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Spatial Analysis and Assessment of the Impact of Critical Imports on the Sustainability of Regional Economic Growth

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ABSTRACT: The study examines import-substitution models under conditions of global economic fragmentation, external trade restrictions, and disruptions in international supply chains. The aim of the article is to develop a methodological approach for identifying critically significant imported goods and assessing their relationship with the sustainability of regional economic growth. The empirical analysis focuses on the regions of the Volga Federal District of the Russian Federation. The study combines a three-stage authentication procedure for identifying critical imports at the HS/FEACN-code level, FEACN–RCPEA matching, and panel-data modeling. The novelty of the study lies in linking commodity-level critical import identification with regional production categories and estimating the economic significance of critical import dependence at the regional level. The results show that 21 groups of goods can be classified as critical imports. The preferred random effects model indicates that a reduction in critical imports by 1 million rubles is associated with a decrease in production volume by approximately 750 thousand rubles. Theoretically, the study connects import dependence with regional resilience and supply-chain transformation. Practically, the findings support selective import-substitution policy, supplier diversification, and targeted regional industrial support.

Keywords: Import dependence, Critical imports, Sustainability of economic growth, International supply chains, Spatial panel data analysis.

I. INTRODUCTION

In the context of systemic transformations rapidly gaining momentum in the global economy expressed in the shift from globalization to fragmentation of international economic relations, the strengthening of policies aimed at national economic autonomy, the expansion of external trade restrictions, external uncertainty, and similar factors the issues of implementing import substitution policy at both the national and regional levels acquire particular significance for both theory and practice [1-3]. Given the urgency of this matter in the current realities of the reconfiguration of international economic relations, its study requires a comprehensive and adaptive approach that includes not only the identification of critical imports but also the assessment of their impact on the stability of economic system dynamics under external disruptions. Addressing this challenge presupposes the need to systematize accumulated theories and to develop improved methodological approaches for studying import substitution policy through the prism of the unfolding geo-economic agenda.

The theoretical basis of this problem can be considered through several complementary research perspectives. The concept of regional economic resilience emphasizes the ability of regional economies to withstand external shocks, adapt to changing conditions, and restore sustainable growth trajectories [4, 5]. The theory of import dependence and dependency-based approaches indicate that reliance on external sources of intermediate inputs, machinery, technologies, and strategically important goods may increase the vulnerability of national and regional production systems [1, 6]. In turn, studies of global value chains and supply-chain disruptions show that imported intermediate inputs are not only a component of foreign trade flows but also an important factor in the continuity of domestic production and value-added creation [7-9]. Therefore, the analysis of critical imports at the regional level makes it possible to connect the issues of import substitution, regional resilience, and supply-chain transformation within a single analytical framework.

It is important to emphasize that this problem setting requires focusing attention not only at the national level of the economy but also at the regional one. This is due to the fact that meso-level economic systems, despite their integration into a unified national foreign economic policy, demonstrate highly differentiated levels of adaptation to the transformation of international supply chains under systemic transformations [10-14]. In this regard, rethinking the concept of adaptive import substitution policy under the conditions of the reconfiguration of international economic relations must necessarily account for the regional component. Such an approach predetermines the necessity of developing relevant models of economic development at the regional level, taking into consideration a comprehensive assessment of the degree of integration of regions into export-import operations. This is particularly important because the same external trade restrictions may generate different economic effects across regions depending on their industrial specialization, import structure, and participation in value-added chains.

Despite the formation of a substantial body of research on import substitution, import dependence, and regional adaptation to external market perturbations, several methodological gaps remain. Existing studies often focus either on national-level import dependence or on general regional development problems, while the identification of region-specific critical import positions at the HS-code level remains insufficiently elaborated. In addition, previous studies do not always link the revealed critical import groups with domestic production categories and regional value-added dynamics. As a result, the economic consequences of critical import dependence for regional growth sustainability remain only partially assessed. This study addresses this gap by combining the identification of critical import commodity groups with panel-data modeling of their impact on regional production dynamics. Based on this research gap, the study addresses the following research questions:

- RQ1. Which imported commodity groups can be classified as critical for regional economic systems at the HS-code level?
- RQ2. How can imported commodity groups be linked with domestic production categories in order to assess regional vulnerability to external supply-chain disruptions?
- RQ3. How do critical import volumes affect the sustainability of regional production dynamics?
- RQ4. How can panel-data models be used to assess the relationship between critical imports and regional economic growth while accounting for unobserved heterogeneity across commodity groups and regions?

This study's contributions include the following. First, it develops and applies a multi-stage procedure for identifying critical imports at the regional level. Second, it establishes a link between import data by HS codes and domestic production categories using the FEACN–RCPEA mapping. Third, it proposes an empirical model for assessing regional vulnerability to international supply chain transformations. Fourth, it evaluates the relationship between critical import volumes and regional production dynamics using panel data models. These results expand the methodological framework for studying regional import dependence and provide practical evidence for the design of adaptive import substitution policies and regional industrial development.

II. RELATED WORK

The regional economy of import substitution represents a complex economic category. Its non-triviality is manifested primarily in the interpretation of the category itself, as well as in the justification of mechanisms for identifying critical imports, taking into account current institutional and market tasks and constraints that define its forms of implementation (forced import substitution; import substitution as a mechanism for ensuring global competitiveness; import substitution as a mechanism for stimulating local production and improving the efficiency of structural economic development).

An essential component of research on import substitution policy is also the understanding of the directions of strategic adaptation of a region to the transformation of international supply chains. This aspect is determined by the degree of criticality of import supply restrictions with respect to particular product groups supplied to the region from abroad. The identification and definition of critical import parameters at the regional level constitutes a key tool in the development of a comprehensive national agenda in the field of import substitution. At the same time, one of the most significant issues in this context is defining critical dependence on imports [15] and identifying macroeconomic risks generated as a result of its localization within unfolding external restrictions.

The above-mentioned aspects, which are particularly relevant today for the Russian economy and other economies operating under external trade restrictions, have shaped a broad body of academic work dedicated to the development of models of import dependence and its influence on macroeconomic trends under systemic transformations. However, these studies mainly concentrate their research focus on national economic systems. Regions and models of their economic development remain unjustly at the periphery of scholarly inquiry. Yet it is precisely the regional level of research on import substitution that provides the foundation for formulating a unified macroeconomic policy in the sphere of adapted development programs at the national level. Considering this position, subsequent research attention will be directed toward the review, systematization, and critical analysis of models and methods that have emerged in theory and practice for assessing the import dependence of regional economic systems and the prospects for determining the dynamics of their economic development.

At the theoretical level, the study of regional critical imports can be considered at the intersection of several research traditions. The first is the theory of regional economic resilience, which explains the ability of regional economic systems to withstand external shocks, adapt to structural changes, and restore sustainable growth trajectories [4, 5]. Within this approach, critical imports are interpreted not only as a component of foreign trade flows but also as a factor influencing the adaptive capacity and stability of regional production systems. The second perspective is associated with import-dependence and dependency-based approaches, according to which a high reliance on external sources of intermediate inputs, machinery, technologies, and strategically important goods may increase the structural vulnerability of national and regional economies [16, 17]. The third perspective is represented by studies of global value chains and supply-chain disruptions, where imported intermediate inputs are considered as elements of cross-border production networks whose interruption may generate bottlenecks in domestic value-added creation [18-20]. Combining these perspectives makes it possible to interpret regional import substitution not only as a replacement of foreign goods but also as a mechanism for maintaining regional production continuity, reducing vulnerability, and strengthening economic resilience.

Regional aspects of import substitution research, in terms of substantive analysis of definitions, are considered in the works of Russian scholars, including Sukhanova and Lyavina [10], Kuklin [21], Makarov [22], Tatarkin and Romanova [11], Lavrikova et al. [12], Kudrova [23], Animitsa [16], Bukhvald and Ivanov [24], Ershov and Vyzhitovich [25], among others. These studies form an important theoretical and methodological basis for understanding import substitution as a factor of regional economic growth, economic security, industrial modernization, and structural transformation. In particular, the works devoted to regional economic growth and import substitution emphasize that import substitution should not be reduced only to the mechanical replacement of foreign goods by domestic analogues. Rather, it is interpreted as a broader mechanism for stimulating local production, strengthening regional industrial policy, supporting innovation-oriented development, and reducing vulnerability to external market fluctuations [21, 22]. Other studies focus on the institutional, strategic, and territorial dimensions of import substitution, showing that the effectiveness of this policy depends on the industrial profile of regions, the quality of regional development strategies, the capacity of local producers, and the ability of regional economies to adapt to changing conditions of foreign economic activity [16, 23-25].

Regional features of studying import dependence and developing adaptive mechanisms under external market perturbations can be found in the works of A.V. Averin, A.F. Baranova, and Kutyrev [18], Shirov and Gusev [26], Elshin et al. [27], Bulanova et al. [28], Safiullin et al. [13], Peshkova and Samarina [29], and others. These studies are particularly relevant for the present research because they shift attention from the general concept of import substitution to the problem of identifying vulnerable sectors, critical import positions, and possible consequences of external supply restrictions for regional development. For example, studies on critical import insurance, food security, and import-related restrictions demonstrate that external shocks may affect regions unevenly, depending on their sectoral specialization, import structure, and dependence on foreign supplies of intermediate and investment goods [18, 28, 29]. Research on predictive assessment of regional GRP dynamics and economic growth prospects under external restrictions shows that import dependence can become a significant factor influencing regional macroeconomic trajectories [13, 27]. Thus, this group of studies provides a basis for considering import substitution not only as an industrial policy instrument but also as a mechanism of regional economic adaptation and resilience.

Among foreign works relevant to the analysis of import substitution, import dependence, and economic adaptation under external restrictions, one should highlight the studies of Ullrich [30], Dong et al. [31], Connolly and Hanson [1], Aspromourgos [32], and others. Ullrich [30] examines the Russian experience of import substitution during recessionary conditions, which is important for understanding the macroeconomic background of import-substitution policy. Connolly and Hanson [1] analyze import substitution in connection with economic sovereignty, emphasizing the strategic role of domestic production capacity under changing external conditions. The work of Aspromourgos [32], although historical in its focus, is useful for understanding the evolution of economic thought regarding production capacity, national economic development, and the role of domestic resources in economic policy. Sector-specific technological studies, including Dong et al. [31], are relevant in the context of technologically complex industries, where dependence on imported equipment, technologies, and intermediate inputs may become a constraint for production continuity and modernization. Together, these studies complement the domestic literature by placing import substitution within broader discussions of economic sovereignty, industrial capacity, technological dependence, and adaptation to external shocks.

Despite the formation of a scientific base in the study of import substitution economies at the meso-level, the research block devoted to assessing and analyzing the impact of evolving parameters of import dependence on prospects for economic dynamics remains the least elaborated. This makes it rather unique, especially when the research context is focused on regional economic systems. At the same time, despite the limited number of academic publications in this area, relevant works do exist. For example, Andreeva and Ratner [33], using statistical data analysis methods, examine Russia's import dependence based on calculating indicators that assess the share of imports in total consumption and production of similar goods in the country. This approach enabled the authors to formulate a set of heuristic assumptions about the prospects for economic growth in the event of potential changes in the structure of foreign product supplies, specifically concerning critically important imports.

A similar approach to assessing import dependence and its impact on the sustainability of macroeconomic processes is presented in the works of Feng et al. [7], Hufbauer et al. [2], Adewale [34], Bali and Rapelanoro [3], Connolly and Hanson [1], and others. The study by Feng et al. [7] is especially important because it demonstrates the connection between imported intermediate inputs and firms' export performance, thereby confirming that imports may be embedded in domestic production and value-added chains rather than representing only final consumption. Hufbauer et al. [2], as well as Bali and Rapelanoro [3], focus on the economic effects and modeling of external restrictions, providing an analytical basis for understanding how trade constraints may transform import flows and affect economic systems. Adewale [34] examines import substitution industrialization and economic growth using evidence from BRICS countries, which allows import substitution to be considered not only as a response to external shocks but also as a potential development strategy. In turn, Connolly and Hanson [1] link import substitution with economic sovereignty, which is directly relevant to the analysis of critical imports and the strategic vulnerability of regional economies. These works are closely connected with the present study because they substantiate the need to analyze imported goods not only by volume but also by their role in production chains, value-added creation, and the sustainability of economic growth.

A fundamentally different mechanism for assessing the degree of impact of economic import dependence on growth prospects is presented in the work of Belousova [35]. In her study, based on balance sheet data accounting methods and national accounting methodology, she develops a financial flow matrix that reflects the influence of imports on changes in financial flows in the Far Eastern Federal District of Russia. Based on the calculated multipliers, she demonstrates that the intensification of import substitution policy significantly stimulates positive macroeconomic effects in the district.

Of particular interest in this context is the study of Krivenko and Epanshnikova [14], who propose an original toolkit for assessing effective import substitution and its impact on the sustainability of economic dynamics, based on calculating a dynamic import substitution coefficient. This coefficient is defined as the product of specific indicators that, in the authors' view, characterize the effectiveness of import substitution policy at the macro, meso, and micro levels. These include: investment activity aimed at producing import-substituting goods; productivity in the economy; and changes in the ratio of exports to imports of goods.

A separate contribution in this field is the research by Safiullin et al. [13], where the authors attempt to identify critical imports supplied to a region by commodity classification codes (HS) and then construct econometric models to evaluate the impact of critically significant goods on regional economic growth. Overall, despite the existence of studies on regional import substitution economics, there remains a certain fragmentation in the development of methodological tools for assessing the impact of critical imports on the sustainability of regional economic growth. This issue is particularly relevant in analyzing the structural characteristics of import flows, their countries of origin, participation in the creation of value added in the final regional product, and subsequent determination of the influence of these parameters on prospects for economic dynamics under ongoing systemic transformations in the geo-economic agenda. In the conditions of external market turbulence and dynamically transforming processes of international supply chain formation, these components of regional import dependence analysis play a defining role today. This conclusion predetermines the necessity of further expanding the methodological base in studying regional import dependence and developing models for assessing the prospects of regional economic development under ongoing systemic transformations in the external environment. However, the review of existing studies demonstrates that the problem of regional import dependence has been examined from several important perspectives, including import substitution policy, regional economic security, foreign economic activity, and adaptation to external market perturbations. However, several research gaps remain insufficiently addressed.

First, many existing studies assess import dependence either at the national level or through aggregate indicators, while the identification of region-specific critical import positions at the HS/FEACN code level remains less developed. This limits the ability to determine which particular commodity groups create the greatest vulnerability for regional production systems. Second, previous approaches rarely combine commodity-level import diagnostics with the classification of domestically produced goods. As a result, the link between imported commodity groups, domestic production categories, and the creation of regional value added is often considered only indirectly. This makes it difficult to assess the extent to which critical imports are embedded in regional production chains. Third, the economic consequences of critical import dependence for regional growth sustainability are often discussed conceptually, but are less frequently tested using panel-data models that account for differences across commodity groups and regional economic systems. Consequently, the empirical relationship between critical import flows and regional production dynamics requires further methodological development. Fourth, the existing literature insufficiently integrates the analysis of critical imports with the theoretical perspectives of regional resilience, import dependence, and supply-chain disruption. This creates a methodological gap between the identification of vulnerable import positions and the interpretation of their economic significance for regional adaptation under external market turbulence.

The present study addresses these gaps and contributes to the literature in five ways. First, it clarifies the conceptual framework for interpreting regional critical imports as a category linked to import dependence, regional resilience, and supply-chain transformation. Second, it develops and applies a multi-component authentication procedure for identifying critical imports at the regional level. Third, it links HS/FEACN import data with domestic production categories using FEACN–RCPEA concordance, which makes it possible to assess the involvement of imported goods in regional value-added creation. Fourth, it proposes an empirical framework for evaluating regional vulnerability to critical import dependence. Fifth, it estimates the relationship between critical import volumes and regional production dynamics using panel-data models for the regions of the Volga Federal District. These contributions expand the methodological basis for studying regional import dependence and provide practical evidence for designing adaptive import-substitution and regional industrial development policies.

III. MATERIAL AND METHOD

The methodological basis of the study relies on examining the relationship between the transformation of international supply chains, the commodity structure of regional imports, and the sustainability of regional economic development. In this regard, a key research stage is the identification of critical import positions within the commodity nomenclature of foreign economic activity, hereinafter referred to as HS/FEACN codes. These positions are considered as imported commodity groups that may influence regional production dynamics because of their involvement in domestic value-added chains and their importance for the continuity of regional economic activity.

The basic stage of identifying and authenticating critical imports of a region involves selecting HS/FEACN codes whose share exceeds 0.05% of the total volume of imports into the regional economic system. In this study, the 0.05% threshold is used as an operational materiality criterion. It was introduced ex ante to exclude marginal commodity positions that appear in customs statistics but do not have a sufficient scale to influence regional production dynamics or value-added creation. The use of this threshold makes it possible to reduce statistical noise caused by occasional or low-value import flows and to form a more stable empirical base for subsequent econometric analysis. Formally, the share of each HS/FEACN commodity group in the regional import structure is calculated as follows:

$$s_{hrt} = \frac{M_{hrt}}{\sum_{h=1}^{H} Mhrt} \times 100\% \quad (1)$$

where s_{hrt} is the share of commodity group h in total imports of region r in year t; M_{hrt} is the import value of HS/FEACN commodity group h supplied to region r in year t; and $\sum_{h=1}^{H} Mhrt$ is the total import value of all HS/FEACN commodity groups supplied to region r in year t. Commodity groups with $s_{hrt} > 0.05\%$ are retained for the next stage of critical-import authentication. The set of commodity groups retained after applying the 0.05% threshold can be written as:

$$C_{rt}^{0.05} = \{h: S_{hrt} > 0.05\%\} \quad (2)$$

where $C_{rt}^{0.05}$ denotes the set of HS/FEACN commodity groups selected as materially significant in region r in year t.

To address the possible arbitrariness of this cutoff, the robustness of the critical-import identification procedure should additionally be tested using alternative thresholds, including 0.03% and 0.10%. The stability of the selected HS/FEACN set and the corresponding model coefficients under these alternative thresholds is used as an additional criterion confirming that the results are not driven by a single cutoff value.

At the next stage, the level of criticality of the selected HS/FEACN commodity groups is assessed by comparing the value of imported goods with the volume of domestic production of similar goods in the corresponding regional production categories. This approach makes it possible to identify the degree of regional vulnerability to external commodity supplies in those product groups that are involved in value-added creation. If the value of imports is high relative to domestic production of similar goods, the region may be more exposed to external supply-chain disruptions. The implementation of this approach is based on the calculation of a regional import vulnerability index:

$$IVI_{hrt} = \frac{FEACN_{hrt}}{RCPEA_{hrt}} \quad (3)$$

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where IVI_{hrt} is the import vulnerability index for HS/FEACN commodity group h in region r in year t; $FEACN_{hrt}$ is the value of imports of HS/FEACN commodity group h supplied to region r in year t; and $RCPEA_{hrt}$ is the value of domestic production of comparable goods classified according to the Russian Classifier of Products by Economic Activity (RCPEA) in region r in year t.

The index shows the relative scale of imported supplies compared with domestic production of similar goods. A higher value of IVI_{hrt} indicates a higher degree of regional dependence on external supplies for the corresponding commodity group. If $RCPEA_{hrt} = 0$ while imports are positive, the observation is treated as a case of maximum import vulnerability and is additionally checked in the robustness analysis to avoid distortion of the estimated coefficients.

The matching between HS/FEACN import categories and RCPEA domestic production categories is carried out using official conversion keys developed by the Ministry of Economic Development of the Russian Federation. These conversion keys make it possible to link foreign trade commodity codes with domestic production categories and to compare imported goods with similar goods produced by regional residents. In cases where one HS/FEACN code corresponds to several RCPEA categories, the matching procedure is checked manually to ensure consistency between the imported commodity description and the corresponding domestic production group.

An additional element in assigning HS/FEACN codes to the group of critical imports is the country-of-origin structure of the corresponding import flows. In this study, countries of origin are not classified in political terms. Instead, they are grouped according to the degree of potential supply-restriction risk. Jurisdictions subject to external trade restrictions, export-control measures, logistical disruptions, or other institutional barriers that may affect the continuity of supplies are classified as restricted-supply jurisdictions. Jurisdictions for which such restrictions were not identified during the period under study are classified as non-restricted-supply jurisdictions. The share of imports originating from restricted-supply jurisdictions is calculated as follows:

$$RS_{hrt} = \frac{M_{hrt}^{R}}{M_{hrt}} \times 100\% \tag{4}$$

where RS_{hrt} is the share of imports of commodity group hhh supplied to region r in year t from restricted-supply jurisdictions; M_{hrt}^{R} is the import value of this commodity group originating from restricted-supply jurisdictions; and M_{hrt} is the total import value of the same commodity group supplied to region r in year t.

Accordingly, HS/FEACN codes identified as significant at the previous stages are additionally filtered by country of origin. If a commodity group has a high share in regional imports and is substantially involved in value-added creation, while a considerable part of its supply originates from restricted-supply jurisdictions, this commodity group is retained in the final list of critical imports. Conversely, if the commodity group is supplied primarily from non-restricted-supply jurisdictions and does not demonstrate a high supply-restriction risk, it may be excluded from the final critical-import cluster. This procedure reduces the risk of politically biased classification and makes the identification of critical imports more transparent and reproducible.

The implementation of these methodological solutions establishes the foundation for identifying critical imports generated within international supply chains in regional economic systems. Furthermore, the proposed methodological toolkit provides the basis for constructing economic-mathematical models that assess the relationship between critical import flows and regional production dynamics. In the present study, this task is implemented through regional panel-data analysis, which makes it possible to account for differences across commodity groups and regional economic systems when estimating the relationship between critical imports and production volumes. A graphical interpretation of the proposed methodological toolkit is presented in Figure 1.

Collection, systematization, and statistical processing of data on the main types of commodity nomenclature supplied through international supply chains (ISC) to the regions

Identification and selection of the most critical FEACN codes, whose share exceeds 0.05% of ISC imports into the regional group/region in the total volume of cross-border supplies of the federal district

Synchronization of the critical commodity nomenclature generated within ISCs with the Russian Classifier of Products by Economic Activity (RCPEA), based on the transition "keys" developed by the Ministry of Economic Development of the Russian Federation.

Assessment of the ratio of critical imports generated within ISCs to the volume of domestic production of similar goods in the regions (assessment of the region's vulnerability to the transformation of international supply chains).

Formation of the final structure of critical imports (FEACNcrit.) with a high level of participation in the creation of value added of the regional final product, taking into account filtering by the criterion of supply from restricted-supply / non-restricted-supply jurisdictions.

Grouping of FEACN codes by level and degree of impact of ISC transformation potential on the sustainability of regional macroeconomic indicators (determined using the Sturges method).

Spatial data analysis enabling the identification of the impact of the revealed FEACNcrit. on the sustainability of regional economic dynamics.

Development of mechanisms for the strategic adaptation of regional economies to the reconfiguration of international supply chains (ISC) under external restrictions.

Source: developed by the authors.

FIGURE 1. Interpretation of the methodological approach to assessing the transformation of international supply chains and their impact on the sustainability of regional macroeconomic development.

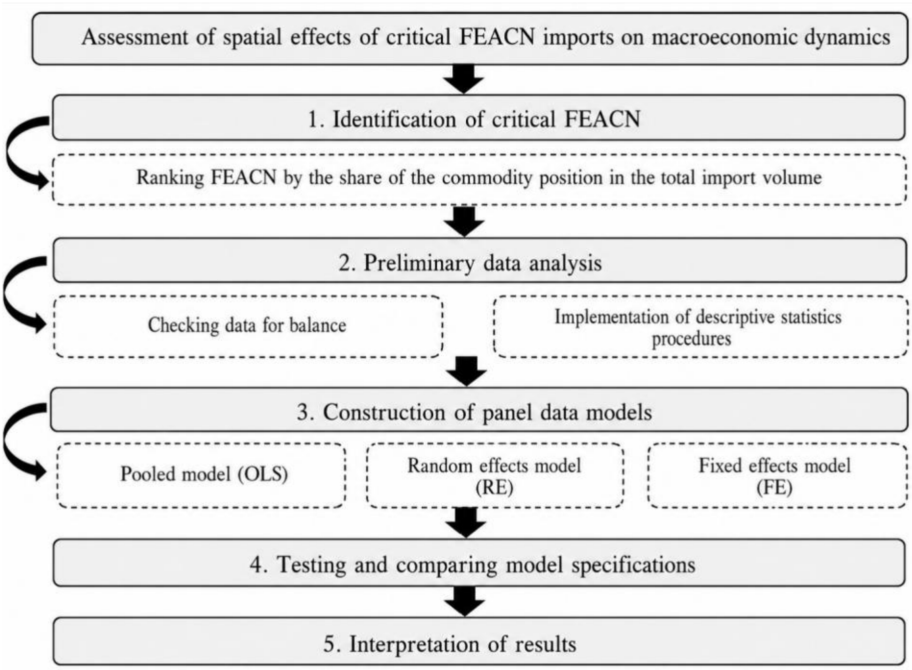
The stages presented in Figure 1 include: collection, systematization, and statistical processing of data on imported commodity groups; identification of HS/FEACN codes exceeding the 0.05% materiality threshold; matching of HS/FEACN codes with RCPEA domestic production categories; calculation of the import vulnerability index; filtering by country-of-origin supply-restriction risk; grouping of HS/FEACN codes by the degree of potential impact on regional macroeconomic indicators; construction of panel-data models; and interpretation of the results for the development of strategic adaptation mechanisms in regional economies. For grouping HS/FEACN codes by the level and degree of potential impact on regional macroeconomic indicators, the Sturges method is used. The number of intervals is calculated as follows:

$$k = 1 + 3.322\, log_{10}(n) \tag{5}$$

where k is the number of grouping intervals and n is the number of observations. The interval width is calculated as:

$$d = \frac{x_{max} - x_{min}}{k} \tag{6}$$

where d is the interval width, x_{max} is the maximum observed value of the indicator, and x_{min} minimum is the minimum observed value of the indicator. The methodological approach to assessing the relationship between critical imports and regional production dynamics is summarized in Figure 2.



Source: developed by the authors.

FIGURE 2. Algorithm of the methodological approach to assessing regional panel-data effects.

From an economic perspective, the proposed methodological approach makes it possible to identify commodity groups that are critical for regional economies in terms of import scale, domestic production comparability, and supply-restriction risk; assess the degree of regional vulnerability associated with dependence on imported goods involved in domestic value-added creation; evaluate the relationship between critical import flows and regional production dynamics.

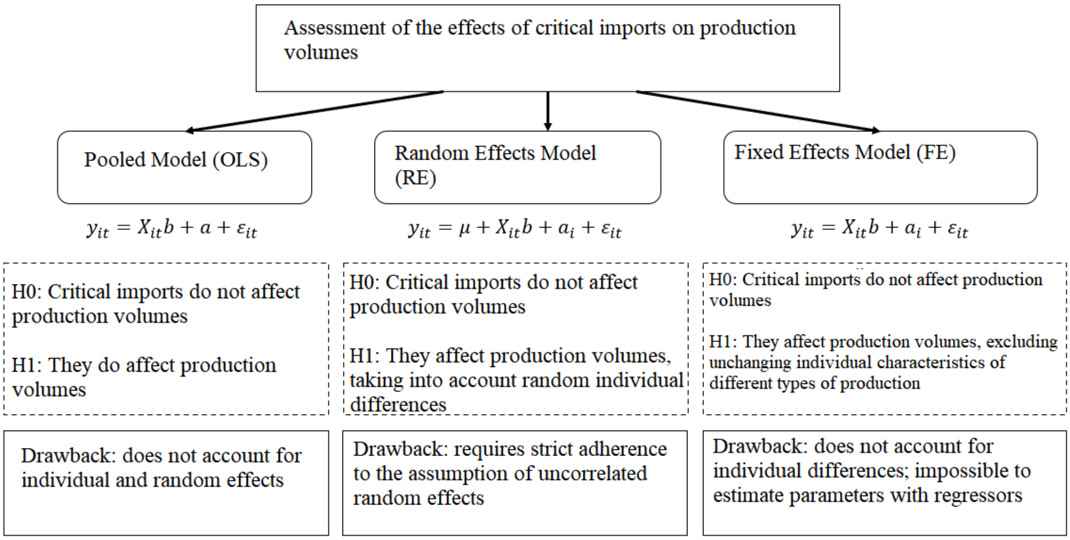
From a methodological and econometric perspective, the practical application of the proposed toolkit makes it possible to construct and test pooled, fixed effects, and random effects panel-data models for assessing the impact of critical import volumes on regional production dynamics; account for unobserved heterogeneity across the studied HS/FEACN commodity groups and regions; compare alternative model specifications using both statistical tests and economic reasoning; test the robustness of the results to alternative threshold values and alternative model specifications. Their comparative characteristics are presented in Figure 3.

The empirical assessment is based on the construction of panel-data models. The panel is formed by combining data on the selected critical HS/FEACN commodity groups, regional production volumes of comparable goods, and the corresponding regional economic systems of the Volga Federal District. In the empirical application, 21 critical FEACN codes form the basis for constructing the panel dataset. The unit of observation is a region–commodity combination observed over the available statistical period. This structure makes it possible to compare the relationship between critical import volumes and production dynamics across different commodity groups and regions.

For the econometric notation used below, the index iii denotes a region–commodity observation unit, and t denotes the time period. The dependent variable Y_{it} represents the production volume of goods comparable to the selected HS/FEACN commodity group. The key explanatory variable CI_{it} represents the value of critical imports for the corresponding commodity group and region. Three econometric specifications are estimated and compared:

- pooled ordinary least squares model, Pooled OLS;
- fixed effects model, FE;

• random effects model, RE.
Their comparative characteristics are presented in Figure 3.



Source: developed by the authors.

FIGURE 3. Comparison of OLS, RE, and FE models.

At the final stage of the calculation, the implemented models are compared using the Hausman and Breusch–Pagan tests. The Hausman test makes it possible to check the hypothesis regarding the choice between the random effects (RE) model and the fixed effects (FE) model. Two hypotheses are formulated:

- H0: The differences between the FE and RE models are insignificant, and the RE model is preferred.
- H1: The differences are significant, and the FE model is chosen.

The Breusch–Pagan test allows for choosing between the pooled model and the random effects model. The final model is selected based on the results of the Hausman and Breusch–Pagan tests. The pooled OLS model is specified as follows:

$$Y_{it} = \alpha + \beta CI_{it} + \varepsilon_{it} \tag{7}$$

where Y_{it} is the production volume of comparable goods for observation unit i in period t; CI_{it} is the volume of critical imports; α is the intercept; β is the coefficient measuring the relationship between critical imports and production volumes; and ε_{it} is the error term. The fixed effects model is specified as follows:

$$Y_{it} = \alpha_i + \beta CI_{it} + \varepsilon_{it} \tag{8}$$

where α_i captures time-invariant unobserved characteristics of the corresponding region–commodity observation unit. These characteristics may include stable differences in regional industrial specialization, technological structure, production capacity, or commodity-specific features that do not vary over time but may influence production volumes. The random effects model is specified as follows:

$$Y_{it} = \alpha + \beta CI_{it} + u_i + \varepsilon_{it} \tag{9}$$

where u_i denotes the individual random effect and ε_{it} is the idiosyncratic error term. The RE specification assumes that the individual effect uiu_iui is not correlated with the explanatory variable CI_{it}.

At the final stage of the calculation, the estimated models are compared using the Hausman and Breusch–Pagan tests. The Hausman test is used to choose between the fixed effects and random effects specifications. The null hypothesis assumes that the individual effects are not correlated with the explanatory variable and that the RE estimator is consistent. The alternative hypothesis assumes that such correlation exists and that the FE estimator is preferable:

$$H_0: cov(u_i, CI_{it}) = 0 \quad (10)$$
$$H_1: cov(u_i, CI_{it}) \neq 0$$

The Breusch–Pagan Lagrange Multiplier test is used to compare the pooled OLS and random effects specifications. A statistically significant test result indicates the presence of individual heterogeneity and supports the use of a panel specification instead of a pooled model.

However, the final choice between FE and RE is not based only on statistical tests. From an economic perspective, the RE model may be appropriate if the unobserved differences across HS/FEACN categories and regions are interpreted as random heterogeneity that is not systematically correlated with the volume of critical imports. The FE model is preferable if these unobserved differences reflect stable structural characteristics, such as regional industrial specialization, technological capacity, or persistent differences in production structure, that may be correlated with critical import volumes. Therefore, the final model selection combines statistical diagnostics with economic interpretation of the nature of unobserved heterogeneity.

A potential methodological limitation of the estimated relationship is the risk of endogeneity. In particular, reverse causality may arise because higher regional production volumes can increase demand for imported intermediate inputs, while critical imports may also influence production volumes. To reduce this risk, the robustness analysis includes an alternative specification with lagged critical import variables:

$$Y_{it} = \alpha + \beta CI_{i,t-1} + \varepsilon_{it} \quad (11)$$

where $CI_{i,t-1}$ is the lagged value of critical imports. This specification partially reduces simultaneity between the dependent and explanatory variables, because imports from the previous period are used to explain current production volumes. In addition, the interpretation of the estimated coefficients is formulated as an assessment of statistical association rather than as strict causal identification unless additional instrumental-variable or dynamic panel procedures are implemented.

To test the robustness of the obtained results, several sensitivity checks are applied. First, the identification of critical imports is repeated using alternative threshold values of 0.03% and 0.10%. Second, the panel models are re-estimated for the alternative sets of HS/FEACN codes obtained under these thresholds. Third, the stability of the sign, magnitude, and statistical significance of the import coefficient is compared across model specifications. Fourth, where data availability allows, additional control variables reflecting regional industrial specialization, investment activity, and general economic scale are included to reduce the influence of potential confounding factors.

An additional robustness specification is estimated in logarithmic form:

$$ln(Y_{it} + 1) = \alpha + \beta\, ln(CI_{it} + 1) + \varepsilon_{it} \quad (12)$$

where the logarithmic transformation makes it possible to interpret the coefficient β as an elasticity-like estimate. The addition of one unit is used to retain observations with zero values in the sample.

Given the regional nature of the study, additional clustering or spatial-dependence diagnostics may be used to check whether the residuals of the panel models demonstrate spatial correlation across regions. For this purpose, a spatial weights matrix W can be constructed on the basis of territorial contiguity between regions of the Volga Federal District. The matrix is row-standardized so that the sum of weights in each row equals one. Spatial autocorrelation in residuals can be tested using Moran's I:

$$I = \frac{n}{s_0}\frac{\Sigma_i \Sigma_j w_{ij} e_i e_j}{\Sigma_i e_i^2} \quad (13)$$

where n is the number of spatial units, w_{ij} is an element of the spatial weight's matrix W, $e_i e_j$ are residuals for regions i and j, and $s_0 = \Sigma_i \Sigma_j w_{ij}$. If statistically significant spatial autocorrelation is detected, the results should be interpreted with caution, and spatial econometric specifications may be considered as an extension of the baseline panel-data approach.

Panel model diagnostics also include tests for heteroskedasticity, serial correlation, and cross-sectional dependence. If these diagnostics reveal violations of standard assumptions, robust standard errors are used.

Depending on the structure of the final panel, cluster-robust standard errors or Driscoll–Kraay standard errors may be applied to increase the reliability of inference.

Finally, the methodology includes an error-analysis component. Potential sources of measurement error may arise from HS/FEACN–RCPEA concordance, differences in the level of aggregation across classifications, country-of-origin filtering, and reporting inconsistencies in trade and production statistics. To reduce these risks, the study applies manual checks of classification matches, reports the final list of critical HS/FEACN codes, and provides the concordance logic used to connect import flows with domestic production categories.

IV. RESULTS

The empirical analysis was conducted in three consecutive stages. First, the final set of critical FEACN codes for the regions of the Volga Federal District was identified. Second, descriptive statistics were calculated for the initial variables used in the panel-data models. Third, pooled OLS, fixed effects, and random effects specifications were estimated and compared in order to determine the most appropriate model for assessing the relationship between critical import volumes and production volumes of comparable goods. Table 1 presents the FEACN commodity groups that were identified as critical for the Volga Federal District in 2021.

Table 1. Critical FEACN codes of the Volga federal district, 2021.

No.	FEACN
1	Compression-ignition internal combustion piston engines (diesel or semi-diesel)
2	Bulldozers with fixed or angled blades, graders, levelers, scrapers, mechanical shovels, excavators, single-bucket loaders, tamping machines, and self-propelled road rollers
3	Spark-ignition internal combustion piston engines with rotary or reciprocating piston movement
4	Machinery and equipment for lifting, moving, loading, or unloading (e.g., lifts, escalators, conveyors, cableways), other
5	Foundry molds; foundry pallets; foundry patterns; molds for casting metals (excluding ingot molds), metal carbides, glass, mineral materials, rubber, or plastics
6	Forklift trucks; other trucks equipped with lifting or loading/unloading equipment
7	Metal-cutting lathes (including multifunctional lathes)
8	Machining centers, single- and multi-station unit machines for metalworking
9	Other machines and mechanisms for moving, leveling, profiling, developing, tamping, compacting, excavating, or drilling soil, minerals, or ores; pile-driving and extracting equipment; snow plows and snow blowers
10	Hoists and lifting equipment (except skip hoists); winches and capstans; jacks
11	Machinery (including nail-, staple-, or glue-assembling machines, etc.) for working wood, cork, bone, hard rubber, hard plastics, or similar hard materials
12	Grinding, sharpening, honing, lapping, polishing, and other finishing machines for metals or cermets, using grinding stones, abrasives, or polishing products, except…
13	Metal-cutting machines (including line-building unit machines) for drilling, boring, milling, threading (internal or external), except lathes (including multifunctional lathes)
14	Planing, slotting, shaping, broaching, gear-cutting, gear-grinding, gear-finishing, sawing, cutting-off, and other machines for metalworking or cermet machining by material removal, not elsewhere specified
15	Electric motors and generators (excluding generating sets)
16	Radio broadcasting receivers, combined or not in the same housing with sound recording or reproducing equipment or clocks
17	Organic chemical compounds
18	Compounds containing other nitrogen-functional groups
19	Other organo-inorganic compounds

20	Flat-rolled products of iron or non-alloy steel, of a width of 600 mm or more, cold-rolled, not clad, plated, or coated
21	Ferro-alloys

Source: compiled by the authors.

Thus, 21 critical FEACN codes were selected. These commodity groups accounted for a significant share of imports originating from jurisdictions associated with potential supply-restriction risks and played an important role in the creation of final and intermediate gross product in the studied regions. The identified FEACN codes formed the empirical basis for constructing the panel dataset for the regions of the Volga Federal District, including data on regional production volumes of comparable goods and deliveries of critical imports. At the next stage, a preliminary analysis of the data was performed. Critical import volumes were used as the explanatory variable, while production volumes of comparable goods were used as the dependent variable. Descriptive statistics of the initial data are presented in Table 2.

Table 2. Descriptive statistics of the initial data.

	Critical imports	**Critical imports**
Mean	492,396.23	45,415.05
Standard error	171,024.33	12,295.94
Median	9,117.65	582
Mode	173	170
Standard dev.	1,904,446.38	141,803.68
Sample variance	3.62692E+12	20,108,283,649
Kurtosis	16.03	11.81
Skewness	4.14	3.56
Range	9,775,496	676,961
Minimum	103	0
Maximum	9,775,599	676,961

Source: authors' calculations.

The descriptive statistics indicate substantial heterogeneity in both critical import volumes and production volumes of comparable goods. The mean values are considerably higher than the medians, which indicates a high concentration of observations around relatively small values and the presence of several very large observations. The skewness values of 4.14 for critical imports and 3.56 for production volumes confirm a right-skewed distribution. The kurtosis values of 16.03 and 11.81 also indicate heavy-tailed distributions and possible outliers. Therefore, the subsequent econometric interpretation should take into account the heterogeneity of FEACN categories and the non-normal distribution of the initial variables. This also justifies the use of panel-data specifications, which make it possible to account for unobserved differences across region–commodity observation units.

According to the proposed algorithm, the next step was the construction of panel-data models. At the first stage, the pooled OLS model was estimated. The calculation results are shown in Table 3.

Table 3. Results of pooled panel data model estimation.

	Coefficients	**Std. error**	**t-statistic**	**p-value**	**Approx. 95% confidence interval**
Intercept	11555.43	4366.033	2.65	0.009	[2998.01; 20112.85]
Import volume	0.72521	0.002	35.33	2.18E-59	[0.721; 0.729]

Model statistics: $R^2 = 0.96$; F-test significance: $p < 0.001$.
Source: authors' calculations.

The calculations indicate that the pooled OLS model is statistically significant. In the absence of individual effects, the relationship between critical import volumes and production volumes can be expressed as follows:

$$V_{prod,it} = 11555.43 + 0.725V_{imp,it} + \varepsilon_{it} \tag{14}$$

According to this specification, an increase in critical imports by 1 million rubles is associated with an increase in production volumes of comparable goods by approximately 0.725 million rubles. The coefficient is statistically significant and economically meaningful, indicating that critical imports are closely connected with regional production processes. At the next iteration, the fixed effects model was estimated using the within-transformation method. The results are presented in Table 4.

Table 4. Results of fixed effects model estimation.

	Coefficient	Std. error	t-statistic	p-vslue	Approx. 95% confidence interval
Import volume	0.145	0.0015	9.58	2.4041E-15	[0.142; 0.148]

Model statistics: $R^2 = 0.99$; F-test significance: $p < 0.001$.
Source: authors' calculations.

The obtained equation is statistically significant. Under fixed individual effects, an increase in critical imports by 1 million rubles is associated with an increase in production volumes of comparable goods by approximately 0.145 million rubles. The lower coefficient in comparison with the pooled OLS model indicates that a part of the relationship between critical imports and production volumes is explained by time-invariant characteristics of region–commodity observation units, including sectoral specialization, technological structure, and commodity-specific production conditions. The random effects model was estimated at the next stage. The results are presented in Table 5.

Table 5. Results of random effects model estimation.

	Coefficient	Std. error	t-statistic	p-vslue	Approx. 95% confidence interval
Intercept	9877.59	3316.4033	2.97	0.003	[3377.44; 16377.74]
Import volume	0.75	0.0015	47.31	1.0847E-71	[0.747; 0.753]

Model statistics: $R^2 = 0.98$; F-test significance: $p < 0.001$.
Source: authors' calculations.

As in the previous specifications, the random effects model and its coefficients are statistically significant. The import coefficient is equal to 0.75, which indicates that an increase in critical imports by 1 million rubles is associated with an increase in production volumes of comparable goods by approximately 0.75 million rubles. The confidence interval is narrow, which confirms the stability of the estimated coefficient within the model specification. The results of all panel-data models are summarized in Table 6.

Table 6. Results of panel data model estimations.

	R^2	Coefficients Intercept	Std. error Import coefficient	t-stat	P-value	Approx. 95% confidence interval for import coefficient	
Pooled model	0.96	11,555.43	0.725	0.002	35.33	2.18E-59	[0.721; 0.729]
Fixed effects model	0.99	–	0.145	0.0015	9.58	2.4041E-15	[0.142; 0.148]
Random effects model	0.98	9,877.59	0.75	0.0015	47.31	1.0847E-71	[0.747; 0.753]

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Hausman Test	0,09
Breusch-Pagan test	0,005

Source: authors' calculations.

The results confirm the statistical significance of the estimated models. The Hausman test p-value is 0.09, which is greater than the 0.05 significance level. Therefore, the null hypothesis that the random effects estimator is consistent is not rejected. This means that the random effects model is preferable to the fixed effects model for the current dataset. The Breusch–Pagan test p-value is 0.005, which is below 0.05; therefore, the pooled OLS model is rejected in favor of the random effects specification. Accordingly, the random effects model was selected as the final specification for modeling the relationship between production volumes and critical import volumes:

$$V_{prod,it} = 9877.59 + 0.725V_{imp,it} + u_i + \varepsilon_{it} \quad (15)$$

The obtained equation indicates that an increase in critical imports by 1 million rubles is associated with an increase in production volumes of comparable goods by approximately 750 thousand rubles. Conversely, under the same model assumptions, a reduction in critical imports by 1 million rubles corresponds to a decrease in production volumes by approximately 750 thousand rubles. This result demonstrates the economic significance of critical imports for regional production dynamics and confirms the importance of identifying those import categories that are most strongly connected with domestic value-added creation.

At the same time, the estimated coefficients should be interpreted as evidence of a statistically significant association rather than as strict causal effects. This interpretation is necessary because regional production volumes may influence demand for imported intermediate inputs, while imports may simultaneously affect production volumes. Therefore, the obtained results should be considered as a baseline empirical assessment that can be further strengthened through robustness checks, lagged specifications, and additional control variables.

V. DISCUSSION

The results of the empirical assessment demonstrate a statistically significant and economically meaningful relationship between critical import volumes and production volumes of comparable goods in the regions of the Volga Federal District. In all three model specifications pooled OLS, fixed effects, and random effects the estimated import coefficient is positive and statistically significant. This indicates that the selected critical FEACN categories are not peripheral import flows, but are closely connected with regional production processes and value-added creation. This result is consistent with studies emphasizing the role of import substitution and import dependence in shaping regional economic development trajectories [10, 12, 33, 35].

The preferred random effects model shows that an increase in critical imports by 1 million rubles is associated with an increase in production volumes by approximately 750 thousand rubles. From the perspective of economic interpretation, this coefficient can be treated as a policy-relevant benchmark. For example, a reduction in critical imports by 1 billion rubles may correspond, under the assumptions of the model, to a decrease in production volumes of comparable goods by approximately 750 million rubles. This translation of the coefficient into monetary terms is important because it demonstrates that critical import dependence is not only a statistical phenomenon but also a practical issue for regional industrial policy. Similar policy-oriented interpretations of import substitution and import dependence are present in studies devoted to regional industrial development, import-substitution strategies, and economic growth under external restrictions [24, 26, 36].

The obtained result should be interpreted in the context of regional economic resilience and import dependence. From the perspective of regional resilience theory, regional economies differ in their ability to withstand external shocks, adapt to structural changes, and restore stable development trajectories [4, 5]. In this sense, critical imports may perform a dual function. On the one hand, they support the continuity of production and technological renewal. On the other hand, excessive dependence on external supplies of strategically important goods may increase the vulnerability of regional economic systems. This interpretation is also consistent with import-dependence and dependency-based approaches, according to which reliance on external sources of intermediate inputs, machinery, technologies, and investment goods may create structural constraints for national and regional development [6].

The positive relationship between critical imports and production volumes confirms that imported commodity groups may support regional production continuity. Many of the selected FEACN categories are related to machinery, equipment, engines, metalworking machines, chemical compounds, and metallurgical inputs. These goods are often used as intermediate or investment goods, and their availability may influence the ability of regional enterprises to maintain production, modernize equipment, and participate in value-added chains. This finding corresponds with studies showing that imported intermediate inputs are embedded in production and export processes and may increase firm-level or regional production capabilities [7, 8]. At the same time, studies of supply-chain disruptions demonstrate that interruptions in the delivery of such inputs may generate bottlenecks in domestic production systems [9].

The structure of the identified critical FEACN codes makes it possible to distinguish several major groups of vulnerability. The first group includes machinery, equipment, engines, lifting machinery, metalworking machines, and electric motors. These categories are directly connected with production capacity, technological renewal, and capital deepening. The second group includes chemical and organo-inorganic compounds, which may be used as intermediate inputs in industrial production. The third group includes metallurgical products, such as flat-rolled steel and ferro-alloys, which are important for manufacturing and construction-related value chains. This decomposition is consistent with the logic of regional import-substitution studies, which emphasize that vulnerability to imports depends not only on the total value of foreign supplies, but also on the functional role of imported goods in regional production systems [17, 19].

The mechanism underlying the obtained relationship can be summarized as follows: critical imports provide machinery, equipment, intermediate inputs, and technological components; these goods support production continuity and capital renewal; production continuity contributes to the creation of regional value added; and the stability of value-added creation supports regional economic growth. In this sense, critical imports should not be interpreted only as a sign of external dependence. They should also be considered as a structural component of regional production systems whose disruption may reduce the adaptive capacity of regional economies. This interpretation connects the empirical results of the present study with the theoretical literature on regional resilience, global value chains, and supply-chain disruption [4-6].

The model comparison also provides important methodological implications. The pooled OLS model shows a strong positive relationship between imports and production volumes but does not account for individual heterogeneity. The fixed effects model controls for time-invariant differences across region–commodity units and produces a lower coefficient, which indicates that part of the relationship is explained by stable structural characteristics. The random effects model, selected on the basis of the Hausman and Breusch–Pagan tests, combines the advantages of panel-data estimation with the assumption that individual differences are random and not systematically correlated with the explanatory variable. Economically, this means that the differences among FEACN categories and regional economic systems are important, but in the current dataset they are better interpreted as random heterogeneity rather than fixed structural effects. This methodological interpretation extends previous regional import-substitution studies, many of which focus primarily on descriptive indicators, balance methods, or aggregate import-dependence measures [14, 34].

The descriptive statistics also require separate interpretation. High skewness and kurtosis indicate that the distribution of both critical imports and production volumes is highly uneven. This reflects the fact that certain FEACN categories are much more significant than others in terms of import scale and production relevance. Such heterogeneity is typical for studies of commodity-level import dependence, where a limited number of imported goods may account for a substantial share of economic vulnerability. Similar conclusions can be found in studies that emphasize the uneven sectoral and regional effects of import substitution, external restrictions, and foreign economic transformations [27, 29]. At the same time, this result indicates the need for careful robustness testing, including log specifications, alternative thresholds for critical-import identification, and robust standard errors.

The findings are consistent with previous studies emphasizing the role of import substitution, regional industrial policy, and external market restrictions in shaping regional development trajectories [11, 12]. At the same time, the present study extends this literature by connecting the identification of critical imports with panel-data modeling of their relationship with regional production dynamics. Earlier works have often focused either on the general share of imports in consumption and production or on broader macroeconomic consequences of import substitution [33-36]. In contrast, the present research identifies specific commodity groups and estimates their association with comparable production volumes at the regional level. This makes it possible to move from a general assessment of import dependence to a more detailed analysis of commodity-level vulnerability in regional production systems.

The results also complement studies that examine imported intermediate inputs and their role in production, exports, and value-added creation [7, 8]. The positive import coefficient obtained in this study supports the idea that imports may be embedded in domestic production chains rather than representing only final consumption. This is particularly important for regional economies, where imported equipment, components, and intermediate goods may support local production and technological modernization. Therefore, import substitution policy should not be limited to reducing imports in general. It should focus on identifying those import categories whose disruption may create the greatest risks for production continuity, technological renewal, and regional value-added creation [1, 13].

From a practical perspective, the results suggest that regional industrial policy should be selective. The 21 identified FEACN categories can be used as a basis for prioritizing import-substitution measures, supplier diversification, technological modernization, and regional industrial support programs. In particular, policy instruments may include support for domestic production of comparable goods, development of alternative suppliers from non-restricted-supply jurisdictions, creation of strategic inventories for highly vulnerable inputs, and targeted support for enterprises whose production depends on critical imported machinery, chemicals, or metallurgical inputs. This corresponds with studies emphasizing the importance of state industrial policy, regional development strategies, and targeted import-substitution instruments under external constraints [11, 13, 23].

The obtained results also have theoretical implications. They show that import substitution should not be interpreted only as a replacement of foreign goods by domestic analogues. Rather, it should be considered as a broader mechanism of regional adaptation to the transformation of international supply chains. This approach is consistent with the literature on regional economic resilience, which emphasizes adaptation, recovery, and the ability of regional systems to maintain development under external shocks. It is also consistent with the literature on global value chains, where imported intermediate inputs are viewed as part of cross-border production networks rather than isolated trade flows. Therefore, the present study contributes to the theoretical integration of import dependence, regional resilience, and supply-chain transformation.

At the same time, the results have several limitations. First, the identification of critical imports depends on the selected 0.05% threshold. Although this threshold is used as a materiality criterion, future research should test the stability of the selected FEACN set using alternative thresholds, such as 0.03% and 0.10%. Second, the FEACN–RCPEA matching procedure may involve classification uncertainty, especially when one import code corresponds to several domestic production categories. Third, the country-of-origin filtering procedure may be affected by reporting limitations and changes in the structure of international supply chains. Fourth, the estimated relationship may be influenced by endogeneity, since production volumes can affect the demand for imported inputs. These limitations are consistent with broader methodological challenges discussed in studies of import dependence, sanctions modeling, and supply-chain disruption.

Overall, the discussion confirms that critical imports perform a dual role in regional economic systems. They support current production and value-added creation, but at the same time they form a channel of vulnerability under external supply-chain disruptions. Therefore, the identification and modeling of critical imports should become an important element of regional economic diagnostics, import-substitution policy, and strategic planning. This conclusion is consistent with Russian and international research emphasizing that regional economic adaptation under external constraints requires a combination of industrial policy, supply-chain analysis, and empirical assessment of import dependence [20, 37].

VI. CONCLUSIONS

The purpose of this study was to develop methodological tools for the multi-component assessment of regional critical imports and to estimate the relationship between critical import volumes and the sustainability of regional economic dynamics. The empirical analysis was conducted for the regions of the Volga Federal District of the Russian Federation using selected FEACN commodity groups, regional production data for comparable goods, and panel-data models.

The results of the study confirm the scientific and practical significance of the proposed approach. First, the study developed and tested a procedure for identifying commodity groups that are critical for regional economies in terms of import scale, domestic production comparability, and country-of-origin supply-restriction risk. As a result, 21 FEACN commodity groups were identified as critical for the Volga Federal District. These groups mainly include machinery and equipment, metalworking machines, engines, electric motors, chemical compounds, and metallurgical products. Second, the study demonstrated that critical imports are significantly associated with production volumes of comparable goods. The pooled OLS, fixed effects, and random effects models all showed a positive and statistically significant relationship between critical import volumes and regional production dynamics. The final model selection procedure indicated that the random effects model is preferable to both the pooled OLS and fixed effects specifications. This result suggests that unobserved differences among region–commodity units are important, but in the current empirical setting they can be interpreted as random heterogeneity. Third, the preferred random effects model showed that an increase in critical imports by 1 million rubles is associated with an increase in production volumes by approximately 750 thousand rubles. This coefficient has clear economic significance. It indicates that critical imports are closely embedded in regional production processes and that their reduction may negatively affect production volumes. In policy terms, a decrease in critical imports by 1 billion rubles may correspond to a reduction in comparable production volumes by approximately 750 million rubles, assuming coefficient stability and other conditions unchanged. Fourth, the study contributes to the development of the theory and methodology of regional import dependence analysis. It shows that critical imports should be interpreted not only as foreign supplies of goods but also as elements of regional value-added chains. This approach makes it possible to connect import substitution policy with regional resilience, supply-chain transformation, and industrial development strategies. The study therefore expands the methodological base for assessing the vulnerability of regional economic systems under external market turbulence. Fifth, the obtained results have practical relevance for regional and national economic policy. The proposed toolkit can be used by public authorities and analytical institutions in preparing strategic planning documents, designing adaptive import-substitution policies, identifying vulnerable industries, and selecting priority areas for industrial support. The results show that policy measures should focus not on reducing all imports, but on managing those import flows that are most important for production continuity and regional value-added creation.

At the same time, several limitations should be acknowledged. The first limitation concerns the threshold used to identify critical imports. The 0.05% cutoff is justified as a materiality criterion, but future studies should test the robustness of the results using alternative thresholds. The second limitation is related to the FEACN–RCPEA concordance procedure, since the matching of foreign trade codes with domestic production categories may involve aggregation and classification errors. Future research should therefore develop the proposed approach in several directions. First, sensitivity analysis should be conducted using alternative critical-import thresholds, including 0.03% and 0.10%. Second, additional dependent variables, such as gross regional product, industrial production indices, and value added, may be used to test the stability of the results. Third, lagged import variables, instrumental-variable approaches, or dynamic panel models may be applied to reduce endogeneity risks. Fourth, spatial econometric models may be introduced if statistically significant spatial dependence is detected across regions. Fifth, the analysis can be expanded by decomposing critical imports into major functional groups, including machinery and equipment, chemicals, and metallurgical inputs. Overall, the study confirms that critical imports are an important factor associated with the sustainability of regional economic growth. The developed methodological toolkit provides a basis for identifying vulnerable import positions, assessing their connection with regional production dynamics, and designing more targeted regional industrial and import-substitution policies.

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Author Contributions

All authors made an equal contribution to the development and planning of the study.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

Data are available from the authors upon request.

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