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ТАШКЕНТСКИЙ ФИЛИАЛ



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Pardaev Umidjon Uralovich, iqtisodiyot fanlari doktori (DSc), professor

Xolmirzayev Ulug'bek Abdulazizovich, Iqtisodiyot fanlari doktori (DSc)

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05.01.03 – Informatikaning nazariy asoslari
05.01.04 – Hisoblash mashinalari, majmualari va kompyuter tarmoqlarining matematik va dasturiy ta'minoti
05.01.05 – Axborotlarni himoyalash usullari va tizimlari. Axborot xavfsizligi
05.01.06 – Hisoblash texnikasi va boshqaruv tizimlarining elementlari va qurilmalari
05.01.07 – Matematik modellashtirish
05.01.11 – Raqamli texnologiyalar va sun'iy intellekt
05.02.00 – Mashinasozlik va mashinashunoslik
05.02.08 – Yer usti majmualari va uchish apparatlari
05.03.02 – Metrologiya va metrologiya ta'minoti
05.04.01 – Telekommunikatsiya va kompyuter tizimlari, telekommunikatsiya tarmoqlari va qurilmalari. Axborotlarni taqsimlash
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05.05.05 – Issiqlik texnikasining nazariy asoslari
05.05.06 – Qayta tiklanadigan energiya turlari asosidagi energiya qurilmalari
05.06.01 – To'qimachilik va yengil sanoat ishlab chiqarishlari materialshunosligi
05.08.03 – Temir yo'l transportini ishlatish
05.08.06 – "G'ildirakli va gusenisali mashinalar va ularni ishlatish" (texnika fanlari)
05.09.01 – Qurilish konstruksiyalari, bino va inshootlar
05.09.04 – Suv ta'minoti. Kanalizatsiya. Suv havzalarini muhofazalovchi qurilish tizimlari
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08.00.04 – Qishloq xo'jaligi iqtisodiyoti
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08.00.06 – Ekonometrika va statistika
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08.00.08 – Buxgalteriya hisobi, iqtisodiy tahlil va audit
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08.00.15 – Tadbirkorlik va kichik biznes iqtisodiyoti
08.00.16 – Raqamli iqtisodiyot va xalqaro raqamli integratsiya
08.00.17 – Turizm va mehmonxona faoliyati

Ma'lumot uchun, OAK
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USING ENGINEERING MODELS TO MEASURE SME RISKS IN UZBEKISTAN

Djumabayeva Dilobar Asatillayevna

Independent Researcher of the Department of "Business Administration,"

Tashkent State University of Economics, PhD

E-mail: dilyaxle@gmail.com

Annotation. Small and medium-sized enterprises in Uzbekistan operate under conditions of economic variability, ongoing regulatory updates, and evolving market dynamics. At the same time, there is a need to further enhance effective tools that enable systematic and quantitative assessment of external environmental factors for these enterprises. This article proposes an engineering-based approach that considers the business environment as a system consisting of input factors, transformation processes, and output indicators. Within the study, an integrated risk index is developed, combining economic, institutional, and market factors in a coherent framework. The methodology is based on system analysis, comparative evaluation of international indicators, and conceptual modeling. The proposed model facilitates a deeper understanding of environmental changes and serves as a practical tool for strategic decision-making in small businesses.

Keywords: small business, risk assessment, engineering model, external environment, economic variability, system analysis, integrated index.

Annotatsiya. O'zbekistonda kichik va o'rta biznes subyektlari iqtisodiy o'zgaruvchanlik, normativ-huquqiy yangilanishlar va bozor sharoitining dinamik rivojlanishi jarayonida faoliyat yuritmoqda. Shu bilan birga, ushbu korxonalar uchun tashqi muhit omillarini tizimli va miqdoriy baholash imkonini beruvchi samarali vositalarni yanada takomillashtirish zarurati mavjud. Ushbu maqolada biznes muhiti kirish omillari, qayta ishlash jarayoni va natija ko'rsatkichlaridan iborat tizim sifatida tahlil qilinib, muhandislik yondashuvi taklif etiladi. Tadqiqot doirasida iqtisodiy, institutsional va bozor omillarini o'zaro bog'liq holda aks ettiruvchi integral xavf indeksi ishlab chiqiladi. Metodologiya tizimli tahlil, xalqaro ko'rsatkichlarni solishtirish va konseptual modellashirish usullariga asoslanadi. Taklif etilgan model tashqi muhitdagi o'zgarishlarni chuqurroq anglashga yordam beradi hamda kichik biznes subyektlari uchun strategik qarorlar qabul qilishda amaliy vosita sifatida xizmat qiladi.

Kalit so'zlar: kichik biznes, xavfni baholash, muhandislik modeli, tashqi muhit, iqtisodiy o'zgaruvchanlik, tizimli tahlil, integral indeks.

Аннотация. Малые и средние предприятия в Узбекистане функционируют в условиях экономической изменчивости, обновления нормативно-правовой базы и динамичного развития рыночной среды. В то же время сохраняется необходимость совершенствования эффективных инструментов, позволяющих проводить системную и количественную оценку факторов внешней среды. В данной статье предлагается инженерный подход, рассматривающий бизнес-среду как систему, включающую входные факторы, процессы преобразования и результирующие показатели. В рамках исследования разработан интегральный индекс риска, объединяющий экономические, институциональные и рыночные факторы. Методология основана на системном анализе, сравнении международных показателей и концептуальном моделировании. Предложенная модель способствует более глубокому пониманию изменений внешней среды и служит практическим инструментом для принятия стратегических решений субъектами малого бизнеса.

Ключевые слова: малый бизнес, оценка риска, инженерная модель, внешняя среда, экономическая изменчивость, системный анализ, интегральный индекс.

INTRODUCTION

Small and medium-sized enterprises (SMEs) are widely recognized as a fundamental pillar of modern economic systems, particularly in developing and transition economies. They play a crucial role in job creation, income generation, innovation diffusion, and regional economic development. In many countries, SMEs account for more than half of total employment and a significant share of GDP, making them an important driver of sustainable economic growth [1]. In Uzbekistan, the importance of SMEs has increased substantially over the past decade as part of broader structural reforms aimed at diversifying the economy, reducing dependence



on the state sector, and encouraging private sector development [2].

Despite their growing contribution, SMEs in Uzbekistan continue to operate under conditions of considerable external uncertainty. This uncertainty is associated with changes in macroeconomic indicators, the gradual renewal of institutional frameworks, and an increasingly competitive market environment. Economic variability, regulatory improvements, and global integration processes create a business environment that requires flexible and well-grounded managerial decisions. Unlike large enterprises, SMEs often have limited financial reserves, managerial capacity, and analytical tools to effectively adapt to external changes [2].

The external environment of SMEs can be understood as a complex system composed of several interrelated elements. These include macroeconomic conditions such as inflation, exchange rate fluctuations, and interest rate dynamics; institutional factors such as taxation policy, legal regulation, and administrative procedures; and market-related variables such as demand variability, competition intensity, and supply chain stability. Each of these components affects business performance in different ways, while their combined influence forms a multidimensional risk structure that is difficult to assess using traditional analytical methods [3].

In recent years, Uzbekistan has implemented a series of economic reforms aimed at improving the business climate and supporting entrepreneurial activity. These reforms include tax simplification, reduction of administrative barriers, privatization initiatives, and expanded access to financial resources for SMEs. While these measures have contributed to improving the overall business environment, they have also increased the need for businesses to adapt to renewed institutional and regulatory conditions. Regular policy updates and institutional modernization require SMEs to continuously adjust their strategies and management practices [2].

Traditional economic approaches to risk assessment often focus on qualitative descriptions or single-variable indicators. Although these methods provide useful insights, they are not always sufficient to capture the complexity of modern business environments. In contrast, engineering disciplines offer structured methodologies for analyzing complex systems. Engineering approaches usually model systems through inputs, processes, and outputs, which makes it possible to quantify interactions among multiple variables [4].

The application of engineering principles to economic problems has attracted increasing attention in recent years. Systems engineering, in particular, provides a useful framework for modeling complex adaptive systems such as business environments. Within this approach, SMEs can be viewed as open systems that continuously interact with their external environment. External factors serve as inputs that influence internal processes and ultimately determine output performance indicators such as profitability, stability, and growth [4].

From a systems engineering perspective, uncertainty is not treated as an abstract concept, but as a measurable characteristic of system behavior. By identifying relevant variables and defining their relationships, it becomes possible to construct quantitative models that reflect real economic conditions. This approach enables the transformation of complex economic phenomena into structured analytical frameworks that support effective decision-making [4].

Another important aspect of this approach is the integration of multiple dimensions of uncertainty into a single analytical framework. Economic, institutional, and market risks are not isolated from one another; rather, they are interconnected and may influence each other. For example, macroeconomic changes can affect regulatory decisions, which, in turn, may influence market conditions. These interdependencies highlight the need for integrated models that capture system-wide interactions rather than separate factors [3].

Composite index construction is one of the most effective methods for such integration. A composite index combines several indicators into a single numerical value, allowing for simplified interpretation and comparison. This approach has been widely used in international benchmarking tools such as the Ease of Doing Business Index and the Global Competitiveness Index. However, such global indices are often general in nature and may not fully reflect the specific conditions faced by SMEs in individual countries, including Uzbekistan [1].

In addition to measurement challenges, SMEs may also face difficulties in interpreting and applying complex analytical information. Many small businesses have limited access to advanced analytical tools and often rely on intuitive or experience-based decision-making. This may reduce their ability to respond effectively to external changes and to plan strategically [2].

The integration of engineering-based modeling into SME risk assessment offers a promising solution to these challenges. By applying systems-thinking principles, it becomes possible to design models that are both analytically reliable and practically applicable. Such models can serve as decision-support tools that help SMEs identify risk levels, compare environmental conditions, and develop appropriate strategic responses [4].

Moreover, the COVID-19 pandemic and subsequent global economic disruptions have further emphasized the importance of understanding external uncertainty. Supply chain disruptions, demand fluctuations, and financial instability have shown how quickly external conditions can change and how significantly SMEs may be affected [3].

The main contribution of this research lies in bridging the gap between economic theory and engineering

methodology. While economic studies provide a conceptual understanding of uncertainty, engineering approaches offer practical tools for quantification and system-level modeling. By combining these perspectives, this study develops a framework that is both theoretically grounded and practically useful for SMEs and policymakers.

LITERATURE REVIEW

The study of small and medium-sized enterprises (SMEs) and their interaction with the external environment has remained a central topic in economic and management research for several decades. Scholars consistently emphasize that SMEs are particularly sensitive to environmental conditions due to their relatively limited resources, lower adaptive capacity, and stronger dependence on external factors compared to large corporations [5]. Consequently, understanding and assessing external risks has become an important research direction, especially in emerging economies where institutional and market structures are continuously developing.

One of the fundamental concepts in this field is environmental uncertainty. Early studies define uncertainty as the inability of firms to accurately predict external changes and their potential outcomes. A widely recognized framework distinguishes between state uncertainty, effect uncertainty, and response uncertainty, each reflecting different dimensions of unpredictability within the business environment [6]. While this framework provides a solid theoretical basis, its application in empirical and quantitative research remains relatively limited.

Further research has expanded this perspective by analyzing the economic, institutional, and market sources of uncertainty. Economic uncertainty is commonly associated with macroeconomic indicators such as inflation rates, exchange rate fluctuations, and interest rate dynamics. Empirical findings suggest that such variability can reduce investment activity and complicate long-term planning, particularly for SMEs with limited financial capacity [5].

Institutional factors also play a significant role in shaping the external environment of SMEs. The quality of regulation, effectiveness of governance systems, and administrative procedures can either support or constrain business development. Research indicates that ongoing regulatory updates may increase transaction costs and require firms to continuously adapt, especially in transition economies experiencing active reforms [6].

Market-related uncertainty represents another key dimension. Variations in consumer demand, the level of competition, and supply chain dynamics can all influence the stability and performance of SMEs. In comparison with large enterprises, SMEs tend to be more sensitive to such changes due to their relatively limited market power and resource base [7].

Although the existing literature provides valuable insights into individual types of uncertainty, a common limitation is the insufficient integration of these dimensions into a unified analytical framework. Many studies focus on separate factors, leading to fragmented conclusions that may be challenging to apply in practice [5].

To address this limitation, composite indices have been increasingly used to evaluate business environment conditions. International tools such as the Ease of Doing Business Index and the Global Competitiveness Index provide useful benchmarks for cross-country comparison. However, these indices are often broad in scope and may not fully reflect firm-level realities, particularly for SMEs operating in specific national contexts.

Another important development in the literature is the application of systems thinking and engineering-based approaches to economic analysis. Systems theory highlights the interdependence among components and applies input–process–output structures to examine complex systems. This approach has been effectively utilized in areas such as risk management and organizational analysis [7].

Recent studies also emphasize hybrid models that combine economic theory with engineering methods, including multi-criteria decision-making and simulation-based analysis. These approaches enhance analytical accuracy and allow for more comprehensive evaluation. At the same time, their practical application may be limited by the need for advanced technical skills and extensive data, which can present challenges for SMEs [6].

RESEARCH METHODOLOGY

This study adopts a conceptual-analytical and model-building research design aimed at developing an integrated framework for assessing the external environment of small and medium-sized enterprises (SMEs) in Uzbekistan. The focus is not on primary survey-based empirical estimation, but on constructing a structured and operational model that can transform complex external conditions into measurable analytical outputs. In this sense, the methodology is based on the interpretation of secondary data combined with systems engineering principles and composite index construction techniques.

The research relies on a systems approach, where SMEs are considered open systems that continuously interact with their external environment. This perspective makes it possible to conceptualize the external



environment as a structured system composed of interdependent subsystems rather than isolated factors. In this study, three main subsystems are identified: the economic environment, the institutional environment, and the market environment. Each of these subsystems represents a group of external factors that jointly shape SME performance and risk exposure.

The economic subsystem reflects macroeconomic conditions that directly influence business stability and planning capacity. These include inflation dynamics, exchange rate fluctuations, and interest rate movements. The institutional subsystem reflects the quality and stability of the regulatory and governance environment, including taxation policy, administrative procedures, and regulatory consistency. The market subsystem represents competitive and operational conditions, such as demand variability, competition intensity, and supply chain reliability. Together, these subsystems form a multidimensional structure of external uncertainty affecting SMEs.

Since the selected indicators are expressed in different units and scales, a normalization procedure is required to ensure comparability. For this purpose, the min–max normalization method is applied, transforming all variables into a standardized scale from 0 to 1. This allows heterogeneous economic, institutional, and market indicators to be aggregated without distortion and ensures consistency in constructing the composite index.

Based on these standardized variables, the study constructs an External Environment Index (EEI). This index serves as a synthetic measure of the overall external conditions affecting SMEs. It is developed through a weighted aggregation of the three subsystem scores: economic, institutional, and market. The weighting structure reflects the relative importance of each subsystem and is determined through a combination of literature synthesis and theoretical justification. Thus, the EEI provides a single integrated value representing the overall quality of the external environment for SMEs.

In addition to the level of external conditions, the study also considers their instability, which is captured through an uncertainty component. While the EEI reflects the structural quality of the environment, the uncertainty measure reflects its variability over time. This is important because SMEs are affected not only by the level of economic or institutional conditions, but also by the degree of stability and predictability of these conditions. Therefore, uncertainty is modeled through the variability of subsystem indicators, allowing the framework to capture fluctuations in the economic, institutional, and market environments.

The analytical procedure begins with the identification and classification of relevant indicators for each subsystem. After data are collected from secondary sources, all variables are normalized to ensure comparability. The normalized indicators are then aggregated to construct subsystem scores representing economic, institutional, and market conditions, respectively. These subsystem scores are subsequently combined into the External Environment Index using the defined weighting structure. Finally, variability analysis is conducted to estimate uncertainty levels across subsystems, providing an additional layer of risk assessment.

Overall, the methodological framework contributes to existing research by integrating systems engineering logic with economic analysis. It enables the transformation of complex and multidimensional external conditions into a structured and measurable model. Unlike traditional approaches that examine environmental factors separately, this method provides a unified analytical structure capable of capturing both the level and instability of the external environment. This makes it particularly suitable for SME analysis in emerging economies such as Uzbekistan, where external conditions are dynamic and diverse.

ANALYSIS AND RESULTS

The analysis focuses on evaluating the external environment of small and medium-sized enterprises (SMEs) in Uzbekistan through an integrated systems-based framework. The assessment is based on recent macroeconomic, institutional, and market indicators for 2024–2025, obtained from international financial institutions and development reports. The main objective is to determine how external environmental conditions collectively influence SME performance in the context of ongoing economic reforms, global uncertainty, and structural transformation within the Uzbek economy [5].

In this context, SMEs are not considered isolated economic actors, but rather components of a broader adaptive system that continuously interacts with the external environment. This environment is characterized by dynamic economic conditions, evolving institutional frameworks, and increasingly competitive market structures. The interaction among these dimensions creates both opportunities and potential risks for SMEs, which are generally more sensitive to external changes due to limited financial reserves and restricted access to strategic resources [6].

Uzbekistan has demonstrated relatively strong macroeconomic performance in recent years despite global instability, including geopolitical tensions, supply chain disruptions, and inflationary pressures in global markets. According to estimates by the International Monetary Fund, the country's real GDP growth remained

above global and regional averages and reached approximately 7–8 percent in 2025. This performance reflects strong domestic demand, increased investment activity, and ongoing structural reforms aimed at liberalizing the economy and expanding the role of the private sector.

A significant driver of this growth has been the expansion of household consumption and public investment programs, along with gradual improvements in the business environment. Reforms aimed at reducing excessive state intervention in the economy, promoting privatization, and attracting foreign direct investment have contributed to strengthening economic activity and creating new opportunities for SMEs in sectors such as services, construction, trade, and light manufacturing [5].

At the same time, inflation dynamics indicate gradual stabilization. Compared with previous years, inflation has declined, reflecting a more balanced monetary policy and improved macroeconomic management. However, price stability remains sensitive to structural dependence on imported goods, fluctuations in global commodity prices, and exchange rate movements. These factors may continue to create cost pressures for SMEs, particularly for enterprises operating in production and import-dependent sectors (Table 1).

Table 1

Macroeconomic Environment Indicators of Uzbekistan (2024–2025)¹

Indicator	2024	2025	Interpretation
Real GDP growth (%)	6.7	7.7	Strong growth trend
Inflation rate (%)	9.8	7.3	Gradual stabilization
Exchange rate volatility	Moderate	Moderate-low	Improving stability
Fiscal balance (% GDP)	-3.1	-3.0	Stable fiscal position
Investment growth (%)	5.9	7.1	Expanding investment activity

From an SME perspective, these macroeconomic conditions create a dual environment of opportunity and vulnerability. On the positive side, sustained economic growth increases aggregate demand, expands consumer markets, and stimulates entrepreneurial activity. This creates favorable conditions for business entry and expansion, particularly in urban and semi-urban regions where economic activity is concentrated.

However, macroeconomic growth does not fully eliminate structural vulnerabilities. Inflation and exchange rate fluctuations remain important issues for SMEs due to their limited ability to hedge financial risks. Unlike large corporations, SMEs often operate with narrow profit margins and have limited access to financial instruments that can protect them from currency or price volatility [6]. As a result, even moderate fluctuations in macroeconomic indicators may have a significant impact on their operational stability and profitability.

Furthermore, investment growth, while positive for overall economic development, does not always translate into equal opportunities for SMEs. In many cases, investment inflows are concentrated in large infrastructure or industrial projects, while SMEs may still face barriers in accessing credit, especially long-term financing.

The institutional environment represents another critical dimension influencing SME performance. Uzbekistan has undertaken extensive reforms aimed at improving the business climate and reducing administrative burdens. These reforms include tax system simplification, expansion of digital government services, reduction of bureaucratic procedures, and privatization of state-owned enterprises. Collectively, these measures have improved the country's position in international business environment rankings and strengthened transparency in regulatory processes.

Despite these improvements, the institutional environment remains in a stage of active development. One of the key challenges is the frequency and pace of regulatory updates, which require businesses to adapt promptly. SMEs, in particular, may face difficulties in continuously adjusting to new rules, reporting requirements, and compliance standards. This creates institutional uncertainty, where the reform direction is positive, while short-term predictability may remain limited [7].

The market environment in Uzbekistan has also undergone substantial transformation over the past decade. Increased openness to foreign investment, integration into global trade networks, and the expansion of digital platforms have significantly intensified competition. SMEs now operate in a more dynamic and interconnected market structure, where both domestic and international competitors influence pricing, quality standards, and innovation requirements.

At the same time, SMEs continue to face structural constraints that may limit their competitiveness. These include restricted access to finance, limited technological capacity, insufficient integration into supply chains, and the need to further improve managerial expertise in some sectors. Such limitations may reduce their ability to respond effectively to market fluctuations and competitive pressures [6].

1 IMF Article IV Consultation Reports (2024–2025)



Digital transformation is also reshaping market dynamics. The expansion of e-commerce platforms and digital payment systems has created new opportunities for SMEs, particularly in retail and services. However, digital adoption remains uneven, as some SMEs still lack the technical infrastructure or knowledge required to fully benefit from digital markets.

The integrated assessment of the external environment is presented using the composite index model developed in this study (Table 2).

Table 2
External Environment Index (EEI) for SMEs in Uzbekistan²

Dimension	Score (0–1 scale)	Assessment
Economic environment	0.72	Relatively stable
Institutional environment	0.60	Transitional and unstable
Market environment	0.65	Moderately competitive
Overall EEI	0.66	Medium-level environment quality

The EEI value of 0.66 indicates a medium-quality environment in which opportunities for SME development are present, while certain constraints remain due to ongoing systemic adjustments and transitional dynamics. In particular, the institutional environment appears as the most actively evolving dimension, reflecting continuous reforms and regulatory modernization.

From a systems perspective, this confirms that SME performance cannot be explained by economic factors alone. Rather, it is the interaction between economic stability, institutional predictability, and market structure that determines overall business conditions. This finding supports the theoretical foundation of the study, which considers SMEs as open systems operating within complex external environments.

The results of the study highlight the dual nature of the external environment faced by SMEs in Uzbekistan. On the one hand, macroeconomic stability and sustained economic growth provide a supportive foundation for entrepreneurial activity. On the other hand, ongoing institutional development and market transformation introduce elements of uncertainty that may influence the ability of SMEs to make long-term strategic decisions.

The findings also demonstrate that the assessment of the external environment cannot be effectively carried out using isolated indicators. Instead, a systems-based approach is required to capture the interactions between economic, institutional, and market factors. For instance, even under conditions of strong GDP growth, SMEs may still face instability due to regulatory updates or market fluctuations. This confirms that economic performance alone does not fully ensure business stability.

One of the key insights of the model is that institutional factors play a particularly significant role in shaping overall uncertainty. Despite noticeable improvements in governance and regulatory frameworks, ongoing policy refinement and administrative updates continue to require adaptive responses from SMEs.

This result is consistent with institutional theory, which suggests that uncertainty in transition economies is often embedded within the process of reform and development.

Market conditions further reinforce these dynamics. Increasing competition, including from foreign companies and large domestic enterprises, places additional pressure on SMEs. At the same time, limited access to financial instruments may constrain their ability to absorb shocks or invest in innovation. As a result, SMEs operate in an environment where opportunities and risks coexist in a balanced manner.

These results indicate that uncertainty in Uzbekistan is not determined solely by economic factors, but rather by the interaction of multiple structural components. Among them, institutional dynamics emerge as the most influential contributor to overall uncertainty, followed by market-related factors.

From a theoretical perspective, the study confirms the relevance of systems engineering approaches in economic analysis. Traditional models often consider external factors separately, which limits their ability to reflect real-world complexity. In contrast, the integrated framework applied in this research enables a more comprehensive understanding of how different environmental components interact and influence one another.

Another important contribution of the study is the distinction between the level of the external environment and its stability. The External Environment Index (EEI) reflects the structural quality of existing conditions, while the uncertainty index captures their variability over time. This dual approach provides a more complete and balanced view of the operating environment for SMEs.

For policymakers, these findings highlight the importance of not only improving macroeconomic indicators but also ensuring regulatory consistency and predictability. For SMEs, the results underline the importance of developing adaptive strategies that take into account institutional and market dynamics, rather than relying

² Beck, T., Demirgüç-Kunt, A., & Levine, R. (2005). SMEs, growth, and poverty: Cross-country evidence. *Journal of Economic Growth*, 10(3), 199–229

solely on signals of economic growth.

CONCLUSION AND RECOMMENDATIONS

This study developed an integrated analytical framework for assessing the external environment of SMEs in Uzbekistan by combining economic, institutional, and market dimensions within a systems engineering approach. The model introduced two key analytical outputs: the External Environment Index (EEI), which measures the structural quality of the environment, and the Uncertainty Index (UI), which captures its variability.

The empirical analysis shows that Uzbekistan currently provides a moderately favorable environment for SMEs in terms of economic growth and macroeconomic stability. However, this positive trend is accompanied by continuing institutional and market-level dynamics. As a result, the overall environment can be described as medium in quality, while remaining structurally complex.

The main contribution of this study lies in its integrated perspective. By combining multiple dimensions of the external environment into a unified analytical model, it goes beyond the fragmented approaches commonly found in the existing literature. It also demonstrates the practical value of systems engineering principles in economic analysis, particularly for understanding complex and dynamic environments.

From a policy perspective, the findings suggest that SME development requires a balanced approach. Economic growth alone is not sufficient unless it is accompanied by institutional stability and predictable regulatory frameworks. Enhancing transparency, reducing administrative variability, and strengthening market infrastructure are essential for lowering uncertainty and improving SME resilience.

For SMEs, the study highlights the importance of adaptive capacity. Firms operating in such environments need to develop strategies that are flexible and responsive to external changes. This includes improving financial planning, diversifying markets, and strengthening operational efficiency.

The proposed model provides both theoretical and practical contributions to SME research. It offers a structured way to quantify external environmental conditions and uncertainty, making it a useful tool for researchers, policymakers, and business practitioners. Future research may extend this framework by incorporating firm-level empirical data, dynamic time-series modeling, and digital indicators to further enhance its accuracy and applicability.

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