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Faculty of World Economy

Department of Economics

Master's Thesis

Climate Change and its impact on the economy of Kazakhstan

ČESKÁ ZEMĚDĚLSKÁ UNIVERZITA V PRAZE

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ZADÁNÍ DIPLOMOVÉ PRÁCE

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Světová ekonomika

Název práce

Dopad změny klimatu na ekonomiku Kazachstánu

Název anglicky

Climate change impact on Kazakhstan economy

Cíle práce

The primary objective of this thesis is to assess the influence of climate change on Kazakhstan's economy through the analysis of secondary data. The author will delve into the theoretical underpinnings of climate change and its potential ramifications on a state's economic landscape. This research endeavors to elucidate the main effects of climate change on Kazakhstan's economy.

- Define the causal relationship of temperature and livestock productivity across the country for different types of crops
- Analyze how climate change (monthly temperature) has impacted the agricultural contribution for the past 15 years?
- Measure the importance of the agricultural sector to the total GDP of Kazakhstan.

Research questions:
- Measure the importance of the agricultural sector to the total GDP of Kazakhstan.
- What is the economic value of Kazakhstan's biodiversity and ecosystem services, and how are these impacted by climate-induced ecosystem shifts?
- How do international climate agreements and regulations impact Kazakhstan's trade and economic relations, particularly in sectors sensitive to emissions policies?
- What are the economic opportunities and challenges associated with transitioning to renewable energy sources in Kazakhstan?

Metodika

The methodology of this thesis consists of two distinct components. The first part entails the development of a theoretical framework, which relies exclusively on secondary sources, including articles and published research papers that explore the impact of climate change on a state's economy.

The second part involves a practical analysis utilizing secondary data obtained from the Bureau of National Statistics of the Agency. This dataset encompasses information regarding annual crop production, the agricultural sector's contribution to the overall GDP, and average temperatures within selected regions. The author relies on secondary data for this practical segment, employing statistical analysis techniques.

Specifically, the study applies the Granger causality test to discern the relationship between annual crop yield and temperature fluctuations.

Doporučený rozsah práce

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Klíčová slova

Agriculture, climate change, temperature, economy, GDP.

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Dinar, A. Weyerhaeuser, D. Preview Hardback Handbook on Climate Change and Agriculture, 2011. Edward Elgar Publishing, ISBN: 978-184980116-4

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Declaration

I declare that I have worked on my master's thesis titled *"Climate Change and its impact on the economy of Kazakhstan"* by myself and I have used only the sources mentioned at the end of the thesis. As the author of the master's thesis, I declare that the thesis does not break any copyrights.

In Prague on 31.03.2024 ____________________________

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I extend my heartfelt gratitude to my thesis supervisor, Doc. Ing. Vladimír Krepl, CSc., for his exceptional guidance, support, and encouragement throughout the completion of this thesis. His expertise, insightful feedback, and unwavering dedication have been invaluable in shaping the direction and quality of this research. I am deeply appreciative of his patience, wisdom, and mentorship, which have greatly enriched my academic journey. Thank you, Doc. Krepl, for your commitment to excellence and for inspiring me to strive for academic achievement.

Climate Change and its impact on the economy of Kazakhstan

Abstract

This thesis examines the impact of climate change on Kazakhstan's economy, focusing on key sectors such as agriculture, energy, and infrastructure. The objectives include analyzing theoretical models and conducting practical analyses to understand the implications of climate change. The theoretical section provides an overview of climate issues in Kazakhstan and explores various modeling approaches, including CGE modeling and macro-econometric IO models. The practical part investigates the significance of the agricultural sector, considering cultivated areas, livestock development, and foreign direct investments. Statistical analyses are conducted to assess the relationship between agricultural production and temperature fluctuations. Results highlight the vulnerability of Kazakhstan's economy to climate change, particularly in agriculture. The study underscores the need for proactive measures to mitigate these impacts and offers insights for policymakers and stakeholders involved in climate adaptation and mitigation efforts.

Keywords: Agriculture, climate change, temperature, economy, GDP.

Změna klimatu a její dopad na ekonomiku Kazachstánu

Abstrakt

Tato diplomová práce zkoumá dopad změny klimatu na kazašské hospodářství se zaměřením na klíčová odvětví, jako je zemědělství, energetika a infrastruktura. Mezi cíle patří analýza teoretických modelů a provedení praktických analýz, aby bylo možné pochopit důsledky změny klimatu. Teoretická část poskytuje přehled problematiky klimatu v Kazachstánu a zkoumá různé přístupy k modelování, včetně CGE modelování a makro ekonometrických IO modelů. Praktická část zkoumá význam zemědělského sektoru s ohledem na obdělávané plochy, rozvoj živočišné výroby a přímé zahraniční investice. Provádějí se statistické analýzy k posouzení vztahu mezi zemědělskou produkcí a kolísáním teplot. Výsledky poukazují na zranitelnost kazašské ekonomiky vůči klimatickým změnám, zejména v oblasti zemědělství. Studie zdůrazňuje potřebu aktivních opatření ke zmírnění těchto dopadů a nabízí poznatky pro tvůrce politik a zúčastněné strany zapojené do úsilí o přizpůsobení se klimatu a jeho zmírnění.

Klíčová slova: Zemědělství, změna klimatu, teplota, ekonomika, HDP.

Table of content

1. Introduction

Kazakhstan is at risk of experiencing major economic repercussions as a result of the problems presented by climate change. On the one hand, Kazakhstan has made a commitment to being carbon neutral by the year 2060, which would require the country to undergo a transformation of its economy that is based on resources. This promise helps contribute to the worldwide efforts that are being made to minimize warmth. There are, on the other hand, progressive climatic changes that Kazakhstan is experiencing, such as an increase in temperatures and an increase in the frequency of severe weather events such as droughts and floods. In order to effectively prepare for the long term, it is necessary to implement both adaptation and mitigation methods.

It is necessary to make significant investments in order to transition to a green economy, and these investments must also be climate resilient in order to limit harm. During his speech to the United Nations General Assembly, President Tokayev brought attention to the fact that Kazakhstan is particularly susceptible to the effects of climate change. The economic effects of climate change are significant, and it has an influence on important businesses such as agriculture, energy, and transportation. The development of a climate-resilient economy requires policymakers to have access to powerful tools that can evaluate the risks and benefits to the economy and investigate the different adaption solutions.

For Kazakhstan to be able to establish resilient economic growth plans, it is essential for the country to have a comprehensive understanding of the impacts of climate change on the economy as well as the sectoral adaptation methods. Economic models that take into account environmental factors and are combined with scenario analysis provide policymakers with vital help in their efforts to solve these difficulties.

2. Objectives and Methodology

2.1 Objectives

The main aim of this thesis is to evaluate the impact of climate change on the economy of Kazakhstan by examining secondary data. The author will explore the theoretical foundations of climate change and its possible consequences on a nation's economic structure. This study seeks to clarify the principal effects of climate change on Kazakhstan's economy.

- Establish the causal link between temperature variations and livestock productivity across diverse regions for various crop types.
- Investigate the influence of climate change, particularly monthly temperature fluctuations, on the agricultural sector's contribution over the previous 15 years.
- Quantify the significance of the agricultural sector's contribution to the total GDP of Kazakhstan.

Research questions:

- Measure the importance of the agricultural sector to the total GDP of Kazakhstan.

- What is the economic value of Kazakhstan's biodiversity and ecosystem services, and how are these impacted by climate-induced ecosystem shifts?

- How do international climate agreements and regulations impact Kazakhstan's trade and economic relations, particularly in sectors sensitive to emissions policies?

- What are the economic opportunities and challenges associated with transitioning to renewable energy sources in Kazakhstan?

2.2 Methodology

The methodology employed in this thesis comprises two distinct components. The first part involves constructing a theoretical framework based solely on secondary sources, such as articles and published research papers, which investigate the impact of climate change on a nation's economy.

The second part entails a practical analysis utilizing secondary data obtained from the Bureau of National Statistics of the Agency. This dataset includes information on annual crop production, the agricultural sector's contribution to the overall GDP, and average temperatures within selected regions. In this practical segment, the author relies on secondary data and employs statistical analysis techniques. Specifically, the study utilizes the Granger causality test to examine the relationship between annual crop yield and temperature fluctuations.

Granger causality is a statistical concept used to determine whether one time series is useful in forecasting another. It's based on the idea that if a variable X "Granger-causes" another variable Y, then past values of X should contain information that helps predict Y above and beyond the information contained in past values of Y alone.

- Can be un-directional or bi-directional
- Both X and Y must be stationary
- VAR format
- Null Hypothesis – No Granger Causality

3. Theoretical part

3.1 Preview of the Climate Problem in Kazakhstan

Although Kazakhstan is the ninth biggest nation in the globe in terms of size, its population is rather low, coming in at around 18 million people. Furthermore, the population is not uniformly dispersed throughout the country, with the majority of its inhabitants living in the south. Desert, semi-desert, and steppes make up the bulk of the landmass that is inside the nation. The vulnerability of the nation to the effects of climate change may be better understood by considering certain geographical factors. For example, climate change is having a negative impact on Kazakhstan's already precarious water security situation (World Bank, 2018). This includes glaciers that are melting at an alarming rate, which is the primary source of drinking water, and a change in the "peak flow of key rivers," which has an effect on the growing season. Additionally, climate change is further contributing to rapid land degradation and desertification, a reduction in agricultural yields, and transboundary conflicts in the region (Bernauer & Siegfried, 2012; Xenarios et al., 2019). This would result in extra annual expenditures of US$550 million to reduce freshwater scarcity in California by the year 2050, according to the Asian Development Bank (CAN, 2014). This is because climate change is already causing the situation to deteriorate, especially from the economic perspective.

The detrimental effects of climate change are distributed disproportionately through Kazakhstan, with greater precipitation in the north and gradually less precipitation in the south. This may do significant harm to the wellness of the people as well as to the agricultural sector in the south. Kazakhstan, like numerous other countries, is expected to see shifts in the spread of infectious illnesses, greater morbidity and mortality from severe climate incidents, and decreased accessibility to potable water (WHO, 2019). These modifications are more likely to occur in Kazakhstan than in numerous other locations. Floods, mudflows, heatwaves (such as the heatwaves that occurred in 2010 and 2014), forest and steppe fires, and rapid changes in climate are all things that Kazakhstan experienced. In fact, the frequency and severity of these natural disasters have been increasing. Extreme weather occurrences, which are related with warming temperatures, have been shown to cause damage to current utility systems as well as be responsible for the destruction of people's homes. In addition, Kazakhstan's agriculture sector is in jeopardy as a result of these issues. Kazakhstan is one of the greatest wheat producers in the globe, and the country has already seen " decreased crop yields due to droughts and fires" (WHO, 2019). During the years 2012 and 2014, for example, fifteen percent and eight percent of the country's crops were either badly damaged or completely destroyed. According to the Ministry of Energy of the Republic of Korea (2017), it is anticipated that if agricultural methods continue as they have been, the yearly yields might decline by as much as 49 percent to account for climate change. It is arguable that climate change also plays a role in the occurrence of man-made disasters. One example of this is the collapse of the dam's foundation of the Sardoba holding tank, which occurred in Uzbekistan but had a significant impact on Kazakhstan, resulting in the destruction of buildings and a loss of ten million dollars in damages to the farming industry (Simonov, 2020), see Figure – 1. Considering that "probably one sixth of the employment workforce in Kazakhstan operates in the forestry, agriculture, and fishing industries" (Ministry of Energy of the RK, 2017), all of these problems have the possibility to pose a danger to the well-being of the nation. Another factor that contributes to Kazakhstan's susceptibility is the nation's excessive dependence on the exploitation of natural assets such as oil and gas, which raises the question of a high dependability of Kazah’s economy.

Figure 1: Sardoba tank explosion.

Source: Simonov (2020).

The persistent prioritization of issues perceived as more pressing, such as economic and political stability, may pose challenges in addressing and mitigating the impacts of climate change. Kazakhstan's environmental strategy must be resilient enough to withstand the ongoing institutional changes it faces. Over the years, Kazakhstan has undergone several transformations in its environmental governance structure. Initially established in 1992, the Ministry of Ecology and Bioresources was the first entity dedicated to environmental matters. Subsequently, the Ministry of Ecology, Geology, and Natural Resources was established in 2019, marking the latest evolution of this ministry. Between these two ministries, there were four additional ministries with overlapping jurisdictions, each known by different titles. Currently, the Department of Climate Policy and Green Technology can be found at ***www.gov.kz.*** However, regional climate action is impeded by a lack of cooperation among neighboring countries. Rather than viewing the issue as an opportunity for collaboration, these governments often perceive it as a potential source of conflict (International Crisis Group, 2011). This dynamic significantly hampers climate initiatives. For example, disputes over the allocation of freshwater and energy resources have led to tensions in the region.

Kazakhstan is vulnerable due to its distinct geographical features and the coexistence of semi-authoritarian leadership with a carbon-intensive economy. Kazakhstan's political past and present foreign policy play a crucial role in shaping the state's character and influencing its environmental change-related procedures and policies. However, this thesis goes beyond the environmental issues that Kazakhstan has faced in recent years. It also explores political agenda and its potential impact of the economy.

3.2 Modelling Approach Towards "Climate change"

Several methods for assessing the economic impacts of global warming are outlined in the literature of (Nordhaus, 1992). William Nordhaus has conducted some of the most well-known computations throughout the beginning of the 1990s. Researchers contributed to the creation of among the first comprehensive evaluation designs, DICE (Nordhaus, 1992), that aimed to illustrate the connections underlying environmental issues and the world's economy in a dynamic approach. As a result, they were awarded the Nobel Prize in 2018. Subsequent models include the FUND modeling managed by

Richard Tol, the REMIND model developed by the Potsdam Institute, and RICE as a regionally defined version of DICE. The commonality across these models is their adherence to neoclassical maximization of utility, where the harms of climate change, represented in an adverse effect function, act as a constraint to achieve stability. These models describe damages caused by climate change based on varying levels of complexity and actual relationships with various climate change indicators. A straightforward approach involves explicitly estimating the impact of elevated temperature on the desired outcome, such as via a linear or exponential relationship. Advanced versions analyze specific damage effects for various climatic indicators like heat, drought, severe rainfall, or flooding for diverse economic sectors such as the agricultural sector, the energy industry, or tourist (Anthoff et al. 2011).

There is a significant scientific debate over such models, focusing on the accuracy of the rates of discounting, the ideal societal discounted rate (Weitzman, 1998), the extreme values in the distribution as an associated with risk related to climate (Hwang et al. 2016), along with other intriguing scientific studies and obstacles. The simulations used fail to explicitly incorporate time and depict the economy's conditions in a state of balance, which are then contrasted with an equilibrium that factors in climate effects or adaptation measures. Comparing two equilibrium states statically does not provide much information about changing processes. These methods have greatly helped in calculating the economic effects on a worldwide scale and in measuring the financial consequences of not taking action.

The effects of climate change and its adaptation might vary greatly at the national, regional, and even individual level, despite the fact that greenhouse gas (GHG) emissions are a common contributor to the phenomenon of climate change. Top-down techniques, including RICE, which was introduced by Ricke et al. (2018), have been used to adjust global projections to local circumstances in order to address the variability that has been seen. Nevertheless, bottom-up methodologies are being used in a growing number of investigations that are now being published in academic journals to determine and quantify the costs of adaptations and harms associated to warming temperatures. For instance, there are studies that have been carried out for European member states through the Joint Research Center of the EU, which are referred to as PESETA (Feyen et al., 2020), for Austria in the COIN3 study that was carried out by Steininger et al. (2015), for the EU COACCH project (2021), for European islands in the SoClimpact4 project, and in the consequences evaluation for the EU 2021 adaptation plan. Furthermore, there are unique research that are particular to the industry that are also accessible.

Based on Ciscar et al. (2011), Ciscar et al. (2014), Nordhaus (2017), integrated macroeconomic assessment of environmental issues is a challenging task that is increasingly being tackled using a mix of bottom-up industry particular models and macroeconomic models. The majority of projects have concentrated on the massive aggregation of geographical areas due to the fact that climate change is a process that occurs on a worldwide basis. Downscaled modeling, on the other hand, offers valuable suggestions for policy from a regional point of view, which depends on the specific macroeconomic features and weaknesses of the geographic area.

According to (NGFS, 2020), economic simulations that evaluate environment hazards may be separated into two categories: integrated climate-economy models and modified macroeconomic models (Figure 2). It is the connecting of climatic and economic models, as well as the relationships among them, that constitutes the primary distinction. Adaptation macroeconomic frameworks take into consideration the effects of warming temperatures on financial markets in particular, in contrast to Integrated Assessment Models (IAM), which take into account both the economic losses caused by global warming as well as the effect of greenhouse gas emissions on the climate. There is a significant amount of variation in the level of modeling detail across all sorts of models. For instance (Botzen et al. 2019, IPCC 2014, Lehr et al. 2020, and Máñez Costa et al. 2016) are some examples that are included in an overview.

Figure 2: Types of economic models to assess climate consequences and risks

Lineage	Model type	Description	Example
Integrated climate-economy models[1]	Cost-benefit IAMs	Highly aggregated model that optimises welfare by determining emissions abatement at each step	DICE, DSICE (Cai et al., 2012, Barrage, 2020)
	IAMs with detailed energy system and land use	Detailed partial (PE) or general equilibrium (GE) models of the energy system and land use. General equilibrium types are linked to a simple growth model	PE: GCAM, IMAGE GE: MESSAGE, REMIND-MAgPIE, WITCH[2]
	Computable General Equilibrium (CGE) IAMs	Multi-sector and region equilibrium models based on optimising behaviour assumptions	G-CUBED, AIM, MIT-EPPA, GTAP, GEM-E3
	Macro-econometric IAMs	Multi-sector and region model similar to CGE but econometrically calibrated	E3ME, Mercure et al., 2018
	Stock-flow consistent IAMs	Highly aggregated model of climate change and the monetary economy that is stock-flow consistent	Bovari et al., 2018
Other climate-economy models	Input-output (IO) models	Model that tracks interdependencies between different sectors to more fully assess impacts	Ju and Chen, 2010 Koks and Thissen, 2016
	Econometric studies	Studies assessing impact of physical risks on macroeconomic variables (e.g GDP, labour productivity) based on historical relationships	Khan et al., 2019 Burke et al., 2015 Dell et al., 2012
	Natural catastrophe models and micro-empirical studies	Spatially granular models and studies assessing bottom-up damages from physical risks	SEAGLASS (e.g. Hsiang et al., 2017)
Modified standard macroeconomic models	DSGE models	Dynamic equilibrium models based on optimal decision rules of rational economic agents	Golosov et al., 2014 Cantelmo et al. 2019
	E-DSGE	Slightly modified standard frameworks (that allow for negative production externalities)	Heutel, 2012
	Large-scale econometric models	Models with dynamic equations to represent demand and supply, coefficients based on regressions	NiGEM (e.g. Vermeulen et al., 2018)

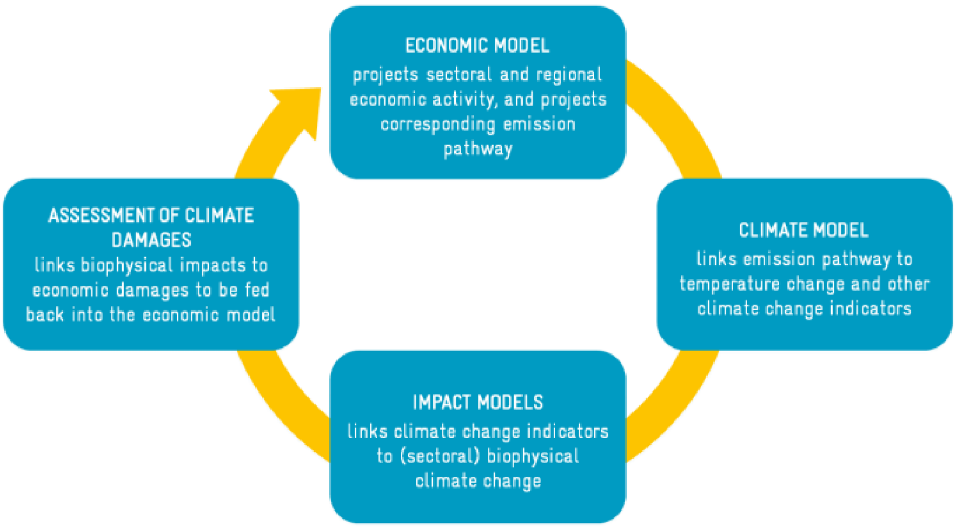
Source: (NGFS, 2020).

Economic frameworks may be categorized according to the economic hypotheses that explain how the economy works and the relationships among its many elements. The models discussed include computable general equilibrium (CGE), static input-output (IO), and macro-econometric (or dynamic) IO models, as cited by Lehr et al. (2020), NGFS (2020), Máñez et al. (2016), and Pollitt and Mercure (2019). The different kinds of models are based on basic presumptions which lead to variations in model results, as shown by Großmann et al. (2016) and Mercure et al. (2019). Integrated Assessment Models (IAMs) combine economic models with climate models to examine the economic impacts of climate change. The integration is achieved by connecting climate simulations to CGE models employing a loss function. Disaster Impact Models (DIMs) evaluate the financial impacts of natural disasters on local economies by adapting CGE or IO models to specific regions.

3.2.1 CGE Modelling

CGE models are primarily employed to examine the consequences of climate change on certain sectors and their overall influence on the economy as a whole, as shown in studies such as (OECD 2015: GEM-E3 in Ciscar et al. 2011). The frameworks are optimization models defined by market-clearance presumptions, completely adjustable pricing, and rapid replacement in their simplest form. CGE models are appropriate for addressing long-term concerns assuming well-operating markets, however they often underestimate the costs associated with climate change and adjustment (Botzen et al. 2019, p. 183, OECD 2015: 30).

Figure 3: Linking economic and climate change models



Source: OECD (2015: 30)

In contrast to IAMs, that utilize the oversimplified harm models to establish a connection between environmental and economic variables, ENV-Linkages and GEM-E3, for instance, use an alternative technique, that is illustrated in Figure 2 (Ciscar et al. 2011, OECD 2015, Ortiz, Markandya, 2009).

Emission routes are derived from the economy, and the financial modelling include industry details. Input into climate simulations, that are used to determine climate indicators such as temperature rise, carbon dioxide emissions serve as the input. In order to acquire particular consequences (such as changes in agricultural output or energy consumption), the climatic variables are subsequently used in simulations that are employed in the ecological industry. The economic harm caused by climate change, which may have an impact on both the supply and demand sides of the economy, are ultimately used as inputs in its model.

The implications of global warming on economic activity are represented in the PESETA venture, which makes use of GEM-E3, in one of three ways: either via destruction to the stock of capital, via departmental productivity losses, or as decreased welfare suffered by private individuals respectively (Feyen et al. 2020). The latter might be the consequence of an increase in requests for power to be used for cooling, or it could be a consequence of extra expenses that are incurred involuntarily for the repair of flood damage. According to Steininger et al. (2015), the COIN project for Austria employs a methodology that is comparable to this one.

3.2.2 Static IO models

Static input-output models rely on input-output databases to offer a comprehensive perspective on inter-industry connections and the connection between demand and supply (United Nations 2018, Miller and Blair, 2009). IO models originated from Leontief's mathematical representation of the repercussions of increased demand on a specific sector and its broader direct and indirect consequences on the whole economy. The stationary IO method is suitable for short-term analysis because of its consistent economic framework. Unlike the majority of CGE models, instantaneous replacement is not present. Temporary supply restrictions caused by production losses should be represented by adjusting the input factors that reflect the required inputs for producing industry-specific output. The long-term adjustments are unable to be captured in a dynamic IO paradigm because it does not account for adaptation mechanisms as time passes. Adaptation prices are often exaggerated in this estimation type due to its failure to account for replacement processes in the face of increased costs (Botzen et al. 2019, pp. 172, Lehr et al. 2020, Máñez Costa et al. 2016). Disaster Impact Research utilizes Input-Output models to calculate the both direct and indirect impacts of activities such as rebuilding to address the harm that results from Extreme Weather Events (EWEs) at both national and subnational levels (e.g., Bockarjova et al., 2004; Okuyama et al., 2004).

3.2.3 Macro-Econometric (or Dynamic) IO Models

Macro-econometric IO theories, such as those by Almon (2014) and West (1995), improve over static IO modelling by addressing their shortcomings and presumptions, including the lack of consideration for time and capacity restrictions. Prices reflect constraints caused by limitations in production. Dynamic models explicitly include time, allowing them to depict economic progress annually and illustrate the chronological rehabilitation route from environmental impacts and the adaption adjustment phase. The dynamic approach of IO models, like stationary IO models, are usually demand-driven. The demand is decided internally rather than externally. Income, affected by the prevailing labor market conditions and consumer pricing, plays a crucial role in determining consumer demand (Miller and Blair, 2009). Another advantage of dynamic IO models is that they allow for the evaluation of income-induced consequences in addition to both direct and indirect consequences.

Macro-econometric Input-Output models use a detailed dataset to analyze the price and volume responses by actual estimates, in contrast to CGE models which depend on validated variables from a certain base year. Historical trends have been predicted to continue the effect on the future outcomes which is deemed as a (homogeneity roots), allowing for a more accurate mid- to long-term prediction by relaxing the presumption of a fixed financial framework and import reliance. Future technology advancements and developments might enhance the model's use in analyzing structural changes (Mercure et al., 2019). However, assuming that parameters remain constant, based on prior observations, becomes less true as time goes on.

3.2.4 Modelling the Approach for Kazakhstan

International studies demonstrate the existence of many methodologies for modelling the economic implications of global warming and recovery. Currently, there is no universal answer that applies to all. Each method has its benefits and constraints (Keen, 2020: Keppo et al. 2021). Multiple complementary models may be employed simultaneously, as shown by Feyen et al. (2020) and Lehr et al. (2018). The TALAP 2019 study revealed a discrepancy between the macroeconomic and climate modelling groups in Kazakhstan.

Currently, modelling professionals in Kazakhstan lack a grasp of how to include environmental consequences into economic simulations.

In general, the most important specifications for an economic model that will be competent to represent the effects of climate change are as follows: it has to include the most significant economic effects (such as decreases in output and revenue), industries (such as energy, agriculture, and infrastructure) which have been impacted by climate change, as well as must take into consideration supply chains (Miller and Blair, 2009: Almon, 1991: Lewney et al. 2019). Neither does such a model of economics need to take into account the long-term macroeconomic changes in relation to the potential implications of climate change (Lewney et al. 2019), but in addition it must take into account the adaptation responses that occur in the decades that follow a climatic catastrophe (Lehr et al. 2016).

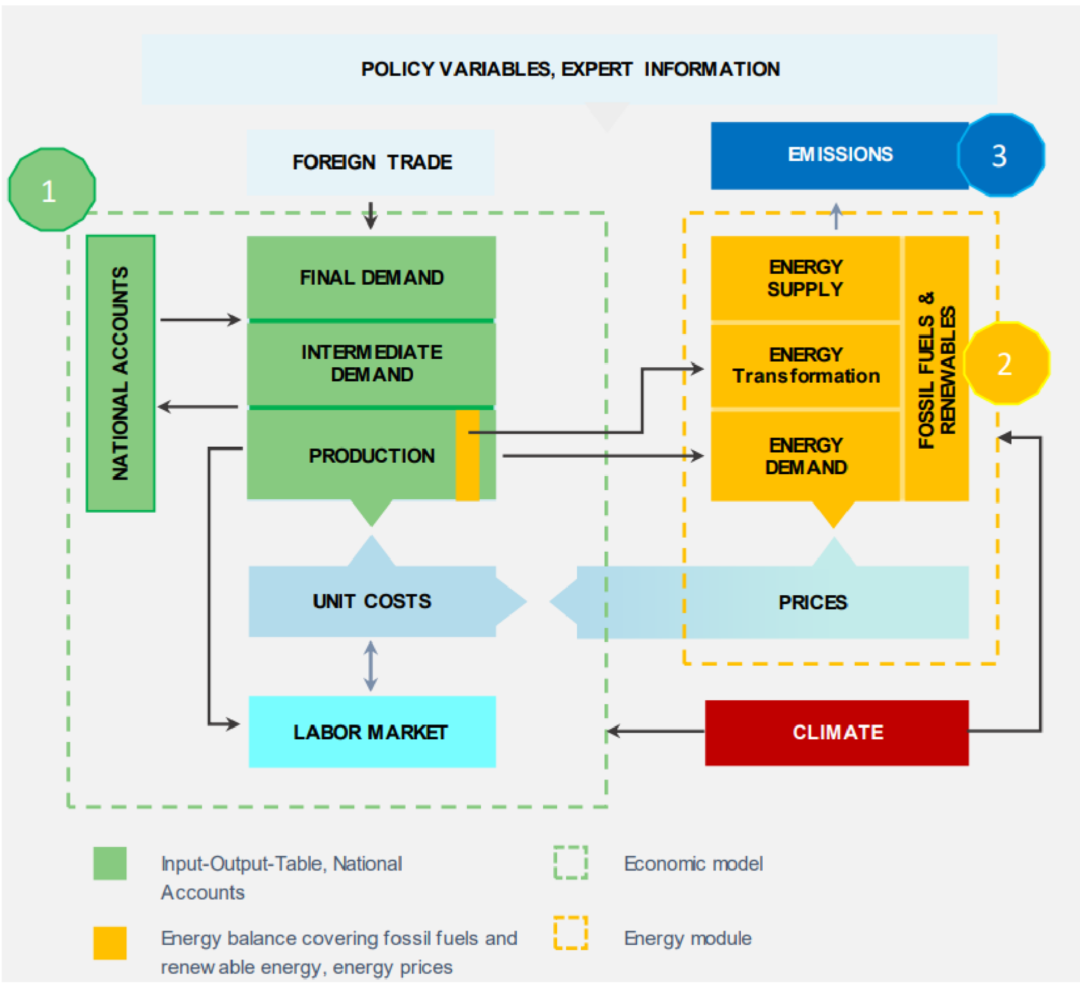
3.2.4.1 3e Model of Kazakhstan

The e3.kz framework, that stands for the economic, energy, and emission model for Kazakhstan, is a prediction and simulation apparatus that was built in collaboration with Kazakh partnerships with the objective of evaluating the effects of climate change as well as adjustment techniques on economic activity for the whole country. The Kazakh economy, the energy system, and carbon dioxide emissions are all modelled by E3.kz inside a comprehensive and consistent model framework. This framework has the benefit of being able to compute consequences concurrently for each year up to the conclusion of the simulated time frame, which in this particular case is projected up to 2050 *(Figure 4)*. Each part is founded on an extensive and current database that is presented in the form of time series. This enables the empirical derivation of model linkages among the components.

The economical modeling component of the ***e3.kz*** model is primarily an evolving IO (input-output) approach, also known as a macro-econometric IO approach, that follows the INFORUM technique developed by (Almon, 1991: 2014). Various models exist in various forms and levels of sophistication, such as those by (Eurostat, 2008, Großmann, Hohmann 2016: 75-78, Lehr et al. 2016: 35-43, Lewney et al. 2019: 16-21, and Stocker et al. 2011). They are often constructed using IO tables and national accounts to illustrate the main and auxiliary sectors, their connections, and the factors influencing economic development from both domestic and international sources. The whole cycle of economics is shown, including manufacturing, revenue development, income redistribution, and income use, See *(Figure 4)*.

Each of the parts of GDP are initially calculated, and then they are assigned to the individual industries by applying constant percentages for each final demand classification. This is done in accordance with the top-down, demand-side driven approaches. It is the Leontief manufacturing process that illustrates the link that exists between supply and demand.

Figure 4: E3.kz model overview



Source: GWS (2022).

Firstly, each component of GDP undergoes initial calculation, followed by allocation to individual industries using fixed percentages for each final demand classification Meyer and Ahlert (2019) and. This process aligns with top-down, demand-side driven methodologies. The Leontief manufacturing process serves to illustrate the interconnectedness between supply and demand.

The supply and pricing factors are also taken into consideration in order to take into account the potential supply restrictions that are brought about by EWEs. The cost structure of intermediate goods, such as energy, may be determined from supply chains; this can be done by referring to the IO table Meyer and Ahlert (2019). Main inputs, such as the remuneration of personnel and the net taxes on output, may be used to extract the overall expenses of any industry. It is on the basis of these costs that manufacturing rates are established. The macro-econometric IO model takes into consideration the eventual passing trend in expenses as experienced in previous decades, and as a result, it incorporates the competitive edge on the various goods markets and the job market Meyer and Ahlert (2019). The price and volume responses in this model are derived empirically. According to Meyer and Ahlert (2019), the use of econometric tools makes it possible to consider imperfect markets and restricted reasoning. According to Lutz et al. (2014), the projections for financial players are shortsighted and in accordance with patterns that have been established in the past. As a result, ***e3.kz*** is not a CGE model, which is a model in which prices are in equilibrium with supply and demand and homes and businesses improve their positioning (Meyer and Ahlert, 2019).

The framework incorporates income and employment adjustments so that their effects on financial status and employment may be tracked. The demand for labor is directly related to economic growth in industries that take worker efficiency into account. Using the Phillips curve's method and the employment scarcity indicator, which is the proportion of the people of working age to total labor demand, it is possible to calculate the overall economic rate of earnings.

3.3 Climate Change and its Effect on Kazakhstan

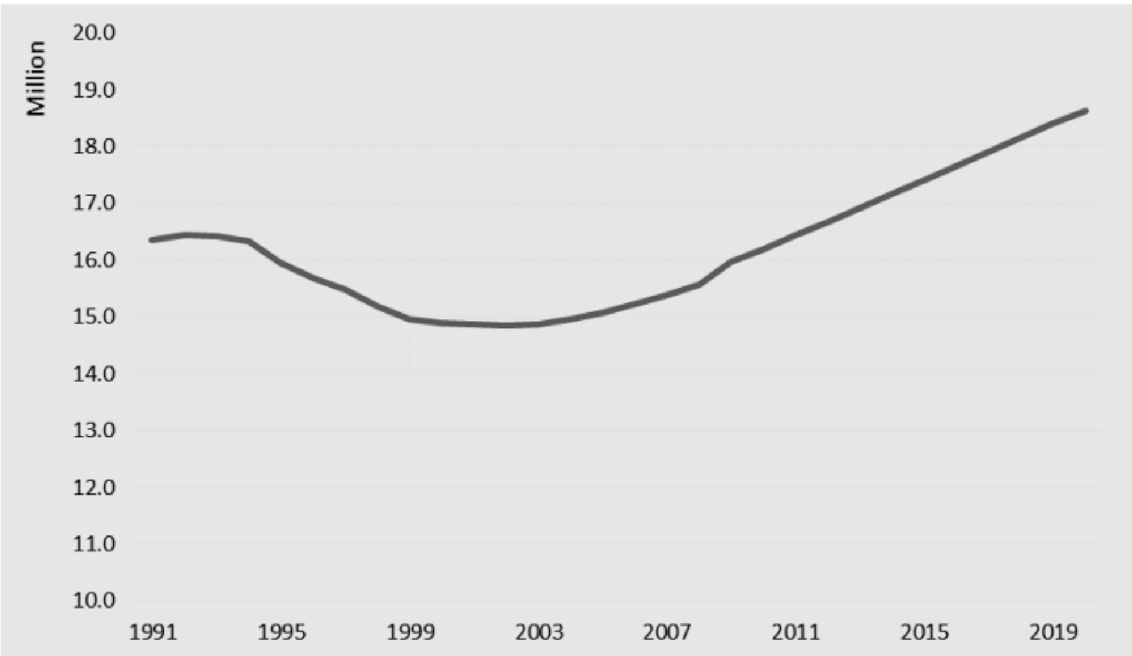
3.3.1 Country Information

Kazakhstan is a Central Asian nation that is divided and has a huge region of nearly two million square miles. It is bordered by the Caspian Sea to the West, the Altay Mountains to the East, and the Tian-Shan mountains to the South (Ministry of National Economy, 2021). The country has borders with Russia to the North, China to the East, and Kyrgyzstan, Uzbekistan, and Turkmenistan to the South.

3.3.1.1 Population

The overall population has been consistently growing since 2003 and hit 18.5 million in 2019, with 58% residing in urban areas (Figure 5). Almaty is the biggest city having roughly two million residents, which is followed by the main city (Astana) and Shymkent, each having approximately one million people (Ministry of National Economy, 2021: 8).

Figure 5: Population 1990-2020



Source: Muzbay (2020)

The year 1991 marked the beginning of Kazakhstan's social, political, and economic reforms, which began with the country's proclamation of independence (Bertelsmann Stiftung, 2020). Even though the economy was in the middle of a very rapid downturn, the first moves toward democratic reform were taken in the first few years after the country gained its freedom. The economic recovery started in the middle of the 1990s and has been making significant progress ever since the discovery of a massive oil field in the year 2000. Among the post-Soviet republic nations that have successfully made the shift from a centralized economy to a market-based economy, Kazakhstan is one of the countries that has achieved this transformation. (Bertelsmann, 2020).

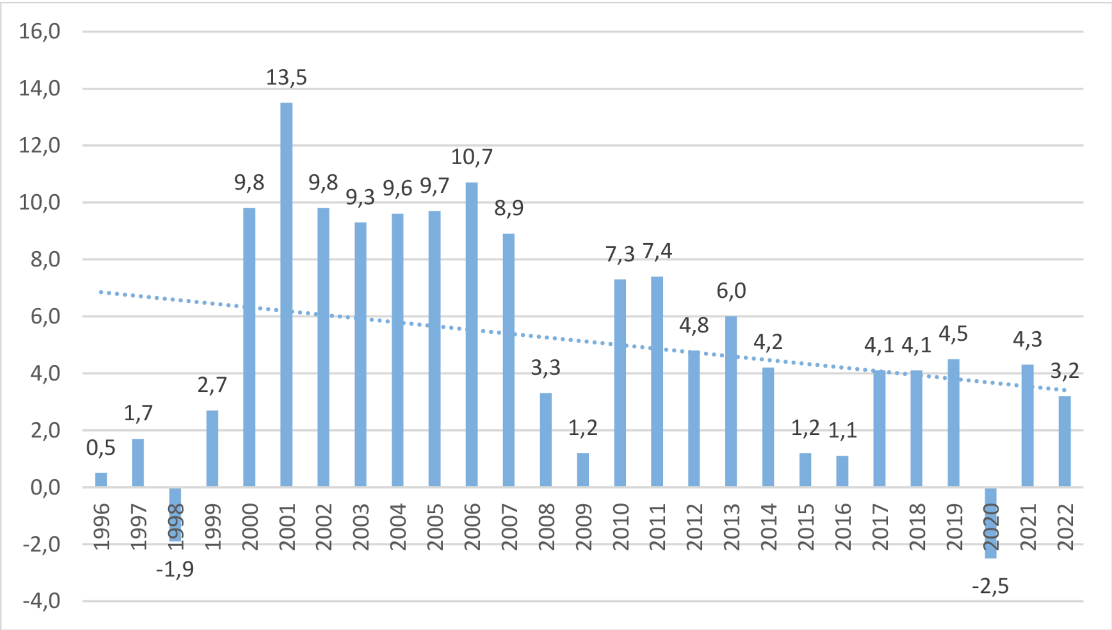
In accordance with the Heritage Foundation's Index of Economic Freedom, Kazakhstan is categorized as a "moderately free" nation (Batsaikhan and Dabrowski, 2017). Since its participation in the Central Asia Regional Economic Cooperation (CAREC) program in 2001, Kazakhstan has been working toward the enhancement of regional economic collaboration, notably in the areas of transportation, energy, commerce, and the construction of economic zones (CAREC, 2021).

3.3.1.2 Economic Background of Kazakhstan

The Kazakh industry reaps the advantages of the natural riches that the nation has. Of special significance are the gas and oil reserves of Mangystau, Atyrau, and Aktobe, which are located in the western and southwestern regions of Kazakhstan. A significant hard coal extraction region may be found in Karaganda, which is situated in the Middle East region of the nation. As an additional point of interest, Kazakhstan has deposits of many other raw resources, including uranium, copper, iron ore, and rare earths. At the same time as Kazakhstan's economy is becoming more dependent on oil and gas, efforts are being made to diversify the country's economy (World Bank, 2018). By increasing the amount of value that is created via the additional refining of raw materials, an effort is being made to reduce the country's reliance on the prices that are found on the global market. The cities of Almaty, Karaganda, Shymkent, Pavlodar, and Aktobe are home to significant industrial hubs that are responsible for the production of metals, chemical production, and plastic goods. In addition, Kazakhstan made a commitment in December 2020 to achieve carbon-free by the year 2060, which is a far more ambitious goal compared to the "Green Economy" idea (UNDP, 2013). The worldwide economic and financial crisis that occurred in 2008-2009 and the subsequent recession that began in 2014 (Figure 6) both halted Kazakhstan's robust economic development that had been occurring from the year 2000 up to that point. A growth rate of 6.4% was seen in Kazakhstan's economy on average over the years 2000 and 2022. According to COMSTAT (2021), the gross domestic product (GDP) in 2019 was KZT 48 trillion, which is equivalent to KZT 2.6 million per person.

The rise of the economy has had a favorable influence on social indices, and there has been progress done in terms of reducing unemployment and poverty. According to the Asian Development Bank (2024), Kazakhstan began its transition to an upper-middle income nation in the year 2006. There was a decrease in the poverty rate from 55% in 2006 to 20% in 2015, according to the World Bank (2018). Moreover, the creation of new jobs was a concurrent phenomenon with the expansion of the economy. According to COMSTA (2021), the unemployment rate has decreased from 10.4% in the year 2001 to 4.9% in the year 2018. Kazakhstan received a rating of 0.825 on the Human Development Index in 2019, which is a composite statistic that includes life expectancy, education, and income indices (UNDP, 2020). This placed Kazakhstan in the 51st position on the index.

Figure 6: Real GDP growth rate (% p.a.) 1996-2022

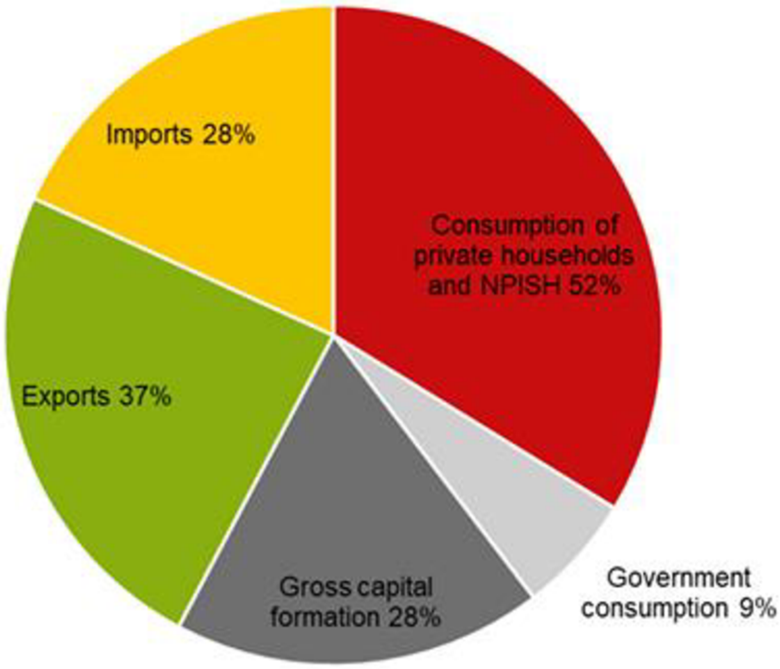


Source: World Bank (2023).

3.3.1.3 GDP Structure

Over half of Kazakhstan's Gross Domestic Product (GDP) is attributed to the expenditure of individual households and non-profit organizations supporting households (NPISH), a significant portion depicted in Figure 9. Meanwhile, the creation of capital contributes around 28% to the GDP. Notably, services and goods exporters collectively account for approximately 37% of the nation's total exports, with a substantial 50% attributed to oil and gas exports COMSTAT (2021). Conversely, imports, which encompass both foreign intermediary goods and final commodities, constitute 28% of the foreign trade balance, offsetting 9% of the total balance. Kazakhstan's heavy reliance on imported goods is particularly pronounced in the industrial sector, where a considerable 85% of the overall demand for electrical goods and 91% for equipment is sourced from overseas, as indicated in the IO table for the year 2021 COMSTAT (2021a). This reliance underscores the significance of international trade partnerships and highlights areas where domestic production may require bolstering for economic resilience and self-sustainability COMSTAT (2021a).

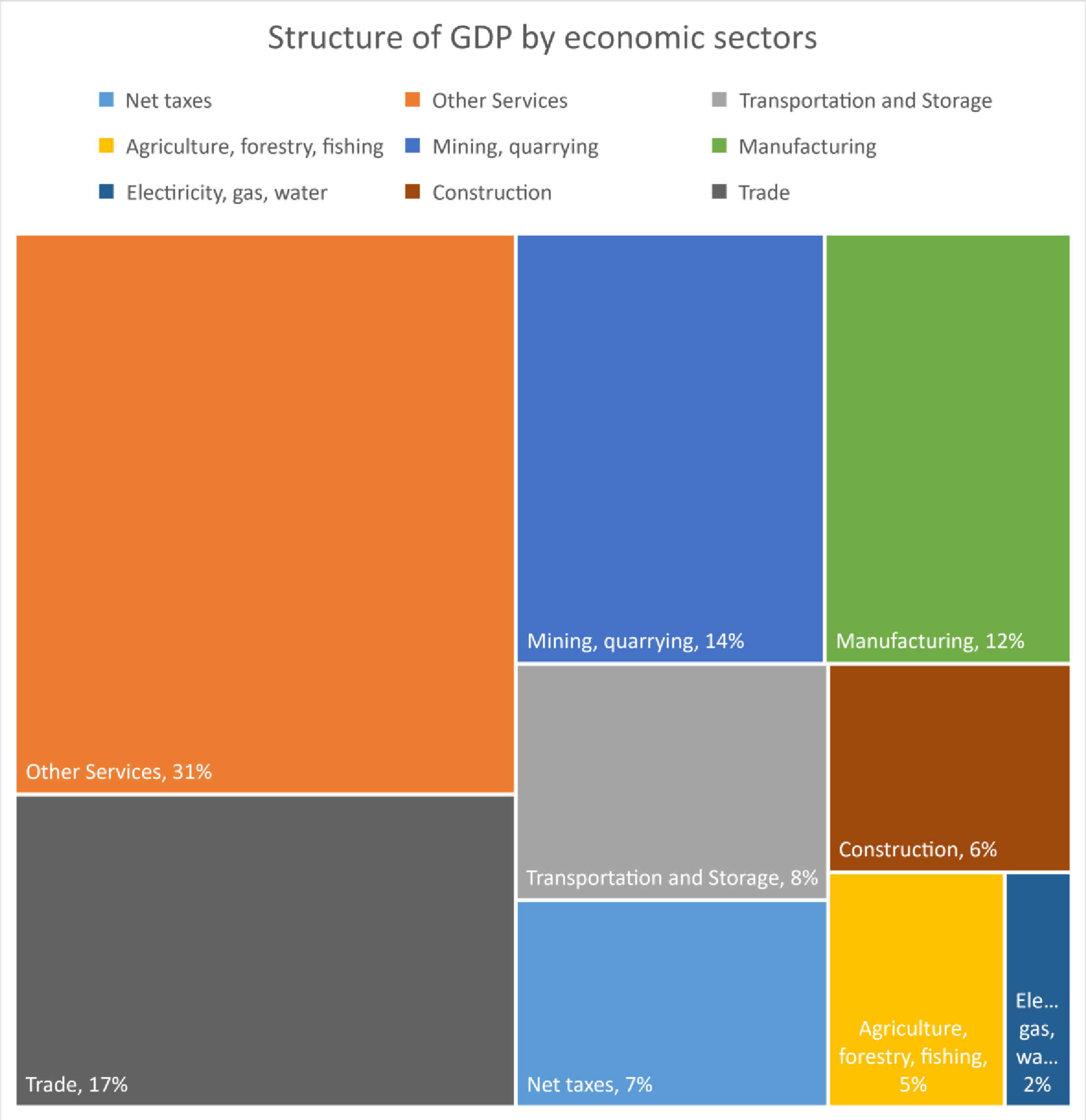
Figure 7: Structure of GDP by expenditures, 2022.



Source: COMSTAT (2022)

This comprehensive breakdown sheds light on the diverse economic sectors shaping Kazakhstan's GDP and highlights the significant contributions of each sector to the country's economic landscape.

Figure 8: Construction of GDP, by sector by 2022

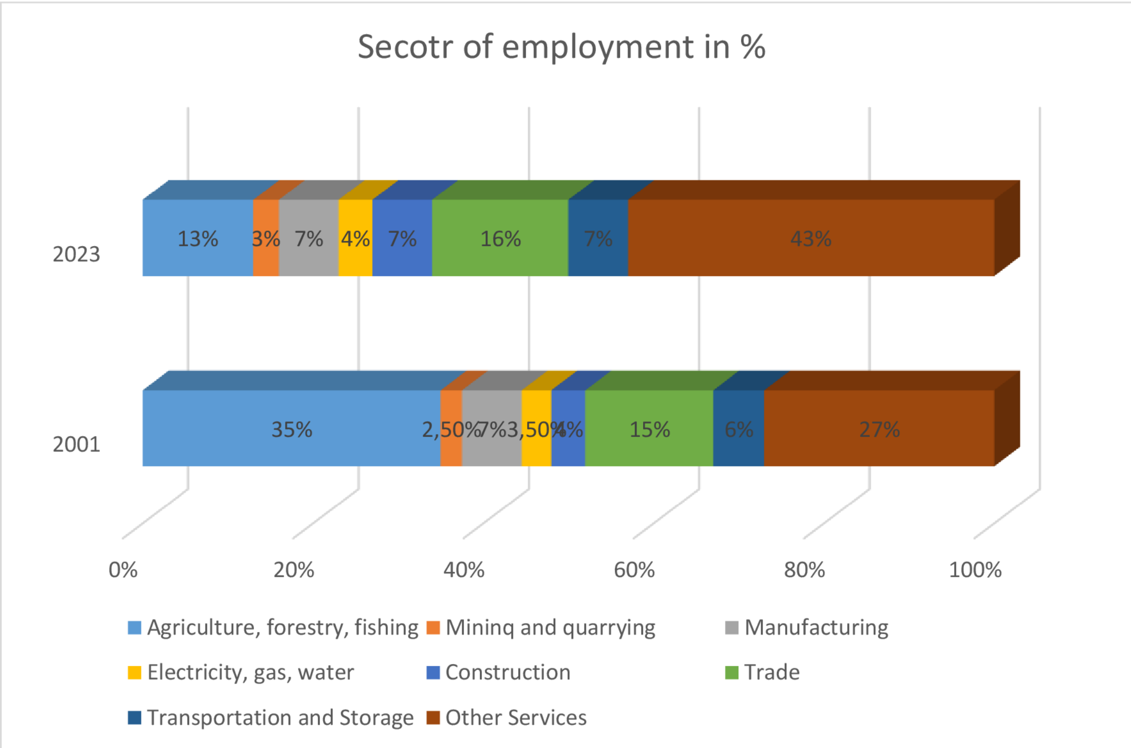


Source: COMSTAT (2022)

With road infrastructure being the most dominating, accounting for 88% of the country's transport and logistics services, Kazakhstan, which is situated on the Eurasian continent, is strongly dependent on the infrastructure that supports commerce and transportation. In an effort to strengthen collaboration across continents, China has proposed the Belt and

Road Initiative, which is often referred to as the New Silk Road. This nation is a participant in the initiative. According to the findings of the World Bank's investigation, the program and its transportation corridors have the potential to dramatically enhance living standards, as well as commerce and foreign investment, for the nations that are engaged (World Bank, 2023: 13). For the period beginning in 2001 and ending in 2023, the number of people who are employed rose from 6.7 million to 8.8 million (Ministry of National Economy, 2023). In terms of economic significance, agriculture was the most significant sector, followed by the commerce and service industries (Ministry of National Economy, 2023). Some of the other factors that contributed to employment were education, commerce, transportation, manufacturing, and building.

Figure 9: Sector of employment in %, 2001 – 2023



Source: (Ministry of National Economy, 2023b)

Figure 9 illustrates the progression of employment as a function of the economy from the year 2001 to the year 2023. A total of 8.8 million people were employed throughout this time period, which is up from the previous figure of 6.7 million. When it came to the number of people who were employed, farming became the most significant sector of the economy in 2001, accounting for 35% of the total. However, in 2023, the commerce sector was the most dominating, accounting for 16% of the total, being followed by agricultural for 13%. Additionally, a significant percentage of people are engaged in the higher education sector, which makes up for 13 percent of the total, the trade sector, which represents for 16%, the storage and transport sector, the manufacturing industry, and the construction industry (each one sector contributes for seven percent in 2023).

3.3.1.4 Climate Conditions of Kazakhstan

Kazakhstan is characterized by a continental climate that is characterized by strong seasonal fluctuations, such as hot summers and harsh winters, in addition to having less precipitation than other countries. The climatic conditions, such as temperature and rainfall, demonstrate significant variations from one place to another due to the vastness of the country and the variety of its terrain. Moving eastward, the terrain changes via the Caspian depression, the lowland region of Turan, and the Kazakh lowlands, slowly climbing to the Kazakh mountain region. There are mountain ranges that predominate the eastern and southeastern areas, and some of these hill ranges have peaks that reach heights of up to 7,000 meters. According to a study published by the World Bank (2021), the topography is mostly composed of flatlands or landscapes that gradually undulate. According to the Ministry of Energy of the Republic of Kazakhstan in 2017, almost all of the nation is comprised of arid natural zones, which include deserts, semi-deserts, and dry steppe. On the other hand, sections of moist forest-steppe are only found in the northern part of Kazakhstan.

The weather throughout the country displays a variety of patterns, with dry deserts dominating the middle and western areas, while the southern, eastern, and southeastern parts are characterized by hilly landscapes and get the most rainfall in the whole nation. In the northern part of the country, winters are marked by lengthy and harsh conditions, with typical temperatures dropping to -20 degrees Celsius and sometimes plunging much lower to a bone-chilling -37 degrees Celsius. In contrast, summers in the North remain rather warm, with typical temperatures of about 18 degrees Celsius. When relocating to the South, the average temperature range varies from a chilly -5 degrees Celsius in wintertime to a much higher twenty degrees Celsius throughout the summertime. The summer months in Central and Western Kazakhstan are characterized by prolonged periods of extreme conditions, as documented in publications by (USAID, 2018) and the (World Bank, 2021). Conversely, winters in these regions are marked by very cold weather.

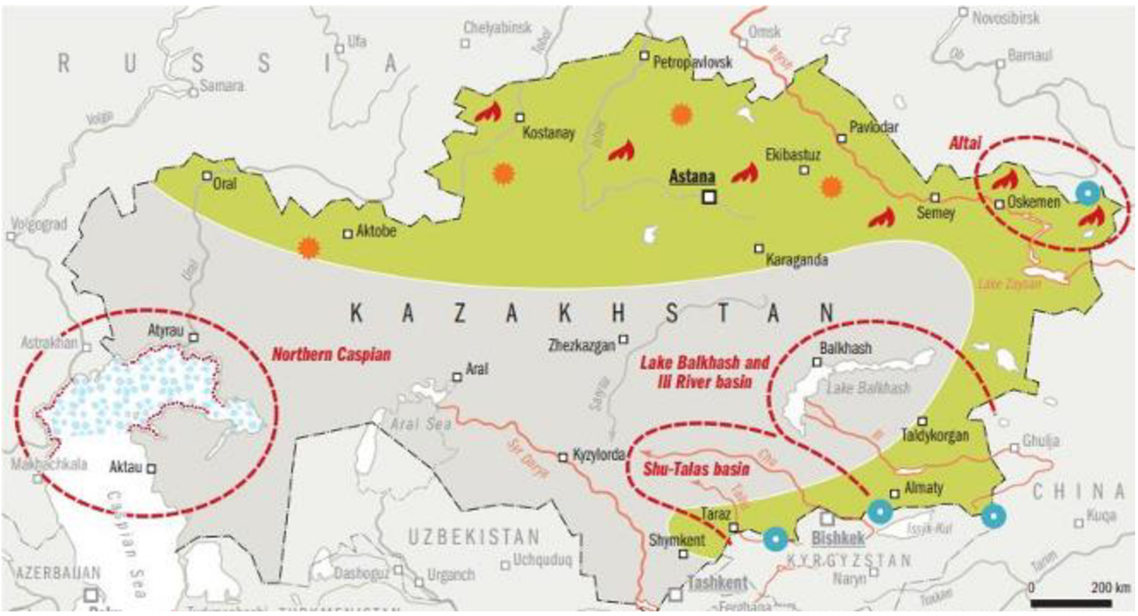
The World Bank (2021) report indicates that Kazakhstan has witnessed a steady and pervasive increase in its average monthly temperature of the air of 0.28 Celsius per decade across the last several decades. The rising temperature tendency is at its peak in intensity throughout the winter season. Since 1950, the Tien Shan glacier has undergone a significant rate of erosion, with estimates indicating a range of 14% to 30% (USAID, 2017). Furthermore, a significant rise in the occurrence of days with outside temperatures surpassing 25 degrees Celsius was observed, along with extended periods of intense heat waves, primarily in the southern and western regions of the country. Droughts transpire via notable frequency each five years or so, with major droughts being documented at roughly between five and seven-year periods, according to data sourced from the FAO (2019) and the World Bank (2021). Arid conditions prevailed in the southern and western regions of Kazakhstan in 2021, with temperatures plummeting to an unprecedented 46.5 degrees Celsius. The consequences of this phenomenon were swift discharges into reservoirs and rivers, as confirmed by the International Federation of Red Cross and Red Crescent Societies (IFRC, 2021). As a result of the combined effects of heatwaves and droughts, the likelihood of fires in forests and the spread of diseases is significantly increased.

High mountains and a highly seasonal precipitation pattern, on the other hand, render the nation susceptible to mudslides, landslides, and flooding. In addition to lowland rivers in Western, Northern, and Central Kazakhstan, infrequent occurrences of flooding have been documented in the mountainous regions of Southern and Eastern Kazakhstan (MNE et al. 2017, USAID 2018). Flooding manifests itself in various forms, including flash floods and river flooding, which are primarily induced by persistent and intense precipitation, quick melting of snow and glaciers (e.g., Tien Shen), and breaking of frozen lakes (UNESCAP, 2020). Wind-driven inundations are prevalent in the Ural River basin and the Caspian Sea littoral region characterized by swells of seawater (Kozhakhmetov. 2016, UNESCAP, 2020).

At least a portion of the flooding that has occurred in Kazakhstan can be ascribed to dam failures precipitated by insufficient maintenance and the buildup of substantial quantities of water. Prominent instances encompass the Kyzyl-Agash dam failure of 2010, the Jumabek dam failure of 2011, and the Kokpekty dam failure of 2014, all of which have been meticulously documented by the (OECD, 2020). Furthermore, the OECD has noted that Kazakhstan's susceptibility to inundation is exacerbated by the abundance of transboundary rivers in the region. As a result, Kazakhstan may be significantly impacted by dam failures in neighboring countries, such as the Sar Doba dam breach that occurred in Uzbekistan in 2020, this case was demonstrated in chapter 3.1. This would amplify the vulnerability of Kazakhstan to flooding and its consequences.

The number of hydrometeorological catastrophes, specifically excessive precipitation, flooding, and mudslides, was approximately double the average for the year 2015 (MNE et al. 2017). 75% of the time, intense precipitation and 22% of the time, moraine lake outbursts result in mudflows (Kozhakhmetov, 2016). In 2015, the most recent mudflow in Almaty transpired. The dam shielded the city from mudflow-related damages in 2019, See Figure 10.

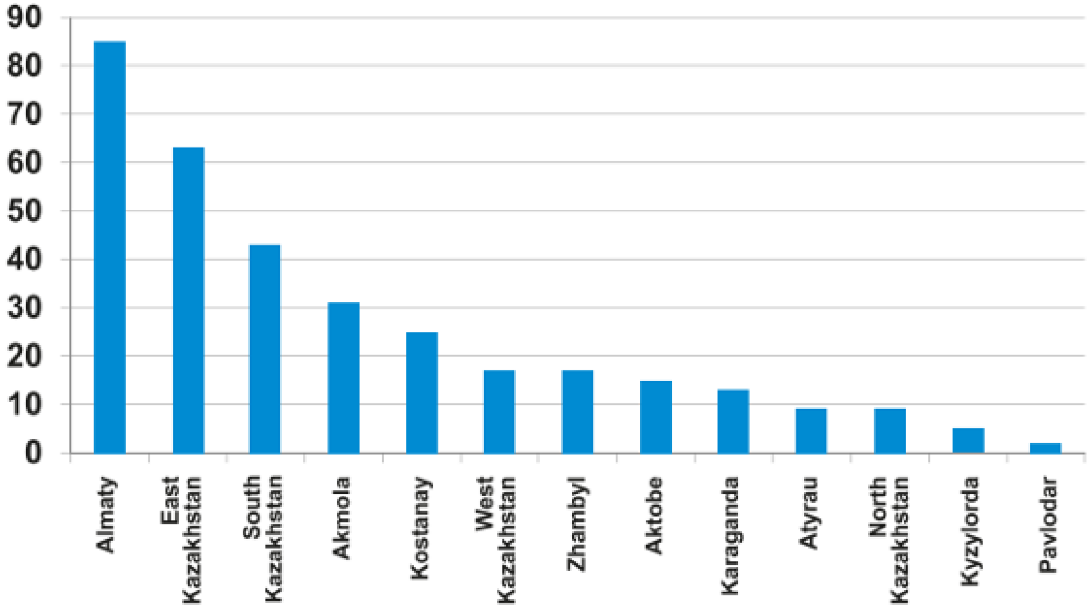
Figure 10: Impact of Climate Change for 2018



Source: Navarro & Jordà (2021).

As shown in Figure 11, the majority of Extreme Weather Events (EWEs) transpired in the southern, southeast, and northern regions of Kazakhstan from 1967 to 2015. According to UNESCAP's 2021 report, although droughts are more common in the western and southern regions of the Republic of Kazakhstan, significant flooding occurred in the lowland rivers of the western, northern, and central regions, as well as the mountainous areas of the southeast and western Kazakhstan. Mudflows pose a significant hazard to around 13% of the nation's landmass, with the Southeast region, which accommodates more than 26% of the Kazakh populace and includes the capital city of Almaty, being especially susceptible. According to the UNDP (2011), an estimated 800 mudflows have been recorded over the last 150 years, highlighting the enduring danger that this hazard presents.

Figure 11: Number of EWEs in Kazakhstan by regions, 1967-2016



Source: Kozhakhmetov and Nikiforova (2016)

3.4 Most Vulnerable Sectors of Economy

Extreme weather events (EWEs) that are more frequent and intense are anticipated to exacerbate climate change, resulting in economic consequences such as cost increases, disruptions to vital economic processes, and threats to the livelihoods, wealth, and lives of the Kazakh people. Health, transportation, water, agriculture, manufacturing, and forestry are among those most sensitive industries. The effects of climate change differ in accordance with the age of the dam. Climate occurrences are anticipated to have economic ramifications in Kazakhstan and other nations as a worldwide phenomenon. These repercussions may be transboundary in nature, encompassing disturbances in international value chains or transportation routes. Table 1, summarizes potential climate change impacts on economy of Kazakhstan.

Table 1: Potential climate change impacts on economic sectors

Climate Change Pattern and EWE	Agriculture	Energy	Health	Infrastructure (Transport, Buildings, Industry)
Changing average and extreme temperature	- Wheat yield reduction due to crop land degradation related to heat stress - Reduced pasture productivity related to heat stress - Increased sunflower yields	- Reduced thermal power generation capacity due to insufficient cooling water - Reduced hydro power generation capacity - Increased demand for cooling in summer, reduced demand for heating in winter - Reduced efficiency of solar panels - Reduced efficiency of transmission lines - Economic losses due to power outages	- Vector-borne infectious diseases - Health hazards caused by heat waves - Changes in fitness and activity level - Increased demand for health care services - Increased morbidity and mortality	- Melting road surfaces - Buckling of railway lines - Damages to roads due to melting of seasonal ground frost - Expansion of bridge joints - Impaired shipping
Changing precipitation patterns and extreme precipitation, floods, mudflows, landslide	- Wheat yield reduction due to crop land degradation related to reduced soil moisture - Reduced pasture productivity - Damaged crops and livestock due to floods	- Damages to the physical infrastructure (e.g., transmission lines, power plants, coal mines, pipelines, offshore platforms) causing disruption of energy supply - Reduced hydro power generation capacity	- Impaired shipping - Degraded water quality - Water-borne disease outbreaks - Decrease in service reliability - Increased mortality and	- Disruption of transport due to flooding of roads, railways, tunnels, etc. - Impaired shipping

		- Reduced efficiency of transmission lines - Economic losses due to power outages - Wash out of road surfaces - Damage to rail and road infrastructure	morbidity related to EWEs, especially mudflows	
Droughts	- Increased wheat yield variability - Increased incidence of pests and diseases (Hessian fly and wheat rust)	- Reduced hydro power generation capacity - Impaired shipping	- Expansion of infectious disease vectors (ticks and mites) - Degraded water quality causing gastrointestinal disease	- Economic losses due to power outages
Extreme wind	- Soil degradation	- Damage to physical infrastructure e.g. wind farms, distribution networks	- Deaths and injuries	- Damage to assets such as bridges, buildings, production facilities - Disruption to ports and airports - Accidents - Decrease in service reliability
Wildfire	- Destroyed harvest	- Damages to the physical infrastructure	- Deaths and injuries	- Damages to the physical infrastructure

Source: OECD (2020), UNESCAP (2020), USAID (2018), World Bank (2021).

3.4.1 Agriculture

Due to the fact that agriculture is a highly susceptible industry to the effects of climate change, drought poses a substantial threat, especially to the production of rain-fed wheat. The impacts of climate change are responsible for the accelerated desertification in flatland regions of Western, Northern, and Central Kazakhstan, specifically in the Akmola and Kostanay areas. The primary challenges encompass soil degradation, desertification, diminished moisture and salinity levels, heightened pest and disease infestations, and reduced variability in yields. The prevalence of livestock husbandry is higher in the southern region, which experiences diminished pasture availability and decreased productivity as a result of elevated temperatures and water availability. Due to increased precipitation, grassland vegetation productivity is anticipated to increase in the spring, but it may decline during the second vegetation period. A severe heat wave in 2021 caused food and water scarcity in the western and southern regions of Kazakhstan, which resulted in animal mortality and dearth. Glacier erosion is accelerated by rising temperatures, endangering water supplies by the middle of the century. It is anticipated that these patterns will exacerbate land degradation and erosion, leading to a decline in agricultural output. The susceptibility of national development, agricultural security, and the natural environment is being further aggravated by climate change.

3.4.2 Energy Sector

Significant hazards are posed to the energy sector by climate change, specifically in Kazakhstan. 10% of Kazakhstan's electricity production is dependent on hydropower, which is threatened by low water levels and inadequate cooling brought on by increasing temperatures, heatwaves, and insufficient precipitation during droughts. Due to the fact that the majority of hydropower plants are situated in regions afflicted with high or extremely high-water stress, the 1998 drought could have reduced hydropower generation potential by 20%.

Hydropower potential is projected to decrease by 25% in European countries and by as much as 49% in southern Spain, according to international studies. Glacial discharge provides short-term advantages to hydroelectric power stations that rely on glacier water for power generation. However, the adverse effects of long-term climate change on water supply endure. The hydropower potential is jeopardized by increased withdrawals by neighboring countries along transboundary rivers.

The exploitation of fossil fuels is extremely water-intensive and may be hampered by the worsening water shortage. Summertime highs increase cooling demand by 0.5 to 8.5%, whereas wintertime heating demand may decline. The effects of urban heat islands in significant metropolitan areas amplify these consequences.

The energy infrastructure is susceptible to increasingly frequent and destructive Extreme Weather Events (EWEs), including cyclones, floods, and landslides. Pipeline damage, ground adjustments, breaches, and landslides may result from heavy precipitation. The water level of the Caspian Sea is determined by river inflow and evaporation; however, some scientists hypothesize that rising precipitation in the Volga Basin will cause sea level rise.

3.4.3 Infrastructure

Transportation, structures, and water systems that operate efficiently are essential for economic and social progress. Kazakhstan, which serves as a transit nation between China and Europe, intends to construct the New Silk Road. However, increasing temperatures, precipitation, and extreme weather events (EWEs) pose a threat to infrastructure. Elevated temperatures may precipitate road surface deterioration, bridge joint expansion, and rail track deformation, all of which result in increased reconstruction expenses and diminished transportation velocity. The effects of heat stress on human health and labor productivity in buildings are possible. Flooding, mudslides, and landslides can result from accelerated glacier runoff and extreme precipitation, causing physical damage to infrastructure. Roads, bridges, and tunnels may also experience effects on their structural integrity due to elevated soil moisture. In addition to interior furnishings, road surfaces, bridges, and railroad tracks can be severely damaged by floods and heavy precipitation. Severe wind events have the potential to damage power lines, information and communication technology infrastructure, gas and water supply systems, and toss roofing off. Dust storms may contribute to land degradation and heighten the likelihood of traffic collisions.

4. Practical Part

The empirical section relies on secondary data, employing comparative analysis, synthesis, and a statistical methodology.

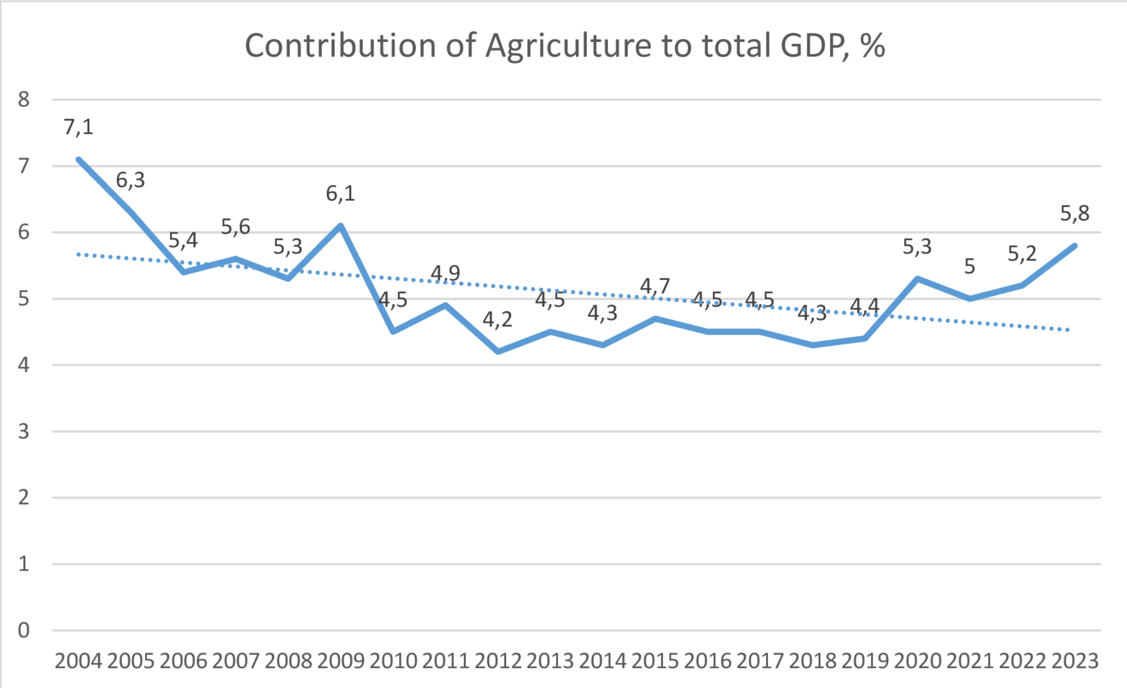
4.1 Agricultural Sector and its Importance

The Kazakhstani agricultural sector underwent a challenging time of transition, as the Organization for Economic Cooperation and Development (2013) aptly notes. During the initial phases of independence, the industry had no way to receive state support due to the severe financial meltdown that ensued after the Soviet Union's dissolution. During the early 2000s, the federal government implemented a policy for assistance and stability. Baubekova et. el. (2021) claims that Kazakhstan's agriculture was profoundly impacted by the resource growth of the 2000s.

Agricultural product nominal production has increased significantly (at current prices and exchange rates) since independence. The aggregate production, which amounted to $1.2 billion in 1993, escalated to around $21 billion by 2022. During the same time period, plant cultivation and livestock production increased from $674 million to $12.6 billion (nearly 19- and 22-times growth, respectively) and $363 million to $7.9 billion, respectively. As shown in Table 2, the proportion of total production attributable to plant growth shifted from 59% to 61%, while the proportion of animals grew from 32% to 39%. Agricultural activities constitute a negligible portion. The agricultural industry reaped the benefits of the favorable price adjustments. FAO statistics indicate that Kazakhstan wheat producer prices per ton dropped to $104.5 in 1994 with $50.5 in 1999, before beginning a progressive ascent. As a result of a sharp ascent that commenced in 2006, prices peaked in 2008 at $224.3 per ton.

The collective impact of the agricultural sector is depicted in Figure 12, spanning a 20-year period, revealing a declining trend. Figure 9 illustrates a notable shift in employment within the agricultural sectors: in 2001, the employment rate stood at 35%, yet over the subsequent 24 years, this figure declined significantly to 13.5%. This trend highlights the evolving landscape of agricultural employment over time.

Figure 12: Contribution of agriculture in %, 2004-2023



Source: World Bank (2023).

Table 2: Agricultural Production in Kazakhstan

Year	Total Output (million tenge)	Total Output (million USD)	Plant Growing (million tenge)	Plant Growing (million USD)	Share in Total (%)	Livestock (million tenge)	Livestock (million USD)	Share in Total (%)
1993	6 046	150	3 541	674	59%	1 907	363	32%
1995	208 919	3 428	107 410	1 762	51%	91 681	1504	44%
2000	404 146	2 843	223 503	1 573	55%	178 543	1256	44%
2005	749 078	5 637	389 527	2 931	52%	355 786	2678	47%
2010	1 822 074	12 366	895 425	6 077	49%	920 777	6249	51%
2015	3 307 010	14 915	1 825 237	8 232	55%	1 469 923	6629	44%
2020	6 334 669	15 340	3 687 310	8 929	58%	2 637 461	6387	42%
2022	9 481 180	20 590	5 808 260	12 613	61%	3 658 758	7946	39%

Source: Bureau of National Statistics (2023)

Prices were relatively high prior to 2015, then plunged in 2016, followed by a period of progressive recovery. 2009 saw a marginal decline in nominal output, subsequent to the transient repercussions of the global financial crisis. Output was negatively impacted by the economic downturn that began in 2013 and the substantial currency appreciation caused by the decline in crude prices. The amount declined from $19.4 billion in 2013 to $10.8 billion in 2016, followed by a gradual recovery. Consequently, Kazakhstan's agricultural output peaked at an all-time high in 2022 (Baubekova et. el. 2021).

4.1.1 Cultivated area

Variations in total cultivated area and output by-products are detailed in Table 2. The overall cultivated land area experienced a decline from its peak of 35.2 million hectares in 1990 to 16.2 million hectares in 2000. With the assistance of government policies, the cultivated area began to expand during the subsequent decade, reaching nearly 23.2 million hectares in 2022. Additionally, production patterns were altered. From 1990 to 2005, the proportion of cereals cultivated area in relation to the total cultivated area increased from 66.4% to 80.5%. Thereafter, this proportion declined until it reached 69.6% in 2022. Consequently, the production of cereals experienced a decline of over 20 million tons by 2022, from 28.5 million tons in 1990.

Table 3: Cultivated Area (th. hectares) and Total Production (th. tons).

Year	1990	1995	2000	2005	2010	2015	2022
Cultivated Area Total	35182,1	28679,6	16195,3	18445,2	21438,7	21022,9	23162,1
Cereals	23355,9	18877,7	12438,2	14841,9	16619,1	14982,2	16114,4
Oilseeds	266,5	548,6	448,2	669,7	1748,1	2009,7	3461,8
Sunflower Seeds	136,9	346,2	313,9	454,5	869,3	740,7	1094,6
Potato	205,9	205,9	160,3	168,2	179,5	190,6	199,5
Vegetables	70,8	76,1	102,6	110,8	120,3	139,5	170,2
Gourds	35,8	27,7	38,8	43,4	63,3	94,7	100,3
Sugar Beet	43,6	40,8	22,5	17,5	11,2	9,2	10,2

Forage Crops	11065,5	8788,9	2823,7	2380,6	2555,6	3497,1	2978
Cereals	28487,7	9505,5	11565	13781,4	12185,2	18672,8	22030,5
Oilseeds	229,8	162	140,1	439,7	775,4	1547,5	3051,3
Sunflower Seeds	126,3	98,7	104,6	267,3	328,9	534	1304,3
Potato	2324,3	1719,7	1692,6	2520,8	2554,6	3521	4080,5
Vegetables	1136,4	779,7	1543,6	2168,7	2576,9	3564,9	4792,6
Gourds	301,5	162,3	421,6	683,8	1118,2	2087,6	2560,3
Sugar Beet	1043,7	371	272,7	310,8	152	174,1	305,7

Source: Bureau of National Statistics (2023)

This demonstrates a diversification of productivity, as oilseeds have replaced cereals in the harvest. The oilseeds' area proportion was relatively small at 0.8% in 1990. However, as cultivation experience gained, this percentage nearly tripled to 15% by 2022. The cultivation of forage crops experienced a substantial decline from 1990 to 2009. Specifically, the proportion of land devoted to forage crop cultivation decreased from 31.5% in 1990 to 12.9% in 2022. This decline indicates that the transition period had an adverse impact on livestock production as well. Vegetable and gourd production and cultivated area increased, whereas both indicators declined for sugar beet.

4.1.2 Livestock Development

A substantial decline in livestock was observed in comparison to the initial period (Table 4). In 2022, there were substantially fewer cattle (1.1 times), sheep (1.6 times), swine (4.2 times), and poultry (1.2 times) than there were in 1991. The horse count surpassed the starting point by a factor of 2.3, increasing from 1.7 million to 3.9 million.

Table 4: Number of Livestock (thousands) and Poultry (millions)

Year	Cattle	Sheep	Pigs	Horses	Poultry
1991	9592.4	34555.7	2976.1	1666.4	59.9
1995	6859.9	19583.9	1622.7	1556.9	20.8
2000	4106.6	9981.1	1076.0	976.0	19.7
2005	5457.4	14334.5	1281.9	1163.5	26.2
2010	6175.3	17988.1	1344.0	1528.3	32.8
2015	6183.9	18015.5	887.6	2070.3	35.6
2018	7150.9	18699.1	798.7	2646.5	44.3
2022	8538.1	21786	705	3856	49.8

Source: Bureau of National Statistics (2023)

Notably, the northern region of Kazakhstan is preoccupied with cereal production, while the eastern region focuses on livestock raising. Horticultural products are primarily cultivated in the agricultural southern area of the country. According to the OECD (2015), agriculture in northern Kazakhstan requires more capital than in the south, where labor is more valuable.

4.1.3 FDI's in Agriculture

As illustrated in Table 5, agricultural investment levels continue to be notably low. Agriculture received a meager $1.3 million in foreign direct investment (FDI) in 2005, which accounted for a mere 0.017% of total FDI. However, by 2015, that figure had skyrocketed to nearly $72 million, or 0.467% of total FDI. Nevertheless, this amount experienced a substantial decrease in the years that followed, reaching a mere $9.5 million by 2020. It is important to emphasize that foreign direct investment (FDI) has substantial residual effects, as it grants recipient nations access to foreign management practices, technology, expertise, and knowledge—all of which contribute to the improvement of agricultural productivity. As a result, the insufficient degree of financial commitment presents a significant obstacle, hindering the progress of the agricultural sector in Kazakhstan.

Table 5: FDI's Inflow by sector, in $ millions

Sectors	2005	2010	2015	2020	2022
Agriculture	1.3	6.0	71.8	9.5	32.5
Share of Agriculture	0.017	0.027	0.467	0.0006	0.001
Extractive Industries	1930.1	5982.2	3455.1	8226.5	12075.9
Manufacturing	346.6	2243.8	2588.5	3175.8	5427.6
Total	7916	22246	15368	17155	28028

Source: Bureau of National Statistics (2023)

4.2 Statistical Analysis of Selected Variables

In this part, the analysis of bivariate Granger Causality is tested to see the bi-directional causality of selected variables. The author claims that there is a bi-directional causality between X and Y, whereas:

Y_1 = Production of barley (th. tons)

Y_2 = Production of winter wheat (th. tons)

X_1 = Average Temperature per month

N = 180 months (2009 – 2023)

Summary Statistics, using the observations 2009:01 - 2023:12
(missing values were skipped)

Variable	Mean	Median	S.D.	Min	Max
AverageMeanSurfaceAirTemper	3.91	5.40	14.2	-24.4	24.5
productionofwheatwinterin	1.11	0.200	1.79	0.000	7.50
Barleyandmaizeintonns	0.301	0.000	0.594	0.000	2.30
d_AverageMeanSurfaceAirTemper	-0.00832	1.78	7.87	-18.0	15.9
d_productionofwheatwinterin	-0.000559	0.000	1.57	-3.90	5.10
d_Barleyandmaizeintonns	0.000	0.000	0.586	-1.90	1.80
ld_AverageMeanSurfaceAirTemper	0.0173	0.0925	0.656	-2.33	1.29
ld_productionofwheatwinterin	-0.0522	-0.0645	1.55	-4.09	3.04
ld_Barleyandmaizeintonns	0.173	0.288	0.963	-2.35	1.70

Source: Own processing in Gretl.

4.2.1 Augmented Dickey-Fuller test Unit Root Test

A stationarity test is a statistical method used to determine whether a time series data set is stationary or non-stationary. Stationarity refers to the property of a time series where its statistical properties such as mean, variance, and autocorrelation structure remain constant over time. The first variable to see is the 1st time difference of Average Temperature of Surface per Month. See Figure 13.

Figure 13: Augmented Dickey-Fuller test Unit Root Test for Temperature.

gretl: ADF test

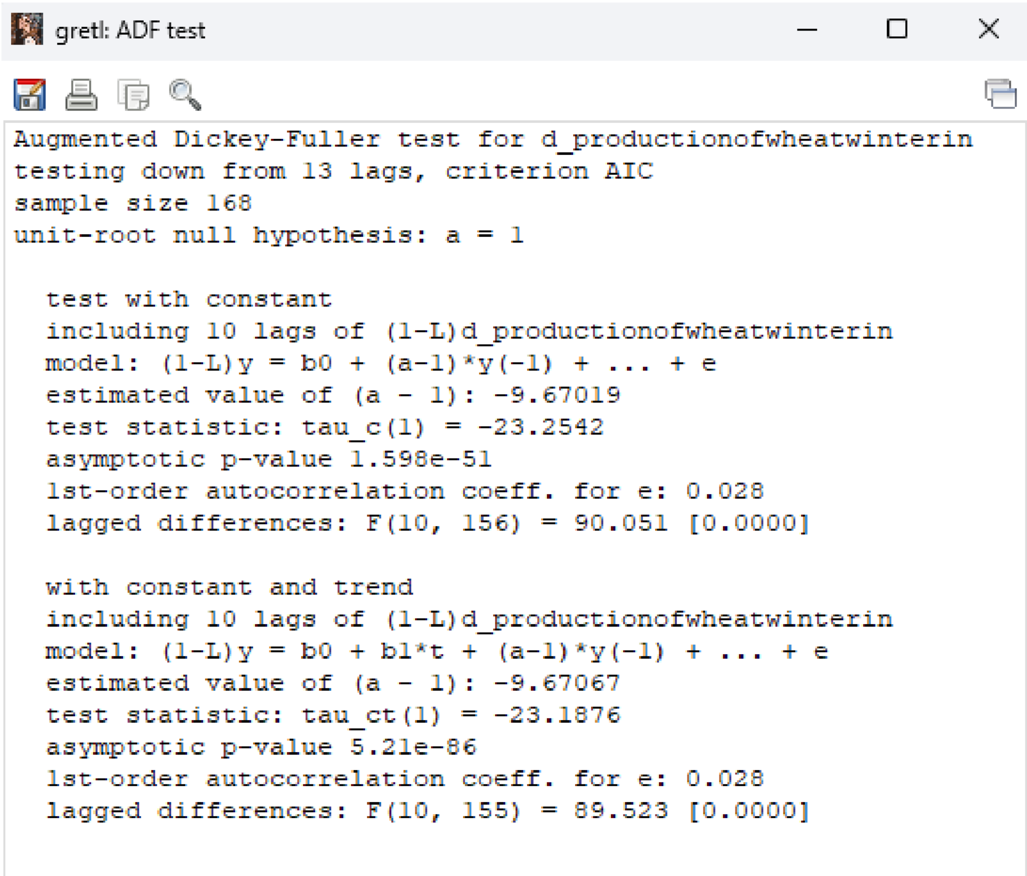
```
Augmented Dickey-Fuller test for d_AverageMeanSurfaceAirTemper
testing down from 13 lags, criterion AIC
sample size 167
unit-root null hypothesis: a = 1

  test with constant
  including 11 lags of (1-L)d_AverageMeanSurfaceAirTemper
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -5.0603
  test statistic: tau_c(1) = -7.17965
  asymptotic p-value 1.073e-10
  1st-order autocorrelation coeff. for e: -0.008
  lagged differences: F(11, 154) = 45.274 [0.0000]

  with constant and trend
  including 11 lags of (1-L)d_AverageMeanSurfaceAirTemper
  model: (1-L)y = b0 + b1*t + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -5.14506
  test statistic: tau_ct(1) = -7.24617
  asymptotic p-value 4.678e-10
  1st-order autocorrelation coeff. for e: -0.007
  lagged differences: F(11, 153) = 45.304 [0.0000]
```

Source: Own processing in Gretl.

It is seen that the p – value is equal to 4.678e-10, meaning that it is less than 0.05 alpha level. Meaning that the d_AverageMeanSurfaceAirTemper is Stationary.

The second variable to see is the 1st time difference of production of wheat winter per month. See Figure 14.

Figure 14: Augmented Dickey-Fuller test Unit Root Test for Wheat



gretl: ADF test

```
Augmented Dickey-Fuller test for d_productionofwheatwinterin
testing down from 13 lags, criterion AIC
sample size 168
unit-root null hypothesis: a = 1

  test with constant
  including 10 lags of (1-L)d_productionofwheatwinterin
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -9.67019
  test statistic: tau_c(1) = -23.2542
  asymptotic p-value 1.598e-51
  1st-order autocorrelation coeff. for e: 0.028
  lagged differences: F(10, 156) = 90.051 [0.0000]

  with constant and trend
  including 10 lags of (1-L)d_productionofwheatwinterin
  model: (1-L)y = b0 + b1*t + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -9.67067
  test statistic: tau_ct(1) = -23.1876
  asymptotic p-value 5.21e-86
  1st-order autocorrelation coeff. for e: 0.028
  lagged differences: F(10, 155) = 89.523 [0.0000]
```

Source: Own processing in Gretl.

It is seen that the p – value is equal to 1.598e-51, meaning that it is less than 0.05 alpha level. Meaning that the d_productionofwheatwinter is Stationary.

The second variable to see is the 1st time difference of production of wheat winter per month. See Figure 15.

Figure 15: Augmented Dickey-Fuller test Unit Root Test for Wheat

gretl: ADF test

```
Augmented Dickey-Fuller test for d_Barleyandmaizeintonns
testing down from 13 lags, criterion AIC
sample size 166
unit-root null hypothesis: a = 1

  test with constant
  including 12 lags of (1-L)d_Barleyandmaizeintonns
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -10.3113
  test statistic: tau_c(1) = -7.92149
  asymptotic p-value 8.479e-13
  1st-order autocorrelation coeff. for e: 0.004
  lagged differences: F(12, 152) = 66.325 [0.0000]

  with constant and trend
  including 12 lags of (1-L)d_Barleyandmaizeintonns
  model: (1-L)y = b0 + b1*t + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -10.3113
  test statistic: tau_ct(1) = -7.8956
  asymptotic p-value 4.297e-12
  1st-order autocorrelation coeff. for e: 0.004
  lagged differences: F(12, 151) = 65.884 [0.0000]
```

Source: Own processing in Gretl.

It is seen that the p – value is equal to 4.297e-12, meaning that it is less than 0.05 alpha level. Meaning that the d_production of barley is Stationary.

4.2.1 Multivariate Time Series

By running a Multivariate Time Series, there is a need to find out how many prior observations should be included.

VAR system, maximum lag order 22

The asterisks below indicate the best (that is, minimized) values of the respective information criteria, AIC = Akaike criterion, BIC = Schwarz Bayesian criterion and HQC = Hannan-Quinn criterion.

lags	loglik	p(LR)	AIC	BIC	HQC
1	-275.64168		3.562314	3.640181	3.593939
2	-247.76966	0.00000	3.219996	3.317328	3.259526
3	-244.09146	0.00668	3.185879	3.302678	3.233315
4	-244.07360	0.85010	3.198390	3.334656	3.253732
5	-244.07339	0.98339	3.211126	3.366858	3.274374
6	-240.68534	0.00924	3.180705	3.355904	3.251859
7	-237.41329	0.01052	3.151762	3.346427	3.230822
8	-237.01223	0.37045	3.159391	3.373523	3.246358
9	-226.42981	0.00000	3.037322	3.270921	3.132195
10	-169.78915	0.00000	2.328524	2.581589	2.431303
11	-128.80020	0.00000	1.819111*	2.091642*	1.929795*
12	-128.77776	0.83224	1.831564	2.123562	1.950154
13	-127.69985	0.14203	1.830571	2.142036	1.957068
14	-126.18849	0.08211	1.824057	2.154988	1.958460
15	-126.09124	0.65920	1.835557	2.185955	1.977866
16	-126.04522	0.76160	1.847710	2.217574	1.997925
17	-125.99320	0.74702	1.859786	2.249117	2.017907
18	-125.90691	0.67784	1.871426	2.280223	2.037452
19	-125.84978	0.73533	1.883437	2.311700	2.057370
20	-125.64390	0.52108	1.893553	2.341283	2.075392
21	-125.64379	0.98816	1.906290	2.373487	2.096035
22	-122.64488	0.01432	1.880826	2.367490	2.078477

All AIC, BIC and HQC claim that 11 observations should be selected.

4.2.2 VAR Model of Wheat and Temperature

Table 6: d_AverageMeanSurfaceAirTemper VAR

	Coefficient	*Std. Error*	*t-ratio*	*p-value*	
const	−0.518496	0.430456	−1.205	0.2304	
Temp1	−0.370756	0.0827145	−4.482	<0.0001	***
Temp2	−0.338679	0.0809495	−4.184	<0.0001	***
Temp3	−0.410025	0.0819578	−5.003	<0.0001	***
Temp4	−0.284440	0.0811885	−3.503	0.0006	***
Temp5	−0.346226	0.0670193	−5.166	<0.0001	***
Temp6	−0.478705	0.0699713	−6.841	<0.0001	***
Temp7	−0.327918	0.0778611	−4.212	<0.0001	***
Temp8	−0.487003	0.0675006	−7.215	<0.0001	***
Temp9	−0.485260	0.0789843	−6.144	<0.0001	***
Temp10	−0.268950	0.0962167	−2.795	0.0059	***
Temp11	−0.280318	0.0802554	−3.493	0.0006	***
Wheat1	−0.264882	0.272345	−0.9726	0.3324	
Wheat2	−0.272415	0.364839	−0.7467	0.4565	
Wheat3	−0.606213	0.417177	−1.453	0.1484	
Wheat4	−1.31139	0.504280	−2.601	0.0103	**
Wheat5	−1.59804	0.477577	−3.346	0.0010	***
Wheat6	−1.22624	0.530793	−2.310	0.0223	**
Wheat7	−1.51563	0.487085	−3.112	0.0022	***
Wheat8	−0.400635	0.477456	−0.8391	0.4028	
Wheat9	−0.290055	0.381215	−0.7609	0.4480	
Wheat10	−0.246491	0.305683	−0.8064	0.4214	
Wheat11	0.0822731	0.282287	0.2915	0.7711	
time	0.00468073	0.00422883	1.107	0.2702	

Mean dependent var	−0.025298		S.D. dependent var	7.934685
Sum squared resid	1080.068		S.E. of regression	2.738699
R-squared	0.897275		Adjusted R-squared	0.880868
F(23, 144)	77.34805		P-value(F)	2.39e-69
rho	0.001994		Durbin-Watson	1.987111

Source: Own processing in Gretl.

Based on the results, the R-Squared equals to 89 %, the p-value – 2.39e-69, which is lower than 0.05, which indicates the Granger Causality between two variables, Wheat production monthly and temperature. Durbin and Watson Test demonstrates that the model doesn't have an autocorrelation problem.

Table 7: d_Productionofwheatwinterin

	Coefficient	*Std. Error*	*t-ratio*	*p-value*	
const	0.00445512	0.119808	0.03719	0.9704	
Temp1	−0.00856559	0.0170766	−0.5016	0.6167	
Temp2	0.0155273	0.0137653	1.128	0.2612	
Temp3	−0.00344732	0.0116449	−0.2960	0.7676	
Temp4	−0.0111885	0.0166153	−0.6734	0.5018	
Temp5	−0.0302362	0.0184271	−1.641	0.1030	
Temp6	−0.0164609	0.0155352	−1.060	0.2911	
Temp7	−0.0238228	0.0168153	−1.417	0.1587	
Temp8	−0.0481004	0.0192225	−2.502	0.0135	**
Temp9	−0.0408475	0.0160540	−2.544	0.0120	**
Temp10	−0.00524452	0.0171288	−0.3062	0.7599	
Temp11	−0.0277806	0.0151731	−1.831	0.0692	*
Wheat1	−0.753389	0.0817237	−9.219	<0.0001	***
Wheat2	−0.925709	0.0641864	−14.42	<0.0001	***
Wheat3	−0.864870	0.0787923	−10.98	<0.0001	***
Wheat4	−0.758657	0.0947147	−8.010	<0.0001	***
Wheat5	−0.704253	0.101464	−6.941	<0.0001	***
Wheat6	−0.558898	0.123857	−4.512	<0.0001	***
Wheat7	−0.536075	0.125832	−4.260	<0.0001	***
Wheat8	−0.500527	0.122957	−4.071	<0.0001	***
Wheat9	−0.503958	0.129885	−3.880	0.0002	***
Wheat10	−0.697231	0.101950	−6.839	<0.0001	***
Wheat11	−0.529756	0.119049	−4.450	<0.0001	***
time	−2.91833e-06	0.00105158	−0.002775	0.9978	

Mean dependent var	1.15e-17		S.D. dependent var	1.571316
Sum squared resid	49.32126		S.E. of regression	0.585242
R-squared	0.880384		Adjusted R-squared	0.861278
F(23, 144)	42.48988		P-value(F)	9.53e-53
rho	0.017334		Durbin-Watson	1.964847

Source: Own processing in Gretl.

Based on the results, the R-Squared equals to 88 %, the p-value – 9.53e-53, which is lower than 0.05, which indicates the Granger Causality between two variables, Wheat production monthly and temperature. Durbin and Watson Test demonstrates that the model doesn't have an autocorrelation problem.

4.2.3 Var Model of Barley and Temperature

Table 8: d_AverageMeanSurfaceAirTemper

	Coefficient	*Std. Error*	*t-ratio*	*p-value*	
const	−0.558440	0.483101	−1.156	0.2496	
Temp1	−0.363217	0.0824068	−4.408	<0.0001	***
Temp2	−0.303668	0.0866832	−3.503	0.0006	***
Temp3	−0.419738	0.0821919	−5.107	<0.0001	***
Temp4	−0.330016	0.0807929	−4.085	<0.0001	***
Temp5	−0.389527	0.0818989	−4.756	<0.0001	***
Temp6	−0.512483	0.0781834	−6.555	<0.0001	***
Temp7	−0.349762	0.0819224	−4.269	<0.0001	***
Temp8	−0.411097	0.0822796	−4.996	<0.0001	***
Temp9	−0.410621	0.0810461	−5.067	<0.0001	***
Temp10	−0.189957	0.0862513	−2.202	0.0292	**
Temp11	−0.196223	0.0844632	−2.323	0.0216	**
Barleyandmaizein1	−0.487967	0.812614	−0.6005	0.5491	
Barleyandmaizein2	−2.39128	0.883690	−2.706	0.0076	***
Barleyandmaizein3	−3.26297	1.16932	−2.790	0.0060	***
Barleyandmaizein4	−3.13093	1.36888	−2.287	0.0236	**
Barleyandmaizein5	−3.68592	1.47949	−2.491	0.0139	**
Barleyandmaizein6	−2.40017	1.53510	−1.564	0.1201	
Barleyandmaizein7	−2.01889	1.48694	−1.358	0.1767	
Barleyandmaizein8	−2.69948	1.38120	−1.954	0.0526	*
Barleyandmaizein9	−1.41434	1.19968	−1.179	0.2404	
Barleyandmaizein10	−1.15274	0.910120	−1.267	0.2074	
Barleyandmaizein11	−0.559957	0.802056	−0.6982	0.4862	
time	0.00500060	0.00447289	1.118	0.2654	

Mean dependent var	−0.025298		S.D. dependent var	7.934685
Sum squared resid	1122.785		S.E. of regression	2.792332
R-squared	0.893212		Adjusted R-squared	0.876156
F(23, 144)	52.36833		P-value(F)	2.09e-58
rho	0.012793		Durbin-Watson	1.967180

Source: Own processing in Gretl.

Based on the results, the R-Squared equals to 89 %, the p-value – 2.09e-58, which is lower than 0.05, which indicates the Granger Causality between two variables, Wheat production monthly and temperature. Durbin and Watson Test demonstrates that the model doesn't have an autocorrelation problem.

Table 9: d_Barleyandmaizeintonns

	Coefficient	*Std. Error*	*t-ratio*	*p-value*	
const	−0.00594908	0.0417419	−0.1425	0.8869	
Temp1	0.000593654	0.00712028	0.08338	0.9337	
Temp2	−0.00869250	0.00748978	−1.161	0.2477	
Temp3	0.00299207	0.00710172	0.4213	0.6742	
Temp4	0.00789883	0.00698084	1.132	0.2597	
Temp5	−0.00184643	0.00707640	−0.2609	0.7945	
Temp6	0.00230916	0.00675536	0.3418	0.7330	
Temp7	−0.000140485	0.00707843	−0.01985	0.9842	
Temp8	−0.000979030	0.00710929	−0.1377	0.8907	
Temp9	−0.00143301	0.00700271	−0.2046	0.8381	
Temp10	−0.0191059	0.00745246	−2.564	0.0114	**
Temp11	−0.00718607	0.00729796	−0.9847	0.3264	
Barleyandmaizein1	−0.856046	0.0702131	−12.19	<0.0001	***
Barleyandmaizein2	−0.976625	0.0763544	−12.79	<0.0001	***
Barleyandmaizein3	−0.943517	0.101034	−9.339	<0.0001	***
Barleyandmaizein4	−0.884879	0.118277	−7.481	<0.0001	***
Barleyandmaizein5	−0.816263	0.127834	−6.385	<0.0001	***
Barleyandmaizein6	−0.695628	0.132639	−5.245	<0.0001	***
Barleyandmaizein7	−0.636338	0.128478	−4.953	<0.0001	***
Barleyandmaizein8	−0.591405	0.119342	−4.956	<0.0001	***
Barleyandmaizein9	−0.525086	0.103657	−5.066	<0.0001	***
Barleyandmaizein10	−0.726877	0.0786380	−9.243	<0.0001	***
Barleyandmaizein11	−0.536542	0.0693009	−7.742	<0.0001	***
time	3.30442e-05	0.000386476	0.08550	0.9320	

Mean dependent var	0.000000		S.D. dependent var	0.586683
Sum squared resid	8.382329		S.E. of regression	0.241269
R-squared	0.854172		Adjusted R-squared	0.830880
F(23, 144)	36.67228		P-value(F)	7.28e-49
rho	−0.064647		Durbin-Watson	2.128709

Source: Own processing in Gretl.

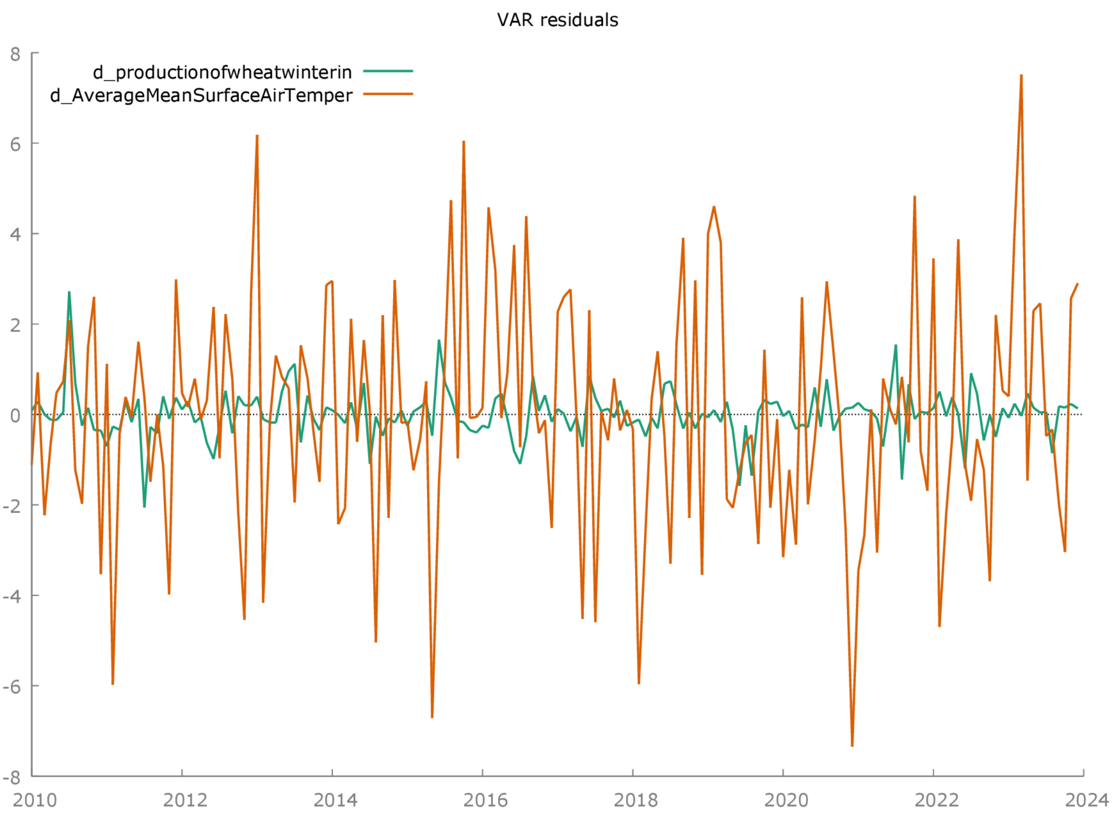
Based on the results, the R-Squared equals to 85 %, the p-value – 7.28e-49, which is lower than 0.05, which indicates the Granger Causality between two variables, Wheat production monthly and temperature. Durbin and Watson Test demonstrates that the model doesn’t have an autocorrelation problem.

5. Results and Discussion

5.1 Production of Wheat and Temperature

The VAR (Vector Autoregressive) model revealed a mutual causal relationship between two key variables: wheat production and the average surface air temperature. Through rigorous data analysis, it was established that the time series data exhibited stationarity after undergoing time differencing. Moreover, the presence of seasonality effects emerged prominently, particularly concerning the monthly variations in both wheat cultivation and temperature trends, as depicted in Figure 16.

Figure 16: VAR of residuals

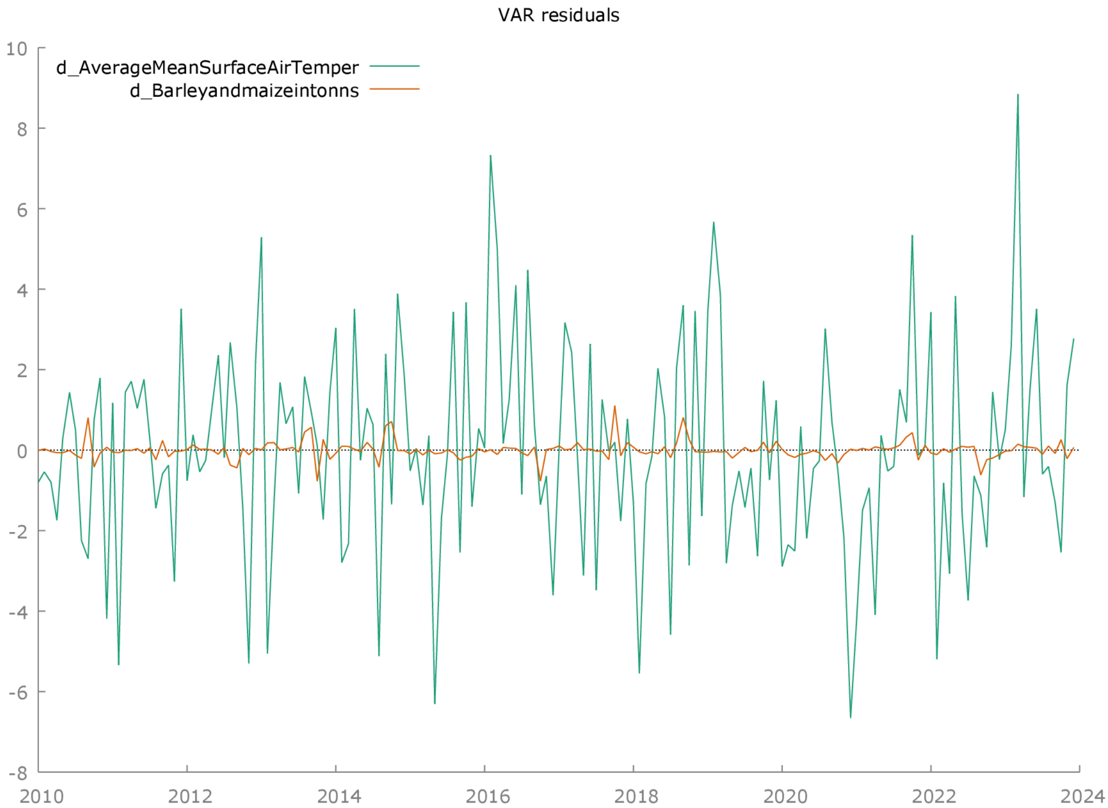


Source: Own processing in Gretl.

5.2 Production of Maize/Barley and Temperature

The same applied for maize and barely production and temperature. The VAR model has a causal relationship between two variables. Again, the seasonal effect should be considered when analyzing the data, See Figure 17.

Figure 17: VAR of residuals



Source: Own processing in Gretl.

5.3 Research Questions

- Measure the importance of the agricultural sector to the total GDP of Kazakhstan.

When assessing the significance of the agricultural sector to the total GDP, it's noteworthy that following Kazakhstan's declaration of independence, both the agricultural sector and the oil and gas sectors collectively contributed 80% to the total GDP, with agriculture accounting for 35% and oil and gas for 45%. Over time, however, the agricultural sector's contribution to the total GDP has been declining, as depicted in Figure 12, while the contribution of the oil and gas sectors has remained relatively stable.

- What is the economic value of Kazakhstan's biodiversity and ecosystem services, and how are these impacted by climate-induced ecosystem shifts?

For Kazakhstan, which boasts diverse landscapes including steppes, mountains, deserts, and wetlands, the economic value of biodiversity and ecosystem services is significant. The country's biodiversity supports various sectors, such as agriculture and forestry, providing resources like timber, crops, and grazing land. Additionally, Kazakhstan's ecosystems offer critical services like water filtration, carbon sequestration, and soil fertility maintenance, which are essential for sustaining human well-being and economic activities.

- How do international climate agreements and regulations impact Kazakhstan's trade and economic relations, particularly in sectors sensitive to emissions policies?

Kazakhstan's compliance with international climate agreements which leads to stricter regulations on industries with high emissions, potentially increasing production costs and making goods less competitive in international markets. This impacts trade balances and reduce exports. Import costs also increase due to carbon pricing mechanisms or emissions trading schemes, affecting consumers and businesses reliant on imported inputs. Because of it, investment flows may be influenced by international climate agreements, favoring countries with stronger commitments to emissions reductions and clean energy development. Participation in climate agreements often involves technology transfer and capacity-building initiatives, providing Kazakhstan with access to new technologies and expertise for emissions reduction and adaptation efforts. However, this may require investments in upgrading infrastructure and retraining workers. Diversification strategies may be pursued to diversify the economy away from carbon-intensive sectors towards cleaner alternatives, such as renewable energy, energy efficiency, and sustainable agriculture. Active participation in international climate negotiations can enhance Kazakhstan's diplomatic standing and strengthen its bargaining position in trade discussions.

- What are the economic opportunities and challenges associated with transitioning to renewable energy sources in Kazakhstan?

Transitioning to renewables allows Kazakhstan to diversify its energy mix, reducing reliance on fossil fuels such as coal and natural gas. This can enhance energy security and resilience to price volatility in global energy markets. Due to global trend "Go green", all economies try to adopt. Kazakhstan so far, lags behind the stated trend. However, transitioning to renewable energy, potentially could lead to more sustainable economy and its development. Due to high dependency on oil and gas, Kazakhstan should look into that opportunity.

Additionally, the renewable energy infrastructure deployment in developing economies like Kazakhstan can be challenging due to substantial upfront capital investment, intermittent power generation, and grid instability. Developing storage technologies and upgrading grid infrastructure for variable renewable energy sources requires significant investment and technical expertise. Inconsistent or inadequate policy and regulatory frameworks can hinder renewable energy projects. Clear and supportive policies, including incentives like feed-in tariffs and renewable energy targets, are essential for attracting investment and fostering market competitiveness. Building domestic technological and human capacity is crucial for the design, construction, operation, and maintenance of renewable energy infrastructure. Balancing the interests of incumbent energy players with those of renewable energy developers is essential for a smooth transition.

6. Conclusion

The purpose of this research is to get an understanding of the effects that climate change will have on Kazakhstan's economy via the use of both theoretical and practical assessments. In the theoretical portion, an overview of climate change challenges in the nation is presented, and several modeling tools, such as CGE modeling and macro-econometric IO models, are investigated in order to evaluate the influence that climate change will have on important economic sectors such as agriculture, energy, and infrastructure. The section that focuses on practical aspects investigates the relevance of the agricultural industry by investigating cultivated lands, livestock development, and direct investments from other countries.

For the purpose of determining the nature of the connection that exists between temperature changes and agricultural productivity, statistical studies are implemented. It is clear from these findings that Kazakhstan's economy is very susceptible to the effects of climate change, especially in the agricultural sector. Consequently, it has been determined that preventative actions are required in order to lessen the severity of these consequences. These efforts include programs that aim to improve agricultural resilience and encourage sustainable energy practices. According to the findings of the research, policymakers and other institutions in Kazakhstan who are participating in climate adaptation and mitigation initiatives might benefit from useful insights.

7. References

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8. List of pictures, tables, graphs and abbreviations

8.1 List of tables

8.2 List of figures

8.3 List of Abbreviations

CAREC – Central Asia Regional Economic Cooperation

CGE – Computable General Equilibrium

DIM – Disaster Impact Models

E3 – Economy, Energy, Environment.

FDI – Foreign Direct Investments

GDP – Gross domestic product

GHG – Greenhouse gas emissions

IAM – Integrated Assessment Models

NPISH – Non-Profit Institutions Serving Households

OECD – Organization for Economic Co-operation and Development

OI – Input – Output

WHO – World Health Organization

IFRC – International Federation of Red Cross and Red Crescent Societies