols, truncheons).	0.891	43,029	24
2711	Petroleum gases and other gaseous hydrocarbons	0.825	5,855,210	29

HS4	Product description	HHI	Total imports (thousand USD)	Number of suppliers
2203	Beer made from malt	0.765	70,431	31
2702	Lignite, whether or not agglomerated (excluding jet)	0.721	47,588	9
8602	Other rail locomotives; locomotive tenders	0.717	93,170	5
8475	Machines for assembling electric or electronic lamps, tubes or valves or flashbulbs	0.660	81,482	23
8707	Bodies (incl. cabs), for the motor vehicles	0.656	50,343	28

Source: Author's calculations based on BACI International Trade Database (CEPII)

Table 2 presents the corresponding ranking for 2023. As in 2022, several product categories remain highly concentrated, with HHI values above 0.9 in three cases (HS 8401, HS 2711, and HS 9304). Import values range from USD 43 million (HS 9304) to more than USD 2.5 billion for petroleum gases (HS 2711) and crude petroleum oils (HS 2709), while the number of suppliers ranges from 4 to 34. This indicates that highly concentrated dependencies persisted in 2023, although their composition changed moderately.

Tab. 2 Top 10 strategic import dependencies in Slovakia, 2023 (HS4 level)

HS4	Product description	HHI	Total imports (thousand USD)	Number of suppliers
8401	Nuclear reactors	0.999	201,876	5
2711	Petroleum gases and other gaseous hydrocarbons	0.963	2,541,004	30
9304	Other arms (e.g., spring, air or gas guns and pistols, truncheons).	0.905	43,193	22
8601	Rail locomotives powered from an external source of electricity.	0.866	70,413	4
2601	Iron ores and concentrates, incl. roasted iron pyrites	0.776	571,266	13
2203	Beer made from malt	0.767	84,412	34
8702	Motor vehicles for the transport of 10 or more persons, incl. the driver	0.735	168,632	20
8707	Bodies (incl. cabs), for the motor vehicles	0.734	126,490	24
2901	Acyclic hydrocarbons	0.724	101,079	23
2709	Petroleum oils and oils obtained from bituminous minerals, crude.	0.715	2,494,633	12

Source: Author's calculations based on BACI International Trade Database (CEPII)

Across both years, energy-related commodities and heavy industrial inputs appear recurrently among the most concentrated and economically significant categories. This suggests that

concentration is particularly pronounced in upstream segments of the production structure rather than uniformly distributed across the import portfolio.

At the same time, the classification used in this paper refers to strategic import dependencies within product groups, defined quantitatively by the combination of supplier concentration and economic relevance, rather than to strategically critical goods in an intrinsic policy or security sense.

Taken together, the product-level evidence supports the distributional patterns observed in Figures 3 and 4 and indicates that the 2022 increase in concentration was driven both by a larger number of strategic product categories and by elevated concentration within economically significant imports.

3.4 Discussion

The increase in average supplier concentration in 2022, accompanied by an expansion in the number of strategically dependent product categories, can be interpreted within the broader debate on economic security and open strategic autonomy in the European Union. Recent contributions emphasise that supply chain resilience has become central to EU trade and industrial policy, particularly in the context of geopolitical fragmentation and external shocks (Schmitz & Seidl, 2023; Helwig, 2023).

The Slovak evidence suggests that the 2022 spike reflects a temporary intensification of concentration rather than a systemic breakdown of diversification. This pattern is consistent with arguments that global value chains may experience short-term adjustments in sourcing structures under conditions of heightened uncertainty (Gereffi et al., 2021). The partial moderation observed in 2023 further supports the interpretation of a shock-induced concentration effect rather than a sustained structural shift.

Importantly, product-level analysis shows that high concentration is not confined to marginal trade flows but includes economically significant categories such as energy-related commodities and selected industrial inputs. This aligns with the European Commission's identification of strategic dependencies in critical raw materials, energy, and advanced manufacturing segments (European Commission, 2021). The findings are also broadly consistent with recent national evidence for Slovakia (Steinhauser & Bolčo, 2025), which highlights elevated concentration in similar product groups. However, the HS4-level and time-sensitive approach adopted here reveals that the intensification in 2022 was concentrated within specific segments rather than uniformly distributed across the import structure.

The coexistence of high concentration and high import value underscores the importance of jointly analysing supplier concentration and economic relevance. As argued by Magerman and Consonni (2025), concentration metrics alone may overstate vulnerability unless combined with exposure measures that capture economic significance. At the same time, the results also illustrate the limits of purely quantitative classifications, as not all product categories identified as "strategic" necessarily correspond to critical dependencies in a policy sense. This suggests that concentration indicators should be interpreted together with sector-specific knowledge and policy context.

For small open economies embedded in European manufacturing networks, exposure to concentrated supplier structures is structurally embedded in their production model. The literature suggests that such economies may face heightened sensitivity to upstream disruptions due to limited substitution capacity in specialised industrial inputs (Coveri et al., 2025; Capello et al., 2025). From a practical perspective, the findings suggest that policy attention should focus on a relatively limited set of economically significant product groups, particularly energy-related and industrial inputs, where concentration is highest. This is consistent with the broader policy emphasis on targeted resilience measures within the framework of open strategic autonomy, rather than broad-based retrenchment or

indiscriminate intervention (European Commission, 2021; Schmitz & Seidl, 2023; Mariotti, 2025). The Slovak case therefore illustrates how supplier concentration can intensify under external shocks without implying a broad-based restructuring of trade patterns. Rather than systemic dependency, the evidence points to concentrated exposure within specific economically significant segments.

CONCLUSION

This paper examined supplier concentration and strategic import dependence in Slovakia between 2019 and 2023 using HS4-level trade data and the Herfindahl-Hirschman Index (HHI). By combining concentration thresholds with an economic relevance criterion, the analysis identified product categories that simultaneously exhibit high supplier concentration and significant import value.

The results indicate that while average concentration levels remained relatively stable in 2019-2021, a noticeable increase occurred in 2022, accompanied by a substantial rise in the number of strategically dependent product categories. Although partial moderation is observed in 2023, concentration levels and the scope of strategic dependencies remain above the levels recorded prior to 2022.

Product-level evidence shows that highly concentrated imports include economically significant categories, particularly energy-related and industrial inputs. This suggests that strategic import dependence in Slovakia is not broadly systemic but concentrated within a specific subset of product groups. Rather than indicating system-wide concentration across the import portfolio, the results point to a temporary intensification of supplier dependence in 2022, followed by only partial moderation in 2023.

From a practical and policy perspective, the findings suggest that attention should focus on a relatively limited set of economically significant product groups where concentration is highest, especially in energy-related and selected industrial inputs. This implies that targeted monitoring and diversification measures may be more appropriate than broad-based intervention across the entire import structure. The paper therefore contributes to the debate on economic security and open strategic autonomy by providing HS4-level evidence from a small open EU economy.

At the same time, the results should be interpreted in light of several limitations. The analysis is based on gross trade flows and the HHI captures supplier concentration, but not substitutability between suppliers or the geopolitical risk associated with specific partner countries. In addition, the identification of strategic dependencies depends partly on threshold choices. These limitations suggest that quantitative concentration indicators should be complemented by sector-specific and policy-oriented assessment.

Future research could extend the analysis by weighting identified dependencies according to their relative share in Slovakia's total imports, by examining supplier-level and firm-level exposure, and by comparing concentration patterns across EU member states. It would also be valuable to assess whether renewed geopolitical tensions and recent disruptions in energy, fertiliser, and rare-gas supply chains intensify strategic dependencies once relevant trade data become available (European Commission, 2025; World Bank, 2025).

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