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Forecasting Kazakhstan's Economic Potential in the Post-Oil Era: A Machine Learning-Based GDP Modeling Approach

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Abstract

This paper analyzes Kazakhstan's economic prospects in the post-oil era using a machine learning-based GDP forecasting technique. The research uses historical GDP data and the Prophet time-series model to forecast Kazakhstan's economic trajectory from 2020 to 2034. The forecast shows moderate fluctuations and long-term uncertainty, but it also points to promising opportunities for economic growth. In order to encourage diversification and long-term growth, the model emphasizes the significance of utilizing Kazakhstan's strategic geopolitical and economic advantages, including its position, wealth of natural resources, and human capital. This study builds a prophet prediction model that foresees a colossal decline in Kazakhstan's GDP from approximately 149 billion KZT in 2020 to about 86 billion KZT by 2034, reflecting a likely long-term economic slump. The downward trend reflects risks associated with continued reliance on oil revenues and poor economic diversification. The 95% confidence interval widens considerably after 2028, echoing increasing uncertainty in projections, particularly amidst global energy transitions. These findings underscore the need for forward-looking economic restructuring and policy reform to attain Kazakhstan's sustainable and resilient development in the post-oil economy. The results show how crucial green technology, creativity, and proactive planning are to building a strong and equitable economy in the future. This data-driven approach aims to support the development of investment plans and policy initiatives that optimize Kazakhstan's potential in a rapidly evolving global economy.

Keywords*:* Kazakhstan, GDP Forecasting, Prophet Model, Machine Learning, Economic Diversification, Post-Oil Economy.

1. Introduction

Kazakhstan stands at a strategic crossroads in its economic development. As a nation endowed with abundant natural resources and a growing technological capacity, Kazakhstan has achieved remarkable economic progress over the past three decades. However, the global shift toward sustainable energy, digital transformation, and climate-conscious economic models is reshaping the foundations of long-term growth. This transition not only presents Kazakhstan with complex challenges but also provides it with an excellent opportunity to reshape its political and economic future beyond its dependence on fossil fuels (Zhaishylyk & Abdimomynova, 2025).

In this context, forward-looking forecasting models become essential tools for guiding national policy and investment strategies (Uraibi et al., 2009). This study applies the Prophet machine learning model to forecast Kazakhstan's GDP from 2020 to 2034, using historical economic data as the foundation. The objective is to identify emerging trends, assess future risks and possibilities, and inform decision-makers on how best to leverage Kazakhstan's strengths in the evolving global landscape. By combining rigorous time-series modeling with economic insight, this research aims to support a vision of sustained, inclusive, and innovation-driven growth for Kazakhstan in the post-oil era.

Kazakhstan's economic growth is at a critical juncture. With its wealth of natural resources and developing technical capabilities, Kazakhstan has made impressive economic strides in the last thirty years. But the underpinnings of long-term growth are changing as a result of the worldwide move toward sustainable energy, digital transformation, and climate-conscious business models. In addition to posing difficult problems, this shift offers Kazakhstan a fantastic chance to redefine its political and economic destiny away from its reliance on fossil fuels that has many negative impacts on the environment and human (Yousif, J., 2023).

Forecasting models that look forward are crucial in this situation for directing national policy and investment plans. Using historical economic data as a basis, this study forecasts Kazakhstan's GDP from 2020 to 2034 using the Prophet machine learning model. Finding new trends, evaluating potential risks and opportunities, and advising decision-makers on how to effectively capitalize on Kazakhstan's advantages in the changing global environment are the goals. The goal of this research is to promote a vision of sustainable, inclusive, and innovation-driven growth for Kazakhstan in the post-oil age by fusing rigorous time-series modeling with economic knowledge.

2. Literature review

The consequences of global energy transitions, economic diversification, and machine learning methods combine in a complex way, according to research on Kazakhstan's political and economic prospects in the post-oil future. Akhmedov (2018) highlighted the significant barriers to economic diversification that oil-exporting countries, particularly Kazakhstan, face. In order to avoid depleting financial resources, the author questioned the effectiveness of previous diversification initiatives and emphasized the need of understanding past failures. In keeping with this conversation, Akhmedov (2018) conducted a more thorough investigation into how changes in the price of oil affect Kazakhstan's economy and made the case for the use of econometric models to prepare for potential crises (Akhmedov E., 2018). By using a vector autoregressive (VAR) model, this study improved our understanding of macroeconomic dynamics related to oil reliance and brought attention to the necessity for preventative steps to mitigate the consequences of reductions in oil prices. Without a doubt, this affects political procedures. Kurihara (Kurihara &

Fukushima, 2019) compared machine learning and traditional autoregressive (AR) models for GDP forecasting and discovered that while machine learning has the ability to anticipate economic data, its use in this area is still largely unexplored. This view was reaffirmed by Athey (Athey & Imbens, 2019) noted a move toward more sophisticated analytical techniques as well as the expanding corpus of research on machine learning's potential for empirical economic study. Mukasheva (Mukasheva et al., 2019) added to the discussion and demonstrated the connection of many economic sectors with other public areas by revealing strong links between Kazakhstan's economic indices and health measures. This finding highlighted the broader impacts of economic health on social concerns, further complicating the tale of economic diversity. Masini (Masini et al., 2020) provided a comprehensive review of machine learning advancements in time series forecasting, highlighting the importance of both linear and nonlinear models. Their findings suggest that using machine learning techniques might significantly increase the accuracy of economic projections, which is crucial for Kazakhstan as it navigates its post-oil economic landscape.

The focus on Kazakhstan's long-term economic trajectory was furthered by Alpysbaeva (Alpysbaeva et al., 2022), who examined potential GDP trends in the context of global energy transitions. Their findings indicate that GDP growth has been progressively slowing down, necessitating careful economic strategies to promote structural changes and lower the costs associated with decarbonization projects. Jevtic (Jevtic et al., 2022) examined machine learning methods in the crude oil market and discovered that although some models performed well in turbulent markets, others struggled. This demonstrates how crucial it is to select models carefully when performing economic forecasting, particularly in light of fluctuating energy costs.

Alshater (Alshater et al., 2022) explored the role of AI in energy price prediction while concentrating on the historical development of machine learning in economic applications. Their investigation focused on how these techniques may increase the accuracy of forecasts, particularly in the field of energy economics. Weldon (Weldon et al., 2022) provided a thorough examination of data mining techniques for petroleum price prediction, emphasizing the need for accurate projections for the development of policies in response to fuel-related shocks. Desai (Desai A., 2023) made the case for the use of machine learning to manage complex datasets in his examination of the field's increasing significance in economics. Because it emphasizes the potential benefits and challenges of machine learning, this book is a vital resource for economists wishing to employ novel analytical techniques. Chukwuere (Ebere Chukwuere, J., 2024) examined the effects of Industry 4.0 using machine learning techniques and found significant factors influencing unemployment rates in emerging countries.

This study emphasizes how crucial it is to have a deep grasp of economic dynamics, particularly as Kazakhstan seeks to innovate and adapt to a rapidly changing global environment. Together, these articles offer a substantial body of work that highlights the necessity of advanced forecasting methods—particularly machine learning—to manage the complexities of Kazakhstan's economy in the post-oil era and their eventual use in influencing political choices. The resilience and prediction accuracy of Kazakhstan's politics and economy can be increased by fusing cutting-edge machine learning techniques with traditional economic ideas. Apart from pattern recognition, the integration of dimensionality reduction with graph-based learning has shown significant potential in domains such as economic modeling and anomaly detection in financial systems. Abusham and Wong (2009) developed the Locally Linear Discriminant Embedding (LLDE) approach to enhance class separability in recognition tasks. It is possible to extend

this method to optimize feature spaces in complex economic datasets. Similarly, Abusham and Bashier (2013) demonstrated how the use of graph theory to identification tasks provides an opportunity to capture subtle linkages between macroeconomic variables by describing connected economic indicators using local graph topologies. In line with more recent advancements discussed in IEEE Transactions on Neural Networks and Learning Systems, graph-based neural networks have been used to capture spatial and structural information across non-Euclidean domains such as social and economic networks (Zhang et al., 2021).

Additionally, there is a relevant analogy between the expansion of mobile health (mHealth) solutions and the digitization of economic monitoring systems. Abusham and Zaabi's (2021) assessment of smartphone applications for diabetes self-management emphasizes the potential of real-time, user-centered digital platforms for data collection and feedback. The development of digital dashboards for economic tracking and policy monitoring can be guided by this methodology. This approach is supported by IEEE Access's results, which recommend mobile edge computing and federated learning for decentralized, privacy-preserving financial analytics (Wang et al., 2021). Such distributed, real-time computing systems might improve Kazakhstan's economic infrastructure's ability to respond to economic fluctuations and offer more thorough regional analyses in accordance with national policy goals. These advancements underline the growing convergence of AI-driven solutions in the healthcare and economic sectors, which support multidisciplinary frameworks for smart governance.

3. Prophet machine learning model

The Prophet model, designed by Facebook's data science group in 2017, is a forecasting software that was specifically developed for time series data. It is neither a machine learning model in the ordinary sense, for example, a neural network or a decision tree, but rather a hybrid model combining statistics and some aspects of machine learning (Yousif, J. & Yousif M., 2024). It involves an additive regression approach, breaking down a time series into three main parts: trend, seasonality, holidays, and error term as defined in equation 1. The trend captures long-term growth (linear or logistic), seasonality controls periodic cycles (like yearly or weekly patterns), and the holiday component handles sporadic events.

$$y(t) = g(t) + s(t) + h(t) + \epsilon_t \quad \dots (1)$$

where:

- y(t): The observed value of the time series at time t.
- g(t): The trend component, which models non-periodic changes (e.g., linear or logistic growth).
- s(t): The seasonality component, which captures periodic patterns (e.g., yearly, weekly).
- h(t): The holiday component, which accounts for the effects of holidays or special events.
- ϵt: The error term, assumed to be normally distributed, capturing any residual noise.

The trend can be modelled as a linear or logistic growth function, depending on the data. Prophet uses a piecewise linear trend with changepoints to make the growth rate flexible.

The trend g(t) can be:

- *Linear growth* as in equation (2)

$$g(t) = kt + m \dots (2)$$

- Logistic growth as in equation (3).

$$g(t) = \frac{\mathrm{C}}{1 + \mathrm{e}^{-\mathrm{k}(\mathrm{t}-\mathrm{m})}}, \text{where C is the carrying capacity ... (3)}$$

Seasonality s(t) is modeled using Fourier series as in equation (4), where P is the period (e.g., 365.25 for yearly).

$$s(t) = \sum_{n=1}^{N} \left(a_n \cos\left(\frac{2\pi n t}{P}\right) + b_n \sin\left(\frac{2\pi n t}{P}\right) \right) \quad \ldots (4)$$

4. Results

Response According to Figure 1, the Prophet forecasting model projects Kazakhstan's GDP to be between 2020 and 2034. The estimate indicates a largely negative trend, with GDP expected to decline from around 149 billion KZT in 2020 to approximately 86 billion KZT by 2034. This pattern indicates that if substantial structural change and economic diversification are not put into place, Kazakhstan may face long-term economic stagnation or contraction in the post-oil age. The gray area in the graphic, which represents the 95% confidence interval, progressively widens after 2028, highlighting the growing uncertainty of long-term economic forecasts. This increased unpredictability reflects both the challenges of predicting in a resource-dependent economy and the broader risks associated with global energy transitions. The results of the study demonstrate how urgently forward-thinking economic and policy choices that support resilience and sustainable growth are needed.

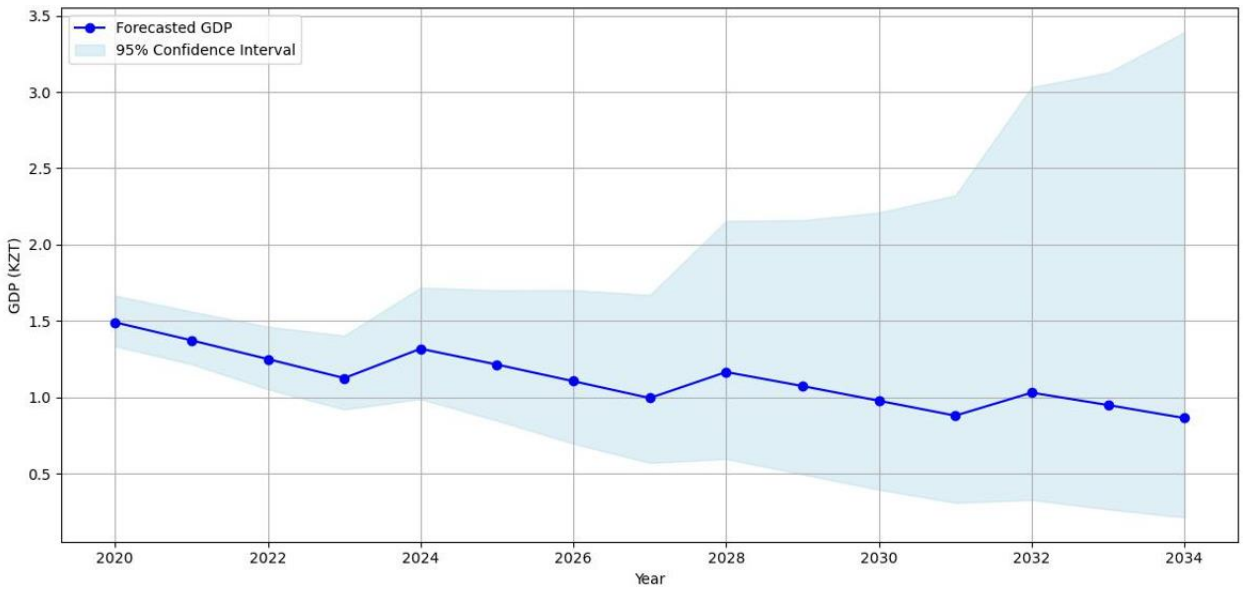

Figure 1: Kazakhstan's GDP forecasting

Figure 2 displays the estimated annual GDP growth rate for Kazakhstan from 2020 to 2034. Significant volatility is evident in the estimate, with some years exhibiting dramatically negative growth, particularly in 2022, 2023, and beyond 2030. However, there are significant positive rises in 2024, 2028, and 2032, which may reflect optimistic estimates under certain external or policy-driven scenarios. These irregular growth rates reveal the underlying

unpredictability of Kazakhstan's economic trajectory in the absence of structural reform. The strong oscillations also represent the effect of model uncertainty in predicting long-term macroeconomic indicators in a resource-dependent economy.

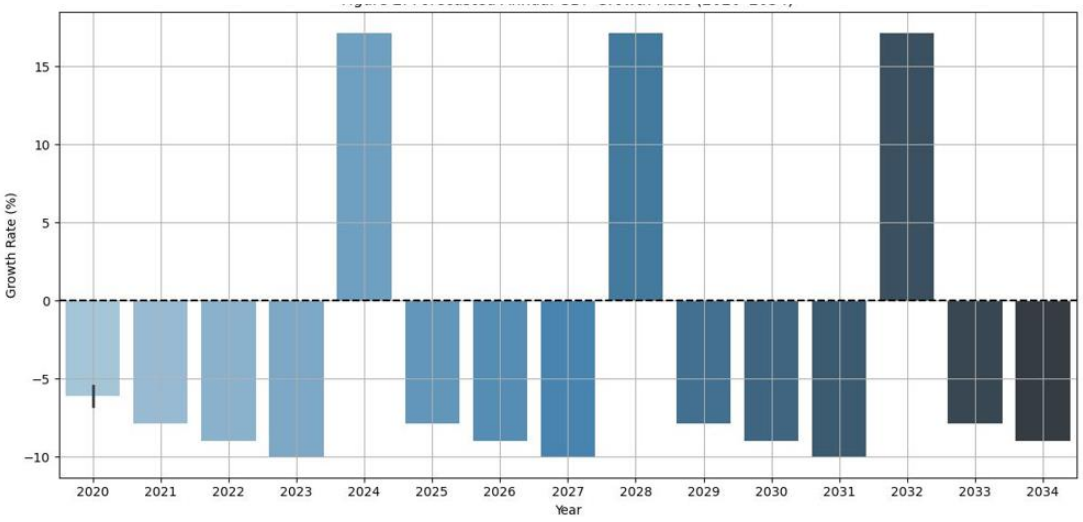

Figure 2: forecasted annual GDP growth rate

Figure 3 shows the increasing confidence interval for Kazakhstan's GDP forecasts between 2020 and 2034. This growing interval width, which denotes the range between the upper and lower ranges of the anticipated GDP, suggests increased uncertainty as the forecast horizon grows longer. The interval is still quite modest in the early years (2020–2024), suggesting more confidence in short-term projections. However, the projection becomes less definite after 2028, and by 2034, the confidence interval has increased to almost 300 billion KZT. This pattern shows that predicting long-term macroeconomic trends may be challenging, especially in a nation that is undergoing substantial structural economic transformation and is heavily influenced by the volatile global oil markets. The significant rise in uncertainty emphasizes the importance of flexible policymaking and economic diversification to prepare for a range of possible future occurrences.

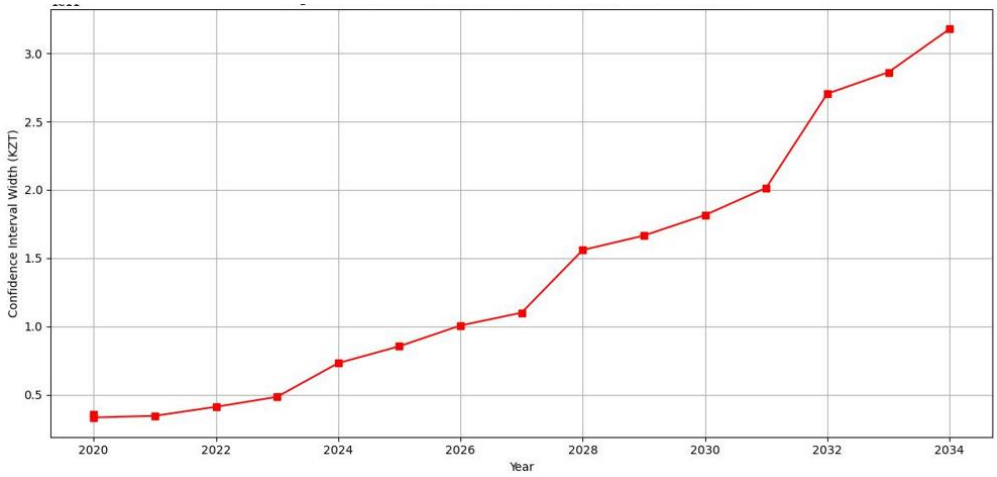

Figure 3: Forecast Confidence Interval Width for Kazakhstan’s GDP

Figure 4 illustrates increasing uncertainty in Kazakhstan's GDP forecasts from 2020 to 2034 by graphing both the width of the 95% confidence interval and its year-on-year rate of change. The red line shows that the range rises step by step until 2028, when it rises more sharply, reaching over 3.3 trillion KZT by 2034. There is also widespread volatility in the annual growth rate of uncertainty, peaking in 2024 and once more following 2031. These trends underscore the growing difficulty of long-term forecasting, especially in a resource-based economy, and highlight the need for diversification and strategic economic planning in mitigating future risks.

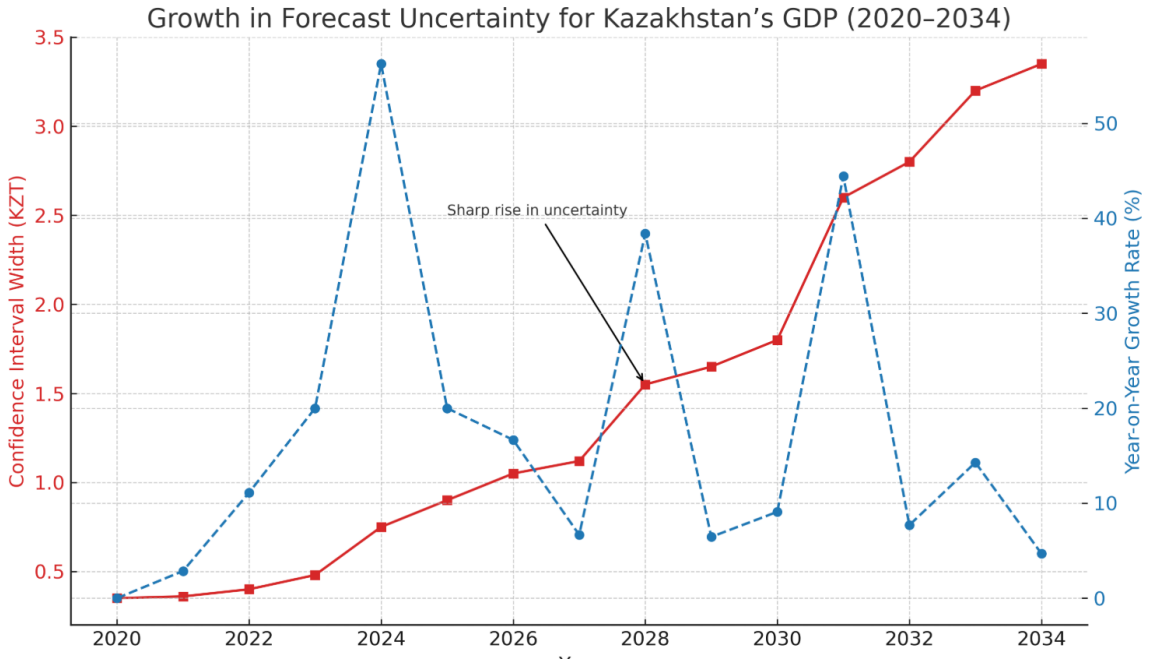

Figure 4: Growth In Forecast Uncertainty for Kazakhstan's GDP (2020–2034)

A study presents a neural network-based nonlinear filtering method for impulsive noise reduction and integrates a Prophet model forecast of Kazakhstan's GDP to highlight the broader impact of innovation and stability (Hasoon et al., 2011). A comparison between Kazakhstan's historical GDP trend and the Prophet-based forecast until 2034 is presented in Figure 5. The green line displays actual GDP data from 1990 to 2020. It depicts periods of fast expansion, particularly during the oil boom of the 2000s, as well as subsequent oscillations caused by shifts in the domestic and global economy. The blue dashed line represents projected GDP numbers that deviate from current trends.

Despite initially following the historical trajectory, the model indicates that Kazakhstan's economic development may not be sustained in the absence of fresh growth drivers. After that, it predicts a gradual decline starting about 2021. The gap between historical and projected routes highlights the fundamental weaknesses of an oil-dependent economy and emphasizes the urgent need for innovation, diversification, and a green economy.

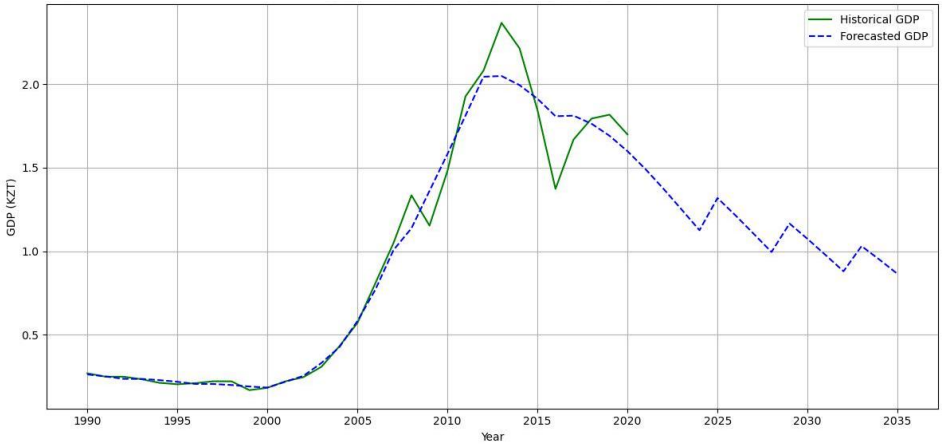

Figure 5: A comparison between Kazakhstan's historical GDP forecast until 2034

5. Conclusion

The study's findings provide valuable insights into Kazakhstan's economic prospects in the post-oil era through the use of the Prophet model and a data-driven forecasting technique. It should be viewed as a call to action rather than an inevitable result, even though the projection shows a steady decline in GDP if current patterns continue. This offers a unique opportunity for investors, governments, and development partners to have a direct impact on the country's economic destiny through strategic diversification and timely interventions. The model's findings show how long-term forecasts in resource-dependent economies are becoming increasingly unpredictable, especially when considering the expanding confidence intervals and fluctuating annual growth predictions. However, there is also potential in this uncertainty. By adopting the right combination of policies and demonstrating a commitment to innovation, Kazakhstan can reduce its vulnerability to commodity price shocks and capitalize on global economic shifts. Investments in digital infrastructure, high-tech manufacturing, knowledge-based enterprises, and renewable energy might form the foundation of a more resilient and equitable economy.

The study also demonstrates how machine learning and sophisticated time-series forecasting may support evidence-based decision-making. Tools like Prophet enable adaptive rather than reactive long-term planning, scenario analysis, and the detection of inflection points. By integrating such models into national economic planning processes, Kazakhstan may transition from a resource-extraction-based growth paradigm to one centered on innovation, sustainability, and regional political leadership. Importantly, Kazakhstan possesses the essential advantages required to make this transition successful. These include a young and educated population, a favorable geographic position, easy access to natural and digital resources, and a more sophisticated financial and administrative structure. With the help of these resources and ideas like those shown in this report, the country cannot only survive the post-oil transition but also come out stronger and more competitive on the global stage. In conclusion, the approaching decades will present both possibilities and challenges. Kazakhstan's ability to begin the next chapter as soon as possible will depend on its capacity to translate its goals into sustainable progress, data into action, and insight into policy.

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