METHODOLOGICAL FOUNDATIONS FOR MODELING UAE–AZERBAIJAN ECONOMIC RELATIONS: A SYSTEM DYNAMICS APPROACH TO TRADE, FDI, ENERGY TRANSITION AND CONNECTIVITY

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Abstract: This article develops a methodological framework for modeling economic relations between the United Arab Emirates and Azerbaijan through a System Dynamics approach. The study begins by reviewing the main methodological tools used in the analysis of international economic cooperation, including gravity models, CGE/GTAP models, panel econometric approaches, input–output and GVC/TiVA analysis, network analysis, Difference-in-Differences and synthetic control methods. While these approaches provide valuable insights into trade potential, macroeconomic effects, value-chain integration and causal relationships, they are limited in capturing feedback loops, time delays, nonlinear effects and cross-sectoral interactions. The paper argues that UAE–Azerbaijan economic relations should be understood as a dynamic system in which trade, FDI, energy transition, logistics connectivity, tourism mobility and institutional cooperation mutually reinforce or constrain each other over time. The proposed System Dynamics framework conceptualizes bilateral economic integration through stocks such as Bilateral Economic Integration Stock, UAE FDI Stock in Azerbaijan, Renewable Energy Cooperation Capacity, Logistics Connectivity Capacity, Tourism and Mobility Intensity and Institutional Cooperation Strength.

Keywords: System Dynamics; UAE–Azerbaijan economic relations; trade and FDI; energy transition; logistics connectivity; methodological framework.

Introduction

There are studies using SD – System Dynamics methodology in the study of economic cooperation between two or more countries, but this literature is not yet as extensive as gravity model, CGE/GTAP, panel data and input–output/GVC analyses. SD is mostly applied under the following names: regional economic integration, cross-border value chains, cross-border logistics, cross-border e-commerce, FDI dynamics, international supply chains, economic corridors, energy cooperation and regional connectivity.

The SD methodology is still rarely used in classical "trade potential between two countries" studies, but it seems to be a very useful method in explaining cross-country cooperation as a dynamic, feedback-driven, delayed and multi-sectoral system.

One of the closest studies to this topic was conducted by Grobbelaar and Meyer. The authors analyze why regional economic integration is poorly developed within the Southern African Customs Union (SACU) and how cross-border value chains can strengthen integration using the SD approach. Although the mathematical stock–flow model is not fully established in the study, the authors explain the process of regional integration using systems thinking, dynamic hypothesis and feedback loop approaches. Their main argument is that regional integration is a dynamic process related not only to tariff reduction, but also to transport, logistics, border management, technical standards and value chain development .[11] The article itself states that the study examines the dynamics of regional economic integration and cross-border value chain development in SACU using systems thinking.

This study is very useful for your UAE–Azerbaijan topic. Because here, too, the issue is not just “is there trade?”, but the relationship of trade + logistics + investment + value chain + institutional coordination.

Zhang analyzes the relationship between cross-border logistics and the ecological environment using the SD model. The main idea of the study is that international trade and cross-border logistics interact with each other: as import–export trade volume increases, logistics activity increases, and logistics activity affects both trade efficiency and ecological pressure .[25] The author emphasizes that SD is suitable for analyzing multivariate, delayed, and nonlinear systems; the study models the positive and delayed relationships between import–export trade volume and freight turnover.

The methodological lesson of this study for the UAE–Azerbaijan topic is that logistics is not just an auxiliary variable, but can be considered as a central feedback mechanism of economic cooperation. For example:

Logistics capacity → trade cost reduction → bilateral trade expansion → logistics demand → new logistics investment

Chen et al. investigate China’s cross-border e-commerce B2B export trade system during the COVID-19 period using the SD model. The study assesses the impact of the “dual circulation” policy on cross-border B2B export trade. Here, dynamic relationships are established between government support, customs efficiency, financial subsidies, logistics infrastructure and enterprises’ export behavior [2]. The bibliographic information of the article indicates that the study is “cross-border e-commerce B2B export trade based on system dynamics”.

This study is very important in the context of the UAE-Azerbaijan CEPA. Because CEPA is not only about tariff reduction; it requires coordination of customs, digital trade, investment and business environment. Different implementation scenarios of CEPA can be modeled with the SD model.

Duan et al. simulate the transfer of risks in cross-border e-commerce logistics with the SD model. The authors note that cross-border logistics risks are more complex due to multiple participants, long distance, customs procedures, political uncertainty, pandemic and process delays [5] They model risk factors not as independent variables, but as a system with causal relationships and risk transmission mechanisms. The study identifies customs risk, process risk, and cooperation risk as the main risks.

For the UAE–Azerbaijan model, this study shows that not only growth mechanisms but also risk transmission loops should be considered in logistics and trade relations. For example:

Geopolitical risk → logistics delay → trade cost increase → trade volume decline → investor confidence decline

Zhu et al. link port resilience in Maritime Silk Road countries to ESG governance within the SD framework. The paper shows that ports play a critical role in connectivity, maritime trade corridors and economic cooperation between participating countries [26]. The study considers port resilience not only as a technical infrastructure issue, but also as a system variable related to the stability of trade corridors, ESG governance and regional economic cooperation.

This is very suitable for the UAE–Azerbaijan study. Because the UAE has global experience in port, logistics and free zone management; Azerbaijan wants to become a regional logistics hub through the Alat Port, Alat Free Economic Zone and the Middle Corridor.

Chunxing analyzes China–Russia agricultural economic cooperation as a “bilateral agro-economic nexus” and uses a case study + system dynamics modeling approach. The study examines variables such as production, processing, distribution, logistics, technology, regulatory asymmetry and food security within the framework of a smart supply chain.[3] The author states in the article that this study provides an evidence-based governance framework for bilateral integration.

This example is particularly interesting for the UAE-Azerbaijan case because here, cooperation between the two countries is modeled not only as trade, but also as supply chain integration, digitalization, policy harmonization and targeted investment pathways. In the UAE-

Azerbaijan relations, agrarian trade, food security, halal food supply chain, logistics and re-export opportunities can also be built as separate SD modules.

Hajian Heidary examines the impact of the COVID-19 pandemic on FDI and supply chains using the SD model. The study is not a direct case study of two countries, but is relevant to international economic relations as it models feedback mechanisms between global FDI flows and international supply chain disruptions.[14] The article shows that the pandemic has reduced FDI flows, and factors such as supply chain disruption and transport delay have had a negative impact on investment decisions.

This example for the UAE–Azerbaijan study shows that when building an FDI model, external shocks, transport disruption, global uncertainty and delay effects should be taken into account, not just "investor interest".

A number of SD studies on cross-border e-commerce model the relationships between overseas warehouse, logistics service quality, customer satisfaction and export transaction volume. For example, the quality of overseas warehouse services is taken as a system factor affecting cross-border e-commerce transaction volume; sensitivity analysis and historical testing are applied via Vensim (Anonymous preprint, 2021) This work should be used with caution as a primary source as it is a preprint, but from a methodological point of view it shows that SD is used to model the relationships between cross-border trade and logistics service quality.

For UAE–Azerbaijan, this approach can be adapted not in the form of an "overseas warehouse", but as a free economic zone, logistics hub, re-export platform and regional distribution center.

Although Fisunoglu does not directly study economic cooperation, he explains the application of SD in international relations. The author shows that SD is useful as an alternative to traditional qualitative and quantitative methods for modeling dynamic interactions between variables, behavioral trajectories and alternative policy choices.[9] This approach can be used as a theoretical and methodological basis for UAE–Azerbaijan economic relations, since economic cooperation is an integral part of both economic and geopolitical and institutional relations.

The general conclusion of these examples is as follows: the SD method allows us to study economic cooperation between two or more countries not as a direct "trade volume", but as a multi-level and interdependent system. Grobbelaar and Meyer explain regional integration through cross-border value chains; Zhang shows lagged relationships between cross-border logistics and trade volume; Chen et al. model the impact of government policies, customs and logistics infrastructure on cross-border export trade; Duan et al. show how risks are spread within a cross-border logistics system; Zhu et al. establish a link between port resilience and economic cooperation; and Chunxing explain bilateral agricultural supply chain cooperation with SD [11;2;5;26;3]

Four main methodological implications for the UAE–Azerbaijan study emerge from these.

First, economic cooperation can be taken as a stock. For example, a stock called "Bilateral Economic Cooperation Stock" could reflect the cumulative effect of trade, FDI, energy projects, logistics linkages, tourism flows and institutional agreements.

Second, trade and FDI are not independent variables but parts of a feedback loop. For example:

FDI → production/logistics capacity → export potential → trade growth → investor confidence → new FDI

Third, logistics and mobility should be included as central variables. The literature shows that cross-border logistics is not just a technical aspect of trade, but a key mechanism shaping its dynamics [25;5]

Fourth, risks and delays should be an integral part of the model. CEPA, energy projects, logistics corridors and tourism cooperation do not produce immediate results; their impact emerges with a delay through institutional implementation, investment decisions, infrastructure readiness and market reactions.

For our research topic, it is appropriate to link the SD model to the Regional integration and value chain line, the Cross-border logistics and trade line, the Cross-border e-commerce and policy support line, as well as the Port, corridor and maritime cooperation line and the Bilateral supply chain cooperation line. Grobbelaar and Meyer can be a key methodological reference.

Their study on SACU shows that regional economic cooperation is not just a formal integration agreement, but a dynamic process involving the formation of cross-border value chains and the reduction of institutional barriers .[11] Zhang and Duan et al. can be used. These studies show that there are feedback relationships between logistics, customs, risks and trade volume. [25] Chen et al. can provide a methodological basis for the CEPA and digital trade model. Their study models the impact of government policies, customs efficiency and infrastructure on B2B export trade with SD .[2]

Here, Zhu et al. can be used for UAE–Azerbaijan logistics and the Middle Corridor cooperation. In particular, a link can be made between the UAE's port and logistics experience and Azerbaijan's Alat Port and Middle Corridor strategy [26]

Chunxing's China–Russia agricultural supply chain study is useful here. This approach can be a model for modeling UAE–Azerbaijan agrarian, food security, halal food, re-export, and logistics hub cooperation .[3]

Methodological relevance of the System Dynamics approach for international economic relations

International economic relations in modern times are formed as a complex, multi-level and interdependent system. Traditional economic models often analyze trade, foreign direct investment, energy cooperation, logistics, tourism and institutional changes as separate blocks. However, in real economic relations, these areas do not operate in isolation. The increase in bilateral trade strengthens the demand for logistics infrastructure; the expansion of logistics capabilities increases the attractiveness of FDI; FDI creates new production and export potential in the energy, tourism and service sectors; and energy cooperation opens up new policy opportunities for both macroeconomic stability and the green transition. Therefore, it is more appropriate to study the UAE-Azerbaijan economic relations not only on the basis of statistical relationships, but also on the basis of systemic interactions and feedback mechanisms.

The SD approach is a suitable methodological tool for the analysis of such complex systems. SD models the interaction of economic, social, technological and institutional variables over time through stocks, flows, auxiliary variables, delays and feedback loops. The main advantage of this approach is that it does not only show linear cause-and-effect relationships of the type "variable A affects variable B", but also shows how this effect changes the behavior of the system over time. This is especially important in international economic relations, since trade, investment, energy and logistics policies often produce results not immediately, but with a delay. For example, trade turnover may not increase immediately after the signing of a trade agreement; first, business confidence, logistics readiness, customs procedures, investor decisions and cross-sectoral adaptation stages occur. In recent years, the SD approach has been more widely used in energy transition, sustainable development, supply chains, transport systems, industrial decarbonization and complex policy modeling. For example, SD is applied to model the interactions between technology costs, investment decisions, public policies, carbon prices, energy demand, and infrastructure delays in energy transition models .[13;12] The usefulness of SD for energy and economic policy is due to its ability to perform "what-if" scenarios, sensitivity analysis, and compare long-term policy outcomes. In 2024, uncertainty and sensitivity analysis are particularly important in SD applications to energy policy, as the energy transition depends on political priorities, technological costs, and international market conditions.

The relevance of SD in international economic relations is also due to the increased instability of the global economic system in recent years. The COVID-19 pandemic, the Russia–Ukraine war, logistics risks in the Red Sea, energy price shocks, trade protectionism, and geoeconomic fragmentation have brought the issue of the sustainability of global value chains to the forefront. According to OECD modeling, a sharp localization of supply chains can significantly reduce global trade and lead to real GDP losses; therefore, openness and geographic diversification are presented as a more rational strategy instead of full "reshoring". This result also provides a methodological lesson for the UAE–Azerbaijani relationship: economic cooperation should be modeled not only as an increase in bilateral trade, but also as a strengthening of regional connections, alternative logistics routes and cross-sectoral integration.

The SD approach can fulfill three methodological functions in the UAE–Azerbaijani study. First, the conceptual function: through SD, it is possible to build a causal loop diagram between bilateral trade, FDI, energy cooperation, energy transition, logistics, tourism and mobility. Second, the analytical function: these relationships can be transformed into a stock–flow model and simulated over time. Third, the policy function: different scenarios — for example, "Business-as-usual", "Green investment acceleration", "Logistics corridor integration", "Tourism-mobility expansion", "Integrated economic partnership" — can be compared. Thus, SD is not only a descriptive method; it is also a tool for policy design, risk assessment, and strategic planning.

Conceptualizing International Economic Relations as an SD Model

To model UAE–Azerbaijan economic relations within the SD framework, the system boundaries must first be defined. The system boundary indicates which variables the study includes and which variables it considers as external factors. For this study, the main system boundary is the economic integration process between the two countries. This process includes bilateral trade, FDI flows, energy cooperation, green energy investments, logistics connections, tourism flows, business mobility, and institutional cooperation. Global energy prices, regional geopolitical risks, world trade conditions, and the global financial environment can be taken as exogenous or scenario drivers in the model.

The first methodological step of the SD model is to define the problem statement and reference mode. The reference mode describes the past behavior of the system and the expected future dynamics. In the UAE–Azerbaijan case, the following behavioral patterns can be taken as reference modes: the growth trend of bilateral trade turnover, the shift of FDI projects across sectors, the expansion of energy cooperation from hydrocarbons to renewable energy projects, the increase in aviation and tourism mobility, and the increasing strategic importance of logistics and Middle Corridor connections. These reference modes are not just statistical trends, but also the system behavior that the model should explain.

The second stage is the construction of a causal loop diagram (CLD). CLD shows the cause-effect relationships and feedback loops between the main variables in the system. At least four main feedback loops can be identified for the UAE–Azerbaijani relationship. The first loop is the "trade–logistics–investment" loop: as trade volume increases, the demand for logistics services increases; expanding logistics capabilities reduces trade costs; reducing trade costs increases investor confidence and FDI flows; and FDI further stimulates trade by expanding production and service capabilities. This is a reinforcing feedback loop.

The second loop is the "energy cooperation–green FDI–energy transition" loop. Political and business cooperation in the energy sector expands the UAE's investment opportunities in green energy projects in Azerbaijan; green FDI increases renewable energy capacity; renewable energy capacity strengthens Azerbaijan's energy diversification; energy diversification enhances the country's green image and energy security; this in turn stimulates new energy cooperation and investment projects. In terms of SD, this loop shows how the energy transition in UAE–Azerbaijan relations can be transformed into economic integration. Masdar's renewable energy projects in Azerbaijan constitute the real institutional basis for this type of feedback mechanism.

The third loop is the "tourism–mobility–services trade" loop. The increase in tourism flows stimulates the expansion of air links and service infrastructure; the expansion of air links increases business mobility; business mobility creates new investment and service trade relations; service trade and economic recognition further strengthen tourism flows. This loop systematically combines the UAE's role as an aviation and tourism hub with Azerbaijan's regional tourism and logistics potential.

The fourth loop is the "institutional cooperation–economic confidence–integration" loop. Bilateral agreements, CEPA-type economic partnership mechanisms, business forums, and intergovernmental commissions increase economic confidence; economic confidence accelerates trade and investment decisions; institutional cooperation deepens as trade and investment outcomes show that cooperation is successful. An important feature of this loop is that its results are visible not in the short term, but in the medium and long term. Therefore, delay functions should be used in the model.

The third stage is the construction of a stock–flow model. At this stage, the qualitative relationships shown in the CLD are quantified. The main stock variables in the UAE–Azerbaijan study can be the following: Bilateral Economic Integration Stock, Accumulated UAE FDI in Azerbaijan, Renewable Energy Cooperation Capacity, Logistics Connectivity Capacity, Tourism and Mobility Intensity, Institutional Cooperation Strength. The flow variables can be defined as Trade Expansion Rate, FDI Inflow Rate, Green Energy Project Completion Rate, Logistics Capacity Expansion Rate, Tourism Flow Growth Rate and Institutional Agreement Implementation Rate.

In this structure, the "Bilateral Economic Integration Stock" can be a composite stock reflecting the overall level of integration. Its inflow is formed by trade growth, FDI growth, energy project implementation, expansion of logistics connections and increased tourism mobility. The outflow can be related to geopolitical risks, market constraints, investment delays, energy price shocks and institutional implementation problems. This approach explains integration not as a static indicator, but as a system reserve that accumulates and can weaken over time.

Complementarity of SD and traditional econometric methods

Econometric methods such as gravity model, panel data analysis, ARDL, VAR, VECM and GMM are widely used in the study of international economic relations. These methods are useful for identifying statistical relationships between trade, FDI, energy prices, GDP, exchange rate and other variables. However, their limitation is that it is often difficult to fully model feedback relationships, lags and policy scenarios between variables. For example, an econometric model can show that logistics performance has a positive effect on trade. But how does logistics performance itself change as a result of trade growth? Does trade growth generate new investment? Does investment re-strengthen logistics infrastructure? These questions are within the scope of the SD approach.

Therefore, in this study, SD and econometric approaches should be considered as complementary methods, not competitors. Econometric analysis can be used to estimate model parameters. For example, parameters such as the elasticity of trade costs to trade volume, the impact of FDI on non-oil exports, the time to convert energy investments into renewable energy, and the impact of tourist flows on service exports can be estimated based on econometric or statistical sources. The SD model, on the other hand, allows for scenario simulation by integrating these parameters within the system structure.

In the contemporary literature, there is growing interest in integrated methods in complex policy modeling. [19] show that different approaches in complex system policy modeling — including SD, agent-based modeling, and network modeling — are useful for explaining the real complexity of politics. This result is also valid for international economic relations. Because in the UAE–Azerbaijan relations, state policies, business decisions, energy markets, logistics infrastructure, and tourism behaviors all have a simultaneous impact.

Econometric methods mainly measure relationships based on past data. SD answers the question "how would the system behave if such a policy were implemented?" For example, the impact of CEPA on trade and investment flows may not yet be fully observed. In this case, there may not be enough post-agreement data for a classical econometric assessment. SD can simulate alternative scenarios by structuring the expected impact channels of CEPA: low implementation, medium implementation, and high implementation scenarios. This is an important methodological advantage for analyzing new institutional changes.

Another advantage of SD is that it can model nonlinear relationships. In international economic relations, impacts are often not linear. For example, an initial improvement in logistics infrastructure can give a large boost to trade, but after a certain level, the marginal effect of additional infrastructure decreases. Similarly, the economic impact of FDI depends on absorptive capacity: if human capital, local business connections and institutional quality are weak, the real impact of FDI may be limited. Such relationships can be modeled in the SD model using nonlinear functions, lookup tables and threshold effects.

Methodological lessons from SD modeling of international trade and FDI relations

The joint analysis of trade and FDI in the SD model provides an important methodological lesson: these two variables do not participate in a simple "cause and effect" relationship, but in mutually reinforcing and sometimes balancing mechanisms. FDI can expand trade by increasing production capacity, technology transfer and export potential. At the same time, expanding trade relations can stimulate FDI by increasing market recognition, risk reduction and profitability expectations for investors. However, this reinforcing relationship does not always have a positive outcome. If FDI is mainly directed towards import-oriented services or real estate, its impact on export diversification may be limited. Therefore, the sectoral structure of FDI should be taken into account separately in the SD model.

Recent UNCTAD reports show that global FDI flows have been volatile in recent years against the backdrop of geopolitical uncertainty, financial conditions and industrial policy changes. The stagnation of FDI flows for 2024 and the increase in investment needs in developing countries are particularly highlighted. This fact is important for the UAE–Azerbaijan model: FDI should be modeled not as a fixed and automatic flow, but as a dynamic flow dependent on investor confidence, risk perception, institutional arrangements, energy projects and logistics capabilities.

In the trade–FDI model, "investor confidence" can be a key auxiliary variable. This variable can be influenced by the level of implementation of CEPA, political stability, logistics performance, energy cooperation, macroeconomic stability and business environment. As investor confidence increases, the FDI Inflow Rate increases. However, the delay for FDI projects to translate into real economic results must be taken into account: there is a time lag between the investment decision, project implementation, the start of production and the appearance of export results. Another methodological lesson is to consider "balancing loops". After a certain stage, trade and FDI growth can create infrastructure overload, skills shortages in the labor market, land and energy demand, regulatory delays and environmental pressures. If these constraints are not included in the model, the simulation results will be overly optimistic. Therefore, variables such as logistics capacity constraint, skilled labor constraint, regulatory delay and environmental pressure should be included in the model as balancing mechanisms.

SD Modeling of Energy Cooperation and Energy Transition

Energy transition is one of the strongest areas of SD applications. This is mainly because energy systems have long investment cycles, technology learning effects, policy lags and infrastructure constraints. Energy transition is not just a change in energy production sources; it is a complex process involving capital investment, technology costs, network capabilities, consumer behavior, government subsidies, carbon policy and international energy markets. Recent reports by IRENA and CPI on energy transition finance show that the scale and structure of investment flows are crucial for energy transition.

In the UAE–Azerbaijan study, energy cooperation should be modeled at two levels. The first level is traditional energy cooperation: oil, gas, energy security and energy diplomacy. The second level is green energy cooperation: solar and wind projects, renewable energy capacity, electricity exports, green technology transfer and carbon emissions reduction. In the SD model, these two levels should be built in a mutually supportive manner, not in conflict with each other. Fossil energy revenues can finance green investments, but dependence on fossil revenues can also delay the energy transition. This can be represented in the SD model as two distinct loops: "fossil revenue enabling green investment" and "fossil dependence delaying transition".

The technology learning curve is of particular importance in energy transition models. As renewable energy projects increase, technology and management experience accumulate, costs decrease, and implementation of new projects becomes easier. This creates a reinforcing loop. However, variables such as grid integration constraints, storage capacity, and regulatory readiness can limit this process. Hafner et al. (2024)

emphasize the importance of systematically operationalizing multidimensionality and policy decisions in energy transition models.

The implementation of projects in Azerbaijan by the UAE through global green energy actors such as Masdar provides a real application area for the SD model. Here, relationships can be established between variables such as Green FDI Inflow, Renewable Capacity Addition, Grid Readiness, Local Value Creation, Energy Diversification, and Export Potential. [6] show that local participation in renewable energy value chains can generate more ambitious policy feedback; that is, as a country creates more local value in the technology chain, a more active energy transition policy can be formed. This lesson is important for Azerbaijan: green energy projects should be modeled not only as electricity generation, but also as mechanisms for local industry, human capital, and technological learning.

Incorporating Logistics, Supply Chains, and Mobility into the SD Model

Logistics and supply chains are a natural application area for SD models, as these systems involve dynamic relationships between order delays, lead times, inventory accumulation, demand fluctuations, infrastructure capacity, and costs. In recent years, the restructuring of global supply chains due to pandemics, geopolitical risks, and trade policies has increased the importance of logistics modeling. The Asian Productivity Organization's 2024 report shows that the transformation of global supply chains in the post-pandemic period is closely linked to productivity, technology integration, and government policies.

In the UAE-Azerbaijan model, logistics should be considered as a central system variable, not a "supporting variable." Because the expansion of economic cooperation between the two countries depends not only on market demand, but also on transport connections, air and sea connections, the capabilities of the Middle Corridor, and the operation of ports and free economic zones. The Logistics Connectivity Capacity stock can reflect the basic infrastructure base for trade and FDI. The inflow of this stock can be new routes, port investments, digitalization of customs procedures, increase in air flights and development of multimodal transport. The outflow can be related to infrastructure obsolescence, geopolitical risks, competition of alternative routes and management inefficiency.

In the logistics model, "trade cost" is the main auxiliary variable. As Logistics Connectivity Capacity increases, trade cost decreases; as trade cost decreases, trade volume increases; as trade volume increases, logistics demand increases; logistics demand stimulates new logistics investments. This is a classic reinforcing loop. However, if logistics capacity lags behind demand, a congestion effect occurs: loading increases, service quality decreases, transportation time increases and trade costs increase again. This is a balancing loop.

Tourism and mobility can also be included in the SD model on a similar principle. The Tourism and Mobility Intensity stock can reflect the overall intensity of human flows, business trips, tourism connections and aviation connections between countries. The increase in this stock is associated with the expansion of air connections, ease of visa procedures, tourism marketing, business forums and quality of service. Its decrease can be associated with price increases, regional risks, deterioration of service quality and aviation restrictions.

An important lesson in the tourism-mobility model is that tourism is not just an outcome variable, but also a mechanism that creates economic integration. Tourist flows increase the recognition of a country, expand business relations, stimulate trade in services and increase investors' knowledge of the market. In this regard, tourism can be modeled as "soft connectivity". Recent studies show that there are nonlinear relationships between tourism, FDI, economic globalization and renewable energy; this requires modeling the tourism sector as part of a broader economic-ecological system.

Model validation, sensitivity analysis and reliability issues

The scientific value of the SD model does not only depend on its interesting diagram construction. Structural validation, measurement unit compatibility, behavioral validation, extreme condition testing and sensitivity analysis should be carried out for the validity of the model. In recent years, the literature on SD validation has emphasized the importance of checking the model not only in terms of outcome consistency, but also in terms of structural logic, expert assessment and policy use. Schwaninger and Groesser (2020) show that structural validity, behavioral compatibility and fitness for purpose are the main criteria in the quality assurance of the SD model.

For structural validation in the UAE–Azerbaijan model, each relationship should be theoretically and empirically justified. For example, the relationship "logistics capacity → trade volume" can be justified by the literature on trade facilitation and logistics performance. The relationship "Green FDI → renewable capacity" should be justified by the literature on energy transition and green investment. The relationship "Tourism mobility → services trade" should be based on the literature on tourism economics and service trade. If the relationship is based only on the author's assumption, this should be clearly stated in the model and checked in a sensitivity analysis.

It is also important to check the units of measurement. In SD models, conceptual variables are often constructed in the form of an index. For example, variables such as Institutional Cooperation Strength and Investor Confidence can be given as an index in the range of 0–1. However, Trade Volume in million USD, FDI Stock in million USD, Renewable Capacity in MW, Tourism Flow in number of people, and Logistics Capacity can be measured as an index or tons/cargo capacity. When establishing an equation between these indicators, normalization and unit matching should be carefully carried out.

Behavioral validation checks whether the model behaves in accordance with historical data. For example, the model should be able to approximately reproduce the trend of UAE-Azerbaijan trade, investment, tourism, and energy cooperation for the years 2015–2025. Of course, complete information may not be available for all variables. In this case, the model can be built on the basis of partial calibration and expert-based parameterization. However, data limitations should not be presented as a weakness of the model, but as a matter of methodological transparency.

Sensitivity analysis is of particular importance in the SD model. This is because the UAE-Azerbaijan economic relationship depends on uncertain factors such as global energy prices, geopolitical risks, investment climate, logistics costs, and policy implementation. In the sensitivity analysis, the stability of the results should be checked by changing key parameters. For example, low–medium–high variants can be simulated for parameters such as CEPA implementation effectiveness, FDI responsiveness to investor confidence, logistics cost elasticity, renewable project delay, and tourism mobility responsiveness.

Scenario design and policy learning

One of the main advantages of SD models is scenario design. At least five scenarios can be proposed in the UAE–Azerbaijan study. The first scenario is the Business-as-usual scenario. In this scenario, it is assumed that the current trade and investment trend continues, but no major structural changes occur. The second scenario is the CEPA acceleration scenario. In this case, simplification of trade procedures, reduction of tariff and non-tariff barriers, expansion of business relations and increase in services trade are assumed. The third scenario is the Green energy partnership scenario. In this scenario, an increase in green energy investments by the UAE in Azerbaijan, an increase in renewable capacity and strengthening of energy diversification are modeled.

The fourth scenario is the Logistics corridor integration scenario. In this scenario, the development of the Middle Corridor, port infrastructure, air links, free economic zones and multimodal transport is taken as the main mechanisms affecting trade and FDI. The fifth scenario is the Integrated partnership scenario. In this scenario, trade, FDI, energy transition, logistics and tourism are strengthened simultaneously. This may be the most complex and realistic policy scenario, because in international economic relations, cross-sectoral synergies often produce stronger results than individual sectoral policies.

The comparison of scenarios should be carried out not only on indicators such as GDP and trade volume, but also on broader indicators: bilateral trade volume, accumulated FDI, non-oil export potential, renewable energy capacity, logistics connectivity, tourism and mobility intensity, institutional cooperation strength, economic diversification index and carbon intensity. These indicators cover economic, energy, logistics and sustainability aspects.

The SD scenario analysis is also useful for policy learning. If the model results show that trade agreements alone are not enough and that trade growth is limited when logistics capacity is weak, this is an important lesson for policymakers. If the model shows that green energy investments only create real export potential when grid readiness is high, this is also an important result for energy policy. If tourism mobility has a greater impact on investor confidence than expected, then aviation and service sectors can be considered as important tools of economic diplomacy.

Methodological implications for the UAE–Azerbaijan study

The above methodological discussion shows that the study of UAE–Azerbaijan international economic relations using the SD approach has high scientific and practical potential. This approach yields several important implications. First, bilateral economic relations should be considered as a dynamic stock. That is, economic relations are not only annual trade and investment statistics, but also a stock of institutional trust, logistics connections, energy projects, business networks and socio-cultural mobility accumulated over time.

Second, although trade, FDI, energy, logistics and tourism are built as separate modules in the model, the feedback relationships between them should be clearly shown. Otherwise, the model will turn into a simple collection of sectors and the main advantage of the SD approach will be lost. Third, lags must be taken into account in the model. It takes time for investment decisions to be translated into results, energy projects to be completed, logistics infrastructure to have an impact, and tourism branding to be formed. Fourth, the model should not consist only of optimistic growth mechanisms; risks, constraints, and balancing loops should be included.

Fifth, the SD model should be supported by econometric evidence. Parameters should be taken from statistical data, international reports, and previous studies whenever possible. Expert assessment and scenario assumptions should be presented openly in the absence of data. Sixth, the main scientific contribution of the model should be to explain system behavior and policy mechanisms rather than to provide specific forecast figures. The purpose of the SD model is not to show the "exact future," but to compare possible dynamic outcomes of alternative policies.

In conclusion, the methodological framework for the topic "System Dynamics application to international economic relationship: United Arab Emirates and Azerbaijan case" can be formulated as follows: first, a conceptual system of bilateral economic relations is established; then the main feedback loops are identified; then a stock–flow model is developed; the model is calibrated with empirical and expert data; Finally, alternative policy scenarios are simulated and compared. This approach allows us to analyze the UAE-Azerbaijan economic relationship not only as a current cooperation, but also as a long-term regional geoeconomic transformation system.

REFERENCES:

1. Asian Productivity Organization. (2024). *New dynamics of global supply chain systems and implications for productivity in Asia*. Asian Productivity Organization.
2. Chen, T., Qiu, Y., Wang, B., & Yang, J. (2022). Analysis of effects on the dual circulation promotion policy for cross-border E-commerce B2B export trade based on system dynamics during COVID-19. *Systems, 10*(1), 13. https://doi.org/10.3390/systems10010013
3. Chunxing, S. (2025). Analysis and research on China–Russia agricultural economic smart supply chain from the perspective of global food security. *Research on World Agricultural Economy*.
4. Collste, D., Pedercini, M., & Cornell, S. E. (2017). Policy coherence to achieve the SDGs: Using integrated simulation models to assess effective policies. *Sustainability Science, 12*, 921–931.
5. Duan, H. W., Zhang, H., Gan, Y., Chang, X., Wang, Y., & Li, Y. (2023). A system dynamics-based simulation model for cross-border logistics risk transmission. *International Journal of Simulation Modelling, 22*(3), 485–496.
6. Eicke, L., & Goldthau, A. (2022). Are we at risk of an uneven low-carbon transition? Assessing evidence from a mixed-method elite study. *Energy Policy, 171*, 113279.

7. Energy Transitions Commission. (2025). *Global trade in the energy transition: Principles for clean energy supply chains and carbon pricing*. Energy Transitions Commission.

8. Feder, C. (2024). The system dynamics approach for a global evolutionary macroeconomics. *Journal of Evolutionary Economics, 34*, 1–32.

9. Fisunoglu, A. (2018). System dynamics modeling in international relations. In *Oxford Research Encyclopedia of International Studies*. Oxford University Press.

10. Ghazalian, P. L. (2023). Does economic growth attract FDI inflows? A dynamic panel data analysis. *Economies, 12*(1), 1.

11. Grobbelaar, S. S., & Meyer, I. A. (2017). The dynamics of regional economic integration: A system dynamics analysis of pathways to the development of value chains in the Southern African Customs Union. *South African Journal of Industrial Engineering, 28*(1), 73–89. https://doi.org/10.7166/28-1-1613

12. Grubb, M., Poncia, A., & Pasqualino, R. (2024). *Dynamics of the energy transition: Innovation, transition economics, path dependency, and decision making*. World Bank.

13. Hafner, S., Ulli-Beer, S., & Pahl-Wostl, C. (2024). How system dynamics models operationalise energy transition complexity: A review of modelling practices. *Energy Policy*.

14. Hajian Heidary, M. (2022). A system dynamics model of the impact of COVID-19 pandemic on foreign direct investment. *Future Business Journal, 8*, Article 38. https://doi.org/10.1186/s43093-022-00155-3

15. International Renewable Energy Agency & Climate Policy Initiative. (2025). *Global landscape of energy transition finance 2025*. IRENA/CPI.

16. Khakdaman, M., Rebs, T., Brandenburg, M., & Seuring, S. (2024). A system dynamics supply chain analysis for the decarbonization of the European aluminum rolled product supply chain. *Sustainability, 16*(20), 8892.

17. OECD. (2024). *Global value and supply chains: Policy issues and resilience*. OECD.

18. Piedrahita, A. R., & colleagues. (2025). Modeling and simulation with system dynamics: Validation approaches and practices. *Journal of Hunan University Natural Sciences, 52*(1).

19. Schünemann, C., et al. (2024). Complex system policy modelling approaches for analysing policy interventions in complex realities. *Policy Design and Practice*.

20. Schwaninger, M., & Groesser, S. (2020). System dynamics modeling: Validation for quality assurance. In *System dynamics: Theory and applications*. University of St. Gallen.

21. UNCTAD. (2024). *World investment report 2024: Investment facilitation and digital government*. United Nations.

22. UNCTAD. (2025). *World investment report 2025: International investment in the digital economy*. United Nations.

23. World Bank. (2024). *Dynamics of the energy transition: Innovation, transition economics, path dependency, and decision making*. World Bank.

24. World Trade Organization. (2023). *World trade report 2023: Re-globalization for a secure, inclusive and sustainable future*. WTO.

25. Zhang, H. N. (2023). Coupling system dynamics model of cross border logistics and ecological environment based on the sustainable perspective of global value chain. *Sustainability, 15*(17), 13099. https://doi.org/10.3390/su151713099

26. Zhu, X., et al. (2025). A system dynamics framework for port resilience enhancement along Maritime Silk Road: Insights from ESG governance. *Systems, 13*(8), 719. https://doi.org/10.3390/systems13080719

BƏƏ-AZƏRBAYCAN İQTİSADİ MÜNASİBƏTLƏRİNİN MODELLƏŞDİRİLMƏSİ ÜÇÜN METODOLOJİ ƏSASLAR: TİCARƏT, XARİCİ BİRBAŞA İNVESTİSİYALAR, ENERJİ KEÇİDİ VƏ BAĞLANTIYA SİSTEM DİNAMİKASI YANAŞMASI

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Xülasə: Bu məqalədə Birləşmiş Ərəb Əmirlikləri ilə Azərbaycan arasında iqtisadi münasibətlərin System Dynamics yanaşması əsasında modelləşdirilməsi üçün metodoloji çərçivə hazırlanır. Tədqiqatda əvvəlcə beynəlxalq iqtisadi əməkdaşlığın təhlilində istifadə olunan əsas metodlar — gravity model, CGE/GTAP modelləri, panel ekonometrik yanaşmalar, input–output və GVC/TiVA təhlili, network analysis, Difference-in-Differences və synthetic control metodları müqayisəli şəkildə nəzərdən keçirilir. Bu metodlar ticarət potensialının, makroiqtisadi təsirlərin, dəyər zənciri inteqrasiyasının və səbəb-nəticə əlaqələrinin öyrənilməsi baxımından əhəmiyyətli olsa da, əks-əlaqə mexanizmlərini, gecikmələri, qeyri-xətti təsirləri və sektorlararası qarşılıqlı asılılıqları tam əks etdirməkdə məhdud qalır. Məqalədə əsaslandırılır ki, UAE–Azərbaycan iqtisadi münasibətləri ticarət, xarici birbaşa investisiya, enerji keçidi, logistika bağlantıları, turizm-mobillik və institusional əməkdaşlığın zaman daxilində bir-birini gücləndirdiyi və ya məhdudlaşdırdığı dinamik sistem kimi araşdırılmalıdır. Təklif olunan System Dynamics çərçivəsində ikitərəfli iqtisadi inteqrasiya Bilateral Economic Integration Stock, Azərbaycanda UAE FDI Stock, Renewable Energy Cooperation Capacity, Logistics Connectivity Capacity, Tourism and Mobility Intensity və Institutional Cooperation Strength kimi əsas stock dəyişənləri vasitəsilə konseptuallaşdırılır.

Açar sözlər: System Dynamics; UAE–Azərbaycan iqtisadi münasibətləri; ticarət və FDI; enerji keçidi; logistika bağlantıları; metodoloji çərçivə

МЕТОДОЛОГИЧЕСКИЕ ОСНОВЫ МОДЕЛИРОВАНИЯ ЭКОНОМИЧЕСКИХ ОТНОШЕНИЙ МЕЖДУ ОАЭ И АЗЕРБАЙДЖАНОМ: СИСТЕМНО-ДИНАМИЧЕСКИЙ ПОДХОД К ТОРГОВЛЕ, ПРЯМЫМ ИНОСТРАННЫМ ИНВЕСТИЦИЯМ, ЭНЕРГЕТИЧЕСКОМУ ПЕРЕХОДУ И ВЗАИМОСВЯЗАННОСТИ

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Резюме: В данной статье разрабатывается методологическая основа для моделирования экономических отношений между Объединёнными Арабскими Эмиратами (ОАЭ) и Азербайджаном на основе подхода System Dynamics (системной динамики). В исследовании сначала проводится сравнительный анализ основных методов, применяемых при изучении международного экономического сотрудничества, включая гравитационную модель (Gravity Model), модели CGE/GTAP, панельные эконометрические методы, анализ «затраты–выпуск» (Input–Output) и глобальных цепочек создания стоимости (GVC/TiVA), сетевой анализ (Network Analysis), а также методы Difference-in-Differences и Synthetic Control. Несмотря на то, что данные подходы позволяют эффективно оценивать торговый потенциал, макроэкономические эффекты, интеграцию в глобальные цепочки создания стоимости и причинно-следственные связи, они имеют ограничения в отражении механизмов обратной связи, временных лагов, нелинейных эффектов и межсекторальных взаимозависимостей.

В статье обосновывается, что экономические отношения между ОАЭ и Азербайджаном следует рассматривать как динамическую систему, в которой торговля, прямые иностранные инвестиции, энергетический переход, развитие логистической взаимосвязанности, туризм, мобильность и институциональное сотрудничество взаимно усиливают либо ограничивают друг друга во времени.

В рамках предложенной методологической модели System Dynamics двусторонняя экономическая интеграция концептуализируется посредством следующих ключевых переменных типа stock (накопителей): Bilateral Economic Integration Stock (накопленный уровень двусторонней экономической интеграции), UAE FDI Stock in Azerbaijan (накопленный объём прямых инвестиций ОАЭ в Азербайджане), Renewable Energy Cooperation Capacity (потенциал сотрудничества в области возобновляемой энерге-

тики), Logistics Connectivity Capacity (потенциал логистической взаимосвязанности), Tourism and Mobility Intensity (интенсивность туризма и мобильности), а также Institutional Cooperation Strength (уровень институционального сотрудничества).
Ключевые слова: System Dynamics; экономические отношения между ОАЭ и Азербайджаном; торговля и прямые иностранные инвестиции (FDI); энергетический переход; логистическая взаимосвязанность; методологическая основа.