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ARTICLE

Structural Analysis of Regional Critical Imports and Their Impact on Economic Dynamics

Análise Estrutural das Importações Críticas Regionais e seu Impacto na Dinâmica Econômica

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ABSTRACT | Objective: In the context of strengthening deglobalization and external pressure, this study develops methodological tools for identifying critically important imported product groups and constructs models that define the relationship between critical imports and regional economic growth. **Methodology/Approach:** Critical imports are identified through a three-stage authentication process: (1) import volumes, (2) share in the value added of the region's final product, and (3) country of origin. The resulting volume and cost parameters serve as the basis for spatial data analysis to determine the impact of critical imports on economic dynamics. Object: regions of the Volga Federal District (Russia). Subject: methodological approaches to assessing critical imports and their impact on the sustainability of regional economic dynamics. **Originality/Relevance:** The study offers a comprehensive regional-level analysis of import dependence aimed at identifying the most critical groups of goods imported into regions; this allows assessment of the vulnerability of regional economic systems and the effects of import localization on sustainable development. **Main Conclusion:** The research identifies commodity groups that form the framework of critical imports for the Volga Federal District and implements economic-mathematical models that quantify the influence of critically important imported goods on industrial growth. **Theoretical/Methodological Contribution:** A clear, criteria-based procedure for detecting critical imports, combined with spatial data analysis and modeling, provides a replicable framework for assessing critical import dependence and its consequences for regional economic dynamics.

Keywords | Import dependence, Import substitution, Regional economic systems, Sustainability of economic dynamics, Global supply chains, Industrial production

RESUMO | Objetivo: No contexto do fortalecimento da desglobalização e da pressão externa, este estudo desenvolve ferramentas metodológicas para identificar grupos de produtos importados de importância crítica e constrói modelos que definem a relação entre importações críticas e o crescimento econômico regional. **Metodologia/Abordagem:** As importações críticas são identificadas por meio de um processo de autenticação em três etapas: (1) volumes de importação, (2) participação no valor

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adicionado do produto final da região e (3) país de origem. Os parâmetros de volume e custo resultantes servem como base para a análise de dados espaciais, a fim de determinar o impacto das importações críticas na dinâmica econômica. Objeto: regiões do Distrito Federal do Volga (Rússia). Tema: abordagens metodológicas para avaliar importações críticas e seu impacto na sustentabilidade da dinâmica econômica regional. **Originalidade/Relevância:** O estudo oferece uma análise abrangente em nível regional da dependência de importações, visando identificar os grupos de bens mais críticos importados para as regiões; isso permite avaliar a vulnerabilidade dos sistemas econômicos regionais e os efeitos da localização das importações no desenvolvimento sustentável. **Conclusão principal:** A pesquisa identifica grupos de produtos que constituem a base das importações críticas para o Distrito Federal do Volga e implementa modelos econômico-matemáticos que quantificam a influência de bens importados de importância crítica no crescimento industrial. **Contribuição teórica/metodológica:** Um procedimento claro, baseado em critérios, para detectar importações críticas, combinado com análise e modelagem de dados espaciais, fornece uma estrutura replicável para avaliar a dependência de importações críticas e suas consequências para a dinâmica econômica regional.

Palavras-chave | Dependência de importações, Substituição de importações, Sistemas econômicos regionais, Sustentabilidade da dinâmica econômica, Cadeias de suprimentos globais, Produção industrial

1 INTRODUCTION

The need to search for and develop import substitution models in the context of global changes – expressed in the intensification of sanctions pressure and the reconfiguration of international economic relations is increasingly attracting the attention of both Russian and foreign scholars (Akshalova et al., 2025). The practice of strengthening global competitive positions by a number of states through the active application of restrictive measures requires a renewed intensity in the study of the theory and practice of import substitution economics, with the aim of finding new solutions for building adaptive models of economic growth (Chumakova et al., 2025). It is necessary to refine the conceptual approaches established in theory for studying effective mechanisms of import substitution, to develop methodological tools for assessing the impact of critical imports on the sustainability of economic development, and, on this basis, to determine the prospects of economic dynamics (Morgacheva et al., 2025).

It is important to emphasize that this problem statement requires focusing attention not only at the national economic level but also at the regional level. This is due to the fact that regions, having very different levels of integration into global supply chains, demonstrate the same heterogeneity in their ability to adapt to transformations in external economic relations (Kamysbayev et al., 2025). In this regard, it is extremely important, when developing a unified state policy, to understand and take into account such subject-level features. This approach, consistent with the position of a number of Russian and foreign scholars (Bachmann et al., 2015; Malik & Wickramasinghe, 2013; Safiullin & Elshin, 2023), will allow for the formation of more effective trajectories for implementing import substitution policies at the national level (Abdullayev et al., 2025).

Within the framework of sustainable competitive intelligence, the identification of critical imports is treated not as descriptive accounting but as a rules-based instrument for decision-making. In this study, criticality is defined as product groups imported from unfriendly countries whose contribution to the value added of the region's final output exceeds 30 percent; the econometric model with random effects shows that a reduction of one million rubles in gross critical imports

is associated with approximately 0.75 million rubles lower industrial output. Taken together, the screening criterion and the quantitative estimate transform trade statistics into leading indicators for policy, enabling predefined thresholds for intervention instead of unsystematic reactions.

Viewed through this lens, the resulting list of priority product groups supports long-term strategies of economic resilience at both regional and national levels. It indicates where diversification toward friendly countries should be pursued, where localization should be supported through supplier development and targeted finance, and where acceleration of standardization and certification, together with directed research and development, is warranted when substitutability is limited; the set of measures is then updated in an iterative cycle of monitoring, assessment, decision-making, and learning as origin structure, supplier concentration, and lead times evolve.

In other words, understanding the degree of regional integration into global supply chains and identifying, on this basis, the product groups that are critical for the regional economy provides a foundation not only for developing predictive assessments of regional economic progress but also for determining the priorities for implementing import substitution policies both at the regional level and at the level of the national economy through the aggregation of territorial data.

2 THEORETHICAL FRAMEWORK

The study of import dependence in economic systems and the implementation of import substitution strategies is well elaborated in economic theory. Over the course of many decades, approaches and perspectives on these phenomena have changed, shaped by the challenges of the time and forming corresponding concepts for the implementation of foreign economic policy mechanisms.

Modern realities are characterized by new opportunities and threats, primarily associated with turbulence in foreign markets amid intensifying competitive pressures in the global economy. Under these conditions, new perspectives and approaches are emerging for the implementation of import substitution policies, taking into account the transforming institutional and market environment. At the forefront are scholarly works focused on developing measures for implementing forced import substitution policies. These studies are particularly relevant in the context of global expansion of sanction restrictions, which disrupt established market trajectories of export–import flows and pose threats to the sustainable development of economic systems both those subjected to external pressure and those initiating sanctions.

The rethinking of theoretical approaches under a paradigm shift in global economic relations and the reconfiguration of the world order predetermines the need for the development of relevant models of economic development. These should be based, among other things, on foreign economic policy that reflects the transforming institutional and market environment. It is important to emphasize that such models must rely primarily on a comprehensive and systemic assessment of critical imports, since restrictions on their supply entail risks for economic development. In other words, the issue arises of a methodological justification for critical import dependence. Its objective identification will significantly determine the subsequent directions of import substitution policy, including with consideration of identified regional specificities.

When referring to the study of import dependence as a separate category in economic theory, it should be noted that, in the broadest sense, it is understood as a condition of the economy in which economic actors are dependent on imported goods. The majority of academic works focus their empirical assessment of this category on the ratio of import volumes to the production of similar goods within the framework of national or regional economic systems. This approach is clearly reflected in the works of Mukhanov (2016), Faltsman (2015), Bragin (2024), Ogudjouiba et al. (2011), Feng et al. (2012), Warburton (2012), and others.

A high level of advancement in the study of import dependence at the level of individual economic systems is demonstrated in the works of Kadochnikov (2006), Moiseev (2022), Bukhvald and Ivanov (2017), Connolly and Hanson (2016), de la Poza (2022), Xiao et al. (2018), and others. Their research is based on international trade data that take into account and assess the creation of value added in the process of goods moving along international supply chains (construction of inter-country input–output tables) (Kuzminov et al., 2023). Among the significant scientific research projects in this field are also the works of Casella et al. 2019.

The key aspect revealing the essence of their approach is the analysis of time series covering 189 countries, reflecting flows of export–import operations in the world economy according to such indicators as foreign value added (FVA), domestic value added (DVA), and indirect value added (DVX). The constructed input–output tables demonstrate the value flows of added value created in one country and its import into others. Thus, these tables provide the basis for assessing the import dependence of national economic systems and forecasting their development, taking into account scenario-based modeling of external factors relevant to specific jurisdictions.

Undoubtedly, the approaches presented are not exhaustive in the study and assessment of import dependence in economic systems. There exists a broad body of academic work in this field. Among them are studies that focus on regional aspects of these issues, including those related to the development of mechanisms for implementing import substitution policies under external constraints (Aspromourgos, 1988; Connolly & Hanson, 2016; Dong et al., 2019; Ullrich, 2017).

A rapid review of Russian and foreign approaches to assessing import dependence and its potential impact on the sustainability of economic dynamics allows us to highlight three key aspects that require strengthening and further development within the framework of methodological solutions:

1. Insufficient consideration of the country of origin of imported goods (friendly/unfriendly). If a country falls into the category of “unfriendly,” even minor disruptions in its import supply chains may lead to significant consequences for the sustainable development of the economy. This approach largely aligns with the critical analysis of existing theoretical methodological solutions for assessing import dependence, as presented by the Higher School of Economics (Connolly & Hanson, 2016). According to it, “an analysis of gross imports does not allow for the assessment of the real producer of a given product” (Connolly & Hanson, 2016, p. 2).
2. The need to strengthen research on import dependence at the meso-level. This level is an essential component in the development of national programs for import substitution under systemic transformations, including those caused by external constraints.

3. The need to enhance methodological approaches enabling the construction of economic–mathematical models. These models should assess the impact of the economy's vulnerability to imports on its prospects for economic growth.

The content and specification of these aspects require methodological advancement and theoretical reflection. An attempt at a partial solution to the outlined problems and promising directions for developing the theory and practice of import substitution economics is presented in this study. The proposed conceptual perspective on the existing debates and directions of economic theory development in the field of import substitution policy relies on three basic elements: (1) the affiliation of imports to unfriendly jurisdictions, (2) the prioritization of the meso-level of research, and (3) the need to construct model frameworks that assess the impact of import structural characteristics on the economic dynamics of regional economic systems. Together, these elements form the basis for the development of methodological tools and their subsequent testing.

Guided by the identified aspects and substantive arguments, the purpose of this study is to develop methodological tools that allow for the assessment and identification of critical regional imports and, on this basis, the construction of econometric equations that provide a foundation for analyzing the impact of critically important imported product groups on the prospects for industrial development of regional economic systems.

3 METHODS AND MATERIALS

The initial stage of the study, aimed at identifying patterns of the influence of import dependence in regional economic systems on the prospects of their economic dynamics, is the identification of critical imports. In this study, critical imports are defined as product groups imported from unfriendly countries whose share in the creation of value added in the region's final output exceeds 30%. This threshold was determined based on statistical grouping (using Sturges' method) of imported product categories supplied to the regions of the Volga Federal District.

Assuming that products imported through global supply chains depend on the level of aggregate demand for them, a significant excess of FEACN import over local production volumes indicates a critical level of dependence on such imported goods. In this case, disruptions in established supply chains may lead to cost-push inflation and adjustments to production processes under conditions of limited availability of required products for final and intermediate consumption.

The identification of a region's critical imports provides the foundation for constructing models to diagnose their impact on key macroeconomic indicators. In this study, one such indicator is the volume of industrial production. The methodological basis of the research is the spatial analysis of panel data, which includes critical types of imported product groups and industrial production volumes of the studied regional group (subjects of the Volga Federal District). Since the data analyzed have a panel structure, their use offers several advantages. A large number of observations increases the degrees of freedom, reduces multicollinearity of explanatory variables, and allows for more efficient parameter estimates. Another advantage of panel data is the ability to control for heterogeneity across units in the sample, preventing aggregation bias that may arise in the analysis of dynamic or

cross-sectional data. Moreover, panel models can reveal effects that cannot be observed separately in cross-sectional data or time series, namely by tracing individual effects across time.

The algorithm and sequence of iterative steps for assessing the spatial effects of critical imports on the parameters of a region's economic development are presented below:

- **Step 1.** Identification of critically significant goods imported into the region.
- **Step 2.** Construction of panel data including parameters characterizing critical imports and industrial development volumes of the regional group.
- **Step 3.** Testing of panel data within the framework of constructing specific classes of models: pooled OLS (POLS), random effects model (RE), and fixed effects model (FE).

  Pooled OLS model.

  The pooled model can assess the influence of critical import volumes on the production volumes of similar goods without accounting for individual and random effects. In general form, it is written as:

$$y_{it} = X_{it}b + a \quad (1)$$

  Fixed effects model (FE).

  In this model, unobservable and unknown variables influencing production volumes are accounted for by adding dummy variables for all analyzed FEACN. Thus, this method incorporates the influence of common effects on the analyzed "panels." The model assumes the existence of an unobservable effect that is identical for all dependent variables.

$$y_{it} = \mu + X_{it}b + a_i + \varepsilon_{it} \quad (2)$$

  The results of this stage make it possible to assess the relationship between import volumes of critical FEACN and production volumes. However, the inclusion of dummy variables in the model makes it impossible to interpret the parameters of the resulting equation.

  Random effects model (RE).

  To account for individual effects influencing the analyzed foreign economic activities, a panel data model with random effects is applied.

- **Step 4.** Justification of the choice and specification of the panel data model using the Hausman test and Breusch–Pagan test. The Hausman test allows verification of the hypothesis when choosing between a random effects model and a fixed effects model. Two hypotheses are tested:
- **Step 5.** Assessment of the influence of identified critical FEACN on macroeconomic dynamics.

  For the analysis, indicators characterizing import volumes and production volumes in the Volga Federal District across 103 FEACN for the period 2015–2022 (a total of 824 observations) were selected. At the first stage, critical product groups for the economies of the Volga Federal District regions were identified.

4 RESULTS

Based on the results of the analysis, within the framework of the proposed methodological tools, the group of critical imports of the studied regions of the Volga Federal District included 21 product categories:

- Compression-ignition internal combustion piston engines (diesel or semi-diesel);
- Bulldozers with straight or angled blades, graders, levelers, scrapers, mechanical shovels, excavators, single-bucket loaders, tamping machines, and road rollers, self-propelled;
- Machinery and equipment for lifting, moving, loading, or unloading (e.g., lifts, escalators, conveyors, cableways), other;
- Moulding boxes for metal foundry; foundry pallets; foundry patterns; moulds for casting metals (except ingot moulds), metal carbides, glass, mineral materials, rubber, or plastics;
- Fork-lift trucks; other trucks fitted with lifting or handling equipment;
- Lathes (including multi-purpose lathes), metal-cutting;
- Grinding, sharpening, polishing, honing, lapping, finishing machines for working metal or cermets with grinding stones, abrasives, or polishing agents;
- Metal-cutting machines (including unit construction machines of linear design) for drilling, boring, milling, threading external or internal threads by metal removal, other than lathes (including multi-purpose lathes);
- Electric motors and generators (excluding generating sets);
- Organic chemical compounds;
- Other organo-inorganic compounds;
- Flat-rolled products of iron or non-alloy steel, of a width of 600 mm or more, cold-rolled (cold-reduced), not clad, plated, or coated;
- Ferroalloys.

According to the proposed algorithm, at the next step panel data models are constructed, including the identified types of critical imports in relation to the production volumes of similar goods in the studied regional group. As an example, the data structure for the HS code “Bulldozers with straight or angled blades, graders, levelers, scrapers…” is presented in Table 1.

Table 1. Demonstration of the structure of the initial data using the example of FEACN "Bulldozers with straight or angled blades..."

		X,	Y
FEACN name	**Time period**	**Import volume**	**Production volume**
Bulldozers with straight or angled blades, graders, levelers, scrapers, mechanical shovels, excavators, single-bucket loaders, tamping machines, and self-propelled road rollers	2015	103	204
	2016	173	105
	2017	584	184
	2018	963	226
	2019	2017	302
	2020	2004	581
	2021	3672	841

Source: compiled by the authors based on the data of the Federal State Statistics Service (n.d.).

Guided by the proposed methodological approach, pooled models, fixed effects models, and random effects models were constructed. Based on the results of the calculations, it was established that for modeling the dependence of industrial production volumes on critical import volumes, the most statistically significant is the equation of the model with random effects:

$$V_{prod} = 9877{,}59 + 0{,}75V_{imp} \quad (3)$$

The results of the random effects model are presented in Table 2.

Table 2. Results of the random effects model

	Coefficients	Standard error	t-statistic	P-Value
Y-intercept	9877.59	3316.4033	2.97	0.003
Import volume	0.75	0.0015	47.31	1.0847E-71

Source: calculated by the authors.

$$R^2 = 0{,}98;\ F_{stat} = 0 \quad (4)$$

The interpretation of the developed equation allows the following fundamental conclusion: a reduction in gross critical imports by 1 million rubles leads to a slowdown in industrial production volumes in the studied regional group by 750 thousand rubles.

According to the proposed five-step research scheme, the next stage of the study is an analysis of the impact of critical FEACN on macroeconomic dynamics. For this purpose, a correlation-regression analysis was carried out for product groups critically significant to the regions of the Volga Federal District. The results are presented in Table 3.

Table 3. Results of regression analysis

FEACN	R2	B1 (elasticity coefficient)	t_{stat}	P value
Compression-ignition internal combustion piston engines (diesel or semi-diesel)	0.79	158881	2.41	0.03
Bulldozers with straight or angled blades, graders, levelers, scrapers, mechanical shovels, excavators, single-bucket loaders, tamping machines, and self-propelled road rollers	0.97	176491	9.07	0
Machinery and equipment for lifting, moving, loading or unloading (e.g., lifts, escalators, conveyors, cableways), other	0.71	546137	2.66	0.03
Moulding boxes for foundry; foundry pallets; foundry patterns; moulds for casting metals (except ingot moulds), metal carbides, glass, mineral materials, rubber, or plastics	0.70	2266276	2.39	0.04
Fork-lift trucks; other trucks fitted with lifting or handling equipment	0.96	236514	8.77	0
Lathes (including multi-purpose lathes), metal-cutting	0.67	24395364	2.70	0.04
Grinding, sharpening, polishing, honing, lapping, finishing machines for working metal or cermets with grinding stones, abrasives, or polishing agents	0.79	107723	2.89	0.03
Metal-cutting machines (including unit construction machines of linear design) for drilling, boring, milling, threading external or internal threads by metal removal, other than lathes (including multi-purpose lathes)	0.60	774117	2.66	0.04
Electric motors and generators (excluding generating sets)	0.76	929	2.60	0.04
Organic chemical compounds	0.66	48657	2.46	
Other organo-inorganic compounds	0.70	511665	2.11	0.04
Flat-rolled products of iron or non-alloy steel, of a width of 600 mm or more, cold-rolled (cold-reduced), not clad, plated, or coated	0.84	206687	3.51	0.01
Ferroalloys	0.60	598497	2.10	0.01

Source: developed by the authors.

5 DISCUSSION

The obtained estimates allow us to make the following basic conclusion: critical imports significantly determine the dynamics of economic growth in the regions of the Volga Federal District. The implemented spatial data analysis, revealing the features of the relationship between critically important imported product categories and industrial production volumes, indicates a very high level of correlation for the studied regional group. This conceptual conclusion formed the basis for constructing econometric models that assess the required parameters for each critical FEACN. The derived estimates clearly demonstrate the importance of ensuring the supply of critical imports to the regions of the Volga Federal District. Their restriction, judging by the data showing R^2 coefficient values (Table 3, Figure 1), may entail substantial risks of slowing economic dynamics as a result of disruptions in the regularity of business and reproduction processes.

At the same time, it is important to emphasize that, according to the results of the assessments, not all of the analyzed critical FEACN have a decisive impact on economic dynamics in the regions of the Volga Federal District. The list of product categories that do not exert a determining influence on GSP among the analyzed critical imports includes:

- Electric motors and generators (excluding generating sets);
- Ferroalloys.

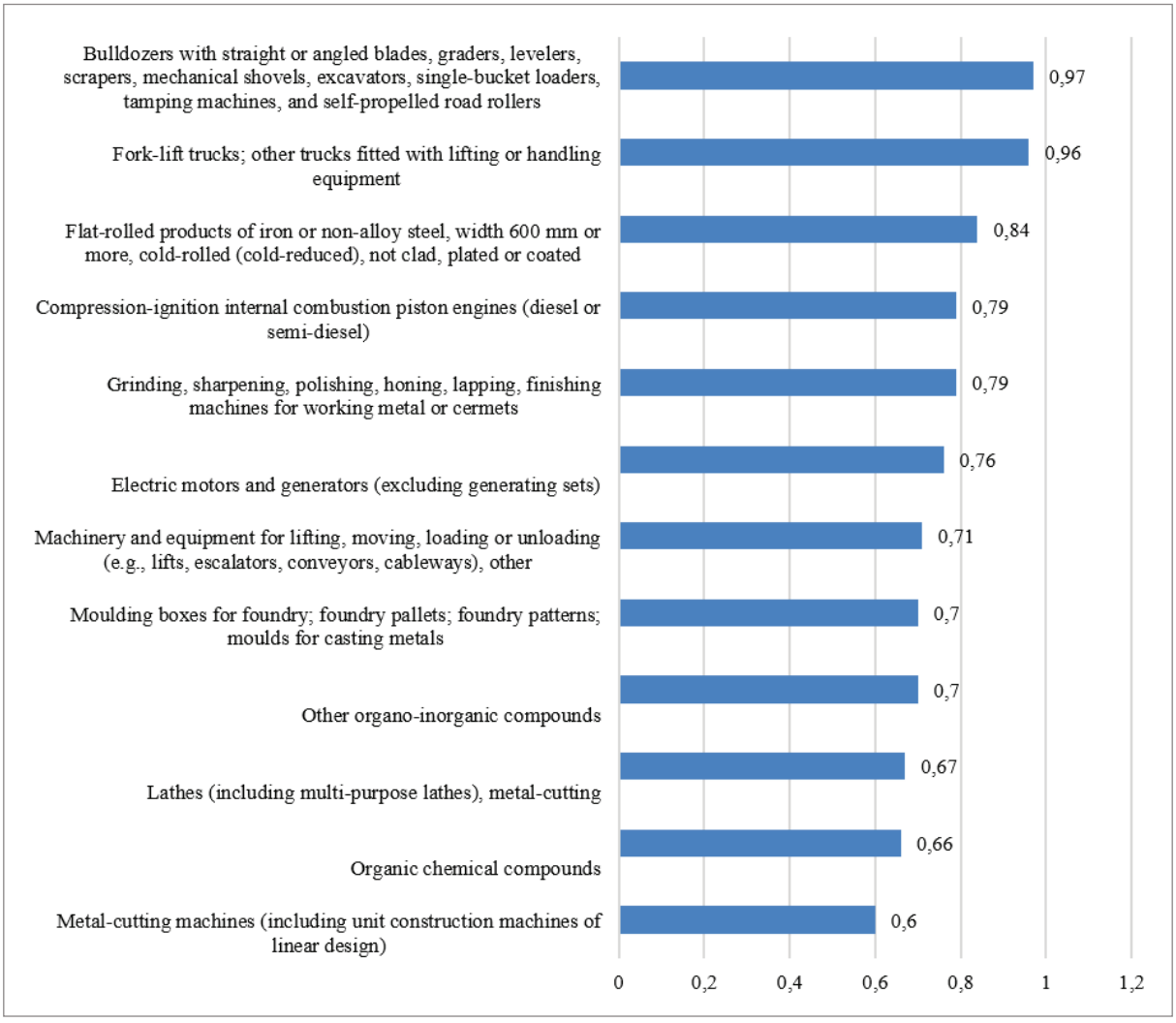

Figure 1. Correlation coefficient values between FEACNcrit. and the growth rates of aggregated GRP of the Volga Federal District

Source: developed by the authors.

In general, it should be noted that the obtained estimates largely correspond to the results of studies conducted by Russian and foreign researchers in the context of the issues studied here. At the same time, the distinctive feature of this work compared to existing studies is the proposed methodological toolkit, which provides the possibility of studying the impact of critical imports on the prospects of economic dynamics in regional economic systems. This approach differs from existing ones in its orientation toward the meso-level of research, as well as in its new perspective for obtaining empirical estimates generated on the basis of spatial data analysis and the construction of corresponding regression models, which are maximally adapted to the identification and assessment of the influence of critical imports on the sustainability of regional economic dynamics.

Using the study's definition of *critical imports* (share ≥30% of value added and originating from unfriendly jurisdictions), the preferred random-effects model shows that a 1 million-ruble shortfall

in critical imports is associated with a ~0.75 million-ruble decline in industrial output. With 21 FEACN groups identified as critical (e.g., precision machine tools, moulds/tooling, construction and handling equipment, organo-inorganic chemicals, flat-rolled steel), the results indicate concentrated exposure where even brief supply interruptions can propagate to regional growth.

- Considering everything said in this study, we would suggest the following for regional and national policymakers:
- Diversify and friend-shore key imports by securing alternative suppliers for high-impact FEACN groups (machinery, tooling, construction equipment).
- Build short-term safety buffers (up to 90 days) for components that cannot yet be replaced domestically.
- Accelerate approval and standards processes to integrate new suppliers and substitute products more quickly.
- Support local substitution through targeted financing, SME development, and joint R&D in complex sectors such as precision tools and mechatronics.
- Use public procurement and trade corridors to guarantee demand for domestic substitutes and strengthen links with friendly-origin partners.
- Invest in workforce skills and maintenance capacity to reduce dependence on external servicing.
- Monitor low-impact categories only, focusing resources on imports with the highest value-added share and sensitivity to shocks.

6 CONCLUSIONS

The implemented analysis, aimed at identifying patterns of the influence of critical imports in the Volga Federal District on the prospects and sustainability of its economic dynamics through the use of panel data tools, demonstrates a very high level of validity of the developed methodological framework. It makes it possible not only to identify critical import positions for the regional group but also to determine the general patterns of their impact on gross regional product. Thus, the results of the study established that critical imports significantly determine the dynamics of economic growth in the regions of the Volga Federal District. Restrictions on their supply unequivocally lead to a slowdown in economic growth in the absence of alternative supplies from friendly countries or domestic production of similar goods substituting for critical imports.

The obtained methodological and practical results contribute to the expansion of the methodological foundation for research in the theory of import substitution economics and define the contours of the development of regional economic theory in the context of models of sustainable development of economic systems. The proposed methodological tools open a new research perspective for assessing the import dependence of regional economic systems, identifying potential threats, opportunities, and risks, as well as determining strategies of import substitution at both the macro- and meso-levels adapted to the emerging institutional and market environment.

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