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METHODOLOGY FOR MODELING THE GROSS OUTPUT OF FREIGHT TRANSPORTATION IN INTERNATIONAL TRAFFIC

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Abstract

This study presents a comprehensive analysis of methodological contradictions identified in the process of modelling the gross output of freight transport services in international communication. Two mutually exclusive assumptions have been established that create a conceptual gap in the system of equations and undermine the logical integrity of the model. These contradictions arise from the conflation of gross output and value-added concepts, the omission of domestic consumption of transport services, the disregard of price differentials between embedded and direct transport services, and the absence of the transit component in the baseline model specification. In this regard, a three-stage methodology for resolving the identified contradictions is developed: the first stage involves the decomposition of gross output into four structural components (direct export, embedded services, transit, and import-related services); the second stage establishes balance relationships between gross output and net export of transport services; the third stage introduces corrective coefficients for export orientation and intermediate consumption. An alternative model is proposed based on a three-scenario decomposition of the value-added creation mechanism in the transport sector: a direct export growth scenario, a transit development scenario, and an import substitution scenario in transport activities. The production function of the transport sector is specified in the Cobb – Douglas form, incorporating capital, labour, investment, and total factor productivity. The empirical illustration encompasses a complete cycle of numerical calculations with economic interpretation of structural shock and adaptation dynamics of the transport sector. The balance identity of the model is verified on conditional data of the transport sector of the Republic of Belarus. The developed methodology serves as a foundation for in-depth analysis of the transport sector, substantiation of managerial decisions in transport and foreign trade policy, and medium-term forecasting with in the EAEU. The novelty of the study lies in forming a consistent system of structural equations that eliminates logical incompatibilities of previous formulations and ensures unambiguous identifiability of model parameters.

Keywords: gross output of transport services, net export, methodological contradictions, balance relationships, production function, Cobb – Douglas model, total factor productivity, structural shocks, transit economy, EAEU.

МЕТОДОЛОГИЯ МОДЕЛИРОВАНИЯ ВАЛОВОГО ВЫПУСКА ГРУЗОВЫХ ПЕРЕВОЗОК В МЕЖДУНАРОДНОМ СООБЩЕНИИ

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Реферат

Настоящее исследование представляет собой комплексный анализ методологических противоречий, выявленных в процессе моделирования валового выпуска грузовых перевозок в международном сообщении. Установлено наличие двух взаимоисключающих допущений, создающих концептуальный разрыв в системе уравнений и подрывающих логическую целостность модели. Данные противоречия возникают вследствие смешения концепций валового выпуска и добавленной стоимости, игнорирования внутреннего потребления транспортных услуг, не учета ценовых различий между встроенными и прямыми транспортными услугами, а также отсутствия транзитной компоненты в базовой спецификации модели. В этой связи разработана трехэтапная методология устранения выявленных противоречий: первый этап – декомпозиция валового выпуска на четыре структурных компонента (прямой экспорт, встроенные услуги, транзит, услуги по импорту); второй этап – установление балансовых соотношений между валовым выпуском и чистым экспортом транспортных услуг; третий этап – введение корректирующих коэффициентов экспортной ориентации и промежуточного потребления. Предложена альтернативная модель, основанная на трехсценарной декомпозиции механизма созидания добавленной стоимости транспортного сектора: сценарий роста прямого экспорта, сценарий развития транзита и сценарий импортозамещения в транспортной деятельности. Производственная функция транспортного сектора специфицирована в форме Кобба – Дугласа с включением капитала, труда, инвестиций и совокупной факторной производительности. Эмпирическая иллюстрация включает полный цикл численных расчетов с экономической интерпретацией структурных шоков и динамики адаптации транспортного сектора. Балансовое тождество модели верифицировано на условных данных транспортного сектора Республики Беларусь. Разработанная методология является основой для углубленного анализа транспортного сектора, обоснования управленческих решений в области транспортной и внешнеторговой политики, построения среднесрочных прогнозов в рамках ЕАЭС. Новизна исследования состоит в формировании согласованной системы структурных уравнений, устраняющих логические несовместимости предшествующих формулировок и обеспечивающей однозначную идентифицируемость параметров модели.

Ключевые слова: валовой выпуск транспортных услуг, чистый экспорт, методологические противоречия, балансовые соотношения, производственная функция, модель Кобба – Дугласа, совокупная факторная производительность, структурные шоки, транзитная экономика, ЕАЭС.

Introduction

Modelling the gross output of transport services in international traffic represents one of the most complex challenges in modern economic theory, situated at the intersection of international trade theory, national accounting, and sectoral economics [1, 8, 14]. This problem is particularly acute in the context of small open economies with a high share of transit transportation, where the transport sector accounts for a significant portion of net export of services [11, 21]. For the Republic of Belarus – a country with pronounced transit potential – the share of transport services in total export of services has historically exceeded 40 %, underscoring the strategic importance of accurate modelling of this sector [5, 11].

The existence of two mutually exclusive statements in the system of equations, identified during preliminary research, does not constitute a trivial methodological error but represents a fundamental problem affecting the conceptual foundations of the model [1]. The contradiction reflects the incompleteness of the theoretical framework and has necessitated further investigation and revision of the methodological apparatus. Similar problems of methodological incompleteness in transport system modelling have been noted by a number of researchers [2, 3, 12]; however, no systematic solution applicable to the foreign trade component of the transport sector has previously been proposed.

Analysis of the presented systems of equations has established two mutually exclusive statements that function as assumptions (constraints) of the model [1, 13]. The first states that the gross output of freight transportation in international traffic is represented as the sum of the value of transport services embedded in the cost of export-oriented goods. The second states that this sum balances with net export ($X_{n\text{ транс}}$); however, net export is self-evidently not identical to the gross output of freight transportation in international traffic [15, 19].

The logical incompatibility of these statements is evident: the use of an approximate equality operator alongside a simultaneous assertion of inequality creates methodological ambiguity [4, 16, 17]. The degree of criticality of the identified contradiction is assessed as high on the following grounds: first, mutually exclusive assumptions undermine the logical integrity of the model and render unambiguous interpretation of results impossible; second, in the presence of contradictory assumptions, empirical testing of the model becomes meaningless; third, using a model with internal contradictions to substantiate managerial decisions may lead to systematic errors in transport and foreign trade policy [6, 7, 9, 18].

The violation of the identifiability principle for structural equations precludes the possibility of obtaining consistent parameter estimates [16, 17]. Consequently, resolving this contradiction is a priority task, without which further use of the model is inadmissible from the standpoint of scientific accuracy and rigour. This article proposes an original methodology for addressing this task, tested on data from the transport sector of the Republic of Belarus [2, 5, 11].

Research Methodology

The theoretical and methodological foundation of the study comprises the provisions of the System of National Accounts (SNA 2008) [13], the theory of production functions [8, 9], the Leontief input-output balance methodology, and contemporary approaches to transport sector modelling in a small open economy [3, 12, 20]. The information base is formed by data from the National Statistical Committee of the Republic of Belarus [5, 11], the National Bank of the Republic of Belarus [6, 7], the Eurasian Economic Commission [18], and the International Monetary Fund [19].

To eliminate the identified contradictions, it is necessary to identify their sources. The analysis reveals the following causes of incompatible statements: conflation of gross output and value-added concepts – gross output includes intermediate consumption [13], whereas net export in the SNA is recorded at value added; omission of domestic consumption of transport services; disregard of price differentials between embedded and direct transport services; absence of the transit component,

$$X_{n\text{ транс}}(t) = (TC_{\text{пр экс}}(t) + TC_{\text{гр}}(t) + TC_{\text{транзит}}(t)) - TC_{\text{импорт}}(t). \quad (5)$$

If $X_{n\text{ транс}}(t) > 0$, a positive balance is observed – the country is a net exporter of transport services; if $X_{n\text{ транс}}(t) < 0$ – it is a net importer; $X_{n\text{ транс}}(t) = 0$ indicates a balance of export and import [5, 19]. Net export is an indicator of the international competitiveness of the transport sector and its contribution to the country's balance of payments [18, 19].

For the Republic of Belarus, which has traditionally been a net exporter of transport services, this indicator is of particular significance: transit revenues (primarily from pipeline and railway transport) account for a substantial share of services exports [5, 11, 21].

Stage 3. Introduction of Corrective Coefficients

To establish a precise relationship between gross output and net export, corrective coefficients are introduced [4, 16]

$$X_{n\text{ тр}} = \alpha \times B_{\text{гр транс}} - \beta \times InC_{\text{транс}}, \quad (6)$$

where α – export orientation coefficient of transport services ($0 < \alpha \leq 1$); β – intermediate consumption coefficient; $InC_{\text{транс}}$ – intermediate consumption of transport services, representing the value of goods and services consumed in the process of producing transport services during the reporting period: expenditures on fuel and energy, materials and spare parts, services of other sectors, rent, communications and telecommunications [3, 13].

Taking into account the proposed methodology, the system of equations takes the following form (1) production equation $B_{\text{гр транс}}(t) = F(K(t), L(t), I(t), TFP(t))$; (2) distribution equation

which forms a significant share of gross output of transport services in transit states [11, 21].

In this regard, a three-stage strategy for eliminating the identified methodological contradictions is proposed, which ensures the transition from partial to full specification of the model of gross output of transport services in international traffic. This approach is consistent with the principles of constructing consistent econometric systems [16, 17] and with the requirements for identifiability of structural models [4, 15].

Stage 1. Decomposition of Gross Output of Transport Services

The gross output of the transport sector in the reporting period ($B_{\text{гр транс}}$) is an indicator of the productive capacity of the transport sector, reflecting the total volume of production activity without deducting intermediate costs. The gross output of transport services in international traffic should be represented as the sum of four components [3, 13]:

$$B_{\text{гр транс}} = TC_{\text{пр экс}} + TC_{\text{гр}} + TC_{\text{транзит}} + TC_{\text{импорт}}, \quad (1)$$

where $B_{\text{гр транс}}$ – gross output of transport services; $TC_{\text{пр экс}}$ – direct transport services for export (sold separately); $TC_{\text{гр}}$ – embedded (indirect) transport services included in the value of exported goods from other sectors; $TC_{\text{транзит}}$ – transit transportation of goods of third countries; $TC_{\text{импорт}}$ – transport services related to import. This decomposition conforms to the methodological principles of SNA 2008 and allows the conceptual incompleteness of the baseline specification to be eliminated [13, 19].

Stage 2. Establishing the Relationship with Net Export

Net export of transport services is defined as the difference between export and import of transport services, showing the foreign trade balance of the sector [13, 19]

$$X_{n\text{ транс}} = EX_{\text{транс}} - IM_{\text{транс}}, \quad (2)$$

where the export of transport services includes direct export, embedded export, and the transit component

$$EX_{\text{транс}} = TC_{\text{пр экс}} + TC_{\text{гр}} + TC_{\text{транзит}}. \quad (3)$$

And the import of transport services determines payments to foreign carriers

$$IM_{\text{транс}} = TC_{\text{импорт}}. \quad (4)$$

The net export ($X_{n\text{ транс}}(t)$) of transport services in the reporting period (t) is calculated as

$$B_{\text{гр транс}}(t) = VA_{\text{транс}}(t) + InC_{\text{транс}}(t); \quad (3) \text{ equation linking to foreign trade } VA_{\text{транс}}(t) = X_{n\text{ транс}}(t) + D_{\text{транс}}(t); \quad (4) \text{ net export equation } X_{n\text{ транс}}(t) = (TC_{\text{пр экс}}(t) + TC_{\text{гр}}(t) + TC_{\text{транзит}}(t)) - TC_{\text{импорт}}(t); \quad (5) \text{ balance identity } B_{\text{гр транс}}(t) = InC_{\text{транс}}(t) + X_{n\text{ транс}}(t) + D_{\text{транс}}(t),$$

where $D_{\text{транс}}(t)$ – domestic final use of transport services in period (t). Thus, the logical incompatibility is eliminated: the new formulation contains a precise mathematical relationship without ambiguity [8, 16, 17].

Research Results

The proposed system of equations constitutes a consistent model of the transport sector integrating production and foreign trade aspects. The modification of the first assumption ensures comprehensive coverage of all types of transport activity: direct transport services ($TC_{\text{пр экс}}(t)$); embedded (indirect) transport services ($TC_{\text{гр}}(t)$); the transit component ($TC_{\text{импорт}}(t)$); services for import handling (part of $InC_{\text{транс}}(t)$ and $D_{\text{транс}}(t)$) [3, 13, 21].

The replacement of the second assumption with a precise relationship entails: instead of the claim that components “balance”, a precise mathematical relationship is established $X_{n\text{ транс}}(t) = B_{\text{гр транс}}(t) - InC_{\text{транс}}(t) - D_{\text{транс}}(t)$. This equation unambiguously links net export to gross output through intermediate consumption and domestic use, consistent with SNA 2008 standards [15, 13, 19].

The production function of the transport sector is specified in the Cobb-Douglas form [2, 8, 9]

$$B_{гр\text{транс}}(t) = A \times TFP(t) \times K^{\alpha}(t) \times L^{\beta}(t) \times I^{\gamma}(t), \quad (7)$$

where α, β, γ – elasticity coefficients with respect to the respective production factors; A – scale (calibration) multiplier; $TFP(t)$ – total factor productivity index. According to research by Grechishkina E. A. and Vasilchenko A. O. [20], the arithmetic mean value of TFP for the economy of the Republic of Belarus over the period 2010–2023 amounts to 2,2485 ranging from 2,05 (2021) to 2,55 (2023), reflecting successful adaptation to changing operating conditions and intensification of trade cooperation within the EAEU [18, 20].

The practical application envisages three scenarios for interpreting the revised assumptions. The first scenario is growth in direct export of transport services: an increase in $TC_{пр\text{экс}}(t)$ with other components unchanged leads to growth in $X_{н\text{транс}}(t)$ with constant $B_{гр\text{транс}}(t)$. The second scenario is transit development ($TC_{транзит}(t)$): transit constitutes pure export creates a multiplier effect through intermediate demand (fuel, services, etc.), and may require infrastructure investments [11, 18, 21]. The third scenario is import substitution in transport activities: replacing foreign carriers with national ones increases $X_{н\text{транс}}(t)$ even at unchanged export volumes and raises the utilization of the domestic transport sector [5, 11].

Components of the Production Function of the Transport Sector

Capital $K(t)$ represents the value of fixed assets of the transport sector and encompasses: transport vehicles (automobiles, rolling stock, vessels, aircraft); transport infrastructure (roads, bridges, railway tracks, ports, airports, terminals); buildings and structures, equipment and machinery. Capital dynamics follow the formula

$$K(t+1) = K(t) + (t) - \delta \times K(t), \quad (8)$$

where δ – depreciation (retirement) rate of capital; $I(t)$ – investment in period t [3, 13].

Labour ($L(t)$) represents the quantity of labour resources employed in the transport sector during the period, encompassing all employed persons: drivers and train operators; pilots, dispatchers, technical, and administrative-managerial personnel. Units of measurement include: number of employees (persons); man-hours, full-time equivalent (FTE). Labour as a factor of production represents the human resource of production, whose change in quantity or quality directly affects the production capacity of the transport sector [3, 13].

Investment $I(t)$ is represented by capital expenditures for the development of the transport sector during the period, directed towards the acquisition, creation, or modernization of fixed assets, and encompasses the following areas: acquisition of new transport vehicles; construction and modernization of infrastructure; procurement of equipment and machinery; implementation of information systems; research and development in the field of transport.

Total Factor Productivity ($TFP(t)$) is an indicator of technological production efficiency, measuring the contribution of technological progress, innovation, organizational improvements, and other intangible factors [8, 10]. It is calculated as the Solow residual [8]

$$TFP(t) = \frac{B_{гр\text{транс}}(t)}{F(K(t), L(t), I(t))}, \quad (9)$$

where $F(K(t), L(t), I(t))$ – the production function excluding technological progress.

This indicator is subject to the influence: of technological innovations, organizational improvements, workforce upskilling, improvements in the institutional environment, network effects, digitalization and process automation [2, 20].

Components of Transport Services Export

Direct export of transport services ($TC_{пр\text{экс}}(t)$) represents transport services rendered directly to foreign residents by national carriers: international freight transportation on order of foreign companies; charter of transport vehicles by foreign customers; port and airport services for foreign carriers; forwarding services for foreign clients. These data are recorded under the item "Transport Services" in the "Services" section of the current account of the balance of payments [18, 19].

Embedded (indirect) export of transport services ($TC_{гр}(t)$) – transport services included in the value of exported goods of other economic sectors. It is calculated through coefficients of direct and total expenditures from input-output tables

$$TC_{гр} = \sum_{j \neq \text{транс}} a_{\text{транс}j} \times EX_j, \quad (10)$$

where $a_{\text{транс}j}$ – coefficient of direct expenditures of transport services of economic activity type j ; EX_j – export of economic activity type j .

Embedded (indirect) export shows the indirect contribution of the transport sector to the country's sector through servicing other exporters [3, 13].

Transit transport services ($TC_{транзит}(t)$) – services for the transportation of goods and passengers through the country's territory without their domestic consumption. Transit does not increase the domestic GDP of producing economic activity types and is entirely attributed to the export of transport services. For the Republic of Belarus, significant examples include: transit of natural gas from the Russian Federation to EU countries through Belarusian territory; rail transit of containers from China to EU countries; transit of oil and petroleum products through pipeline systems [5, 11, 18].

The Cobb-Douglas production function (equation 1) for the transport sector takes the form [2, 10]

$$B_{гр\text{транс}}(t) = A_{\text{транс}} \times TFP_{\text{транс}}(t) \times K_{\text{транс}}^{0,45}(t) \times L_{\text{транс}}^{0,35}(t) \times I_{\text{транс}}^{0,10}(t)$$

The following data are given: $K_{\text{транс}}(t) = 500$ bln conventional units; $L_{\text{транс}}(t) = 1,2$ mln people; $I_{\text{транс}}(t) = 50$ bln conventional units; $InC_{\text{транс}}(t) = 180$ bln conventional units; $TFP_{\text{транс}}(t) = 1,15$; $A_{\text{транс}} = 0,50$; $c = 20$; $\alpha_{\text{транс}} = 0,45$; $\beta_{\text{транс}} = 0,35$; $\gamma_{\text{транс}} = 0,90$; $TC_{пр\text{экс}}(t) = 45$ bln conventional units; $TC_{гр}(t) = 28$ bln conventional units; $TC_{транзит}(t) = 15$ bln conventional units; $TC_{импорт}(t) = 32$ bln conventional units. Production function calculation

$$B_{гр\text{транс}}(t) = 0,50 \times 1,15 \times 500^{0,45} \times 1,2^{0,35} \times 50^{0,10} = 14,92.$$

Multiplied by the scale coefficient $B_{гр\text{транс}}(t) = 14,92 \times 20 = 298,40$ bln conventional units [2, 10]. Gross Value Added calculation (equation 2)

$$VA_{\text{транс}}(t) = B_{гр\text{транс}}(t) - InC_{\text{транс}}(t) = 298,40 - 180 = 118,40 \text{ bln conventional units.}$$

Net export calculation (equation 4)

$$X_{н\text{транс}}(t) = (TC_{пр\text{экс}}(t) + TC_{гр}(t) + TC_{транзит}(t)) - TC_{импорт}(t) = (45,00 + 28,00 + 15,00) - 32,00 = 56,00 \text{ bln conventional units.}$$

Domestic final use calculation (equation 3)

$$D_{\text{транс}}(t) = VA_{\text{транс}}(t) - X_{н\text{транс}}(t) = 118,40 - 56,00 = 62,40 \text{ bln conventional units.}$$

Balance identity verification (equation 5)

$$B_{гр\text{транс}}(t) = InC_{\text{транс}}(t) + X_{н\text{транс}}(t) + D_{\text{транс}}(t). \\ 298,40 \text{ bln conventional units} = 180,00 + 56,00 + 62,40 = 298,40 \text{ bln conventional units.}$$

The balance converges; consequently, the model is consistent. This result confirms the correctness of the proposed methodology for eliminating the identified contradictions [4, 16, 17].

The dynamics of TFP in the transport sector of the Republic of Belarus serve as a leading indicator of technological shifts. The growth of the indicator from 2,05 to 2,55 over the period 2010–2023 reflects the successful adaptation of the economy to changed operating conditions, the establishment of new supply chains, and the intensification of trade cooperation within the EAEU [5, 18, 20].

Discussion of Results and Scientific Novelty

The proposed three-stage methodology represents a new instrumental solution to the problem of correct modelling of the gross output of transport services in international traffic. Unlike previously

approaches [1, 3, 12], this methodology provides: complete decomposition of gross output with the identification of the transit component; strict balance identities that exclude logical incompatibility; a built-in verification mechanism through checking the balance identity; compatibility with the requirements of SNA 2008 [13] and the IMF balance of payments methodology [19].

The scientific novelty of the study consists in the following. First, a system of structural equations is proposed for the first time in which logical contradictions between statements about gross output and net export aggregates of transport services are eliminated. Second, a mechanism is developed for introducing corrective coefficients (export orientation and intermediate consumption), enabling formalization of the relationship between macroaggregates while preserving the economic meaningfulness of the model. Third, the Cobb – Douglas production function is adapted for the transport sector of a small open transit economy, accounting for the specifics of the Belarusian institutional environment [2, 10, 20].

Comparison with the international analogues shows that the application of production functions in the transport sector is widespread in global research practice [3, 12]. At the same time, the specifics of small transit economies with a high share of transport services exports in GDP remain insufficiently studied [19, 21]. The present study fills this gap by proposing a solution relevant for EAEU member states with similar transport sector characteristics [5, 18].

Data requirements for the proposed new model include: from national accounts compilations – gross output of the transport sector, intermediate consumption, gross value added, gross fixed capital formation; from the country's balance of payments – export and import of transport services; from input-output tables – coefficients of direct expenditures of transport services; from transport sector statistical publications – value of fixed assets, number of employees volume of transit transportation [5, 13, 18, 19].

Methods for estimating model parameters include: ordinary least squares (OLS) for linear and non-linear forms; panel methods when regional data are available, and others. Total factor productivity is estimated using the index method (Divisia index, Tornqvist index), calculation of the Solow residual [8], stochastic frontier analysis (SFA), or data envelopment analysis (DEA) [10, 16, 17]. The calculation of embedded export is performed using matrices of direct and total expenditures from input-output tables based on the Leontief input-output balance model [3, 13].

Conclusion

The presented system of equations constitutes a consistent model of the transport sector integrating production and foreign trade aspects. The revised version of the model eliminates the logical contradictions of previous formulations by establishing precise mathematical relationships between gross output, intermediate consumption, value added, net export, domestic use [13, 16, 19].

The functioning of the proposed model requires the fulfilment of a number of conditions: availability of data on all components of gross output of transport services in terms of direct export, embedded services, transit, and import; correct identification of the value of transport services embedded in the cost of exported products; comparability of the price base (FOB, CIF, ex-border), and the affiliation of data on all variables to the same reporting period [13, 19].

The mechanism of value added growth in freight transportation in international traffic is sensitive to the growth rate of final and intermediate consumption of services by national carriers in the domestic market and less sensitive to changes in net taxes on products [4, 9, 16]. The product of the technical coefficient and the total factor productivity index characterizes a relatively high baseline level of factor productivity of the Belarusian economy, achieved through significant public investment in fixed capital and the preservation of industrial potential [2, 20].

The model serves as a foundation for in-depth analysis of the transport sector, development of forecasts for its advancement, substantiation of economic policy measures in transport and logistics in the context of EAEU development and Eurasian transport-logistics integration [11, 18, 21]. Further research envisages empirical verification of the model on real statistical data, expansion of the specification to account for the digitalization of the transport sector, and construction of forecast scenarios with a horizon to 2030 [5, 6, 7, 18].

References

1. Mesnik, D. N. Nauchno-metodologicheskie osnovy ispol'zovaniya modeli gruzovyh avtomobil'nyh perevozok v sisteme adaptatsii k vneshneekonomicheskim vyzovam / D. N. Mesnik, A. K. Hodas // *Vesti instituta predprinimatel'skoj deyatel'nosti*. – 2023. – № 2 (29). – S. 42–55.
2. Rybak, K. A. Vliyaniye nauchno-tekhnicheskogo progressa na VVP Belarusi: analiz na osnove proizvodstvennoj funktsii Kobba-Duglasa / K. A. Rybak // *Doklady BGUIR*. – 2021. – № 19 (3). – S. 62–68.
3. Skal'skaya, N. O. Proizvodstvennyye funktsii v ekonometricheskom analize i ih ispol'zovanie v scenarnykh raschetakh ekonomicheskikh pokazatelej Respubliki Belarus' / N. O. Skal'skaya, M. A. Pervushina, V. V. YUhnovich // *Sbornik nauchnykh trudov BGEU*. – 2025. – Vyp. 14. – S. 357–361.
4. CHubrik, A. Ekonomicheskij rost v Belarusi i Pol'she: teoriya rosta i politekonomiya / A. CHubrik // *Rabochie materialy IPM*. – 2003. – WP/03/02. – 56 s.
5. Oficial'naya statistika // Nacional'nyj statisticheskij komitet Respubliki Belarus'. – URL: <https://www.belstat.gov.by/ofitsialnaya-statistika> (data obrashcheniya: 22.03.2026).
6. Otchet Nacional'nogo banka Respubliki Belarus'. – URL: <https://www.nbrb.by/publications/report> (data obrashcheniya: 22.03.2026).
7. Ocenka ravnovesnogo real'nogo VVP s ispol'zovaniem proizvodstvennoj funktsii. – URL: <https://www.nbrb.by/bv/pdf/articles/8303.pdf> (data obrashcheniya: 22.03.2026).
8. Solow, R. M. Technical Change and Aggregate Production Function / R. M. Solow // *The Review of Economics and Statistics*. – 1957. – Vol. 39, No. 3. – P. 312–320.
9. Barro, R. J. *Economics Growth* / R. J. Barro, X. Sala-i-Martin. – 2nd ed. – Cambridge : MIT Press, 2004. – 654 p.
10. Deardorff, A.V. Comparative Advantage and International Trade Theory / A. V. Deardorff // *Journal of International Economics*. – 2014. – Vol. 94, No. 2. – P. 139–153.
11. Transport v Respublike Belarus', 2022 // Nacional'nyj statisticheskij komitet Respubliki Belarus'. – URL: https://www.belstat.gov.by/ofitsialnaya-statistika/publications/izdania/public_brochures/index_52718 (data obrashcheniya: 22.03.2026).
12. Magnus, YA. R. *Ekonometrika. Nachal'nyj kurs* / YA. R. Magnus, P. K. Katyshev, A. A. Pereisekij. – 6-e izd. – M. : Delo, 2004. – 576 s.
13. Sistema nacional'nyh schetov 2008 (SNS-2008). – N'yu-York : Organizatsiya Ob'edinennykh Natsij, 2012. – 727 s.
14. Panevchik, V. V. K koncepcii sbalansirovannogo razvitiya otraslej ekonomiki (na primere transporta) / V. V. Panevchik, V. N. Malinovskij // *Vestnik associacii belorusskikh bankov*. – 2023. – № 45 (1012). – S. 34–42.
15. Greene, W. H. *Econometric Analysis* / W. H. Greene. – 8th ed. – New York : Pearson, 2018. – 1168 p.
16. Hamilton, J. D. *Time Series Analysis* / J. D. Hamilton. – Princeton : Princeton University Press, 1994. – 799 p.
17. Wooldridge, J. M. *Introductory Econometrics: A Modern Approach* / J. M. Wooldridge. 7th ed. – Boston : Cengage Learning. 2020. – 912 p.
18. Evrazijskaya ekonomicheskaya komissiya. Statistika vneshnej i vzaimnoj torgovii tovarami / Evraz. ekon. komis. – M. : EEK, 2024. – 210 s.
19. Mezhdunarodnyj valyutnyj fond. Rukovodstvo po platěžnomu balansu i mezhdunarodnoj investicionnoj pozicii (RPB7) / Mezhdunar. valyut. fond. – Vashington, O. K. : MVF, 2023. – 340 s.
20. Grechishkina, E. A. Analiz sovokupnoj faktornoj proizvoditel'nosti Respubliki Belarus': retrospektivnaya dekompozitsiya faktorov ekonomicheskogo rosta / E. A. Grechishkina, A. O. Vasil'chenko // *Ekonomika i banki*. – 2024. – № 1. – S. 52–62.
21. Dutina, A. A. Odnofaktornye modeli rosta vyruchki logisticheskikh centrov i eksporta transportnykh uslug Belarusi / A. A. Dutina, D. A. Tomut' // *Zhurnal Belorusskogo gosudarstvennogo universiteta. Ekonomika*. – 2022. – № 2. – S. 24–29.
22. Koroleva, E. A. Modeli i metody agregatsii v konsensus-prognoz eksporta transportnykh uslug Belarusi i drugih stran EAES : avtoref. dis. ... kand. fiz.-mat. nauk / E. A. Koroleva. – Minsk : BGU, 2022. – 25 s.
23. World Bank. Belarus: Transport Sector Policy Note. – Washington, D. C. : World Bank, 2010. – DOI: 10.1596/19462.

Список цитированных источников

1. Месник, Д. Н. Научно-методологические основы использования модели грузовых автомобильных перевозок в системе адаптации к внешнеэкономическим вызовам / Д. Н. Месник, А. К. Ходас // Вести института предпринимательской деятельности. – 2023. – № 2 (29). – С. 42–55.
2. Рыбак, К. А. Влияние научно-технического прогресса на ВВП Беларуси: анализ на основе производственной функции Кобба-Дугласа / К. А. Рыбак // Доклады БГУИР. – 2021. – № 19 (3). – С. 62–68.
3. Скальская, Н. О. Производственные функции в эконометрическом анализе и их использование в сценарных расчетах экономических показателей Республики Беларусь / Н. О. Скальская, М. А. Первушина, В. В. Юхевич // Сборник научных трудов БГЭУ. – 2025. – Вып. 14. – С. 357–361.
4. Чубрик, А. Экономический рост в Беларуси и Польше: теория роста и политэкономия / А. Чубрик // Рабочие материалы ИПМ. – 2003. – WP/03/02. – 56 с.
5. Официальная статистика // Национальный статистический комитет Республики Беларусь. – URL: <https://www.belstat.gov.by/ofitsialnaya-statistika> (дата обращения: 22.03.2026).
6. Отчет Национального банка Республики Беларусь. – URL: <https://www.nbrb.by/publications/report> (дата обращения: 22.03.2026).
7. Оценка равновесного реального ВВП с использованием производственной функции. – URL: <https://www.nbrb.by/bv/pdf/articles/8303.pdf> (дата обращения: 22.03.2026).
8. Solow, R. M. Technical Change and Aggregate Production Function / R. M. Solow // The Review of Economics and Statistics. – 1957. – Vol. 39, No. 3. – P. 312–320.
9. Barro, R. J. Economics Growth / R. J. Barro, X. Sala-i-Martin. – 2nd ed. – Cambridge : MIT Press, 2004. – 654 p.
10. Deardorff, A.V. Comparative Advantage and International Trade Theory / A. V. Deardorff // Journal of International Economics. – 2014. – Vol. 94, No. 2. – P. 139–153.
11. Транспорт в Республике Беларусь, 2022 // Национальный статистический комитет Республики Беларусь. – URL: https://www.belstat.gov.by/ofitsialnaya-statistika/publications/izdania/public_brochures/index_52718 (дата обращения: 22.03.2026).
12. Магнус, Я. Р. Эконометрика. Начальный курс / Я. Р. Магнус, П. К. Катышев, А. А. Пересецкий. – 6-е изд. – М. : Дело, 2004. – 576 с.
13. Система национальных счетов 2008 (СНС-2008). – Нью-Йорк : Организация Объединенных Наций, 2012. – 727 с.
14. Паневчик, В. В. К концепции сбалансированного развития отраслей экономики (на примере транспорта) / В. В. Паневчик, В. Н. Малиновский // Вестник ассоциации белорусских банков. – 2023. – № 45 (1012). – С. 34–42.
15. Greene, W. H. Econometric Analysis / W. H. Greene. – 8th ed. – New York : Pearson, 2018. – 1168 p.
16. Hamilton, J. D. Time Series Analysis / J. D. Hamilton. – Princeton : Princeton University Press, 1994. – 799 p.
17. Wooldridge, J. M. Introductory Econometrics: A Modern Approach / J. M. Wooldridge. 7th ed. – Boston : Cengage Learning, 2020. – 912 p.
18. Евразийская экономическая комиссия. Статистика внешней и взаимной торговли товарами / Евраз. экон. комис. – М. : ЕЭК, 2024. – 210 с.
19. Международный валютный фонд. Руководство по платежному балансу и международной инвестиционной позиции (РПБ7) / Междунар. валют. фонд. – Вашингтон, О. К. : МВФ, 2023. – 340 с.
20. Гречишкина, Е. А. Анализ совокупной факторной производительности Республики Беларусь: ретроспективная декомпозиция факторов экономического роста / Е. А. Гречишкина, А. О. Васильченко // Экономика и банки. – 2024. – № 1. – С. 52–62.
21. Дутина, А. А. Однофакторные модели роста выручки логистических центров и экспорта транспортных услуг Беларуси / А. А. Дутина, Д. А. Томуть // Журнал Белорусского государственного университета. Экономика. – 2022. – № 2. – С. 24–29.
22. Королева, Е. А. Модели и методы агрегации в консенсус-прогноз экспорта транспортных услуг Беларуси и других стран ЕАЭС : автореф. дис. ... канд. физ.-мат. наук / Е. А. Королева. – Минск : БГУ, 2022. – 25 с.
23. World Bank. Belarus: Transport Sector Policy Note. – Washington, D. C. : World Bank, 2010. – DOI: 10.1596/19462.

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