

Faculté des bioingénieurs

The Impact of Market Structure and Capital Obsolescence on Agricultural Productivity at the Macroeconomic Level

Case of Kazakhstan

Auteur : Aizhan Mukhametzhanova

Promoteur(s) : Frédéric Gaspart

Lecteur(s) : Paolo Sckokai

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Abstract

This thesis explores the impact of market structure and capital obsolescence on the yield of both spring and winter wheat in the four northern regions of the Republic of Kazakhstan, using data from the Ministry of Agriculture of the Republic of Kazakhstan and the Bureau of National Statistics of the Republic of Kazakhstan. The country, despite being one of the largest exporters of wheat worldwide, faces several issues hindering the productivity of the agricultural sector within all regions, and capital obsolescence is one of the most addressed by the State itself. The study employs a Fixed Effects model, incorporating variables such as sown land, labor, fertilizers, machinery, market power, climate, and policy changes to assess their influence on wheat yields over a ten-year period (2013-2022). The research highlights the negative effects of obsolete agricultural machinery and high temperatures on wheat yield, emphasizing the need for updated practices and climate resilience. It also suggests that while modern machinery positively impacts productivity, market power may lead to strategic production restrictions. The findings call for further research into the economic and environmental trade-offs of replacing outdated machinery, with a focus on food security and policy implications. Ultimately, the study underscores the critical role of addressing capital obsolescence in agriculture to enhance productivity and ensure long-term sustainability.

Keywords: Market Structure, Capital Obsolescence, Wheat Yield, Agricultural Productivity, Fixed Effects, North Kazakhstan, Obsolete Agricultural Machinery, Modernization, Policy Changes, Climate Change, Food Security, Regional Producers Power

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Abbreviations

AIC	Agro-Industrial Complex
DCC	Dynamic Conditional Correlation
EAEU	Eurasian Economic Union
EUV	Export Unit Value
FGLS	Feasible Generalized Least Square
GDP	Gross Domestic Product
GPS	Global Positioning System
MOA RK	Ministry of Agriculture of the Republic of Kazakhstan
QMLE	Quasi-maximum Likelihood Estimation
R&D	Research & Development
SME	Small and Medium-sized Enterprises
SSR	Self-Sufficiency Ratio
TFP	Total Factor Productivity
WTO	World Trade Organization

Introduction

Agriculture's status as the primary economic sector in the industrialized world has long since diminished, and its contribution to the growth of the national economy is sometimes overlooked. An essential production method that significantly benefits every society and economy is agriculture (Johnston & Mellor, 1961; Sinabell Vienna, 2009). Compared to its traditional role as a provider of primary inputs, food, income, and employment, the new expanded role includes the provision of food quality and safety, environment protection, integrated rural development, and the preservation of the social structure and cohesiveness of rural areas (Lichtfouse et al., 2009). Particularly in countries that depend heavily on agriculture, agricultural growth can be crucial in reducing poverty and guaranteeing food security (Hagglblade et al., 2010; Maulu et al., 2021).

Agricultural development can be attained by switching from conventional to modern farming practices and equipment. This change is made possible in large part by elements including the mechanization of agriculture, improved awareness, and the accessibility of better inputs including herbicides, fertilizers, and certified seeds (de Janvry & Sadoulet, 2020). In both productive and fragile agro-ecological settings (Fan & Chan-Kang, 2004; King, 1979), there is a general interest in sustainable intensification to increase agricultural productivity with minimal negative effects on the environment (Friedrich et al., 2012; Friedrich T. & Kassam A., 2011; J. Pretty, 2009; J. N. Pretty et al., 2003; Tilman et al., 2002). Before powered farm implements appeared in the developed world in the nineteenth century and tractorization truly took off in the twentieth century following World War II, global agriculture relied for a long time on human strength and draft animals. Tractorization changed agricultural practices such as plowing, leveling, planting, cultivating, applying chemicals, harvesting, threshing, and transportation, revolutionizing the use of farm machinery and agricultural output (Lawrence & Pearson, 2002; Sims & O'Neill, 2003). In regions where significant farming is practiced, agricultural mechanization is frequently linked to a decrease in the demand for and/or an increase in the scarcity of farm labor (Binswanger, 1986; Pingali, 1997). Incentives for mechanization can also come from agricultural policy (including subsidies), economic growth (Clarke & Bishop, 2002), and agricultural expansion and commercialization (Pingali, 2007).

According to the market approach, imbalances caused by agricultural policies and the inefficiency of most farms are to blame for agriculture's current problems. Agriculture is viewed

as a competitive sector that operates under the principles of perfect competition and uses resources efficiently for profit maximization (Blandford & Hill, 2006). The integrated structural approach, on the other hand, affirms that agriculture has distinct qualities and cannot be viewed or assessed exclusively in terms of absolute financial features (Gardner, 2005). Due to the structural features of the world markets and market distortions brought about by intervention programs, agriculture is a sector with special characteristics that cannot be controlled only by market principles (Darnhofer et al., 2010). Given the significant degree of price and revenue volatility in agriculture, structural interventions and support are deemed important. It is supplier-dominated with low market strength, impacted by numerous industries (Tiffin & Irz, 2006).

This study contributes to the gap of how capital obsolescence, particularly in the form of agricultural machinery influences productivity at the regional level in the Republic of Kazakhstan. In the north of Kazakhstan, where conditions akin to those of Canada's prairies prevail, rainfed, drought-prone spring and winter wheat predominate. It is usually cultivated as a monocrop on sizable farms (Jaleta et al., 2019). This study addresses this gap by investigating the effects of market structure and capital obsolescence on wheat production in the four northern regions of Kazakhstan. Employing a balanced panel data model for four regions in Kazakhstan from 2013 to 2022, this study aims to disentangle the effects of these and several other theoretically motivated factors. Understanding these dynamics will provide valuable insights for policymakers. By considering both market structure and the level of capital obsolescence in the agricultural sector, policymakers can develop strategies to enhance wheat production and overall agricultural productivity in Kazakhstan.

This thesis is organized as follows. Chapter 1 discusses the literature review conducted. In Chapter 2, the data and methodology are described. Finally, the results and discussions are presented in Chapter 3, followed by the conclusion of the thesis. For this study, we collected data on the major wheat-producing regions from the Ministry of Agriculture of the Republic of Kazakhstan and the Information-Analytical System of the Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan.

1. Conceptual Framework and Literature Review

1.1. The Connection between Market Structure and Development

1.1.1. Competition for Fostering Technological Advancements

The main institutions/organizations responsible for distributing limited resources among competing ends at the micro level and for fostering long-term economic growth at the macro level are the company, the market, and the state. They manage economic activity, direct competition for more resources, and produce innovations using their own unique mechanisms (Williamson, 2000). In theory, when the market is endowed with the right to private property and industry-specific rivalry, it can function as a powerful tool for fostering economic growth (Acemoglu & Robinson, 2000; North, 1989). Private property rights, the first pillar of the market system, encourage people to launch their own companies, invest in research and development, and produce new information that can enhance the productivity or quality of their goods. Competition among firms is considered the second pillar of the market mechanism. The two additional benefits that competition among firms is expected to produce at the individual, society, industry, and national levels are (i) static allocative efficiency gains by ensuring that social welfare is maximized and (ii) dynamic efficiency gains that lead to technological innovations and productivity growth over time (Gregory Sidak & Teece, 2009).

Based on whether businesses can raise their prices above marginal cost, the neoclassical economic theory of competition makes a distinction between perfect and imperfect competition. In a perfect market, firms would find that it is best to produce where their marginal cost equals the given market price, increasing social welfare and obtaining the most effective resource allocation result at any given time. Their choices (price, investment, input use, entry, exit, etc.) are not proactive risk-taking tactics that can change the market conditions, but rather passive attempts to adapt to certain uncontrollable market realities. As a result, firms in perfect competition are less likely to engage in psychological competition or rivalry, which limits the space for dynamic competition and eliminates the necessity for strategic actions like investing in R&D to generate innovations that could provide them an advantage over competitors. Perfect competition, according to Schumpeter (1942) is a situation in which technical dynamism is absent since any competitive action is by definition impossible, much like in a monopoly. In conclusion, a fully competitive market would, in the static sense, result in socially effective resource allocation; yet,

over time, it would be harmful to innovations and growth due to its propensity for dynamic inefficiency (Hayek, 2016).

In imperfectly competitive market structures, firms often face welfare losses at certain points in time, but they also frequently engage in non-price competition and make strategic decisions, such as investing in research and development for technological innovations necessary for product differentiation, improving product quality, or lowering production costs, and outperforming competitors in gaining larger market shares for greater profits (Amsden & Singh, 1994; Bauer, 1997). It is commonly held that the conditions of perfect competition are closely met by the agriculture-producing sector due to the large number of small food producers who can't have a significant impact on the market. Moreover, there is little opportunity for product differentiation in agricultural commodities due to their high degree of homogeneity, which naturally restricts the amount of competition for advances in product quality or variation.

The absence of dynamic competition and the lack of incentives for farm enterprises to expand significantly limit the ability of the market mechanism in agriculture to foster technological innovation and agricultural expansion. The "small farm size" (atomistic sector) is cited in the literature on agricultural innovations as the primary justification for farm enterprises' refusal to engage in research and development to produce innovations (Alston & Pardey, 2014). The most important effect of the absence of dynamic competition is that farmers do not have to worry about being forced out of the market even if they do not try to innovate technology or produce better products because they know that others will not do the same. As income rises, Figure 1 illustrates that market insufficiency becomes less significant in low-income nations. There are two distinct phases of the decline: the first is a slow decline from the low-income to the middle-income stage, and the second is a sudden decline from the middle-income to the high-income stage. The issue of market insufficiency is particularly relevant to low-income nations, as they must prioritize increasing agricultural production and output as the main driver of economic growth.

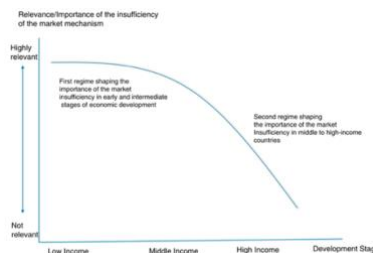


Figure 1 – The market insufficiency problem grows less relevant as income rises

Source: Moon (2022)

1.1.2. Financing of Input Providing Sector for Agricultural Productivity

The classic economic theory of credit markets states that competition among lenders will decrease credit provision for inputs (e.g. Petersen & Rajan, 1995). Despite being socially efficient, contracting may collapse due to unsustainable input provision and rising buyer competition. According to (Worako et al., 2008), in order to solve market failures and the inadequate supply of inputs to increase farmers' income and lower rural poverty, we must shift from "getting prices right" to "getting institutions right". Delpierre (2009) demonstrated that input consumption is inefficiently low in a competitive environment. Private traders have little incentive to supply inputs because they fear that rivals may free-ride on input provision and profit from their own investment. The producers' share of the export price has effectively increased in countries where competitive spot markets have developed; however, a sharp decline in input use has hampered the supply response (for policy studies, see Akiyama et al., (2003) or Shepherd & S. Farolfi (1999)). Moreover, there are findings by Poulton et al. (2004) in Uganda and Gibbon (1999) in Tanzania for the cotton industry, where intense rivalry is linked to reduced input availability. However, there are also cases in which market power and fairly good input availability coexist, for example, Zimbabwe and Zambia show that market power and the availability of agriculture inputs or extension services are positively correlated (Poulton et al., 2004). In cartel conditions, sustainable input credit schemes are also present in Ghana (Poulton, 1998a), Mozambique (Poulton et al., 2004), and Benin, where a government-backed, geographically organized system of monopsonies exists. Pederson & Khitarishvili (1997) describe the rural finance environment in countries undergoing transition as typically not competitive.

Given how frequently equipments are traded globally (Eaton & Kortum, 2001), differences in prices may also be a reflection of opportunities for international commerce as well as non-competitive behavior resulting, for instance, from variations in demand elasticities between nations (Alessandria & Kaboski, 2011). In a Cobb-Douglas way, a vintage capital model combining capital from several vintages with homogenous labor aggregates to a neoclassical model consisting of two sectors: agriculture and equipment manufacturing. As described by Caunedo & Keller (2021), a continuum of uniform farms that generate agricultural products, or ultimate consumption goods, make up the farming industry. The equipment-producing industry is made up of a range of homogeneous companies that create investment goods, or equipment and maintenance services. They provide the farmers in the economy with land, labor, and equipment for rent. Farms use a

declining return technology in land, labor, and equipment services to create the final consumption good. Equipment physically depreciates as a result of usage, but a household can offset this loss by investing in new equipment or buying replacement parts. Any necessary maintenance work is done by the household themselves.

The set of markets and institutions can be conceptually identified as follows: open to new firms entering and exiting the market; availability of funds and capital markets; availability of market information; a reasonably comprehensive range of instruments for financial transactions; legal institutions (e.g., property and collateral laws, bankruptcy and foreclosure laws, laws enforcing business contracts); regulatory and tax laws and agencies; insurance and risk markets and instruments (G.Pederson & T.Khitarishvili, 1999). As Schumpeterian growth theory states while the entry threat lowers the expected rents from doing R&D for incumbents in sectors further from the frontier, it induces innovators in sectors that are initially close to the technological frontier to innovate more, which drives productivity growth. There are two aspects to the marginal cost of producing investment products. First, in direct proportion to the superior quality they offer, higher quality capitals are more costly. Second, when farms adopt them, it becomes profitable for equipment-producing companies in particular to generate higher-quality capital. The presence of these premium capitals on the market causes the lesser-quality capital to become obsolete (Caunedo & Keller, 2021).

Banks and non-traditional lenders are subject to significant regulatory discrepancies that could increase their compliance costs and reduce their competitiveness. Several governmental organizations regulate banks in order to preserve the stability of the banking and monetary systems. In contrast, non-traditional lenders function with a great deal of autonomy from official authorities, although being subject to the same set of property, lien, usury, and security rules. Non-traditional lenders may have a competitive advantage over banks thanks to the channels they employ to offer financial services to their clients. Compared to traditional banking operations, point-of-sale financing of a customer involves less investment in fixed assets and other overhead items. Non-traditional lenders typically have to offer competitive prices and fight for market share through the development of a network of suppliers/dealers, as well as the accessibility and information availability.

Caunedo & Keller (2021) noted that one of the main drivers from the consumer (demand) side of the industry is thought to be the convenience that comes with financing agricultural clients

in a non-traditional way. Low transaction costs and product availability, which include having access to farm inputs and funding at one location, make up convenience. The value placed on cheap transaction costs and competitive lending rates combined with the production inputs required by the agricultural operation is demonstrated by the observed growth in farm-level demand for point-of-sale financing. In order to operate effectively, non-traditional lenders need a prosperous agricultural sector to generate a sufficient demand for their services, an information technology infrastructure to supply such services at a reasonable price, and the availability of financial instruments to expedite transaction structuring. In the case of Kazakhstan, Babaeva et al. (2017) suggested that the creation of a more efficient system for allocating budgetary funds needs to be the foundation for state assistance to farmers and food processing businesses. Measures taken to boost the use of leasing instruments in the agriculture sector should be based on market competition and involve both state and private leasing organizations. To improve collaboration with agricultural businesses, the government should support private leasing firms by partially covering the interest rate on leases at a rate equivalent to the Central Bank's discount rate; or by partially covering the value of leased property following the lessee's initial payment at a rate commensurate with the advance payment, but not exceeding thirty percent.

1.2. Capital Obsolescence and Its Impact on Productivity

1.2.1. The Impact of Technological Obsolescence on Development

Numerous studies in the field of macroeconomic literature establish a connection between the decline in productivity and the rapid growth of technological advancements embodied in capital. Solow attempted to quantify technical development in his 1957 article since it was relevant to growth (R. M. Solow, 1957), but he did not provide an explanation. Nonetheless, Solow's advancements in growth theory have expanded the theory's technical applicability. Since then, technical advancement and acceleration have taken precedence among economists and decision-makers. In their studies, del Río (2002) and Boucekkine et al. (2003) demonstrated that a slowdown in productivity might result from a rise in the obsolescence costs of physical capital brought on by a faster rate of technological advancement reflected in capital. The study by Ma (2021) showed that firms' technological obsolescence foreshadows substantially lower growth, productivity, and reallocation of capital.

Along with winners and financial gains, innovation also results in losers and reduces the value of already-existing technologies (i.e., “competitors’ win is my loss”). Technological obsolescence is the process by which this destruction mechanism operates; once cutting-edge technologies lose their value as they advance in development. Conceptually, technological obsolescence is significant. Endogenous growth theories predict unequivocally that when a firm’s technologies age, their performance (productivity and profitability) would decline. Financial markets also respond to technological advancements, which can have an impact on the price of funding innovation and the economy’s long-term capacity for innovation. Due to the lack of readily observable metrics, technological obsolescence is rarely investigated empirically, despite its significance. Ma (2021), following (Bena & Simintzi, 2019), discovered that higher destruction is linked to product innovation obsolescence meaning that businesses whose technology is becoming more outdated are growing at a substantially slower rate: over a five-year period, slower growth in profit (3.1 percentage points), output (3.2 percentage points), capital (5.2 percentage points), and employment (1.9 percentage points) is related with one standard deviation higher in obsolescence compared to firms in the same industry-year. The broadly dispersed company productivity may be explained by the similar increase in obsolescence, which is linked to a 1.4 percentage point decline in revenue-based total factor productivity (TFP) (Syverson, 2011). The relationship between business outcomes and technical obsolescence differs depending on the type of innovation and the market conditions. As outlined in Garcia-Macia et al. (2019), a company’s technological obsolescence may result from innovation that is either outside the boundaries of the particular industry (e.g., AirBnB disrupting hotels; iPad and Kindle disrupting traditional printing copies) or from cannibalization by the company’s new innovation (Christensen, 1997; Igami, 2017). Moreover, Ma (2021) proved that obsolete enterprises fail far more quickly in industries with high-competition environments. For example, in a high-HHI (Herfindahl-Hirschman Index) industry, a one standard deviation increase in technical obsolescence is linked to a three-year decline in total employment of 2.0 percent and a 3.9 percent decline in capital stock. These effects are almost nonexistent in sectors of the economy where competition is not as intense. It follows that rivalry in the product market fosters creative destruction (Aghion et al., 2009; Cunningham et al., 2021).

Technological obsolescence is caused by a variety of models in which firms’ current innovation portfolios are destroyed at a specific rate, resulting in lower output and profits as well

as the reallocation of labor and capital away from the firm (Grossman & Helpman, 1991; Acemoglu et al., 2018; Aghion & Howitt, 1992; Garcia-Macia et al., 2019; Klette & Kortum, 2004; Lentz & D. T. Mortensen., 2008). Upgrading technology entails disposing of old capital, putting in new capital, and hiring/educating employees to use the new capital, and it is sometimes linked to expensive capital adjustments as well (Caballero & Bertola, 1994; Caballero & Jaffe, 1993). Ma (2021) discovered that when it comes to product innovation, the influence is larger for obsolescence. The theoretical foundation for embodied and disembodied innovation (Berndt, 1990) is in line with this. According to these papers, product (embodied) innovation is embodied in new capital and may result in more creative destruction, whereas process (disembodied) innovation takes the form of increases in labor productivity and is complementary to current investments (Kogan et al., 2020).

1.2.2. The Impact of Capital Obsolescence on Agricultural Productivity

A linear aggregator of farms' output is the farming sector's aggregate output. Despite the assumption of diminishing returns to production elements in every farm, the economy can be represented by a convex cone. Similar to Hornstein & Prescott (1993), the number of production units and total output increase proportionately if all elements of production rise. According to R. Solow (1960), the amount of technology embodied in capital determines the growth in productivity in the equipment sector, and this degree of technology is inversely related to economic obsolescence. Disparities in the intensity of factors used (Chen, 2020; Donovan, 2013; Restuccia et al., 2008), sector-specific variations in hours worked and human capital (Gollin et al., 2014; Lagakos & Waugh, 2013), variations in the returns to human capital across sectors (Herrendorf & Schoellman, 2015), and variations in the frequency of size-dependent distortions on farms (Adamopoulos & Restuccia, 2014) can all contribute to cross-country disparities in agricultural productivity. By bridging the gap in the literature, the work by Caunedo & Keller (2021) accounts for the differences in the quality of the physical capital utilized in production that was previously unaccounted for, as well as the adoption patterns of technology embedded in equipment. Evidence reveals that, on average, impoverished countries maintain their equipment more than rich countries per hour of consumption when seen through the authors' model.

Globally, mechanized production is becoming a crucial component of contemporary agriculture (Binswanger, 1986; Manuelli & Seshadri, 2014). A common tool in contemporary

agricultural production is the tractor, which is used in numerous agricultural production processes and is a widely traded good (Eaton & Kortum, 2001). It is less in the production of livestock and tree crops and more in the production of staple grains. Furthermore, tractors work well with a wide range of other equipment products, including harvesters and tillage tools, which are utilized for various agricultural purposes. For instance, tractors come in a variety of forms, from simple mechanical models that can just push or pull objects to more complex ones with GPS transmitters, hydraulics, and software that can even plant seeds on their own. According to empirical findings, a linear or convex relation adequately describes the data indicating that, after adjusting for observable factors, cumulative maintenance costs in tractors rise with cumulative hours of use (Morris, 1988). According to the study by Caunedo & Keller (2021), there are more low-quality tractors in poorer nations than in affluent nations, and the cost difference between new and old equipment indicates both physical and economic obsolescence. The presence of new quality equipment on the market causes lesser-quality ones to become obsolete. The authors discovered that during the past 25 years, gains in capital quality have contributed significantly to the development of agricultural labor productivity, making up 21% and 35% of productivity growth in affluent and poor nations, respectively. The majority of the labor force in poorer nations is employed in agriculture, so comprehending the reasons behind the striking disparities in agricultural productivity is crucial to comprehending the variations in output per worker across different countries.

1.3. Role of Equipment Leasing in the Development of Agriculture

The ability to apply innovative ideas in the agricultural industry through entrepreneurial drive and expertise is a fundamental driver for improving productivity performance (Adenuga et al., 2021). Experts estimate that the global food consumption will climb by 70% by 2050, and in order to meet this demand, at least 80 billion US dollars would need to be invested in agricultural businesses. Furthermore, given the current circumstances, special attention should be paid to assisting agribusiness organizations, as they are the primary producer category that guarantees the state's food security (Willer & Kilcher, 2009). Agriculture is important for the national economy (contribution to GDP, employment, and natural resources), and each nation strives to assure food security, which is why, the state is concerned about co-financing it (Kuzman et al., 2017). Agricultural output is cyclical in nature and is associated with a high degree of natural and climatic

risks. As such, the state and other financial bodies must take certain methods to finance agriculture (Nurumov & Aymurzina, 2014; Ramazanova et al., 2019). Agribusiness organizations must always look for funding options that can support the establishment of their company as well as its continued growth. In developing countries, the average annual net investment in agriculture, necessary to ensure such production growth, is estimated at USD 83 billion (OECD/FAO, 2015). The opportunities in investment and improving agricultural enterprise management, which arise in agricultural producers due to sale crop production, stimulate the innovative processes in agriculture and contribute to higher yields. Greater income from sale crops and improved technologies can also lead to increased food production in farm enterprises (Swinnen, 2015).

Since agribusiness organizations guarantee the creation and emergence of long-term new jobs, SMEs are one of the main forces behind the socioeconomic development of a nation and its regions. As a result, they act as a guarantee of the people's income and financial capacity (Gamidullaeva et al., 2020; Ndiaye et al., 2018; Obi et al., 2018; Prasetyo & Kistanti, 2020; Ronda et al., 2020). Equal access to labor, capital, materials, information, and natural resources as well as forms of support should be granted to all business entities. However, small and medium-sized enterprises have far less financial resources available to them during operations than do large businesses. In contrast to major corporations, small and medium-sized businesses in the agro-industrial complex represent a substantial portion of the economy and contribute significantly to the state's gross domestic product (Savkin, 2017). Because of the unique characteristics of the agricultural sector, significant financial investments are required to maintain its competitiveness and sustained growth, with the state acting as the primary investor. It goes without saying that the state must enact a number of policies targeted at staff training, rural infrastructure development, attracting young professionals, and advancing agricultural science in order to address the issues surrounding agricultural entrepreneurship. However, these actions ought to be explicit in both their financial and non-financial aspects, not declarative (Dovbii I.P. & Mitrofanova, 2016). It is vital that banks and non-banking organizations extend affordable, flexible, and mutually beneficial loans to small and medium-sized agricultural businesses. This will enable entrepreneurs to supply the necessary financial resources for production, while financial organizations can earn income with minimal credit risks.

Access to credit is a significant part of the agricultural production system. As agriculture has become more industrialized, "borderless" businesses have grown, with producers increasingly leasing production equipment rather than owning them and hiring third parties to do a range of production and marketing tasks (Boehlje, 2019). The need to invest in production development, primarily in the purchase of contemporary machinery and equipment and the provision of it with acceptable financing terms and conditions, is one of the peculiarities of the growth of agriculture in the post-Soviet countries. All of this makes it necessary to look for other financing options for investments, namely leasing.

The government can utilize leasing for state assistance programs and ensure that funds are used for the intended purpose. An equipment manufacturer can improve sales through leasing. A customer who uses the least amount of financial resources is granted the right to use the essential equipment. (Mhitaryan, 2021). By definition, a lease is an agreement wherein ownership and use of a physical item are transferred for a period of time less than the asset's anticipated useful life in exchange for money. From an economic perspective, there are numerous similarities between the terms of lease and rent, such as the fact that they are shorter than the asset's useful life and that the renter receives the asset's residual rights. Technically speaking, though, they are very different; renting simply transmits a temporary license rather than the short-term right to use an asset, and it is not thought of as giving the renter ownership of the asset. A person or legal entity can purchase an object at a lesser cost through leasing than they would have to pay for outright ownership, which is a crucial economic function (Askarova A. K. & Sydykov B. K., 2018).

Leasing is a tool used in investment finance that allows the economic and legal ownership of a commodity to be separated (Kholodilova A., 2018). Operating and financial leases are the two main types of leases that have emerged. An operating lease is a type of short-term rental agreement that gives the lessee access to an asset for a duration significantly shorter than the asset's economic life. Usually, these are setups for a particular season. A financial lease, on the other hand, is an irreversible agreement that grants the lessee access to the asset in exchange for a number of payments. A financial lease's duration often encompasses the majority of the asset's economic life, and the lessee is normally in charge of paying for repairs, upkeep, taxes, and insurance. One feature of lease financing that has made it more popular in agriculture is that it transfers the right to use an asset for a specific amount of time at a predetermined rate and separates use from ownership. Many agricultural assets are currently leased, including cattle, crop and livestock facilities, and

farm production and transportation equipment. In terms of the total volume of leases, machinery and equipment leasing is the most common. Compared to machinery leases, livestock leases are more complex transactions since there are more moving parts (LaDue et al., 1985). Since the majority of agricultural businesses today lack working capital, they are not prepared for an extensive technological re-equipment of operations. They borrow money from banks and try to get investment and budgetary funds. Producers of commodities are also in need of services like leasing.

Figure 2 demonstrates a number of the benefits of leasing agreements. Leasing companies also give the lessee tax advantages in various nations. The leaseholder has the ability to replace obsolete machinery with newer models and achieve competitive production without having to make significant upfront investments. Government-wise, a lot of nations have implemented leasing development policies since they consider them to be a cutting-edge strategy for increasing investment activity. Through its method that guarantees the assured use of investment resources to upgrade output, leasing helps to gather funds for investment activities. Leasing gives providers a chance to make sales of the product. To guarantee a steady sales channel for their goods, they enter into partnerships with leasing companies and offer discounts (Tilov A.A., 2020). These are only some of the benefits that can be leveraged to create competitive financial products. As we can see, some nations exploit leasing benefits to boost economic growth in general or in agriculture specifically. Some nations, like the Ukraine, take advantage of the restricted leasing alternatives available for state assistance projects because, at the moment, there are legal and regulatory obstacles to fully utilizing leasing.

<i>Leasing</i>	<i>Credit</i>
<i>1. As a rule, financial leasing does not presuppose the existence of collateral, as collateral is the subject of the lease, which belongs to the lessor during the entire period of the contract</i>	<i>1. From the moment of receiving the loan until its repayment deadline, the borrower demands a corresponding collateral which can be sold in case of non-fulfillment or improper fulfillment of obligations by the borrower</i>
<i>2. Leasing rent schedule can be based on a mutually agreed schedule</i>	<i>2. The terms and conditions of the loan repayment are not aimed at the borrower's interests but at ensuring the bank's liquidity ratio</i>
<i>3. Preferential period, is before receiving the subject of leasing does not make payments to the leasing company</i>	<i>3. In general, there is no grace period for a loan with seasonal payments</i>
<i>4. Simplicity and speed of registration up to one day</i>	<i>4. A larger package of documents is required when submitting for a loan</i>
<i>5. Leasing can be provided for both short-term, medium-term and long-term</i>	<i>5. Commercial loans are provided for up to 5 years</i>

Figure 2 – Differences between financial leasing and commercial loan
Source: Tilov A.A. (2020)

Leasing is often chosen by producers who are strapped for cash and have restricted access to debt capital as a way to get around an initial capital limitation or to save operating capital. Mature operations may discover that leasing helps them to meet debt covenants in addition to

saving working capital. benefit from the lease payments' tax deduction and steer clear of investing long-term capital in assets that can soon become obsolete. The benefits of leasing, such as the lack of collateral, tax implications, and extra benefits from manufacturers in the event of a lease project, are significant factors in clients' decision-making processes. The degree of formality involved in the application procedures, as well as the types and quantities of security needed, and the terms of payback for non-traditional suppliers vary substantially (Sherrick, 2019). According to certain studies (Biais & Gollier, 1997; Petersen & Rajan, 1997) producers only turn to non-traditional sources when credit from traditional financial institutions is unavailable. Furthermore, they show that companies without a history of banking links tend to borrow more heavily from non-traditional sources than companies with a history of banking relationships.

Kazakhstan has become one of the largest exporting countries in the world. Kazakhstan's membership in the Eurasian Economic Union (EAEU) and the World Trade Organization (WTO) provides opportunities and, at the same time, imposes high requirements on competitiveness in both domestic and foreign markets (Sodano & Verneau, 2014). In this regard, state regulation of AIC is extremely important (State Program for the Development of the Agro Industrial Complex of the Republic of Kazakhstan). Pygay et al. (2018) showed that in order to ensure the development and budgetary support of all forms of ownership and business, it is necessary to combine increasing financial support with tightening controls over the compliance with sanitary requirements, both for imported and domestic food. Small-scale farms, which supply the market with 81% of milk, 64% of meat, and more than half of vegetables and potatoes, should receive particular attention. Additionally, in order to support agriculture to the extent allowed by WTO terms and restore the equal relationship between industry, trade, and agriculture, it is necessary to enhance the mechanisms for the financial leasing of industrial and agricultural equipment for the processing industry. The authors Sartanova et al. (2023) point out that the agricultural sector's growth is hindered by current credit issues, such as a lack of loans available and high interest rates. According to national statistics, the main obstacles limiting the activities of the surveyed agricultural formations were cash shortages, working capital shortages, high interest rates on loans, low purchase prices for goods, and worn-out material and technical base (Figure 3).

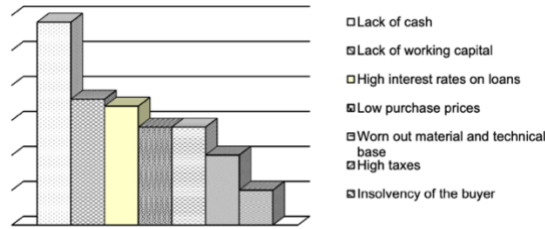


Figure 3 – Factors limiting production activity and entrepreneurial activity in agriculture in Kazakhstan at the end of 2022 (in % of the total number of respondents)

Source: Sartanova et al. (2023)

The study by Misnik et al. (2024) also confirmed the need to develop and improve financing sources for gross agricultural output by assessing the impact of the source of financing on the results of production activities of small and medium-sized businesses in agriculture in Kazakhstan and building a forecast model for the next 5 years, from 2023 to 2027 (Figure 4). The factors included statistical data on the amount of financing that SMEs in the agricultural sector received from own funds, government resources (lease agreements, subsidies, and concessional lending), and non-state financing sources like loans from banks, microfinance institutions, credit partnerships, and leasing firms. The results of the structural analysis examining the influence of funding sources on gross output indicate that non-state funding has the largest effect on the effective feature (47,89%), followed by public funding (40,08%), and own funds (12,03%). According to the authors, to reach the forecasted gross output in 2027, small and medium-sized businesses should increase funding from their funds by 10,8%, the state should increase the volume of concessional lending by 48,1%, subsidies for entities by 40,3% and leasing by 2,6%, credit partnerships, and microfinance organizations to ensure the growth in the volume of transactions by 49,2% and 33,2 %, respectively.

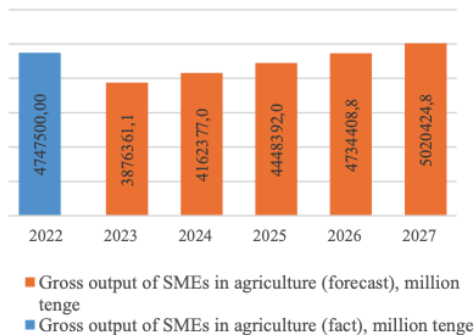


Figure 4 – Forecast of gross output by SMEs in agriculture until 2027

Source: Misnik et al. (2024)

It should be noted that Kazakhstan is currently pursuing a course of action that will undoubtedly increase the availability and demand for financial resources by entrepreneurs. These actions include changes to the way state financial support is provided, a shift from direct support measures to indirect ones in the form of financial organization funding and guarantees, and the creation of a diverse and innovative economy with the operation of business entities with high potential. Future studies will need to evaluate these financing options' efficacy as well as how they affect agricultural businesses' production performance.

1.4. The Transmission of Producer Prices to Domestic Markets

The fluctuations in food prices in developing nations have significant political and economic implications. Since food accounts for a significant portion of household budgets in many economies, fluctuations in food prices directly affect welfare. The fluctuation of food prices mostly impacts impoverished, small-scale farmers whose revenue primarily comes from agricultural sales. Should this price volatility permeate marketplaces in developing nations, farmers and low-income customers may face severe repercussions. First, because they spend a larger portion of their income on food overall and staple foods specifically, low-income consumers are more susceptible to fluctuations in food prices. Second, small-scale, impoverished farmers who depend heavily on food sales for their livelihood and have little control over when to sell are impacted by fluctuations in food prices. Third, price volatility is likely to have long-term effects on both consumers and farmers by stifling agricultural investment and slowing the increase of agricultural production, particularly in the lack of effective risk-sharing systems. Additionally, it is probably going to stifle agricultural investment and slow the increase of agricultural output, which will have long-term effects on farmers and the underprivileged. Therefore, it's critical to comprehend the causes of food price volatility and whether domestic or global agricultural commodities markets play a major role in its transmission. This in turn can aid in the development of more effective national, international, and regional policies to mitigate the extreme volatility of food prices and safeguard the most vulnerable populations (Ceballos et al., 2017). The authors found that price volatility transmission from international to domestic markets seems to occur when the ratio of traded volume to domestic production exceeds or falls below 40 percent. However, while the level of dependence on international trade plays a role in explaining the observed volatility transmission

outcomes, other factors also contribute to the varying degrees of international-domestic interactions.

The transmission of prices from global markets to local markets has been the subject of fewer studies. Using annual pricing data, Mundlak & Larson (1992) calculated the transmission of global food prices to domestic prices in 58 countries. They discovered extremely high rates of price transmission, but since levels were used in the research rather than initial differences, nonstationarity is likely to have caused misleading correlation in the data. In another study, by using co-integration analysis and an error correction model, Quiroz & Soto (1995) replicated the analysis of Mundlak & Larson (1992) and discovered no correlation between local and foreign costs for 30 out of the 78 nations they looked at. Using an error correction model, Conforti (2004) investigated price transmission in 16 countries, including three in Sub-Saharan Africa. His researched found that countries in Africa south of the Sahara have less price transmission than those in Asia and Latin America. Gilbert (2010) showed that price shocks for individual commodities in the context of international agricultural commodity prices are frequently tied to supply, whereas joint price movement can be explained by macroeconomic and monetary factors.

In the study by Guo & Tanaka, (2020) examining global and local price passthrough in cereal markets, Kazakhstan is mentioned as one of the countries with cereal self-sufficiency ratios (SSRs) exceeding 100%. The self-sufficiency ratio (SSR) represents food production as a ratio of available supply, as depicted by the following equation FAO (2012):

$$SSR = Production \times 100 / (Production + Imports - Exports).$$

The hypothesis was that countries like Kazakhstan, with high cereal self-sufficiency rates, are considered to be more resistant to violent fluctuations in international cereal prices. The analysis included data from Kazakhstan along with other developing countries in Africa, Asia, and Latin America to investigate the determinants of grain price volatility transmission from international to local markets. The study used GARCH models with a dynamic conditional correlation (DCC) specification (Engle, 2002; Cappiello et al., 2006) by estimating its parameters by the Bollerslev & Wooldridge (1992) Gaussian quasi-maximum likelihood estimation (QMLE) and panel feasible generalized least square (FGLS) models to explore the impact of self-sufficiency measures on price transmission dynamics. Additionally, the study considered the consumption of substitutive goods, such as rice and maize, amid wheat price transmission, to understand how consumers engaged in substitution behavior in response to price fluctuations in different cereal

markets. Some examples of comparing SSRs to hunger levels in different countries are provided in Figure 5 below compiled by Clapp (2017).

	Countries with SSR < 85%	Countries with SSR = 85–115%	Countries with SSR > 115%
Consumption at or above adequate nutritional intake	These countries produce less food than they consume and yet easily meet domestic dietary needs with very low hunger levels <5% <i>Examples:</i> Japan; South Korea; Greece; Italy; Mexico; Kuwait	These countries produce close to the same amount of food that they consume and easily meet dietary needs with very low hunger levels <5% <i>Examples:</i> South Africa; Brazil; Germany; Turkey; Sweden; Austria	These countries produce more food than they consume and easily meet domestic dietary needs with very low hunger levels <5% <i>Examples:</i> Canada; Australia; Argentina; United States; Russia; Kazakhstan; Hungary
Consumption below adequate nutritional intake	These countries produce less food than they consume and have high levels of hunger >25% <i>Examples:</i> Liberia; Bolivia; Zimbabwe; Namibia; Yemen; Mongolia; Haiti; Mozambique	These countries produce close to the same amount of food that they consume and have moderate (5–25%) to high (>25%) levels of hunger <i>Examples:</i> India; Tanzania; China; Guinea; Cambodia; Malawi; Chad; Zambia	These countries produce more food than they consume and have low to moderate levels of hunger at 5–14.9% <i>Examples:</i> Guyana; Vietnam; Thailand; Paraguay

Figure 5 – SSRs and hunger levels in different countries

Source: FAO Data (Food Balance Sheets 2007–2011 and (FAO, 2015b) Hunger Map 2009–2011).

The specific findings related to Kazakhstan in the study examining global and local price passthrough in cereal markets are not explicitly mentioned in the provided excerpts. However, based on the hypothesis that countries with high cereal self-sufficiency rates, like Kazakhstan, may be more resistant to fluctuations in international cereal prices, it can be inferred that Kazakhstan's high self-sufficiency in cereals could potentially play a role in reducing volatility pass-throughs from global markets. Moreover, raising SSRs may increase domestic price volatility if the domestic yield of a commodity is more volatile than the rate at which foreign exporting regions produce it. This is evident from the section "Identification of potential factors," which states that policymakers must consider the relationship between domestic price volatility and/or domestic yield volatility and import price volatility before enacting agricultural autarky policy. Clapp (2017) provided a world map of the SSRs for starchy roots and grains in various nations from 2007 to 2011 in Figure 6, where darker-colored countries are more self-sufficient in food, whilst lighter-colored countries are less so.



Figure 6 – Food self-sufficiency ratios for cereals and starchy roots, 2007–2011

Source: FAO Food Balance Sheets, 2007–2011 data for cereals and starchy roots by volume produced, imported and exported; Countries not outlined in the graphic did not have sufficient data to calculate SSR; Starchy roots converted to cereal equivalent at 1t starchy roots = 0.26t cereals (following Luan et al. (2013)).

The world price and the Export Unit Value (EUV) for a given nation and commodity can differ significantly. The relationship between changes in global pricing and the prices farmers receive is influenced by numerous factors. The average annual export price, or EUV, that a nation receives is the first step in the conversion from world price to producer price. Depending on factors like quality variations, the nation's seasonal export distribution, the use of forward pricing contracts, and the specific combination of world market locations employed, the EUV need not closely resemble the average annual world price. The real exchange rate determines how EUVs are converted from US dollars to local currency units. Macroeconomic forces and policies influence the real exchange rate, but variations in EUVs and the performance of agricultural exports can also have a significant impact (Hazell et al., 1990). It is plausible that in certain scenarios, fluctuations in EUVs may cause counteracting movements in the real exchange rate, which serve to stabilize the EUV's domestic value (see Gelb (1974)).

According to Hazell et al. 1990), three main elements influence the mapping of EUV in local currency to the average producer price. The first is the portion of production that is carried forward in stocks or sold on the home market. This will be crucial anytime differences in cost or quality cause producer pricing to vary across the domestic and export markets. Second, actions taken by the government in the home market that result in less than completely linked fluctuations between the EUV and the local price, such as export taxes, attempts at price stabilization, or other measures. The magnitude and temporal behavior of the marketing and processing margins held by all relevant market intermediaries constitute the third element.

Nonetheless, it is evident that producer prices are generally far less volatile than EUVs when they are contrasted with the comparable US Dollar EUVs for the same periods. (Hazell, 1988), Macbean & Nguyen (1987), and Krueger et al. (1988) have also reported findings that are similar. This finding demonstrated that a domestic market, government policies, market intermediaries, and real exchange-rate changes all work together to significantly stabilize producer prices. It helps to separate the portion of the variance that producers can forecast from the rest when analyzing the volatility of producer pricing. Producers are always able to adapt their resources, if only little, to foreseeable price fluctuations, potentially preventing significant economic losses. Unpredictable price fluctuations, on the other hand, pose a danger, especially when farmers have to commit resources far in advance of harvest. Prediction mistakes most likely lead to resource usage problems, which in turn cause inefficiencies and financial loss (Hazell et al., 1990).

In the EAEU, 12.8% of agricultural output is produced in Kazakhstan. Over the course of the last five years, the country has considerably increased the amount of food products and agricultural raw materials that the EAEU countries trade internationally. Kazakhstan is the top exporter of live farm animals as well as products from the wheat and grain industries among the EAEU members. Kazakhstan is the second-largest exporter of grains and oilseeds after Russia. Nonetheless, the nation's degree of price competitiveness is far lower than that of Belarusian and Russian goods, for instance, in the production of wheat. An essential metric for assessing the general performance of the agriculture industry is the agricultural price index. The FAO claims that the agricultural price index serves as an indicator of shifts in global pricing. The agricultural industry benefits from a high agricultural price index since it signifies better pricing for agricultural products and higher revenue for farmers (Figure 7).

Types of products	Armenia	Belarus	Kazakhstan	Kyrgyzstan	Russia
Wheat	0.00	1.00	0.62	0.18	0.81
Barley	0.00	1.00	0.79	0.22	0.80
Potatoes	0.00	1.00	0.77	0.34	0.64
Onions	0.00	0.60	1.00	0.61	0.70
Cabbage	0.00	0.53	1.00	0.62	0.39
Carrots	0.00	0.97	1.00	0.63	0.98
Pome fruits	0.36	1.00	0.12	0.18	0.00
Stone fruits	0.96	1.00	0.00	0.95	0.35
Raw milk	0.70	0.84	0.76	1.00	0.00
Butter	0.00	0.75	0.59	1.00	0.34
Cattle meat in live weight	0.00	1.00	0.81	0.61	0.85
Pork meat in live weight	0.00	1.00	0.97	0.83	0.94
Poultry meat	0.00	1.00	0.88	0.71	0.88
Pasta products	0.56	1.00	0.28	0.89	0.00
Eggs	0.00	0.95	1.00	0.44	0.89

Figure 7 – Competitiveness indices of EAEU countries by price of agricultural products
Source: Omarbakiyev et al. (2023)

The main risks of lower food security associated with the Russian-Ukrainian conflict for Kazakh agricultural producers are higher raw material prices, disruptions in logistics chains, and lower price competitiveness of Kazakh products, according to the findings of an expert survey (Figure 8). According to the majority of experts polled, there are prospects for the growth of the domestic agricultural product market presented by the sanctions resulting from the conflict between Russia and Ukraine. For instance, Kazakhstan can expand its agricultural export market and update existing markets by creating new regional integration as a result of the decline in shipments from Russia and Ukraine.

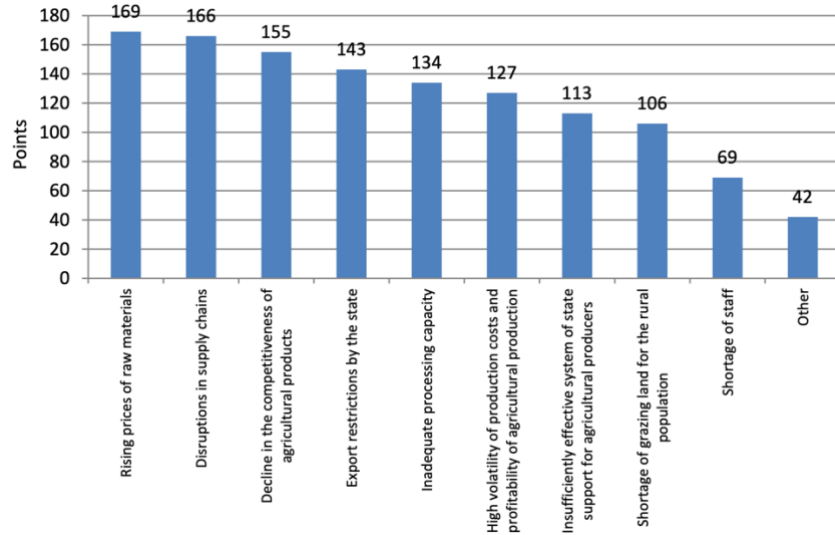


Figure 8 – The main risks of agricultural production in Kazakhstan associated with special operations in Ukraine

Source: Omarbakiyev et al. (2023)

Currently, global manufacturers like Rostselmash, Petersburg Tractor Plant (Russia), Gomelselmash, MTZ (Belarus), Lovol Heavy Industry, Yto Group Corporation (China), CLAAS Gmh (Germany), and SDF Group (Italy) have localized their production on Kazakhstani territory as a result of the introduction of measures to stimulate the agricultural machine-building industry. The agricultural machine-building industry continues to face issues related to high machinery depreciation rates, machinery utilization, subsidized investments in agricultural machinery renewal and interest rates, and the leasing of field machinery, even with the growth in the production of agricultural machinery for the national assembly. Lack of funding results in the upkeep of outdated machinery in poor shape, which lowers labor productivity and raises the price of agricultural produce (Kornilova et al., 2022).

At the moment, plant protection goods, agricultural machinery, and breeding and genetic resources are all heavily imported into Kazakhstan in order to support its agricultural output. The likelihood of a transportation blockade will lower the amount of agricultural and food products that Kazakhstan exports to the EU as well as the amount of imported goods and supplies available for agricultural production. Consequently, this could deter investment in this area and hinder the expansion of the agricultural sector. Kazakhstan must pursue a multivector integration program able to address critical issues in the areas of transportation and logistics, genetics and breeding development, and engineering development in order to guarantee food security.

2. Data and Methodology

2.1. Data Sources and Descriptive Statistics

2.1.1. Country and Regional-level Agricultural Data in Kazakhstan

Study Area. This thesis focuses on the Northern regions of Kazakhstan due to the predominant grain-producing regions of Kazakhstan located in the north, encompassing Akmola, Kostanay, Pavlodar, and North Kazakhstan regions. Farms in this region are characterized by their substantial size, with many exceeding 500,000 hectares. Agricultural production in these areas is heavily dependent on advanced machinery, fertilizer applications, and climatic factors.

Macroeconomic indicator – Labor data. Labor is a valuable macroeconomic indicator that provides insights into the economic structure, sectoral productivity, and development level of a country. To assess these aspects, we compile regional and national labor statistics, particularly focusing on employment within the agricultural sector and the proportion of the population engaged in agriculture. For this study, data on the number of people employed in agriculture was sourced from the Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan, spanning the years 2013 to 2022.

Land data. Kazakhstani agricultural land consists of cropland and pastures, measured in hectares. The distribution of sown areas significantly shapes the socio-economic policy of northern Kazakhstan, which focuses on the development of the agro-industrial complex and agriculture. Economic activities in these regions, particularly wheat production, are highly dependent on natural and climatic factors. In this study, the main focus was wheat, which is why we collected data from the Ministry of Agriculture of the Republic of Kazakhstan on the sown area specifically for this crop across all regions, spanning from 2013 to 2022 (Figure 9). Since the main production is primarily in the northern regions, only four out of 17 regions were chosen for the final model.

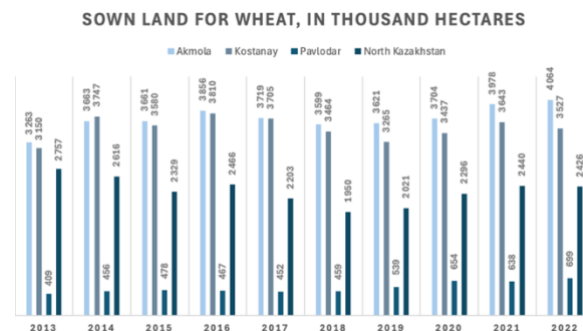


Figure 9 – Sown area for the production of wheat in the northern regions of Kazakhstan
Source: Own illustration based on the data from the MOA of the RK

The previous bar chart depicts the sown land for wheat in four regions of Kazakhstan—Akmola, Kostanay, Pavlodar, and North Kazakhstan—over the years from 2013 to 2022. The sown land area is measured in thousand hectares.

Some key observations from the bar chart above:

1. *Akmola Region:* The sown land area fluctuated but generally showed an upward trend over the period. The lowest area sown was in 2013 (3,263 thousand hectares) and the highest was in 2022 (4,064 thousand hectares).

2. *Kostanay Region:* This region also displayed some fluctuations but with a generally increasing trend. The smallest area sown was in 2013 (3,150 thousand hectares) and the largest was in 2016 (3,810 thousand hectares).

3. *Pavlodar Region:* Pavlodar had significantly smaller sown areas compared to Akmola and Kostanay. The region saw a general increase in the sown area from 2013 (409 thousand hectares) to 2022 (699 thousand hectares).

4. *North Kazakhstan Region:* This region had a consistent area of land sown, with some fluctuations. The lowest sown area was in 2018 (1,950 thousand hectares) and the highest was in 2013 (2,757 thousand hectares).

Overall, Akmola and Kostanay are the leading regions in terms of sown land for wheat, with both showing a steady increase over the years. Pavlodar, while having a smaller sown area, also showed growth, particularly notable from 2019 onwards. North Kazakhstan remained relatively stable with slight increases over the years.

Wheat yield data. Regional data on wheat yields (measured in tons per hectare) was obtained by examining annual sown land areas for this crop across all regions. Our focus was primarily on the four major wheat-producing regions (Akmola, Kostanay, Pavlodar, and North Kazakhstan), with wheat production data collected from the Information-Analytical System of the Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan, covering the period from 2013 to 2022 (Figure 10). This dataset aligns with information available on FAOSTAT, ensuring the accuracy of official reporting.

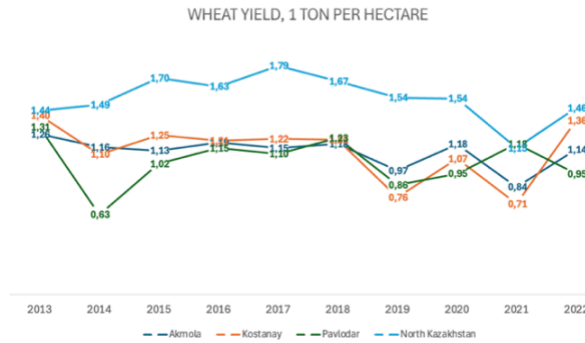


Figure 10 – Wheat yields in northern regions of Kazakhstan, in tons per hectare
Source: Own calculations based on the data from the Information-Analytical System of the Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the RK

The line chart depicts wheat yield (measured in tons per hectare) in four regions of Kazakhstan—Akmola, Kostanay, Pavlodar, and North Kazakhstan—from 2013 to 2022. Each line represents the yield trend for one of the regions over this period.

1. *Akmola (Dark Blue Line)*: Akmola had a fluctuating wheat yield trend. The lowest yield was recorded in 2021 at approximately 0.84 tons per hectare, while the highest was around 1.26 tons per hectare in 2013.

2. *Kostanay (Orange Line)*: Kostanay's yield showed more stability compared to the other regions, with fewer extreme fluctuations. The yield ranged from around 0.71 tons per hectare in 2021 to approximately 1.40 tons per hectare in 2013.

3. *Pavlodar (Green Line)*: Pavlodar displayed significant fluctuations in yield over the years. The yield was as low as around 0.63 tons per hectare in 2014 and peaked at about 1.31 tons per hectare in 2013.

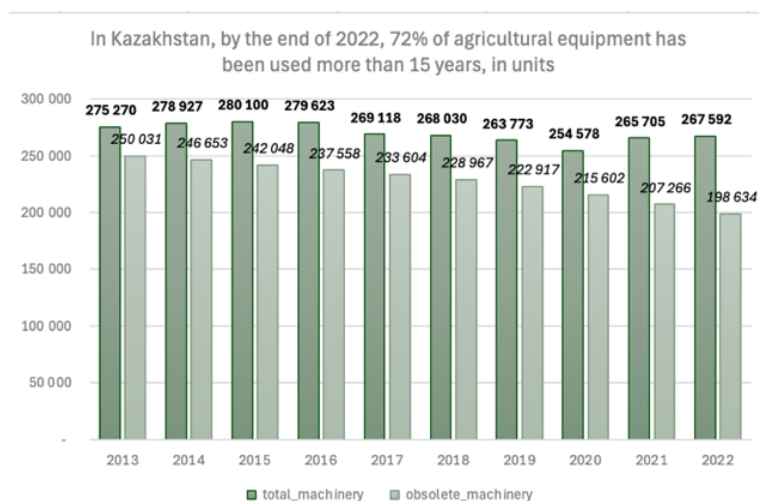
4. *North Kazakhstan (Light Blue Line)*: North Kazakhstan generally had the highest wheat yield among the four regions. The yield fluctuated, peaking at around 1.79 tons per hectare in 2017. The lowest yield recorded was approximately 1.15 tons per hectare in 2021.

All regions experienced fluctuations in wheat yield over the years, indicating variability in factors such as weather, growing conditions, and agricultural practices. Notably, in 2022, most regions except for Pavlodar saw an increase in yield compared to the previous years, suggesting potential improvements in agricultural techniques or favorable growing conditions.

Overall, North Kazakhstan consistently showed higher yields compared to the other regions, suggesting it might have more favorable conditions for wheat cultivation or more advanced

agricultural practices. While it leads in terms of yield, all regions show significant year-to-year variations, reflecting the dynamic nature of agricultural production in the region.

Obsolete capital data. The study also included data on the total number of available agricultural machinery (tractors, harvesters, and seeders), given their significant relevance to wheat production. We specifically examined obsolete machinery within Kazakhstan's agricultural sector due to the country's emphasis on renewing outdated equipment. To evaluate the impact of machinery that has been in use for over 15 years on wheat yields, data was requested and collected from the Ministry of Agriculture of the Republic of Kazakhstan, detailing the quantity and regional distribution of obsolete equipment (Figure 11).



*Figure 11 – Agricultural machinery park’s state (tractors, harvesters, seeders) of the RK
Source: Own illustration based on the data from the MOA of the RK*

The bar chart above provides information on the total number of agricultural machinery units and the number of obsolete machinery units in Kazakhstan from 2013 to 2022. The data shows the total number of machinery and the subset that has been in use for more than 15 years. The total number of agricultural machinery units remained relatively stable over the decade, with minor fluctuations. The highest number was in 2015 (280,100 units), and the lowest was in 2020 (254,578 units). The number of obsolete machinery units, defined as those used for more than 15 years, also showed some variation but generally trended upwards. The highest number was in 2013 (250,031 units), and the lowest was in 2022 (198,634 units). The percentage of obsolete machinery decreased over the years, from around 91% in 2013 to approximately 74% in 2022. Despite the total number of machinery slightly increasing or remaining stable, the portion of machinery classified as obsolete has decreased, indicating some renewal of the agricultural machinery fleet.

This chart underscores the critical issue of aging agricultural machinery in Kazakhstan, illustrating both the stability in the total number of machinery units and the decreasing trend in obsolete machinery over a decade. These insights are important for understanding the current state and progress in agricultural mechanization in the country.

Non-obsolete capital data. Recognizing the importance of machinery in the wheat production process, we distinguished between obsolete (over 15 years old) and non-obsolete (less than 15 years old) machinery to assess their respective impacts on wheat yields. The number of non-obsolete machinery was calculated by subtracting the quantity of obsolete equipment from the total number of agricultural machines (tractors, harvesters, and seeders) which is demonstrated as a share of renewing agricultural machinery in Figure 12.

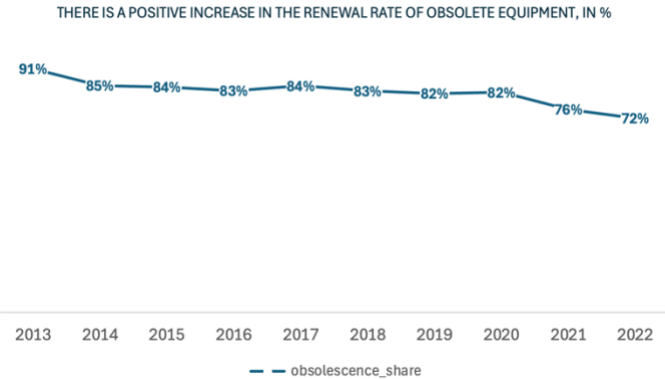


Figure 12 – Renewal rate of the agricultural machinery in the Republic of Kazakhstan
Source: Own calculations based on the data from the MOA of the RK

Fertilizers used data. To understand the impact of fertilizer application on wheat production, we collected detailed data on the quantities of fertilizers used in the agricultural process. Recognizing the crucial role that fertilizers play in enhancing crop yields, this data was sourced from the Ministry of Agriculture of the Republic of Kazakhstan. The dataset spans the period from 2013 to 2022 and is segmented by region, providing a comprehensive overview of fertilizer usage patterns across different parts of the country. This regional breakdown allows for a nuanced analysis of how fertilizer application correlates with wheat yields in various climatic conditions.

Producer prices and market power data. The "market power" variable was included in our analysis to explore its influence on wheat yields. Data on the prices received by local producers for 1 ton of wheat (in the local currency, KZT = Kazakhstani Tenge) was gathered from the Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the Republic of

Kazakhstan, covering the period from 2013 to 2022 across all regions. To assess the market power of Kazakhstani wheat producers relative to global producers, we also collected worldwide producer price data in Euros. By converting the local currency to Euros using the official exchange rates provided by Kazakhstani Halyk Bank, we calculated the ratio of local prices to global prices. This ratio served as a measure of the local market's power in comparison to the international market, Figure 13, the results are the same as in the study by Omarbakiyev et al. (2023).

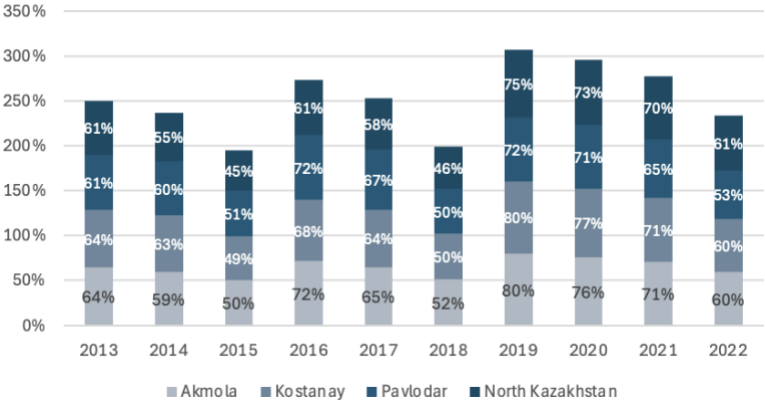


Figure 13 – Market power of the northern regions producers relative to the world producers
Source: Own illustration and calculations based on the data from the Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan

Climate data. Temperature data in Celsius (°C) was obtained from the annual reports of the national hydrometeorological service RSE "Kazhydromet," the sole legally authorized body to provide official meteorological information in Kazakhstan. We extracted data on the number of extremely hot days (with air temperatures exceeding 35°C) from the annual bulletins monitoring climate change in Kazakhstan spanning from 2013 to 2022. Since wheat production thrives at temperatures between 15-21°C, we focused on the northern regions of Kazakhstan, which are known for their favorable conditions for wheat cultivation. Unfortunately, the official bulletins did not provide annual or seasonal average temperature data for any regions. Consequently, the number of days with temperatures above 35°C was used as the primary indicator of hot weather's impact. It is important to note that such high temperatures are rare in northern Kazakhstan.

Table 1 and Table 2 demonstrate the descriptive statistics for the key variables involved in the analysis of wheat yield in the four major wheat-producing regions in Northern Kazakhstan. The table includes the mean, standard deviation (SD), minimum (Min), maximum (Max), and median values for each variable. Here's a detailed description of each variable and its statistics:

Table 1 – Variable description and definition for the regression model

Variable	Definition
Wheat Yield	Yield of wheat, t/ha
Sown Area	Sown area for wheat, ha
Labor	People employed in agriculture, in absolute terms
Obsolete Machinery	Obsolete agricultural machinery, in absolute terms
NON-Obsolete Machinery	NON-obsolete agricultural machinery, in absolute terms
Fertilizers Used	Quantity of fertilizers used (100kg/ha)
Temperature Above 35°C	Days with temperature above 35°C, in absolute terms
Market Power	Ratio of local producer prices for wheat over world wheat prices, in percent

Source: Own representation.

Table 2 represents descriptive statistics for key variables related to wheat production in the four northern regions over the period under study (for each region’s descriptive statistics please refer to **Appendix A** and **Appendix B**). Below is a detailed description of each variable's statistics:

Table 2 – Descriptive statistics for the chosen four northern regions

Variable	Mean	SD	Min	Max	Median
Wheat Yield	1.21	0.27	0.63	1.79	1.18
Sown Area	2569465.62	1330840.42	391900.00	4063703.20	3104260.40
Labor	179162.50	8836.40	160000.00	199000.00	199000.00
Obsolete Machinery	35716.67	7745.73	20895.48	46951.76	38429.26
NON-Obsolete Machinery	6796.35	2582.81	2365.00	13364.00	6880.00
Fertilizers Used	853.82	806.99	0.20	2788.12	712.33
Temperature Above 35°C	6.10	4.09	0.00	15.00	5.00
Market Power	0.63	0.10	0.45	0.81	0.64

Source: Own calculations.

The average wheat yield in these regions is 1.21 tons per hectare, with a standard deviation of 0.27, indicating moderate variability. The yield ranges from 0.63 to 1.79 tons per hectare, with a median of 1.18, showing a slight skew towards higher yields.

The average sown area is approximately 2.57 million hectares, with significant variability as shown by the standard deviation. The sown area ranges from 391,900 to over 4 million hectares, with a median value around 3.1 million hectares, highlights the disparity in agricultural land use across different regions. The labor force in the agricultural sector of these regions is fairly stable and averages around 179,162 people, with relatively low variability (SD = 8,836.40).

The number of people employed ranges from 160,000 to 199,000, with the median at the upper end of this range. On average, there are about 35,717 units of obsolete machinery, with considerable variability (SD = 7,745.73).

The number of obsolete machinery units ranges from 20,895 to 46,952, with a median of 38,429. The obsolete machinery data suggests that a significant proportion of agricultural equipment is outdated, which could impact productivity. Conversely, the presence of non-obsolete machinery varies widely, reflecting differing levels of modernization across regions. The regions have an average of 6,796 units of non-obsolete machinery, with a range from 2,365 to 13,364 units and a median value of 6,880.

Fertilizer usage shows a high degree of variation, indicating diverse agricultural practices or resource availability. The average quantity of fertilizers used is 853.82 tons, with high variability (SD = 806.99). The usage ranges from 0.20 to 2,788.12 tons, with a median of 712.33 tons.

Temperature data suggests that extreme heat events, while present, are relatively infrequent, which is critical for regions reliant on favorable climatic conditions for wheat production. On average, these regions experience about 6.10 days per year with temperatures exceeding 35°C, with variability indicated by a standard deviation of 4.09. The number of very hot days ranges from 0 to 15, with a median of 5 days.

Finally, the market power, measured as the ratio of local to world producer prices, averages 0.63, indicating that local wheat prices are generally lower than world prices, which could influence their production decisions. The ratio varies from 0.45 to 0.81, with a median of 0.64.

These statistics provide a comprehensive overview of the agricultural environment in the four northern regions, highlighting key factors such as yield, labor, agricultural machinery, fertilizer usage, temperature, and market dynamics that can influence wheat production. They provide a foundational understanding of the variables affecting wheat production in Northern Kazakhstan and are crucial for further regression analysis to determine the impact of each factor on wheat yield.

2.2. Methodological Approach

2.2.1. Research Design

This section explains in detail the methods. The impact of obsolete machinery on the agricultural productivity of wheat yields was measured by several theoretically motivated independent and control variables.

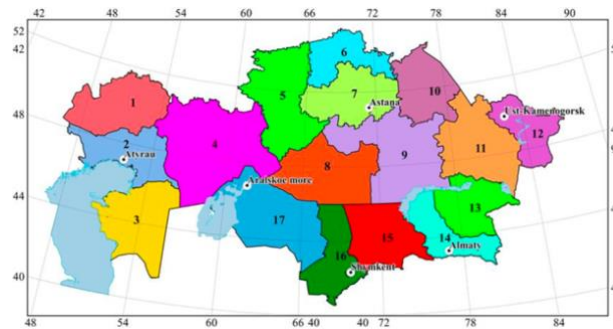
Improving capital inputs is crucial to promoting agriculture. This study selects the balanced panel data of four major wheat-producing regions in Kazakhstan with the 10-year time series from 2013 to 2022 and uses the fixed-effects model to discuss the impact of capital inputs on agricultural productivity. Initially, we considered a comprehensive model covering all 17 regions of Kazakhstan for 10 years, encompassing 170 variables in the dataset. However, upon estimating this model, we observed that the results were not specifically focused on the major wheat-producing regions. This lack of focus led to significant results being diluted across all regions, thus failing to highlight the primary areas of interest. To address this issue, we refined our approach by excluding non-major wheat-producing regions. Specifically, 13 regions that did not significantly contribute to wheat production were excluded, resulting in a reduction of variables from 170 to 40. This refinement ensured that the model remained coherent and focused on the primary wheat-producing regions, providing more precise and relevant insights. By refining the dataset to include only the major wheat-producing regions, the model focuses on the areas that are most relevant for wheat production. This approach ensures that the significant results are not spread thinly across all regions but are concentrated where they matter most. Moreover, the exclusion of non-major wheat-producing regions reduces noise in the data, leading to more precise and reliable estimates of the effects of the explanatory variables on wheat yields. As a result, the total number of observations for the chosen regions in this time period in our final dataset is 40.

Agricultural inputs can significantly promote agricultural productivity in some regions while their absence can hinder the improvement. By letting the model depend on the inputs such as the number of agricultural machinery and other explanatory variables like total sown area, fertilizers, and population employed in agriculture, and control variables such as climate (days with 35°C and hotter), market power, and a dummy for the year with the introduction of quotas on export, we may estimate the input productivity. The final model looked as the following:

$$\log(WY_{it}) = \alpha_i + \beta_1 \log(SA_{it}) + \beta_2 \log(L_{it}) + \beta_3 \log(OM_{it}) + \beta_4 \log(NOM_{it}) + \beta_5 \log(F_{it}) \\ + \beta_6 T_{it} + \beta_7 M_{it} + \beta_8 y22_{it} + u_{it}$$

- α_i represents the individual-specific effects.
- β_1 to β_8 are the coefficients (elasticities) of the respective variables.
- $\log(WY_{it})$ – logarithm of the wheat yields
- $\log(SA_{it})$ – logarithm of the sown area for wheat
- $\log(L_{it})$ – logarithm of the labor, population employed in agriculture
- $\log(OM_{it})$ – logarithm of the obsolete machinery (tractors, harvesters, and seeders)
- $\log(NOM_{it})$ – logarithm of the NON-obsolete machinery (tractors, harvesters, and seeders)
- $\log(F_{it})$ – logarithm of the fertilizers used for the wheat production
- T_{it} – number of very hot days with the temperature above 35°C degrees
- M_{it} – regional wheat market power over global wheat market
- y_{22} – dummy for the year 2022 due to the introduction of the quotas for imports and exports of wheat
- u_{it} is the idiosyncratic error term.

Since our main focus is the impact of obsolete machinery on agricultural productivity, we look at the distributions of outdated equipment (tractors, harvesters, seeders) within 4 major wheat-producing regions (Akmola, Kostanay, Pavlodar, North Kazakhstan). Figure 14 shows the distribution of all 17 regions throughout The Republic of Kazakhstan (we focus only on the northern regions, such as 5,6,7,10). Then, Figure 15 demonstrates the distribution of outdated machinery within these four regions from 2013 to 2022.



- | | |
|---------------------------|---------------------------|
| 1 West Kazakhstan region | 10 Pavlodar region |
| 2 Atyrau region | 11 Abay region |
| 3 Mangistau region | 12 East Kazakhstan region |
| 4 Aktobe region | 13 Almaty region |
| 5 Kostanay region | 14 Zhetisu region |
| 6 North Kazakhstan region | 15 Zhambyl region |
| 7 Akmola region | 16 Turkestan region |
| 8 Ulytau region | 17 Kyzylorda region |
| 9 Karagandy region | |

Figure 14 – Scheme of administrative-territorial division of the Republic of Kazakhstan

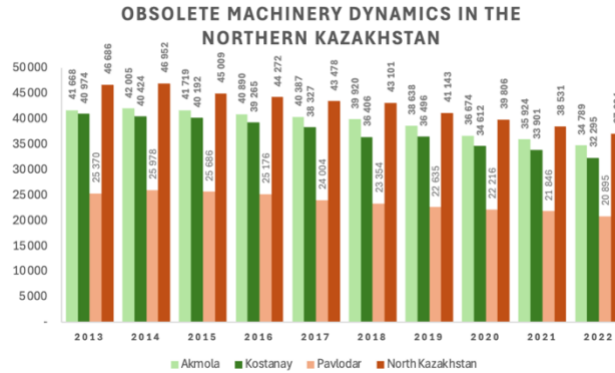


Figure 15 – Outdated machinery (tractors, harvesters, seeders) in Northern Kazakhstan
 Source: Own illustration based on the data from the MOA of the RK

Given that we have balanced panel data (multiple observations for the same regions over time), using fixed effects is a natural choice. The main reasons for choosing this method are the following (Baltagi B., 2008; Greene, 2012; Wooldridge, 2002):

1. Control for Unobserved Heterogeneity: Fixed effects models control for unobserved variables that differ across regions but are constant over time. This approach removes the bias caused by these time-invariant factors, ensuring that the effects we are measuring are more accurately attributed to the variables of interest (e.g., fertilizer use, machinery, temperature).

2. Focus on Within-Entity Variation: Fixed effects models focus on variations within regions over time. This is particularly useful for understanding how changes in the explanatory variables (e.g., the introduction of non-obsolete machinery, changes in fertilizer use, temperature fluctuations) affect wheat yield within the same region. Also, it can provide insights into how regional policies or interventions might impact wheat production within specific regions, helping tailor policy recommendations.

3. Consistency with Data Structure: Since the data spans from 2013 to 2022 across multiple regions, fixed effects help in making valid inferences by comparing each region to itself over time, thus controlling for regional fixed characteristics.

Overall, using fixed effects is justified in this study because the four dummy variables acting as "fixed effects" have indeed a fixed interpretation. The four regions of Kazakhstan under study stay the same for a long period. From a statistical viewpoint, if we were to draw a new sample, these four dummy variables would remain the same number of columns with the same interpretation, i.e. they are "fixed regressors" in the true sense of the word. Hence the fixed effects are part of the specification design, not just an estimation choice.

2.2.2. Variables Used in the Fixed Effects Model

The dependent variable in this study is total wheat production, which includes both spring and winter wheat. The most important variable in the research is the agricultural machinery. It has long been believed that one of the key components of economic progress is agricultural modernization, which is evident in the transition from conventional, labor-intensive methods to contemporary, input-intensive ones (Johnston & J. W. Mellor, 1961; Schultz, 1968; Gollin et al., 2007). One of the most important technological advancements in food production, urbanization, and industrialization is agricultural machinery, which preserves agricultural labor forces (Meng et al., 2024). According to theoretical models such as the agricultural treadmill theory, human capital theory, and induced innovation theory (Balogh & Schultz, 1964; Brinegar & Cochrane, 1958; Hallett et al., 1972; Hume, 1907; Reder & Hicks, 1965), technological innovation has a substantial beneficial impact on economic growth. Subsequent empirical research has concentrated on many specialized technologies, such as seed, irrigation, fertilizer, and, most importantly for us, machinery (McArthur & McCord, 2017; as well as Smale et al., 2018; Yang et al., 2013; Zhang et al., 2017).

Farming machines in this study are classified into different types according to their condition: obsolete and non-obsolete. According to a study by Mel'nikov et al. (2020), a harvester becomes obsolete after 10 years of usage (Figure 16). Following this, we collected data on the agricultural machinery which have been in use for more than 15 years, since this was the threshold year for the MOA of the RK.

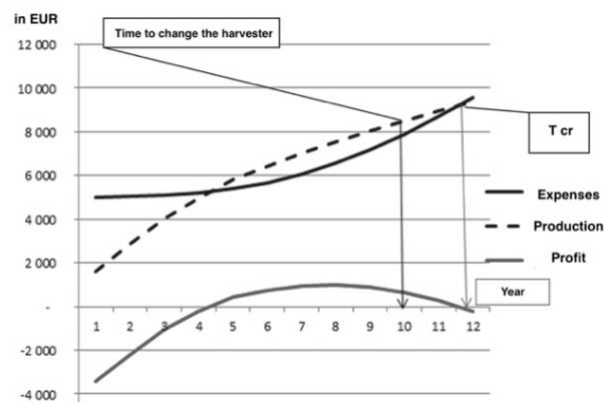


Figure 16 – Theoretical "point of obsolescence" of a harvester and when it should be replaced
Source: Mel'nikov et al. (2020)

Other important explanatory variables are the labor input represented by the number of people employed in agriculture, the land acreage is defined as the sown area of wheat. Meanwhile, the mineral fertilizer was collected as already converted to a pure substance equivalent.

Control variables can be divided into three types. The first part is an agroecological variable such as extremely hot days with the air temperature above 35°C. Wheat production is sensitive to temperature extremes. High temperatures can negatively impact crop yields. By including this variable, the model accounts for the adverse effects of extremely hot days on wheat production, ensuring that the influence of other variables is not confounded by weather conditions. The second part is the market power defined as the ratio of local producer prices for wheat to world producer prices. It serves as a proxy for the economic environment and profitability expectations of local producers. By including market power, we control for the influence of relative price levels on production decisions. Higher local prices relative to world prices might incentivize producers to increase production, while lower prices could discourage it.

The third, and last type is the dummy for the year 2022 due to the introduction of quotas on wheat exports and imports. In Kazakhstan, there have been restrictions and regulations implemented in recent years to protect the domestic market and support local farmers. Year dummy variable captures time-related factors which in our case are the policy changes that might affect wheat production uniformly across regions. Kazakhstan imposed wheat export quotas starting in April of 2022 primarily to ensure domestic food security amid a global surge in food prices. The decision was influenced by several interconnected factors, including disruptions in global supply chains due to the COVID-19 pandemic, rising energy costs affecting transportation and agricultural production, and geopolitical tensions, particularly the Russia-Ukraine conflict, which disrupted grain exports from major producing regions. Domestically, rising food prices threatened affordability and accessibility for vulnerable populations, and there were concerns about potential shortages of essential food commodities. By limiting wheat exports, the government aimed to stabilize domestic prices and ensure sufficient wheat supplies for consumption. Additionally, measures to restrict imports were implemented to protect local farmers from the competition and address concerns about unofficial wheat channel imports called “grey schemes”, particularly from neighboring Russia, which could distort the market and harm local producers. That is why, including this year dummy helps isolate the impact of other variables by controlling for yearly fluctuations.

There is an ongoing debate among scientists regarding the potential impacts of climate change on agricultural production. Due to the complexity of natural processes associated with climate change, making accurate qualitative forecasts is challenging. However, many experts predict that climate change could lead to an increase in adverse events affecting agricultural production, such as more frequent droughts. In order to adjust agricultural production to climate change, it is essential to comprehend the weather signal in crop yield changes. Weather has historically been able to explain around one-third of the variability in global agricultural yields, with severe extreme weather events having the greatest impact on food systems. According to a meta-analysis of the effects of climate change on crops (Challinor et al., 2014), global warming would reduce yields globally, with yields declining on average by 4.9% for every 1°C increase in temperature T_t . In the study by Heino et al. (2023), out of the crops studied, wheat showed the strongest sensitivity to co-occurring climate extremes at the global level **Appendix C**. In order to work toward global food security, it is essential to have a thorough understanding of climate-induced food shocks. The findings represent a significant advancement in our knowledge of the impact of co-occurring extreme events on the production of food crops worldwide. Global initiatives should assist farmers in adapting to weather extremes in addition to lowering emissions that contribute to climate change, as the likelihood of agricultural output declining due to dry and hot weather has increased. As a case for Kazakhstan, the analysis by Kusainova et al. (2020) revealed a positive correlation between high-yielding years with a lower summertime temperature, which is characteristic for the steppe and forest-steppe regions of Northern Kazakhstan, and low-yielding years with a higher summertime temperature and less moisture. That is why, for the prevalence of extreme conditions, following Heino et al. (2023) we collected the number of very hot days (above 35°C) during the wheat growing season in the regions where wheat is largely produced.

3. Results and Discussions

This regression model tried to investigate how the variations in the dependent variable wheat yield could be explained by the chosen independent variables such as the sown area for wheat, labor (population employed in agriculture), the number of obsolete machinery (more than 15 years old), the number of non-obsolete machinery (less than 15 years old), the quantity of fertilizers used, the number of very hot days above 35°C, the market power of local producer prices relative to the world wheat prices, and a dummy for the year 2022 due to the introduction of quotas on wheat exports and imports. The outcomes covering a period of 10 years from 2013 to 2022 were the following (*See Table 3*):

Table 3 – Regression results of the final model

Balanced Panel: n = 4, T = 10, N = 40

Variable	Estimate	Std. Error	t-value	p-value
log_sown_area	0.2175121	0.1559200	1.3950	0.173977
log_labor	0.2299901	0.5401420	0.4258	0.673512
log_obsolete_machinery	-1.3862099	0.4607890	-3.0083	0.005503 **
log_NON_obsolete_machinery	0.3381839	0.1366641	2.4746	0.019664 *
log_fert_use	-0.0185236	0.0161092	-1.1499	0.259922
T_above_35	-0.0599487	0.0084354	-7.1068	9.865e-08 ***
market_power	-0.3655915	0.2184628	-1.6735	0.105372
y22	-0.1309646	0.0892417	-1.4675	0.153377
Observations	40			
Total Sum of Squares:	1.1563			
R-squared:	0.75477			
Adjusted R-squared:	0.65843			
F-statistic:	10.7722 on 8 and 28 DF			
p-value:	8.8814e ⁻⁰⁷			

Source: Own calculations and representation.

*Significance levels: * p < 0.1; ** p < 0.05; *** p < 0.01*

The independent variables used in the right-hand side of the model explain 75,5% of the variance in the dependent variable on the left-hand side, which is the wheat yields, and overall, the model is significant with a p-value of $8.8814e^{-07}$.

The coefficient result for obsolete machinery is -1.3862099, indicating a negative relationship between obsolete machinery and wheat yield. For a 1% increase in obsolete machinery, the log of wheat yield decreases by approximately 1.386%. The p-value is 0.005503, which is less than 0.01, making it statistically significant at the 1% level. This suggests that the effect of obsolete machinery on wheat yield is not due to random chance. The implication could be that the use of obsolete machinery negatively impacts wheat yield, which could be due to inefficiencies and lower productivity associated with older equipment, therefore, farmers should not use outdated machinery in the production process.

On the other hand, the coefficient for non-obsolete machinery is 0.3381839, indicating a positive relationship between non-obsolete machinery and wheat yield. For a 1% increase in non-obsolete machinery, the log of wheat yield increases by approximately 0.338%. The p-value is 0.019664, which is less than 0.05, making it statistically significant at the 5% level. This suggests that the positive effect of non-obsolete machinery on wheat yield is statistically significant. The result implies that investing in and using up-to-date machinery positively impacts wheat yields, likely due to higher efficiency, better technology, and improved productivity. Therefore, with the purchase of new equipment (tractors, harvesters, and seeders) the farmers can improve the productivity of their production while those using outdated machinery deteriorate the yields. This finding suggests that modernizing machinery could potentially improve wheat yields.

There is a strong negative relationship between temperatures above 35°C and wheat yield as the coefficient for this variable is -0.0599487. For each additional day above 35°C, the log of wheat yield decreases by approximately 0.06%. The p-value is $9.865e-08$, which is much less than 0.01, making it highly statistically significant at the 1% level. This indicates that the impact of high temperatures on wheat yield is very unlikely to be due to chance. This implies that higher temperatures above 35° have a detrimental effect on wheat yield, likely due to heat stress affecting and reducing the growth and development of wheat plants. This finding highlights the importance of considering climate factors and possibly implementing measures to mitigate the impact of high temperatures on crop yields.

Despite being not statistically significant, another worth-mentioning result is the negative coefficient of the market power which is -0.3655915, signifying a negative relationship between local wheat producers' market power and wheat yield. This means that as market power increases by 1%, the log of wheat yield decreases by approximately 0.366%. The p-value for market power is 0.105372, which is greater than 0.05, indicating that the coefficient is not statistically significant at the 5% level. However, it is close to being significant, suggesting that there may be a potential impact that warrants further investigation. The negative coefficient suggests that farmers with more market power might produce less wheat. This can be explained by the following economic behaviors:

Market Power: Market power refers to the ability of farmers or agricultural firms to influence the price of their products. Farmers with substantial market power may not need to maximize their production to achieve their financial goals. They can influence prices by controlling supply and maintaining higher prices through reduced output. This might lead to decisions that are not purely focused on maximizing output.

Price Control: With significant market power, farmers might deliberately limit wheat production to keep prices high, thus ensuring higher revenue per unit of wheat sold. By controlling production and keeping supply lower, farmers with market power can ensure that prices remain elevated, which can lead to higher overall revenue despite producing less. This strategy can be beneficial in avoiding market saturation and maintaining profit margins.

Financial Stability: Farmers with more market power often have better financial stability. They do not rely solely on high production volumes to sustain their income, allowing them to produce less and still remain profitable. If farmers have enough financial resources and do not need to produce more to meet their economic needs, they might deliberately limit production to maintain high prices. This can lead to a situation where production levels are kept below what they could be in a more competitive market.

Summary of Key Factors and Their Impacts: *Negative Impact on Wheat Yield (-):*

Obsolete Machinery: Older, inefficient equipment reduces productivity.

High Temperatures (above 35°C): Heat stress adversely affects crop growth and yield.

Market Power: Farmers may restrict production to keep prices high, reducing overall yield.

Positive Impact on Wheat Yield (+):

Non-Obsolete Machinery: Modern, efficient equipment enhances productivity and yield.

The significant negative impacts of obsolete machinery and high temperatures on wheat yield highlight the need for modernizing agricultural practices and addressing climate-related challenges. The positive impact of non-obsolete machinery underscores the benefits of investing in up-to-date technology. Although the impact of market power is not statistically significant, the negative coefficient aligns with economic theories suggesting that farmers with sufficient resources might limit production to maintain higher prices. This strategic behavior, while rational from a revenue-maximization perspective, can have broader implications for food supply and market dynamics.

The scatter plot in Figure 17 titled "Actual vs Predicted Values" compares the actual log-transformed wheat yield (x-axis) against the predicted log-transformed wheat yield (y-axis). The red line represents the line of best fit, indicating a strong linear relationship between the actual and predicted values. Most of the data points are clustered near the line, suggesting that the model's predictions are generally accurate. However, there are some points that deviate further from the line, indicating instances where the model's predictions differ more significantly from the actual values, indicating that the model's predictions are not perfect. The upward slope of the line suggests a positive correlation, meaning that as the actual wheat yield increases, the predicted yield also tends to increase. Overall, the plot suggests that the model is effective at predicting log-transformed wheat yields, as evidenced by the strong linear relationship. This suggests that, with more data points, the coefficients would indeed become more and more significant. The equation is especially effective around the average levels of wheat yields, only some points far from the average are poorly predicted.

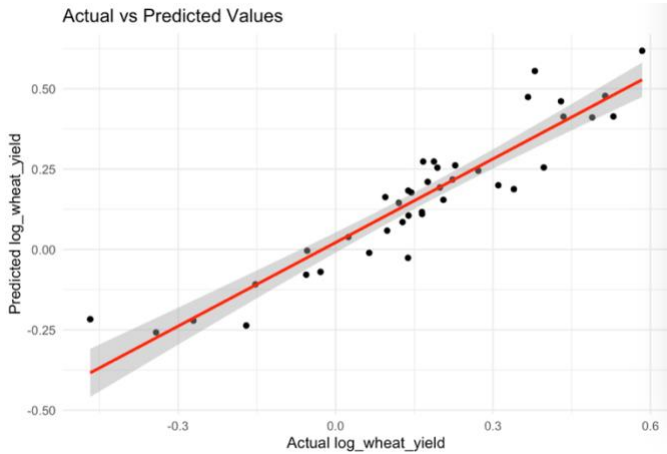


Figure 17 – The plot of actual and predicted values by our model
Source: Own calculations and representation.

Conclusion

This thesis investigated the impact of market structure and capital obsolescence on wheat productivity within four major wheat-producing regions in the Republic of Kazakhstan using data from the Ministry of Agriculture of the Republic of Kazakhstan and the Information-Analytical System of the Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan. A set of theoretically motivated explanatory variables of agricultural inputs such as sown land, labor, fertilizers, farmers' machinery, and control variables such as producers' market power, climate, and policy change were utilized for the Fixed Effects model to explore their impacts on wheat yields. Using fixed effects is justified in this study because it allows to control for unobserved, time-invariant differences between regions and focuses on within-region changes over time. The collected data incorporates the biggest wheat-producing regions in the country located in the North of Kazakhstan which have favorable weather conditions for growing this crop and captured the time period of ten years from 2013 to 2022.

The findings in this study highlight the important role that obsolete capital plays in fostering agricultural productivity, particularly in the context of wheat production in Kazakhstan. Throughout the years, despite the total number of agricultural machinery slightly increasing or remaining stable, the portion of machinery classified as obsolete has decreased, indicating some renewal of the agricultural machinery fleet. The research shows that wheat yield is significantly and negatively impacted by obsolete machinery and high temperatures, underscoring the necessity of updating agricultural practices and tackling climate-related issues. The results displayed the deteriorating impact of outdated machinery such as tractors, harvesters, and seeders on the production of both winter and spring wheat by decreasing their yields. The negative influence of high temperatures on wheat yield highlights the vulnerability of wheat to climate conditions. The advantages of investing in modern technology are shown by the significant positive effects of non-obsolete machinery that is in use on wheat yield. Moreover, the negative coefficient of market power is consistent with economic theories that imply farmers with sufficient resources may restrict production in order to maintain higher prices, even when the impact of market power is not statistically significant. Although this strategic action makes sense from the standpoint of maximizing revenue, it may have wider effects on the dynamics of the food supply and the market.

Understanding the economic and environmental trade-offs of replacing obsolete machinery is an important area that warrants further investigation. The impact of varying levels of capital obsolescence depending on their conditions, age, and maintenance of those machinery present a fertile ground for future research that is crucial for understanding the broader implications on food security and economic stability. Additionally, future research could examine the policy implications of capital obsolescence, particularly how government interventions, such as subsidies for new equipment or incentives for proper maintenance, could mitigate the adverse effects of aging machinery on agricultural output.

In conclusion, the study's findings underscore the importance of addressing capital obsolescence in the agricultural sector, not only to enhance productivity but also to ensure long-term sustainability and food security.

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Appendices

Appendix A

Table 4 – Descriptive Statistics for the Akmola Region

Variable	Mean	SD	Min	Max	Median
Wheat Yield	1.12	0.12	0.84	1.26	1.15
Sown Area	3766121.68	156002.44	3598995.30	4063703.20	3711663.60
Labor	173650.00	14282.95	160000.00	199000.00	171500.00
Obsolete	39261.26	2623.30	34788.71	42005.22	40153.45
Machinery					
NON-Obsolete	7583.64	2341.22	4061.00	12381.00	7014.00
Machinery					
Fertilizers Used	1178.11	684.41	45.08	2494.25	1086.21
Temperature	5.60	4.35	0.00	15.00	4.00
Above 35°C					
Market Power	0.65	0.10	0.50	0.80	0.65

Source: Own calculations.

Table 5 – Descriptive Statistics for the Kostanay Region

Variable	Mean	SD	Min	Max	Median
Wheat Yield	1.13	0.23	0.71	1.40	1.21
Sown Area	3619244.98	213511.06	3264620.80	4014400.00	3611475.85
Labor	181800.00	5181.16	175000.00	189000.00	183000.00
Obsolete	37289.19	3014.94	32295.31	40974.26	37411.31
Machinery					
NON-Obsolete	7423.70	2021.06	4222.00	11511.00	7053.00
Machinery					
Fertilizers Used	608.31	370.29	166.95	1421.14	536.97
Temperature	5.60	4.60	0.00	15.00	4.00
Above 35°C					
Market Power	0.65	0.10	0.49	0.81	0.64

Source: Own calculations.

Appendix B

Table 6 – Descriptive Statistics for the Pavlodar Region

Variable	Mean	SD	Min	Max	Median
Wheat Yield	1.04	0.20	0.63	1.31	1.06
Sown Area	523380.69	104155.10	391900.00	698960.10	472400.00
Labor	179700.00	6412.66	172000.00	188000.00	181500.00
Obsolete Machinery	23716.07	1793.64	20895.48	25978.14	23678.81
NON-Obsolete Machinery	4023.50	1194.40	2365.00	6502.00	3689.50
Fertilizers Used	34.27	32.18	0.20	94.43	28.00
Temperature Above 35°C	8.00	3.97	0.00	15.00	8.50
Market Power	0.62	0.09	0.51	0.72	0.63

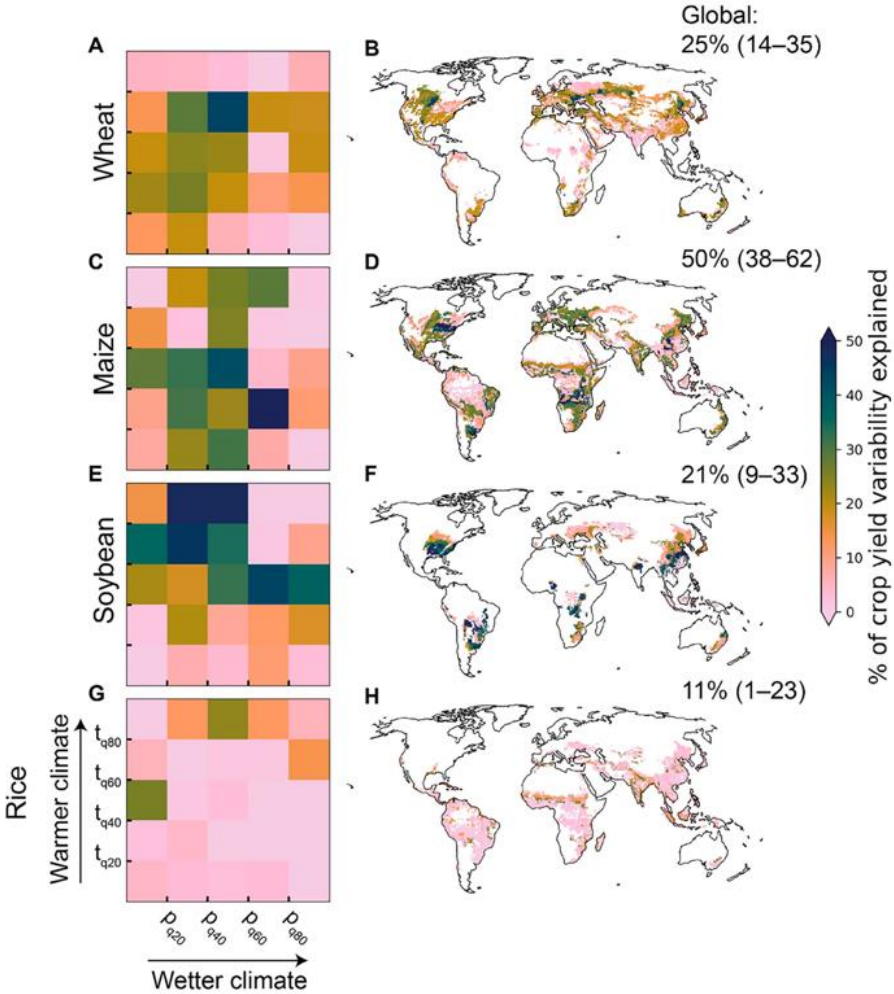
Source: Own calculations.

Table 7 – Descriptive Statistics for the North Kazakhstan Region

Variable	Mean	SD	Min	Max	Median
Wheat Yield	1.54	0.18	1.15	1.79	1.54
Sown Area	2369115.12	286957.48	1949573.70	2943900.00	2377375.60
Labor	181500.00	4301.16	175000.00	186000.00	182000.00
Obsolete Machinery	42600.14	3380.08	37024.26	46951.76	43289.59
NON-Obsolete Machinery	8154.80	2489.10	4538.00	13364.00	7508.50
Fertilizers Used	1594.58	821.98	95.92	2788.12	1537.25
Temperature Above 35°C	5.20	3.36	1.00	13.00	5.00
Market Power	0.60	0.10	0.45	0.75	0.61

Source: Own calculations.

Appendix C



Source: Heino et al. (2023)

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Faculté des bioingénieurs

Croix du Sud, 2 bte L7.05.01, 1348 Louvain-la-Neuve, Belgique | www.uclouvain.be/agro