Staff Consultant's Report

February 2021

Study of the COVID-19 Impact on the Economy of Kazakhstan

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For Asian Development Bank

Asian Development Bank

Acknowledgements

This report was written by Zhanybek Aigazin and prepared under a staff consultancy engagement with the Asian Development Bank to analyze the impact of the COVID-19 crisis on Kazakhstan's economy. Genadiy Rau, Economics Officer from Kazakhstan Resident Mission of ADB, provided overall guidance and contributed valuable comments.

The report also benefited from the constructive inputs of Dias Kumarbekov, Rustam Bekishev, Yevgeniya Pak and from an overview of international experience in modeling the influence of external shocks on the macroeconomic parameters prepared by Gulmira Issimbayeva.

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Executive Summary

The first COVID-19 outbreak occurred in December 2019. There were more than 99 million cases of infection and more than 2 million fatalities around the world at the time of writing. Early in 2020, many countries introduced quarantine regulations, restricted international and domestic movements, placed restrictions on many businesses, and other measures that could reduce direct human contact. In Kazakhstan, the first COVID-19 infection occurred in March 2020. At present, there are more than 170 thousand cases and two thousand fatalities. Some restrictive measures are still in place in Kazakhstan.

The consequences of these restrictions have a negative impact on economic activity. The second quarter of 2020 revealed a significant downturn in economic activity around the world, as well as in Kazakhstan. To assess the development of Kazakhstan's economy, this study presents the results of a macroeconomic forecast taking into account the consequences of the COVID-19 pandemic in the short- and long-term.

The objectives of this study are to:

1. Review and analyze international experience in combating the economic impact of the pandemic,
2. Build a forecasting model,
3. Collect data,
4. Conduct a regression analysis, and
5. Model the impact of COVID-19 on the economy of r Kazakhstan.

This report consists of two parts, i) an analysis of Kazakhstan's economy from the supply and demand side, and ii) an analysis of the impact of COVID-19 on the economy.

Part one presents the theoretical foundations and practical aspects of the forecasting model, taking into account current socio-economic events in Kazakhstan based on the data for aggregate demand, aggregate supply, foreign trade and investment, the social sphere, public finance, monetary policy, and business development conditions in 2000–2019, as well as the construction of a model to assess the impact of the COVID-19 shock on individual sectors of the economy based on the Cobb-Douglas function.

The second part describes the direct impact of COVID-19 on the economy of Kazakhstan.

A. Theoretical base and practical aspects of the forecasting model

A.1 The theoretical base for the forecasting model

1. The theoretical basis of the model is a Keynesian-Neoclassical synthesis, which offers more realistic assumptions compared to purely Keynesian theories.

2. The term ‘Keynesian-Neoclassical synthesis’ was introduced by Paul Samuelson in the mid-1950s to describe a compromise that had emerged from economic schools of thought in the United States driven by the need to develop economic theory. In particular, the Keynesian economic theory suffered from a fundamental flaw, i.e. the lack of microeconomic foundations for model building. The weakness of the neoclassical theory was the assumption of perfect competition. Economists who adopted the Keynesian-Neoclassical synthesis were able to overcome the disadvantages of each by combining the two schools of thought.

3. The main assumptions of Keynesian-Neoclassical synthesis used in this study are:

I. Markets for goods and resources are markets of imperfect competition.
II. Prices of goods and factors of production are not sufficiently flexible for an economy to adapt to changes in market conditions in the short-term. However, in the long-term, prices and wages eventually bring markets into balance.
III. The leading force in market conditions is an aggregate demand in the short-term and an aggregate supply in the long-term.

4. The use of the Keynesian-Neoclassical synthesis as a theoretical basis makes it possible to construct a model of aggregate demand based on the main macroeconomic identity and a model from the supply side based on the Cobb-Douglas production function. At the same time, the use of the main macroeconomic identity makes it possible to connect the model of supply and demand through the identity Investment=Savings, reflecting the formation of fixed capital.

A.2 Structural and behavioral model

5. Jamir (2020) projected India's GDP growth after the COVID-19 pandemic. The results show that India's GDP growth rate will decrease by 6.09%, 5.42% and 5.3% in 2020, 2021, and 2022. Quarterly GDP data for 10 years (Q1 2010–Q1 2020) was used for the short-term forecast until the end of 2021. The methodology included the ARIMA model based on an analysis of one-dimensional time series data.

6. Khan and Ahmad (2020) predicted China's economic growth for 2020–2026 in light of the COVID-19 pandemic. Annual GDP growth year-to-year data for 1961–2019 were used. Stationarity was identified in the first differentiation of the GDP growth. ARIMA (2,1,2) was chosen as the most appropriate model based on the Akaike criterion. Then, a seven-year forecast was made.

7. Primiceri and Tambalotti (2020) formulated several assumptions that make it possible to construct a predictive distribution for the vector of monthly macroeconomic variables based on their historical evolution without any behavioral assumptions. They assumed that exogenous shocks follow independent AR or ARMA processes, and that the endogenous equation fixes the spread of exogenous shocks on endogenous changes.

8. Kelly and Coburn (2014) calculated a macroeconomic forecast for a scenario where an Ebola virus spreads in the USA and Europe in 2014. The macroeconomic scenario analysis was performed using the Oxford Economics Global Economic Model (OEGEM). OEGEM adopts Keynesian principles in the short-term and a monetary view in the long-term.

9. In the Republic of Korea's GDP Forecast Model Evaluation study, Zeng (2011) evaluated various model predictions for the GDP demand components and concluded that simple time series models such as AR1 and LAG tend to work well. For these models, the advantages of using longer data series always outweigh concerns about potential structural discontinuity in a longer sample, and neither indicator models nor time series models dominate each other.

10. Specialists at the French central bank applied the BRIDGE model to forecast GDP (Barhoumi et al., 2011). The BRIDGE model is a system of equations that interconnect dependent macro-parameters. The main new features are monthly forecasting periodicity (three monthly forecasts for the current and future quarters), equation selection as a whole, and a moving forecast taking into account data availability. In terms of standard errors, the new equations are superior to reference models. Moreover, when comparing the BRIDGE model forecast performance by industry and expenditure components, it turns out that the magnitude of standard errors significantly varies by each component. In addition, GDP growth seems to be more accurately projected in terms of supply than in terms of demand.

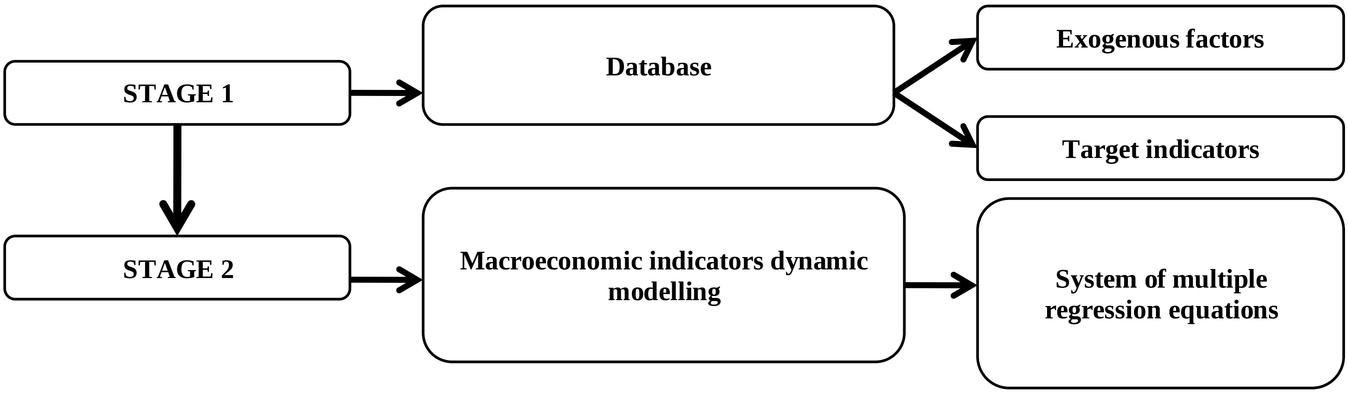
11. Schumacher (2014) compared MIDAS and BRIDGE models using examples of forecasting GDP growth in the Eurozone. MIDAS and BRIDGE with single indicators were evaluated in terms of their out-of-sample accuracy for forecasting in the present. Assessment periods include the recent Great Recessions (2007–2009) and subsequent years. It turns out that the performance of both single value MIDAS and BRIDGE equations changes over time. Compared to control tests, many models worked well during the Great Recession and do not work well after it. The ratings of MIDAS and BRIDGE equations are very different for different indicators.

12. Considering the results of the reviewed research, in this section a combination of structural and behavioral models was used to analyse the impact of the COVID-19 pandemic on the economy of Kazakhstan. The system of scenario analysis of the short- and medium-term macroeconomic development was built on this basis.

B. GDP by expenditure approach: Analysis of Kazakhstan's economy from the demand side

13. The Long-Term Macroeconomic Scenario Analysis System (the System) consists of two steps. The general scheme of the System is shown in figure 1.

Figure 1. Long-Term Macroeconomic Scenario Analysis System



B.1 Stage 1

14. The first stage of the System determines the database of macroeconomic indicators of Kazakhstan and foreign economic indicators presented in the form of annual time series for 1995–2018. In this case, all-time series are divided into exogenous factors and target indicators. Tables 1 and 2 show the indicators that represent exogenous factors and target indicators.

15. It should be noted that exogenous factors or sources of shocks and conditions of forecasts for Kazakhstan development are classified into two sectors (table 1). The first sector includes the most important foreign economic indicators affecting the development of Kazakhstan's domestic economy. These include the growth rate of the world economy, oil prices, world food prices, nominal exchange rates of the Ruble to the US dollar, and inflation in the Russian Federation.

16. The second sector of exogenous factors covers internal indicators for Kazakhstan, the regulation of which to a certain extent might affect the development of macroeconomic processes in the country. For example, the volume of oil and gas condensate production, the growth rate of average monthly nominal wages, and the nominal exchange rate of the Kazakstani Tenge to the Russian Ruble. The main macroeconomic indicators of Kazakhstan that reflect the degree of development and the growth of the country's economy have been determined as target indicators in the System (table 2). Thus, the number of macro-indicators is determined by the physical volume index of GDP calculated by the end-use method and of its components, such as household expenditures on final consumption, gross capital formation, exports and imports, GDP deflator, the consumer price index (CPI), the producer price index in manufacturing (PPI), and the index of real and nominal monetary incomes.

17. It should be noted that time series in the database during modeling at the second stage are converted to growth rates if the indicator was initially calculated in different values, i.e., in Tenge, metric tonnes, dollars. This procedure is performed to bring time series into a stationary form.

Table 1. Exogenous Factors of the Long-term Macroeconomic Scenario Analysis System

Sector	Indicator	Measurement	Sampling period of the time series	Source
External sector	Growth rate of world economy	% change on previous year	1995–2019	https://www.imf.org/en/Home
	Brent oil price	USD on average per year	1995–2019	https://www.eia.gov/
	FAO Food Price Index	% change on previous year	1996–2019	http://www.fao.org/home/en/
	FAO Cereal Price Index	% change on previous year	1996–2019	http://www.fao.org/home/en/
	Nominal exchange rate USD/RUB	on average per year	1995–2019	http://www.cbr.ru/
	CPI in Russian Federation	% change on previous year	1996–2019	https://rosstat.gov.ru/
Internal sector	Oil and gas condensate production volume	millions of metric tonnes	1995–2019	https://stat.gov.kz/
	Growth rate of average monthly nominal wage	% change on previous year	1996–2019	https://stat.gov.kz/
	Nominal exchange rate RUB_KZT	on average per year	2000–2019	https://www.nationalbank.kz/ru
	Fixed capital investment volume	% change on previous year	1995–2019	https://stat.gov.kz/
	Fiscal stance	% of GDP	1997–2019	https://www.gov.kz/memleket/entities/minfin/about?lang=ru

Table 2. Target Indicators of the Long-term Macroeconomic Scenario Analysis System

Indicator	Measurement	Time Series Sampling Period	Source
Macroeconomic Indicators			
Physical volume index of GDP	% change on previous year	1995–2019	https://stat.gov.kz/
Physical volume index of household consumption	% change on previous year	1995–2019	https://stat.gov.kz/
Physical volume index of gross capital formation	% change on previous year	1995–2019	https://stat.gov.kz/
Physical volume index of exports	% change on previous year	1995–2019	https://stat.gov.kz/
Physical volume index of imports	% change on previous year	1995–2019	https://stat.gov.kz/
GDP deflator	% change on previous year, on average	1995–2019	https://stat.gov.kz/

Indicator	Measurement	Time Series Sampling Period	Source
	Macroeconomic Indicators		
PPI in manufacturing	% change on previous year, on average	1996–2019	https://stat.gov.kz/
CPI	% change on previous year, on average	1996–2019	https://stat.gov.kz/
Nominal income index	% change on previous year, on average	1996–2019	https://stat.gov.kz/
Real income index	% change on previous year, on average	1996–2019	ttps://stat.gov.kz/
Exchange rate USD_KZT	on average per year	1995–2019	https://www.nationalbank.kz/ru
C	A element which does not have an economic interpretation and which is included in the model to obtain mathematically optimal estimates of regression equation coefficients.		

B.2 Stage 2

18. The second stage of the System consists of models of macroeconomic indicators in the form of multiple regression equations. They were evaluated with EViews 10 statistical software.

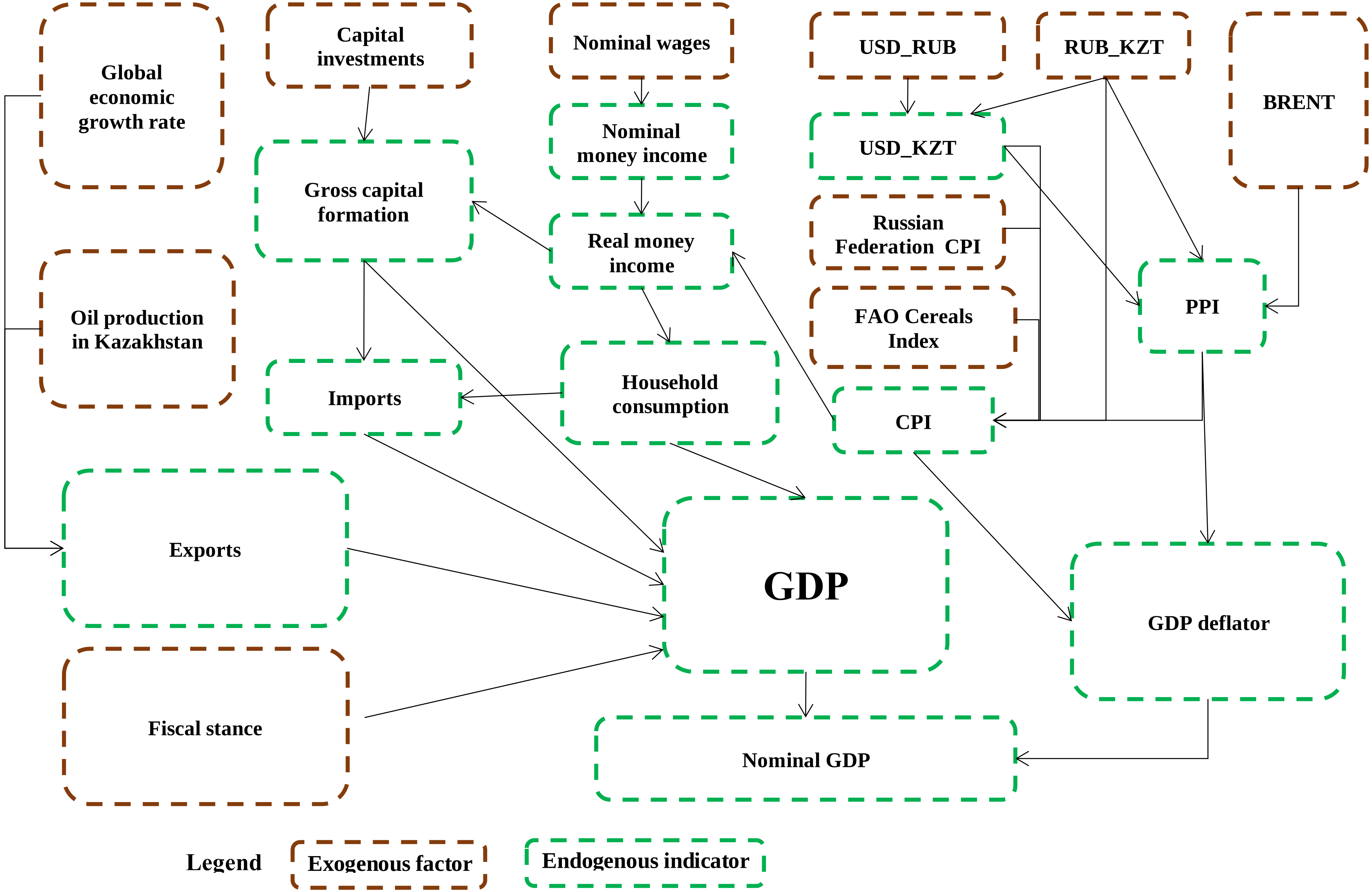
19. Interaction transmission between exogenous and target indicators in the second stage of the System is shown in figure 2. As can be seen from the figure, the physical volume index of the GDP, according to the theoretical structural model of the basic macroeconomic Keynes identity (Formula 1) and the behavioral model of GDP calculated using the end-use method according to the National Account System, is the result of the aggregate interaction of physical volume indices of household consumption, gross capital formation, and export and import or net export. At the same time, the fiscal stance is considered an expenditure of the government (component G) and is included as an additional sum of the GDP. The fiscal stance is the position of the government in the application of fiscal policy. In other words, it is the government's position on whether to balance its expenditures with tax revenue (a planned balanced budget), or deliberately plan for larger expenditures than can be obtained from tax revenue (a planned budget deficit), or deliberately plan to spend less than expected tax revenue (a planned budget surplus).

20. Basic macroeconomic identity or GDP calculated with the end-use method (equation 1).

$$GDP = HH + G + GCF + Ex - Im \qquad (1)$$

where:
GDP is Gross Domestic Product,
HH is Household expenditures,
G is Government expenditures,
GCF is Investment (gross capital formation),
Ex is Exports, and
Im is Imports.

Figure 2. Transmission of Interaction of Macroeconomic Indicators in Stage 2 of the System



21. When estimating this theoretical equation using Kazakhstan data, we obtain the following relations (equation 2).

$$\widehat{GDP\_KZ} = 42.1530 + 0.2558\,(HH) + 0.1986\,(GCF) + 0.2387\,(EX) - 0.0993(IM) + 0.3397\,(FS) \quad (2)$$
$$(5.7872)^{***}\ (0.0948)^{***}\ (0.0298)^{***}\ (0.0564)^{***}\ (0.0309)^{***}\ (0.1870)^{***}$$

$$R^2 = 0.8588\ R^2_{adj} = 0.7999\ F - statistic\ =\ 14.5943$$

22. According to the regression results, there is a positive relationship between GDP and the following macro indicators: household consumption (HH), investment (GCF), exports (EX), and fiscal stance (FS), while the relationship between GDP and imports (IM) is negative. The fiscal stance has a greater influence on GDP. Growth of the fiscal stance in GDP by 1% increases GDP growth by 0.34%, while the growth of household consumption, exports, and investments in GDP increase by 1%, the GDP growth increases by 0.26%, 0.24%, and 0.20% respectively. Imports affect GDP growth the least; a 1% increase reduces the GDP by 0.10%.

23. The resulting model was tested for absence of heteroscedasticity and multicollinearity. The results are shown in Appendix A.

24. The equation for household consumption was modeled on the structural model of Keynes internal consumption according to which household consumption depends on autonomous consumption and disposable income (equation 3).

$$C = Ca = mpc * (Y - T) \quad (3)$$

where:

C is household consumption,
Ca is autonomous consumption,
mpc is marginal propensity to consume, and
(Y-T) is real income, which remains after deducting from nominal income (Y) and tax payments (T).

The estimation for Kazakhstan is given in the following form (equation 4).

$$\widehat{HH} = 31.5588 + 0.6996\,(\frac{NI}{CPI_{kz}} * 100) \quad (4)$$
$$(13.9301)^{***}\ (0.1311)^{***}$$

$$R^2 = 0.5643\ R^2_{adj} = 0.5445\ F - statistic\ =\ 28.4943$$

25. In implementing this model, the average real cash income per capita in Kazakhstan was used as an indicator (Y-T), NI/CPI_KZ*100, where NI is the nominal income index and CPI_KZ is the consumer price index. According to the regression results, per capita average real cash income has a positive impact on household consumption. A 1% growth in real money incomes increases household consumption by 0.70%:

26. The resulting model was tested for absence of heteroscedasticity and multicollinearity. The results are shown in Appendix A.

27. The behavioral equation reflecting the dependence of the analyzed index on the investment in fixed assets (INV_TOT) with gross capital accumulation was estimated with ordinary least squares (OLS). This relationship is explained by the fact that investments create a basis for funding gross capital formation. The model shows that a 1% increase in investment in fixed assets increases the growth of the gross capital formation index by 0.43% (equation 5).

$$\widehat{GCF} = 61.6752 + 0.4315\,(INV\_TOT) \quad (5)$$
$$(13.5840)^{***} \quad (0.1187)^{***}$$

$$R^2 = 0.4235 \; R^2_{adj} = 0.3914 \; F-statistic \; = \; 13.2212$$

28. The obtained model was checked for absence of heteroscedasticity and multicollinearity. The results are shown in Appendix A.

29. As shown in figure 2 and the model calculations, the production value index (PVI) of exports is explained by world economic growth rate dynamics, which is a characteristic of external demand for Kazakhstani goods and volumes of oil and gas condensate production and reflecting the supply of Kazakhstani exports abroad. Thus, the share of oil and gas condensate is 60% to 70% of all exports from Kazakhstan. Regression results show that a 1% increase in the growth of the world economy (W_GDP) increases export growth by 2.37%, and a 1% increase in oil production in Kazakhstan increases the level of exports by 0.47%. Statistically reliable differences in oil and gas condensate production have not been found (equation 6).

$$\widehat{EX} \; = -190.4563 + 0.4745\,\left(\frac{OIL_{PROD_t}}{OIL_{PROD_{t-1}}} * 100\right) + 2.3737(W\_GDP) \quad (6)$$
$$(71.6910)^{***} \quad (0.2932)^{***} \quad (0.6049)^{***}$$

$$R^2 = 0.5847 \; R^2_{adj} = 0.5155 \; F-statistic \; = \; 8.4466$$

30. The obtained model was checked for absence of heteroscedasticity and multicollinearity. The results are shown in Appendix A.

Since Kazakhstani imports consist of consumer goods as well as investments and intermediate goods, the household consumption PVI was used as an explanatory variable in the model equation of imports as a reflection of the demand for imported goods, and the gross capital formation PVI (investment and intermediate imports). As a result, household consumption and gross capital formation affect imports equally. Increasing the growth of each indicator by 1% increases import growth by 0.49% (equation 7).

$$\widehat{IM} = 0.4874\,(HH) + 0.4887\,(GCF) \quad (7)$$
$$(0.2008)^{***} \quad (0.1973)^{***}$$

$$R^2 = 0.4628 \; R^2_{adj} = 0.4394$$

31. The obtained model was checked for absence of heteroscedasticity and multicollinearity. The results are shown in Appendix A.

32. As can be seen in figure 2, real cash income is the result of the difference between nominal cash income and inflation (CPI). In turn, according to the Bureau of National Statistics, nominal monetary income in Kazakhstan consists of more than

60% of nominal wages. The complete equation of the relationship between nominal income and nominal wages and salaries is shown in equation 8.

$$\widehat{NI} = 1.0085\ (NW) \quad (8)$$
$$(0.0067)^{***}$$

$$R^2 = 0.3346\ R^2_{adj} = 0.3346$$

33. According to the results, the index of nominal wages (NW) and nominal income (NI) are directly proportional.

34. The obtained model was checked for absence of heteroscedasticity. The results are shown in Appendix A.

35. Modeling the inflation rate in Kazakhstan (CPI) was simplified to an assessment of the behavioral equation reflecting the degree of dependence of changes in consumer prices in the country on demand factors (real money income), the cost of production, or supply inflation (CPI), imports of inflation from the main trading partner country for imports of goods (CPI Russian Federation), adjusted for changes in the Tenge to Ruble rate), the effect of the transfer of US dollars to Tenge on domestic prices, as well as the impact of world food prices (FAO Food Price Index. The variables are as follows:

- NI is the index of nominal monetary income,
- CPI_KZ is the consumer price index,
- USB_RUB is the nominal exchange rate of the US dollar to the Ruble,
- USB_KZT is the nominal US dollar to Tenge exchange rate,
- CPI_RU is the IPC of the Russian Federation, and
- FAO is the FAO Index.

The results of the econometric evaluation of the inflation equation in Kazakhstan are shown in equation 9.

$$\widehat{CPI\_KZ}_t = 47.66 + 0.21\ (\frac{NI_{t-1}}{CPI_{KZ_{t-1}}}) * 100) + 0.14\ (\frac{USD_{RUB_t} * RUB_{KZT_t}}{USD_{RUB_{t-1}} * RUB_{KZT_{t-1}}} * 100) + 0.07\ (\frac{CPI_{RU_t} * \left(\frac{RUB_{KZT_t}}{RUB_{KZT_{t-1}}} * 100\right)}{100}) + 0.15\ FAO \quad (9)$$

$$(12.2478)^{***}\ \ (0.0827)^{***}\ \ (0.0373)^{***}\ \ (0.0394)^{***}\ \ (0.0480)^{***}$$

$$R^2 = 0.6905\ R^2_{adj} = 0.6131\ F - statistic\ =\ 8.9220$$

36. According to the results, the growth of real cash income, the FAO Food Price Index, the nominal exchange rate of the US dollar through the Ruble, and transfer inflation from the Russian Federation by 1% increases inflation by 0.21%, 0.15%, 0.14%, and 0.07%, respectively. It is worth noting that the consumer price index has a statistical significance of 10%.

37. The model was tested for heteroscedasticity and multicollinearity. The results are shown in Appendix A.

38. The dynamics of producer prices, or PPI, was modeled as the dependence of this indicator on changes in world oil prices, which determine the cost of fuel resources

and lubricants, as well as changes in the rates of the Tenge to the US dollar and Russian Ruble. Thus, the dynamics of exchange rates of the Tenge to the US dollar and the Russian Ruble characterize the rise in price or reduction of import supplies in production, as well as the level of competitiveness of domestic producers. The results of the econometric evaluation of the PPI equation in Kazakhstan are shown in equation 10.

$$\widehat{PPI} = \underset{(0.0375)^{***}}{0.5541} \left(\frac{OIL_{price_t}}{OIL_{price_{t-1}}} * 100\right) + \underset{(0.0481)^{***}}{0.1759} \left(\frac{USD_{RUB_t} * RUB_{KZT_t}}{USD_{RUB_{t-1}} * RUB_{KZT_{t-1}}} * 100\right) + \underset{(0.0562)^{***}}{0.3177} \left(\frac{RUB_{KZT_t}}{RUB_{KZT_{t-1}}} * 100\right) \quad (10)$$

$$R^2 = 0.8888 \; R^2_{adj} = 0.8764$$

39. According to the results, the PPI is mainly dependent on changes in oil prices. A 1% increase in the oil price increases the growth of the PPI by 0.55%. A depreciation of the Ruble against the Tenge and the US dollar against the Tenge reduces PPI growth by 0.18%.

40. The resulting model was tested for absence of heteroscedasticity. The results are shown in Appendix A.

41. The GDP deflator is necessary to calculate the nominal GDP in the presence of к. It was calculated as an indicator determined by changes in prices in production and services, which corresponds to the methodology for calculating this indicator according to the System of National Accounts. For example, as a proxy indicator of prices in production, the PPI was used, and prices in services (CPI) of which more than 30% consists of changes in prices for paid services. The results of the econometric evaluation of the GDP deflator equation are shown in equation 11.

$$\widehat{DEFL} = \underset{(0.0526)^{***}}{0.2534} (PPI) + \underset{(0.0543)^{***}}{0.7690} (CPI\_KZ) \quad (11)$$

$$R^2 = 0.8133 \; R^2_{adj} = 0.8048$$

42. There is a positive relationship between the GDP deflator, PPI, and CPI. Consumer inflation in Kazakhstan has a greater influence on the GDP deflator. A 1% increase in inflation increases the growth of the GDP deflator by 0.77%.

43. The resulting model was tested for absence of heteroscedasticity. The results are shown in Appendix A.

44. The nominal exchange rate of the US dollar to the Tenge within the framework of Stage 2 of the System is calculated as the cross rate between the US dollar to the Ruble and the Ruble to Tenge, which are exogenous system factors.

45. The final performance indicator of Stage 2 of the System, nominal GDP, is calculated as an increase of the last actual value of the analyzed indicator for the product of forecasted real GDP growth rates and the GDP deflator level.

B.3 Model conclusion from the aggregate demand side

46. In the course of this work, we considered the historical dynamics and contributions of the GDP components with the final use method (household

consumption, consumption of government agencies, gross savings, exports and imports of goods) for the years 2000–2019 in the total aggregate demand.

47. At the same time, the main types of economic activities were analyzed (by branches of production of goods and services), which together occupy more than 60% of the GDP structure of the country.

48. A comprehensive historical analysis of foreign trade indicators, including an assessment of the openness of the country's economy and commodity and country structure of exports and imports of goods was also carried out.

49. In addition, a retrospective analysis of gross direct foreign investments was obtained, both in terms of the types of activities of Kazakhstan residents, recipients of investments, and non-resident investors.

50. In this paper, three scenario analyses were constructed using the long-term macroeconomic development for the model from the aggregate demand side consisting of a database, a group of endogenous indicators through which scenario conditions are set, and nine model equations.

C. Impact of COVID-19 on sectors of the economy: Supply-side analysis

C.1 Survey on the application of the Cobb-Douglas production function in international research

51. The Theory of Production (Cobb, Douglas, 1927) has contributed to the explanation of the economies of scale of production, linking it with the coefficients of elasticity for labor and capital. However, an interpretation of elasticity coefficients as indicators of economies of scale is possible only when considering the assumption made by the authors about a perfect substitution between capital and labor. Moreover, the production function was created with the assumption of perfect competition in the market for goods, services, and resources.

52. Willman (2002) constructed a supply model for the Eurozone based on the Cobb-Douglas function. However, when evaluating the aggregated supply model, the author departs from the premise of perfect competition in favor of an imperfect one in sectors of the economy.

53. The general view of the function used by Willman (2002) is identical to the function used by Cobb and Douglas (equation 12).

$$Y_i^j = A^j F(K_i^j, L_i^j) \tag{12}$$

where Y_i^j, K_i^j и L_i^j are output, capital, and labor of the i^th firm in sector j.

54. Since the author departs from the premise of perfect competition, the coefficients of labor and capital are interpreted by him only as the elasticity of output to changes in capital and labor respectively, without indicating the scale effect.

55. Yanqing Jiang's (2014) research based on the Cobb-Douglas function shows the imbalance of economic growth in China comparing regional data. Unlike Willman's work, this study assumes a constant return to scale. To fulfill this premise, the author of the study does not estimate the coefficients of the equation, but sets them exogenously, considering the practice of other countries. Referring to the studies of Hall and Jones (1999) and Iyar and Feirer (2002), Yanqing Jiang suggests that the total coefficient α is equal to one-third for all countries when choosing the likely value of α. Despite the observance of the condition of constant returns to scale, questions arise about the validity of such a model because the rough average estimate of the coefficient α may not correspond to the realities of the Chinese economy. The author of the study himself points out this shortcoming.

56. In some works, various modifications of the Cobb-Douglas function are used. For example, Dritsaki and Stamatiou (2019) modify the Cobb-Douglas function to show the relationship between the openness of the Polish economy and its economic growth. They replace labor and capital indicators in the Cobb-Douglas function with indicators for the openness of the country's trade market and financial sector.

57. Modification of the regressors in the Cobb-Douglas function was also used by Xuefan Dong et al. (2018) to assess factors influencing the duration of public opinion on the Internet using the example of China.

58. More interesting for the purpose of the current study is work with the inclusion of additional explanatory variables in the original Cobb-Douglas function. In particular, Kirilyuk (2013), constructed a production function for the Russian economy which includes the value of oil prices in the Cobb-Douglas equation. As a result, the Cobb-Douglas function appears as follows (equation 13).

$$Y = AK^{\alpha}L^{\beta}P^{\gamma}e^{\zeta t} \tag{13}$$

where
α, β are coefficients characterizing the elasticity of the output to changes in capital and labor respectively (the sum of the coefficients characterizes economy of scale),
P is the value of oil prices for the given years,
γ is the coefficient characterizing the power-law dependence of GDP on world oil prices, and
ζ is a coefficient characterizing an exponential time trend.

59. The inclusion of an exogenous parameter (oil prices) is explained by the high share of mineral exports by the Russian economy, which makes the country's output exposed not only to changes in labor and capital but also to oil prices.

60. The international experience of using the Cobb-Douglas function in research can be used in the current study to assess the 2020 pandemic shock to certain sectors of the economy of Kazakhstan.

61. Despite the simplicity of its economic interpretation, the Cobb-Douglas function is difficult to apply in practice on real data.

62. First, assumptions for the production function of perfect competition and the substitution of capital and labor are not observed in practice, which makes the interpretation of the sum of the elasticities for capital and labor not always possible as an indicator of economies of scale.

63. Second, in the model the values of capital, labor, and output are assumed to be commensurate, i.e., in one unit of measurement. Most often, the value expressions of the specified parameters are used. However, parameters of value, even in constant prices, are characterized by the presence of a trend.

64. Further log-linearization of the Cobb-Douglas function for estimating the coefficients does not solve the problem of a trend, i.e., nonstationarity of time series. The absence of stationarity of the used time series makes the estimates of the equation coefficients biased and the forecast invalid. Different authors use different methods of dealing with nonstationarity. In the previously mentioned work of Kirilyuk (2013), a trend is included in the equation. However, the inclusion of the trend component cannot always solve the problem of nonstationarity. If some of the regressors represented by the time series are non-stationary and some are stationary, then the trend in the equation will be insignificant and the coefficients will still be biased.

65. The most frequently used method of dealing with the presence of trends in time series is taking the first difference. In this case, the first difference in logarithms can be interpreted as a growth rate, i.e. (equation 14).

$$\ln(Y_t) - \ln(Y_{t-1}) \approx \frac{Y_t}{Y_{t-1}} - 1 \quad (14)$$

66. However, there are frequent cases of cointegration of time series for the Cobb-Douglas production function (Stresing et al., 2008), as a result of which a simple model of first differences will not be valid.

67. Therefore, in studies using the Cobb-Douglas production function, estimation occurs in three stages:

i) In the first stage, all variables are checked for stationarity.
ii) In the second stage, if the series are not stationary, the presence of cointegration of the time series in the levels is checked using the Johansen or Engle-Granger test.
iii) In the third stage, upon detection of cointegration, an error correction model (ECM) is built for the first differences.

68. This methodology was used in studies by Stresing et al. (2008), Dushko et al. (2011), as well as Wei-Wei Guo (2018).

69. Thus, the construction of a valid Cobb-Douglas equation is a non-trivial problem that cannot be reduced to a one-step construction of the OLS.

C.2 Basic premises and limitations of the supply-side model

70. Given the goal of identifying the impact of the COVID-19 shock on aggregate supply, the model of equations for individual economic activities is built on the basis of the Cobb-Douglas production function. The use of this function is justified by the assumption that the shock of COVID-19 affects output in certain sectors of the economy through changes in employment, changes in capital indicators, as well as world prices for resources.

71. The microeconomic foundations of macroeconomics in the framework of the Keynesian-Neoclassical synthesis allows us to start the analysis with individual firms or sectors of the economy, then aggregate the results for the entire aggregate supply.

72. When constructing equations based on the Cobb-Douglas function for selected types of economic activity, in addition to the main regressors (capital and employment) exogenous variables are used (e.g., oil prices, metal prices). As a result, the equation looks as follows (equation 15).[1]

$$Y_j = K_j^{\alpha} * L_j^{\beta} * X_j^{\gamma} \quad (15)$$

Where
Y_j is an output of the j[th] sector of the economy,
K_j is a book value of fixed assets of the j[th] sector of the economy,
L_j is the number of people employed in the j[th] sector of the economy, and
X_j is an exogenous parameter for the j[th] sector of the economy.

73. Building a model based on Cobb-Douglas functions is non-trivial because of two theoretical and technical limitations as outlined in paragraphs 75 through to 78.

1. Limitations from economic theory

74. Since the theoretical basic construction of both the demand side model and the supply-side model is a Keynesian-Neoclassical synthesis and not just neoclassical theory, both models assume imperfect competition in the market for goods and resources. This means the premise of constant returns to scale is unacceptable.

75. Within the framework of the Keynesian-Neoclassical synthesis, the violation of the precondition of constant returns to scale is the norm since this theory does not use the basic premises of the neoclassicists (i.e., the assumption of perfect competition in the market for goods, services, resources, and the perfect substitution of capital and labor).[2]

2. Limitations of the technical construction of the model

[1] Cobb, Charles W. and Douglas, Paul H. (1928). A Theory of Production. Papers and Proceedings of the Fortieth Annual Meeting of the American Economic Association (March 1928), Vol. 18, No. 1, Supplement, pp. 139–165.
[2] Boianovsky, M. and Hoover, Kevin D. (2009). The Neoclassical Growth Model and Twentieth-Century Economics. *History of Political Economy* 41 (annual suppl.) DOI 10.1215/00182702-2009-013

76. As mentioned earlier in the framework of the review of international experience in the application of the Cobb-Douglas function (section A2), when using the production function there is a difficulty with the nonstationarity of time series, in particular, capital, employment, and output. Consequently, the construction of a conventional OLS model will give biased estimates of the coefficients.

77. In this case, in Stage 1, it is necessary to overcome the nonstationarity in the time series. The most common method of dealing with nonstationary time series is taking the first difference. However, in the case of the Cobb-Douglas function, several studies have indicated the presence of cointegration between the log-linearized time series of output, capital, and employment (see section C1). For this reason, an ECM must be used to validate the coefficient estimates.

78. Thus, the construction of the model from the supply side will be carried out in the following steps:

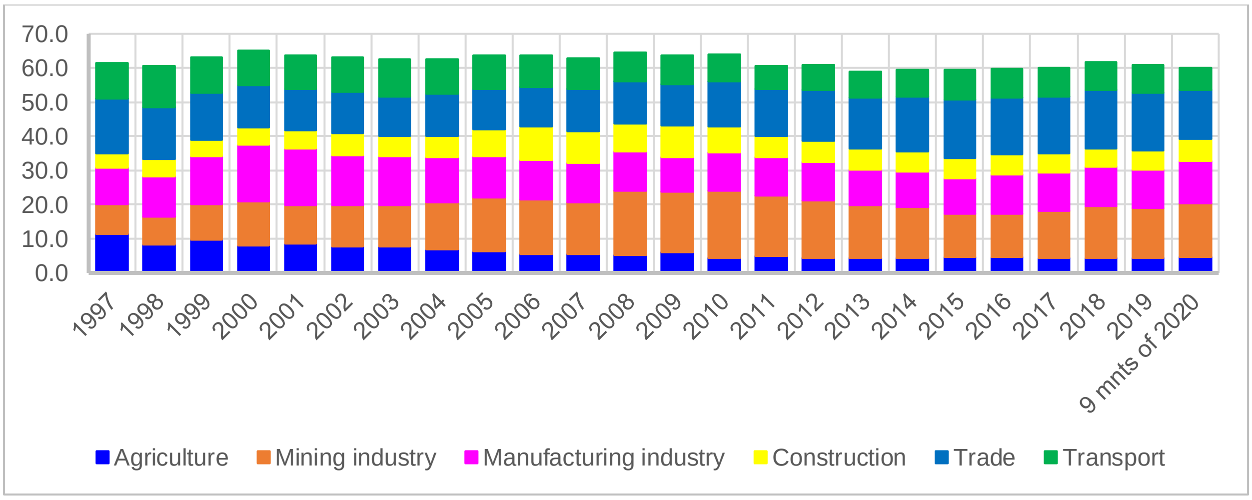
I. Construction of equations for a particular type of economic activity using the steps of the error correction model.
II. Checking for homoscedasticity and multicollinearity. Within the framework of building a model from the supply side, White's heteroscedasticity test will be used when assessing the quality of the Cobb-Douglas equations for individual sectors of the economy.
III. Checking for multicollinearity of time series. One of the tests for detecting multicollinearity is the Variance Inflation Factor or VIF test. As a rule of thumb, we consider a model to be affected by multicollinearity if the centered VIF is greater than 5.[3]

C.3 Data

79. The model consists of constructing equations for the following main types of economic activities in Kazakhstan: mining and quarrying, manufacturing, agriculture, forestry and fisheries, transport and storage, construction, wholesale and retail trade, and repair of cars and motorcycles.

80. These types of economic activities have the largest shares in the structure of GDP and together account for more than 60% of GDP (Figure 3).

[3] James, G., Witten D., Hastie T., Tibshirani R. An Introduction to Statistical Learning with Application in R. ISSN 1431-875X, p. 101.



Source: Compiled from data from the Bureau of National Statistics, Agency for Strategic Planning and Reforms of the Republic of Kazakhstan.

Figure 3. Share of Key Economic Activities in Kazakhstan's GDP

81. For the remaining sectors of the economy (communications, financial activities, real estate transactions, education, etc.), there is not sufficient statistical data to build a valid model. Given their small share of the GDP, not including them in the analysis will not greatly affect the chance of detecting a coronavirus shock on the economy.

82. The names of activities are given in accordance with the current General Classifier of Economic Activities.[4] However, for brevity in the model, these activities will be named as:

i) mining industry
ii) manufacturing industry
iii) agriculture
iv) transport
v) construction
vi) trade

[4] Approved and put into effect by the Order of the Committee for Technical Regulation and Metrology of the Ministry of Industry and Infrastructure Development of the Republic of Kazakhstan dated 22 February 2019, No. 68-od.

Table 3. Data Used in the Model and Data Sources

Variable Name	Decoding	Period	Unit Measurements
Mining industry			
Y_real_mining	Gross output of the mining industry in 2005 prices	1995–2019	M Tenge
K_book_value_mining	Book value of fixed assets in the mining industry in 2005 prices	1995–2019	M Tenge
L__mining	Number of people employed in the mining industry	1995–2019	thousand people
Brent_price	Brent crude oil price	1995–2019	USD/barrel
Manufacturing industry			
Y_real_manuf	Gross output of the manufacturing industry in 2005 prices	1995–2019	M Tenge
K_book_value_manuf	Book value of fixed assets in the manufacturing industry in 2005 prices	1995–2019	M Tenge
L_manuf	Number of people employed in the manufacturing industry	1995–2019	thousand people
Aluminum_Price_Nom	Nominal prices for aluminum	1995–2019	
Agriculture			
Y_real_agriculture	Gross agricultural output in 2005 prices	1995–2019	M Tenge
K_book_value_agriculture	Book value of agricultural fixed assets in 2005 prices	1995–2019	M Tenge
L_agriculture	Number of people employed in agriculture	1995–2019	thousand people
FAO_corn	FAO Cereal Index	1995–2019	y/y in%
Construction			
Y_real_construction	Gross construction output in 2005 prices	1995–2019	M Tenge
K_book_value_construction	Book value of fixed assets in construction, 2005 prices	1995–2019	M Tenge
L_construction	Number of people employed in construction	1995–2019	thousand people
Transport			
Y_real_transport	Gross output of transport in 2005 prices	1995–2019	M Tenge
K_book_value_transport	Book value of fixed assets in transport in 2005 prices	1995–2019	M Tenge
L_transport	Number of people employed in transport	1995–2019	thousand people
Brent_price	Brent crude oil price	1995–2019	USD/barrel
Trade			
Y_real_trade	Gross trade output in 2005 prices	1995–2019	M Tenge
K_book_value_trade	Book value of fixed assets in trade in 2005 prices	1995–2019	M Tenge
L_trade	Number of people employed in trade	1995–2019	thousand people
Nom_exR_USD_KZT	Nominal USD/KAZ exchange rate	1995–2019	Tenge per dollar
C	Intercept (constant)	An element that has no economic interpretation but which is included in the model to obtain mathematically optimal estimates of the coefficients of the regression equation.	

C.4 Model building and testing

C.4.1 Mining

Step 1: log-linearization and check for stationarity

83. In the production function of the Cobb-Douglas for the mining industry, in addition to capital and labor, the Brent oil price was used as a regressor. To estimate the coefficients for labor, capital, and the Brent oil price, the initial dataset was log-linearized and then checked for stationarity using the unit root test. The extended Dickey-Fuller test (ADF test) results for log-linearized mining output, capital, and employment are shown in table 4.

Table 4. Results of the Extended Dickey-Fuller Test for Logarithms of Model Variables

Variables	ADF	Critical Value	Conclusion
LOG_Y_MINING_REAL	-2.518188	-3.737853	non-stationary
LOG_K_BOOK_VALUE _MINING	-2.443920	-3.752946	non-stationary
LOG_L_MINING	-1.287838	-3.752946	non-stationary
LOG_BRENT_PRICE	-1.510105	-3.737853	non-stationary

84. According to the results of the ADF test, the logarithms of the variables are nonstationary. The nonstationarity of the log-linearized data for output, capital, and labor provides a theoretical basis for the use of the cointegration test.

Step 2: Cointegration test

85. The essence of time series cointegration is that a linear combination of two or more non-stationary time series can be stationary. This leads to the fact that, despite the random nature of the change, there may be a relationship between time series which leads to an interrelated change. Ignoring the presence of cointegration in time series can lead to obtaining a false regression during the empirical analysis.

86. Checking for the presence or absence of cointegration is carried out using the Engle-Granger test. If the analysis of the obtained regression residuals rejects the null hypothesis of the presence of a unit root, then there is a stable relationship between these values, i.e., cointegration. The results of the Engle-Granger test for stationarity of the residuals of the model with log-linearized data are provided in table 5.

Table 5. Unit Root Test Results of Residuals of a Log-Linearized Time Series Model

		t-value	p-value
ADF test		-4.098081	**0.0046**
Significance level	1%	-3.752946	
	5%	-2.998064	
	10%	-2.638752	

87. We have received confirmation of the presence of cointegration and instead of the usual linear model, an ECM is built using the first differences, which allows us to

consider error correction terms with a lag of 1. The use of the lagged ECM-terms variable is explained by the long-term analysis. In other words, since a model of aggregate supply is used for a long-term period, the correction variable ECM-terms do not act immediately but with a lag of 1 year, reflecting the long-term period of return of aggregate supply to equilibrium in the event of a shock. The ECM-terms coefficient shows the strength of the shock-related adjustment, i.e., with a deviation from long-term equilibrium.

Step 3: Error correction model construction

88. Before further constructing the ECM, it is necessary to first check for stationarity of the first difference of the logarithms of the variables used for the analysis (table 6).

Table 6.Analysis of Stationarity of First Differences of Variable Logarithms using the Extended Dickey-Fuller Test

Variables	ADF	Critical Value	Conclusion
DELTA_LOG_Y_MINING_REAL	-2.078927	-1.956406	stationary
DELTA_LOG_K_BOOK_VALUE _MINING	-5.800048	-3.831511	stationary
DELTA_LOG_L_MINING	-6.096434	-3.752946	stationary
DELTA_LOG_BRENT_PRICE	-4.184261	-3.752946	stationary

89. The results show that the first differences in the logarithms of output, capital, labor, and oil prices are stationary. Therefore, it is possible to build the ECM (equation 16).

$$\Delta\log(Y_{mining_{real}}) = 0.05 + 0.10\Delta\log(K_{book\ value\ mining}) - 0.03\Delta\log(L_{mining}) + 0.18\Delta\log(Brent\_price) - 0.25\,ECM_{terms} \quad (16)$$

$$0.0111^{***} \quad 0.0466^{***} \quad 0.0883 \quad 0.0529^{***} \quad 0.1187^{***}$$

$$R^2 = 0.5010 \ R^2_{adj} = 0.3901 \ F-statistics = \ 4.5173$$

90. The variable ECM-terms with a lag of 1 is significant, which confirms the cointegration of the time series used in the model and reflects the long-term return of the mining industry output to equilibrium. The ECM-terms coefficient shows the strength of the adjustment associated with a shock, i.e., within the framework of the mining industry model. The short-term deviation of the PVI output from the long-term equilibrium will occur with an adjustment of 0.25 percentage points from a nonequilibrium state back to equilibrium.

91. This equation allows us to conclude that the mining industry is more capital-intensive than labor-intensive as the estimated coefficient for capital turned out to be significant, but this is not the case for labor. Despite the insignificance of the coefficient for labor, the change in employment was not excluded from the model due to both the loss of economic meaning when this variable is excluded and the deterioration of the predictive qualities of the model.

92. The results of the tests for heteroscedasticity and the Variance Inflation Factor of the constructed model are shown in Appendix B.

93. The regression analysis for the remaining types of economic activity is built on the same principles. Therefore, the following description will be more concise.

C.4.2 Manufacturing industry

Error correction model construction

94. A preliminary check for the stationarity of the logarithms and the first difference of the logarithms was made as well as the Engle-Granger test.

95. An ECM model is built for the first differences of the logarithms of the variables, namely: the volume of output, the cost of fixed assets, the number of people employed in the manufacturing industry, and the prices of aluminum. The results are performed in the form of equation 17.

$$\Delta \log(Y_{manuf \quad real}) = 0.04 + 0.10\Delta \log(K_{book\ value\ manuf}) + 0.35\Delta \log(L_{manuf}) + 0.26\Delta \log(aluminium\ price_{nom}) - 0.41\, ECM_{terms} \tag{17}$$
$$0.0093^{***} \quad 0.0869 \quad 0.1863^{*} \quad 0.0628^{***} \quad 0.1356^{***}$$
$$R^2 = 0.6552\ R^2_{adj} = 0.5827\ F - statistics = 9.0280$$

96. The resulting model was tested for the absence of heteroscedasticity and multicollinearity and the results are shown in Appendix B.

C.4.3 Trade

Error correction model construction

97. A preliminary check for the stationarity of the logarithms and the first difference of the logarithms was made as well as the Engle-Granger test. An ECM model is built for the first differences of the logarithms of the variables (equation 18).

$$\Delta \log(Y_{trade_{real}}) = 0.08 + 0.01\Delta \log(K_{book\ value\ trade}) + 0.04\Delta \log(L_{trade}) - 0.22\Delta \log(Nom\ ExR\_usdkzt) - 0.46\, ECM_{terms} \tag{18}$$
$$0.0102^{***} \quad 0.0205 \quad 0.0853 \quad 0.0638^{***} \quad 0.1921^{***}$$
$$R^2 = 0.5003\ R^2_{adj} = 0.3951\ F - statistics = 4.7558$$

98. The resulting model is checked for the absence of heteroscedasticity and multicollinearity and the results are shown in Appendix B.

C.4.4 Construction

Error correction model construction

99. A preliminary check for the stationarity of the logarithms and the first difference of the logarithms was made as well as the Engle-Granger test. The resulting model is shown as equation 19.

$$\Delta \log(Y_{constrction_{real}}) = 0.08 - 0.02\Delta \log(K_{book\ vanue\ constr}) + 1.78\Delta \log(L_{constr}) - 0.43 ECM_{terms} \tag{19}$$
$$0.0338^{***} \quad 0.1417 \quad 0.6645^{**} \quad 0.2303^{*}$$
$$R^2 = 0.3178\ R^2_{adj} = 0.2041\ F - statistics = 2.7952$$

100. The results of tests for the validity of the constructed model, in particular, the test for heteroscedasticity as well as the Variance Inflation Factor, are shown in Appendix B.

C.4.5 Agriculture

101. According to the preliminary results, the first differences in the logarithms of output, capital, and labor are stationary. This allows us to move on to building an ECM model (equation 20).

$$\Delta \log(Y_{agriculture\_real}) = \underset{0.0104^{***}}{0.03} + \underset{0.0544^{***}}{0.16}\Delta \log(K_{book\_value\_agric}) + \underset{0.1189^{*}}{0.21}\Delta \log(L_{agric}) - \underset{0.2178^{***}}{1.46}ECM_{terms} \quad (20)$$

$$R^2 = 0.7497 \; R^2_{adj} = 0.7028 \; F - statistics = 15.9749$$

102. The results of tests for the validity of the constructed model, in particular, the test for heteroscedasticity as well as the Variance Inflation Factor, are shown in Appendix B.

C.4.6 Transport

Error correction model construction

103. According to the preliminary results, the first differences in the logarithms of output, capital, and labor are stationary. This allows us to move on to building an ECM model (equation 21).

$$\Delta \log(Y_{transport\_real}) = \underset{0.0073^{***}}{0.05} + \underset{0.0306}{0.02}\Delta \log(K_{book\ value\ transp}) + \underset{0.0762}{0.04}\Delta \log(L_{trans}) + \underset{0.0264^{**}}{0.04}\Delta \log(Brent\_price) - \underset{0.1863^{***}}{0.50}\, ECM_{terms} \quad (21)$$

$$R^2 = 0.4265 \; R^2_{adj} = 0.3057 \; F - statistics = 3.5326$$

104. The obtained results for the validity of the constructed model, in particular, the test for heteroscedasticity as well as the Variance Inflation Factor, are shown in Appendix B.

C.5 Conclusion for the supply-side model

105. To determine the impact of the COVID-19 pandemic on the economy of Kazakhstan from the supply-side, a model of equations was built for sectors that total more than 60% of GDP. The equations were constructed based on the Cobb-Douglas production function. However, the original Cobb-Douglas function was modified by the inclusion of significant exogenous regressors for some sectors of the economy.

106. Due to the previously described features of the data (nonstationarity of logarithms, presence of cointegration), an ECM was built.

107. Based on the regression analysis results, the following conclusions can be drawn regarding the selected types of economic activity:

i. The mining industry is more capital intensive than labor intensive. Despite the importance of the capital ratio, the influence of capital on output is weak: a one percent change in the book value of fixed assets leads to a change in the output of the mining industry by only 0.098%. Also, the constructed regression equation confirmed the hypothesis about the significance of the influence of the dynamics of oil prices on this type of economic activity.

ii. The manufacturing industry, in contrast, is characterized as a labor-intensive activity rather than capital-intensive as evidenced by the significance of the corresponding coefficients in the equation. At the same time, a one percent change in the number of people employed in this sector of the economy leads to a change in output by 0.35%.

iii. For the trade sector, the coefficients for both labor and capital turned out to be insignificant. This finding is consistent with empirical results for other developing countries (Jansen, Peters, Salazar-Xirinachs, 2011), and is explained by the fact that, due to the high self-employment rate in trade, the employment-to-trade impact is not always obvious. At the same time, the coefficient at the nominal exchange rate of USD to KZT turned out to be significant: a negative coefficient indicates that with an increase in the indicator (nominal depreciation of the Tenge against the dollar) by 1%, the volume of retail and wholesale trade decreases by 0.22%. The latter is because when the nominal exchange rate depreciates, the cost of imported goods increases, followed by an increase in the cost of domestic goods (the effect of exchange rate pass-through on the general price level), which ultimately leads to a decrease in the volume of domestic trade.

iv. In the equation for the construction sector, only the coefficient for a change in the number of employees in this industry was significant. At the same time, this regressor has a high impact on industry output: a change by 1 percent in the number of people employed in construction leads to a change in the output of this sector by 1.78%.

v. In the equation for agriculture, the coefficients for both labor and capital are significant. However, the coefficients of exogenous regressors, such as the FAO Index, were found to be insignificant. As a result, the Cobb-Douglas production function for agriculture includes only labor and capital as independent variables.

vi. For the transport equation, only the coefficient for changes in prices for Brent crude oil turned out to be significant, confirming the initial hypothesis that changes in the dynamics of oil prices lead to changes in traffic volumes due to changes in the volumes of transportation of oil products. According to the results of the regression analysis, a 1% change in the price of Brent crude oil leads to a change in output by 0.05%.

108. All equations were checked for the compliance of the sum of the coefficients to constant returns to scale. The hypothesis of constant returns to scale was rejected for all considered types of economic activities in Kazakhstan. This does not contradict the theoretical basis for constructing the model, namely the premises of the Keynesian-Neoclassical synthesis.

D. Assumptions about the main explanatory variables for the aggregate demand and supply model

109. Kazakhstan's economy is a small open economy, i.e., the economy of a small country with no impact on global development. As a rule, countries with small open economies are absorbers of external shocks.

110. The theoretical basis of the model used to identify the COVID-19 impact on the economy is a Keynesian-Neoclassical synthesis. The reason to select this economic school of thought for the model is that it has more realistic assumptions in comparison to purely neoclassical or Keynesian theories.

111. The main assumptions of a Keynesian-Neoclassical synthesis used in this study are that markets for goods and resources are markets of imperfect competition and prices of goods and factors of production are not flexible enough for an economy to adapt to changes in market conditions in the short-term. However, in the long-term, prices and wages eventually bring markets into balance, and the leading force of market conditions is an aggregate demand in the short-term and an aggregate supply in the long-term.

112. The use of the main macroeconomic identity allows us to connect the model of the supply and the demand through the identity Investment equal to Savings, reflecting the formation of fixed capital. In the equations, the connection between the two models can be traced in the use of a common exogenous factor, i.e., the price of Brent crude oil. The latter has a significant impact on many macroeconomic indicators of the country due to the structure of Kazakhstan's economy. The model of aggregate supply also uses the nominal exchange rate, an endogenous variable of the aggregate demand model, as an exogenous factor.

113. It is well known that interaction between aggregate demand and aggregate supply in a market takes place by means of price mechanisms. Such interaction requires the construction of a dynamic general equilibrium model. The construction of the dynamic model, while costly, answers the question of interaction between monetary and fiscal authorities but does not directly meet the goals of the current study, in particular, to determine the impact of the COVID-19 pandemic shock on the economy of Kazakhstan. Therefore, the regression analysis is limited to the construction of aggregate demand and aggregate supply-side models without further linking them into a dynamic general market equilibrium model.

114. As noted above, separate error correction models are constructed for the model on the supply side. The basis is a Cobb-Douglas production function. Since the Cobb-Douglas function uses as explanatory variables the parameters of real book value of fixed assets and the number of labor forces in the respective sectors of the economy, it is necessary to make assumptions concerning these parameters for forecasting purposes.

Table 7. Assumptions regarding Capital and Labor for Building a Forecast of the Output of Economic Sectors

Economic Sector	Assumption on real fixed assets growth rate, in % to the previous year		Assumption on employment growth rate, in % to the previous year	
	2020	2021	2020	2021
Mining and quarrying	+4%	-2%	+7%	+3%
Manufacturing industry	-5%	+3%	-1,4%	+1%
Agriculture, forestry, and fisheries	+5%	+8%	-1%	+3%
Wholesale and retail trade, repair of cars and motorcycles	+7%	+5%	+2%	+9.5%
Construction	+8%	+14%	+5%	+5%
Transport and storage	-1%	+5%	-50%	+40%

A rationale for why such assumptions were made is detailed in Appendix D.

E. Modeling results: Impact of COVID-19 on aggregate supply and demand of Kazakhstan in 2020 and forecast for 2021

E.1 Forecast scenarios in the framework of the aggregate demand model

115. For a complete analysis of the impact of the COVID-19 pandemic and further development of recommendations for the recovery of Kazakhstan's economy, three scenarios are considered:

- Scenario 1: The COVID-19 pandemic did not occur.
- Scenario 2: The COVID-19 pandemic has occurred and the government has taken additional support measures against the consequences of COVID-19.
- Scenario 3: The COVID-19 pandemic has occurred and the government did not take additional support measures against the consequences of COVID-19.

Scenario 1: The COVID-19 pandemic did not occur

116. For this scenario, the macroeconomic indicators for 2019 and the first quarter of 2020 are used. This scenario is a control scenario to assess the degree of impact of the pandemic on the economy by comparing this forecast with the forecasts of Scenarios 2 and 3.

117. Scenario 1 includes a counterfactual analysis that would allow an analysis of the potential of Kazakhstan's economy in the case where a pandemic had not occurred. Thus, it will be possible to identify the growth rates of the main macroeconomic indicators and to identify the main directions of Kazakhstan's economic recovery to the level of the first quarter of 2020.

118. Scenario 1 is the control scenario, and the treatment scenarios are Scenario 2 and 3. The difference between the two scenarios will determine the degree of the pandemic's impact on the main macroeconomic indicators and identify the main areas of the economy that are subject to this exogenous influence.

Table 8. Exogenous Parameters of Scenario 1

Period	2018	2019	Scenario 1	
Scenario	Fact	Fact	2020	2021
External prerequisites for the forecast				
Brent crude oil price, USD per barrel on average per year	72.8	64.4	63.9	61.5
Economic growth rate in partner countries, % YoY	2.6	2.2	3.2	3.5
Food inflation in the world (FAO Food Price Index), % YoY	-3.5	1.8	-2.9	-2.8
Consumer inflation in Russian Federation, % YoY	2.9	4.5	3.4	4.0
Nominal exchange rate USD to RUB, Rubles on average per year	62.7	64.7	63.2	64.2
Internal prerequisites for the forecast				
Oil and gas condensate production, millions of metric tonnes	90.4	90.6	90.8	91.1
Nominal growth of average monthly wages, % YoY	8.4	14.6	9.5	9.2
Nominal exchange rate RUB to KZT, Tenge on average per year	5.5	5.9	5.9	6.0
Fiscal stance, % of GDP	-0.6	2.3	0.6	0.6
Fixed capital investments, % YoY	17.5	8.5	7.0	7.4

Scenario 2: The COVID-19 pandemic has occurred and the government has taken additional support measures against the consequences of COVID-19

119. The aim of this scenario is to assess the degree of state support impact during the pandemic on the economy by comparing this forecast with the forecast of Scenario 3.

120. Total government spending is used to make this projection. In January–July 2020, budget expenditures amounted to 7.7 trillion Tenge, 23.1% higher than in the corresponding period of 2019. The government took support measures in the areas of social security, health care, and education as follows:

- Social assistance (including unemployment benefits and other support measures) increased by 22.5% in January–July 2020 compared to the corresponding period in 2019.
- Healthcare costs (including the cost of purchasing goods and conducting all medical services to prevent the spread of Covid-19) increased by 38.9% in January–July 2020 compared to the corresponding period in 2020.
- Expenditures on education increased by 44.4% due to higher teachers' salaries.
- Official transfers and debt service increased.

121. The following decisions were made during the pandemic:

- Small and medium businesses and owners of large businesses in vulnerable sectors of the economy were exempted from taxes and liabilities from the wage fund for six and three months respectively.
- Grant deferrals for loans were presented.
- 600 billion Tenge was allocated for lending to SMEs in sectors of the economy deemed vulnerable to the pandemic.
- Support for the agro-industrial complex.

- Other support measures.

122. Scenario 2 is a treatment scenario, while the counterfactual scenario is Scenario 3. The difference between the results of these two scenarios will reveal the main areas that are most effectively influenced by government support.

Table 9. Exogenous Parameters of Scenario 2

Period	2018	2019	Scenario 2	
Scenarios	Fact	Fact	2020	2021
External prerequisites for the forecast				
Brent crude oil price, USD per barrel on average per year	72.8	64.4	41.2	48.5
Economic growth rate in partner countries, % YoY	2.6	2.2	-7.9	4.5
Food inflation in the world (FAO Food Price Index), % YoY	-3.5	1.8	5.0	7.0
Consumer inflation in Russian Federation, % YoY	2.9	4.5	4.4	4.0
Nominal exchange rate USD to RUB, Rubles on average per year	62.7	64.7	72.2	75.0
Internal prerequisites for the forecast				
Oil and gas condensate production, millions of metric tonnes	90.4	90.6	84.9	86.0
Nominal growth of average monthly wages, % YoY	8.4	14.6	7.6	9.2
Nominal exchange rate RUB to KZT, Tenge on average per year	5.5	5.9	5.7	5.8
Fiscal stance, % of GDP	-0.6	2.3	2.9	2.4
Fixed capital investments, % YoY	17.5	8.5	-5.0	2.0

Scenario 3: The COVID-19 pandemic has occurred and the government has not taken additional support measures against the consequences of COVID-19

123. The aim of this scenario is to assess the degree of influence of state support during the pandemic on Kazakhstan’s economy by comparing this forecast with the forecast of Scenario 2. The Scenario 3 forecast will reveal how the economy would have coped with the pandemic without government support, as well as the degree of influence of the pandemic on the main macroeconomic indicators.

Table 10. Exogenous Parameters of Scenario 3

Period	2018	2019	Scenario 3	
Scenarios	Fact	Fact	2020	2021
External prerequisites for the forecast				
Brent crude oil price, USD per barrel on average per year	72.8	64.4	41.2	48.5
Economic growth rate in partner countries, % YoY	2.6	2.2	-7.9	4.5
Food inflation in the world (FAO Food Price Index), % YoY	-3.5	1.8	5.0	7.0
Consumer inflation in Russian Federation, % YoY	2.9	4.5	4.4	4.0
Nominal exchange rate USD to RUB, Rubles on average per year	62.7	64.7	74.0	76.0
Internal prerequisites for the forecast				
Oil and gas condensate production, millions of metric tonnes	90.4	90.6	83.9	84.0

Period	2018	2019	Scenario 3	
Scenarios	**Fact**	**Fact**	**2020**	**2021**
Nominal growth of average monthly wages, % YoY	8.4	14.6	5.4	9.2
Nominal exchange rate RUB to KZT, Tenge on average per year	5.5	5.9	5.7	5.8
Fiscal stance, % of GDP	-0.6	2.3	1.6	1.9
Fixed capital investments, % YoY	17.5	8.5	-9.8	0.0

E.2 Modeling results: Impact of COVID-19 on Kazakhstan's aggregate demand in 2020 and forecast for 2021

124. The simulation results obtained using the specified exogenous factors are presented in this section.

E.2.1 Scenario 1

125. In Scenario 1, the exchange rate of the US dollar against the Tenge on average in 2020 could have reached 373.9 units, demonstrating the strengthening of the Tenge by 3.4% compared to 2019. In 2021, with the price of Brent crude at USD 61.5 per barrel, the USD/KZT rate would have been 385.1 Tenge per dollar.

126. The average annual consumer inflation at the end of 2020 would have formed at 5% and 5.8% in 2021, against 5.3% observed in 2019. Thus, in the absence of the pandemic, inflation in Kazakhstan would be within the target range. The industrial producer price index could have been 3.9% in 2020 and 3.7% in 2021. Household spending on final consumption at the end of 2020 could have grown by 5.1% compared to 2019.

127. According to the model, gross fixed capital formation in 2020 could have increased by 7.8%. Considering the assumptions in accordance with the scenario, the volume of real exports in Kazakhstan could have grown by 2% in 2020 and 2.8% in 2021. Kazakhstan's real imports in 2020 are estimated to grow by 3.9% and by 3.7% in 2021. Thus, the growth rate of real GDP in 2020 could have been 4.7% in 2020 and 4.8% in 2021.

Table 11. Results of Scenario 1 Simulation

Period	2018	2019	Scenario 1	
Scenario	**Fact**	**Fact**	**2020**	**2021**
Forecast of the dynamics of internal inflationary processes, incomes, and the USD to KZT exchange rate				
Consumer inflation (CPI), % YoY	6.0	5.3	5.0	5.8
Industrial inflation (PPI), % YoY	19.0	5.1	3.9	3.7
GDP deflator, % YoY	9.2	6.8	4.8	5.4
Nominal cash income, % YoY	11.30	11.30	10.38	10.14
Real cash income, % YoY	5.00	5.80	5.11	4.09
USD to KZT nominal exchange rate, on average per year	344.7	382.7	373.9	385.1
Forecast of the components of domestic aggregate demand				
Household final consumption expenditure, % YoY	6.1	6.0	5.1	4.4
Gross capital formation, % YoY	5.4	12.9	7.8	8.0
Real exports, % YoY	9.6	2.5	2.0	2.8
Real imports, % YoY	6.6	10.8	3.9	3.7

Period	2018	2019	Scenario 1	
Scenario	**Fact**	**Fact**	**2020**	**2021**
Real GDP growth rate, % YoY	4.1	4.3	4.7	4.8
Nominal GDP, billion Tenge	61820	68639	76937	86764
Nominal GDP, billion USD	179.3	179.3	205.8	225.3

E.2.2 Scenario 2

128. Considering the exogenous factors of Scenario 2, the exchange rate of the US dollar against the Tenge on average in 2020 would be 411.5 Tenge per dollar, demonstrating a weakening of the Tenge by 7.5% compared to 2019. The main factor behind the weakening is a decline in the cost of oil exports, as the Brent crude oil price will amount to USD 41.2 per barrel (a decrease in price by 36%).

129. Average annual consumer inflation by the end of 2020 will be 8.5% and 6.5% in 2021, against 5.3% observed in 2019. Thus, inflation in Kazakhstan is outside the long-term target range of the monetary policy. Nevertheless, it corresponds to the forecast of the National Bank. The industrial producer price index will decline by 13.6% in 2020 and rise to 15.9% in 2021, amid increased government support measures and a low base in 2020. Household spending on final consumption by the end of 2020 will grow by only 1.5% compared to 2019 amid a decline in real incomes of the population, which will amount to -0.02% compared to the previous year.

130. According to the model, gross fixed capital formation is expected to grow by 2.7% in 2020. Due to the COVID-19 pandemic, the real export volume in Kazakhstan will fall by 27.5% in 2020, considering the assumptions of the scenario. In 2021, real exports will grow by 5.7%. The real import volume of Kazakhstan in 2020 is estimated to fall by 0.4%, but it will grow by 2.3% in 2021. Thus, under the COVID-19 scenario with government support, the GDP growth rate in 2020 would be at -3.1% in 2020 and 4.6% in 2021.

Table 12. Results of Scenario 2 Simulation

Period	2018	2019	Scenario 2	
Scenarios	**Fact**	**Fact**	**2020**	**2021**
Forecast of dynamics of internal inflationary processes, incomes, and USD/KZT exchange rate				
Consumer inflation (CPI), % YoY	6.0	5.3	8.5	6.5
Industrial inflation (PPI), % YoY	19.0	5.1	-13.6	15.9
GDP deflator, % YoY	9.2	6.8	5.4	11.3
Nominal cash income, % YoY	11.3	11.3	8.5	10.1
Real cash income, % YoY	5.00	5.80	-0.02	3.37
USD to KZT nominal exchange rate, on average per year	344.7	382.7	411.5	432.8
Forecast of the components of domestic aggregate demand				
Household final consumption expenditure, % YoY	6.1	6.0	1.5	3.9
Gross capital formation, % YoY	5.4	12.9	2.7	5.7
Real exports, % YoY	9.6	2.5	-27.5	5.7
Real imports, % YoY	6.6	10.8	-0.4	2.3
Real GDP growth rate, % YoY	4.1	4.3	-3.1	4.6
Nominal GDP, billion Tenge	61,820	68,639	70,088	82,365
Nominal GDP, billion USD	179.3	179.3	170.3	190.3

E.2.3 Scenario 3

Scenario 3 covers a hypothetical case in which the state did not introduce any measures to support the economy during the COVID-19 pandemic.

131. Under this scenario, annual consumer inflation in 2020 would have been at 7.8%, which is lower than inflation under Scenario 2. This is because the pandemic control measures by the state did not result in an increase in the money supply growth rate, which, in turn, exerts inflationary pressure. In Scenario 3, inflation is forecast to subside to 6.1% in 2021.

132. In the absence of government support, by the end of 2020 industrial deflation would have reached -14.6% and rebounded to 15.7% in 2021.

133. Lack of government support would also slow down the growth rate of nominal cash income to 6.35%. However, in 2021 nominal cash income will grow by 9.5% under this scenario, which is still lower than in Scenario 2 (with state support). At the same time, real money incomes of the population would have decreased by 1.3% by the end of 2020, having recovered by growing 3.8% in 2021 compared to 2020. A decrease in real cash income would lead to a decrease in the growth rate of household spending on final consumption to 0.6% in 2020. In 2021, the growth rate in final consumption would have amounted to 4.2%, which is slightly higher than in Scenario 2 due to the low base effect of 2020 in Scenario 3.

134. Household gross capital formation also grows at a slower pace: 0.6% in 2020 and 4.8% in 2021.

135. In Scenario 3, the nominal USD/KZTexchange rate is 421.8 Tenge and 438.52 Tenge at the end of 2020 and in 2021, respectively. Despite the greater depreciation of the nominal exchange rate in the absence of government support, exports by the end of 2020 demonstrate a strong decline of 28% compared to 2020. In 2021, the export growth rate becomes positive at 5.1%, which is lower than in Scenario 2 (with government support). Similarly, real imports without government support would have fallen by the end of 2020 more strongly in annual terms (-1.8%). The recovery in 2021 of imports would be slower than under Scenario 2 where the growth rate of imports would be 2% compared to 2020.

136. Thus, by the end of 2020, the real GDP of Kazakhstan would have decreased by 4.6% in annual terms without state support. In 2021, the growth rate of Kazakhstan's real GDP would be 3.7% in Scenario 3.

Table 13. Results of Scenario 3 Simulation

Period	**2018**	**2019**	**Scenario 3**	
Scenarios	**Fact**	**Fact**	**2020**	**2021**
Forecast of the dynamics of internal inflationary processes, incomes, and USD to KZT exchange rate				
Consumer inflation (CPI), % YoY	6.0	5.3	7.8	6.1
Industrial inflation (PPI), % YoY	19.0	5.1	-14.6	15.7
GDP deflator, % YoY	9.2	6.8	4.5	8.6
Nominal cash income, % YoY	11.30	11.30	6.35	9.5
Real cash income, % YoY	5.00	5.80	-1.31	3.78

Period	2018	2019	Scenario 3	
Scenarios	Fact	Fact	2020	2021
USD to KZT nominal exchange rate, on average per year	344.7	382.7	421.8	438.52
Forecast of the components of domestic aggregate demand				
Household final consumption expenditure, % YoY	6.1	6.0	0.6	4.2
Gross capital formation, % YoY	5.4	12.9	0.6	4.8
Real exports, % YoY	9.6	2.5	-28.0	5.1
Real imports, % YoY	6.6	10.8	-1.8	2.0
Real GDP growth rate, % YoY	4.1	4.3	-4.6	3.7
Nominal GDP, billion Tenge	61,820	68,639	68,429	79,488
Nominal GDP, billion USD	179.3	179.3	162.2	181.3

E.3 Modeling results: Impact of COVID-19 on Kazakhstan's aggregate supply in 2020 and forecast for 2021

137. The forecasts of certain economic sectors for 2020–2021 were drawn from a baseline scenario. Forecasting only within one scenario is explained by the mathematical features of the error correction model (ECM) used to build the model from the supply-side. The need to include the ECM-terms variable with a lag of 1 requires model reassessment. As a result, a single baseline scenario is considered.

138. The scenario is based on the following economic assumptions:

Table 14. Exogenous Factors for Building a Supply-Side Model

Exogenous factor	Assumption for 2020	Assumption for 2021	Source
Price of Brent crude	USD 45 per barrel	USD 47 per barrel	US Energy Information Administration https://www.eia.gov/
Price of aluminum	USD 1,660 per metric tonne	USD 1,680 per metric tonne	World Bank https://www.worldbank.org/en/research/commodity-markets
Nominal Exchange rate USD to KZT	421.8	432.8	Forecast of the demand-side model

139. To make a prediction for 2021, the model was reassessed for each sector of the economy. Such a reassessment, being necessary for the forecast, is simultaneously a test of the previously obtained model for the robustness of the coefficients and the inclusion of 2020 as an additional observation did not significantly change the estimation of the coefficients of the model built for the 2021 forecast.

140. The deepest drop in output was in the transport and storage sector, which occurred due to:

i) **The direct impact** of restrictive quarantine measures to prevent the spread of COVID-19 in the country. Passenger traffic was limited by the instructions of the Chief Sanitary Doctor of Kazakhstan, including the requirement to keep social distancing of 1.5 meters. As a result, air transport passenger turnover in January to October 2020 fell by 52.1% compared to the corresponding period of 2019 and rail passenger turnover fell by 52% over the same period.[5]

ii) **The indirect impact** of the pandemic, In addition to the direct impact of quarantine measures that drastically reduced passenger traffic, the transport and storage sector was seriously influenced by a decrease in economic activity in other sectors of the economy because the volume of cargo transportation decreased. For example, due to less activity in the mining industry, there was a decrease in the volume of oil products transported.

141. Nevertheless, the gradual recovery of air, rail, and other types of transportation and communication in the third and fourth quarters of 2020 provides evidence to suggest that by the end of 2020, the decline in the PVI of this sector for the whole year of 2020 will be less than the decline from January to October 2020 (approximately 9.3%).[6]

142. The second-largest drop of output was in the wholesale and retail trade sector and repair of cars and motorcycles. The sector was directly influenced by the quarantine measures introduced to prevent the spread of Covid-19 infection. The closure of large retail outlets and shopping and entertainment centers throughout the country led to a decline in the dynamics of wholesale and retail trade. The volume of domestic trade in the country fell by 9.4% from January to October 2020 (the PVI for January–October 2020 was 90.6% against the corresponding period of 2019). If the volume of retail trade decreased by 5.7% compared to the corresponding period of 2019, then the volume of wholesale trade fell by 9.5%.

143. However, since 2 August 2020, quarantine measures have been eased, as a result of which large retail outlets and shopping and entertainment centers resumed business on weekdays. This allows us to conclude that in the third and fourth quarters of 2020 this type of economic activity will gradually recover. And by the end of 2020, according to the estimation, the PVI of this sector will decrease by only 4.1%.

144. The mining industry in Kazakhstan has been affected by the pandemic mainly through a decrease in global energy prices, in particular, oil prices. This year, measures to combat the pandemic have led to a decrease in economic activity in all countries of the world and a corresponding decrease in demand for oil. Thus, prices for Brent crude oil from January–September 2020 decreased by 38.2% compared to the same period in 2019.[7]

145. Since the volume of mining industry output is mainly represented by the value of crude oil production (78% of the whole output of the mining industry), world oil prices have a direct and significant effect on this sector. Thus, the decline in oil prices in 2020 led to a decrease in the PVI of the mining industry in January–October 2020 by 2.2% compared to the corresponding period of 2019.[8]

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[5] Data from the Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan.

[6] Data from the Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan.

[7] Information from the US Energy Information Administration.

[8] Data from the Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan.

146. The deterioration of the epidemiological situation around the world led to oil prices remaining below USD 48 per barrel in November 2020. As a result, the output of the mining industry for 2020 is estimated to decline by 4%.

147. In contrast to these sectors, significant growth for 2020 is estimated in the construction sector. The volume of construction work in the country is expected to grow annually by 6%. This annual growth rate is lower than in 2019 when the PVI of construction was 113.2% over 2018.

148. The slowdown in the growth rate of the volume of construction work without an actual decline is because this sector was not directly or significantly affected by quarantine measures. People in the sector were required to practice social distancing and follow sanitary standards, but there was no complete prohibition of construction work. Moreover, the sector was supported by an increase in investment in housing construction.

149. The COVID-19 pandemic has not greatly affected the agriculture, forestry, and fisheries sectors. Thus, the gross output of products (services) in agriculture, forestry and fisheries from January–October 2020 amounted to 5,395.1 billion Tenge, exceeding the output of the corresponding period of the previous year by 5.2%. The sector was also supported by investments. According to the Bureau of National Statistics, in January–October 2020, investments in fixed assets in agriculture, forestry, and fisheries amounted to 412.5 billion Tenge, an increase of 7.5% compared to the previous year. As a result, the annual growth in the output of agriculture, forestry, and fisheries for 2020 is forecasted to be slightly lower than the indicators for January–October, amounting to 3.7%. This is because of the negative contribution of seasonal decline in output in the fourth quarter.

150. The manufacturing industry is estimated to grow in 2020 and the PVI of this economic sector will be 102.3%.

151. From January–October 2020, the PVI of the manufacturing industry had already amounted to 103.2% compared to the corresponding period of 2019. However, we cannot say there is no negative impact of the pandemic on this sector. The growth rate of manufacturing output had already slowed down in May 2020, dipping to 0.5% compared to May 2019. There was also a negative trend in output in the manufacturing industry in each month of the period April–October 2020 as a percentage of the corresponding month of 2019.

152. The downward dynamics of the PVI of the manufacturing industry will probably continue until the end of the year due to the deterioration of the epidemiological situation since October. Therefore, the annual growth in the output of this sector is estimated at 2.3% for 2020.

153. Based on the forecast of the PVI of these sectors, it is possible to calculate the real GDP growth rate from the supply side for 2020. The structure of Kazakhstan's GDP in 2019 was used for this purpose (figure 4).

Figure 4. Structure of 2019 GDP by Type of Economic Activity as a % of Total GDP

Source: Compiled using data from the Bureau of National Statistics, Agency for Strategic Planning and Reforms of the Republic of Kazakhstan.

154. The share of the analyzed types of economic activities that make up 60% of the GDP is taken as 100%, which implies the calculation of the real GDP growth rate, all other things being equal (i.e., with an assumption of a constant level of output in other sectors of the economy).

Table 15. Calculation of Real 2020 GDP Growth Rate (taking into account the PVI forecast of output of certain industries)

	Share of GDP of 2019, in %	Reassessment of share of corresponding sector	PVI of corresponding sector for 2020
Agriculture, forestry, and fisheries	4.5	7.3	103.7
Mining and quarrying	14.4	23.7	96.0
Manufacturing industry	11.5	18.8	102.3
Construction	5.5	9.0	106.0
Wholesale and retail trade; repair of cars and motorcycles	17.0	27.9	95.9
Transport and storage	8.0	13.2	90.7
Real GDP growth rate	60.8	100.0	97.9

155. Thus, within the framework of the supply-side model, the real GDP annual growth rate is expected to decrease by 2.1% in 2020.

156. This estimate is more optimistic than the estimation of the demand-side model. However, it should be considered that in the supply-side model not all types of economic activities in the structure of GDP were included in the regression analysis, only the most significant ones. As a result, it is possible that economic activities not considered in the framework of this model will make an additional negative contribution to the GDP growth rates of 2020. However, the model from the aggregate supply side provides a detailed picture of the impact of the Covid-19 pandemic on the economy of Kazakhstan.

157. In 2021, within the framework of the revalued error correction model (ECM) for each sector of the economy, growth rates of output are predicted against the

background of the premise of a gradual decrease in the number of COVID-19 cases and a recovery in economic activity around the world.

158. It should be highlighted that if the PVI for agriculture, manufacturing, construction, trade, and transport in 2021 is high, the PVI for the mining industry is only 100.5%, which suggests that in 2021 the output of the mining industry will remain almost at the same level as in 2020. This is because oil prices are projected to fall below the pre-pandemic level of USD 47 to USD 48 per barrel despite the latest decision by the OPEC+ countries.

159. After the shock of the COVID-19 pandemic, in 2021 the drivers of Kazakhstan's economic recovery will be the construction and manufacturing sectors.

160. Considering the PVI forecast for the output of mining, manufacturing, agriculture, transport, trade, and construction for 2021, the GDP growth rate was calculated in accordance with the GDP structure of 2019. Thus, the forecast of annual economic growth of Kazakhstan for 2021 is 3.8% according to the supply-side model.

F. Conclusion

161. The COVID-19 pandemic seriously affected Kazakhstan’s economy. The impact was transmitted through both supply and demand sides. The largest decline in growth rates occurs in exports and real GDP. Household spending has grown at a slower pace than in 2019.

162. In terms of aggregate supply, economic contraction due to the COVID-19 pandemic restrictions were observed in wholesale and retail trades, car and motorcycle repairs, mining, and transportation and warehousing. The manufacturing sector experienced substantial pressure due to the pandemic, although the industry's production value index remains positive.

163. The construction and agriculture sectors were the main economic drivers from the production side. Long-standing and renewed state support programs offset the initial COVID-19 impact and provided strong growth impetus.

164. The COVID-19 pandemic affected economic sectors through various channels. For instance, mining industry output declined due to the global oil demand contraction, while the trade and transportation sectors were negatively impacted by local restrictions and quarantine measures aimed to contain the spread of the virus (see a detailed discussion of sectoral impact in Appendix D).

165. On the demand side, the econometric model assessed three scenarios to estimate COVID-19 impact in 2020 and forecasts for 2021. Scenario 1 assumes a counterfactual reality of no COVID-19; Scenario 2 looks at the COVID-19 impact with government support measures, and Scenario 3 estimates economic impact without government support measures.

- Scenario 1: Real GDP, exports, imports, household expenditures, and real incomes grow, but the growth rate in many instances is lower than in 2019.

There is slower growth in exports, imports, household expenditures on final consumption, and real incomes. Nevertheless, the annual GDP growth rate is higher than in 2019 and further accelerates in 2021 due to a smaller denominator, i.e., a deflator.

- Scenario 2: Real GDP contracts by 3.1% in 2020 and rebounds at 4.6% the next year. The sharpest decline of 27.5% occurs in exports, while imports also decline, but at a slower pace. Real incomes of the population remain stagnant, while expenses grow by 1.5%. In 2021, economic growth rebounds at 4.6% supported by exports recovering by 5.7%. Real incomes of the population grow by 3.4%, while consumption increases by 3.9% compared to 2020.

- Scenario 3: Absence of government support, leads to substantial real GDP contraction of 4.6% in 2020, which is 1.5% lower than in Scenario 2. Real exports, imports, and incomes of the population fall. Similarly, the sharpest decline by 28% is in real exports. In 2021, economic growth resumes at 3.7% of GDP, which is lower than in Scenario 2. This indirectly indicates the effect of the state support measures driving post-COVID-19 recovery.

166. In all three scenarios, the economy will grow in 2021 for different reasons. In Scenario 1, a stable macroeconomic situation and exchange rate ease inflationary pressure making growth an artifact of a diminishing denominator. However, when looking at the two COVID-19 impact scenarios (with and without state support measures), we observe that support measures stabilize the economy in 2020 by preventing deeper contraction and produce an impulse for a quicker rebound. However, in our analysis we omit any discussion about growing government debt and declining National Fund Reserves used to pay for the state support measures when tax revenues declined.

Appendix A: Heteroskedasticity and multicollinearity diagnostics for equations of the demand-side model

Heteroskedasticity Test: White*

	for equation of GDP_kz		
F-statistic	0.664562	Prob. F(5,12)	0.6574
	for equation of HH		
F-statistic	0.224549	Prob. F(1,22)	0.6403
	for equation of GCF		
F-statistic	0.341498	Prob. F(1,18)	0.5662
	for equation of EX		
F-statistic	1.182622	Prob. F(4,10)	0.3757
	for equation of IM		
F-statistic	0.487180	Prob. F(3,21)	0.6949
	for equation of NI		
F-statistic	0.349205	Prob. F(1,8)	0.5709
	for equation of CPI_KZ		
F-statistic	2.089019	Prob. F(11,9)	0.1392
	for equation of PPI		
F-statistic	0.243700	Prob. F(6,14)	0.9540
	for equation of DEFL		
F-statistic	2.345127	Prob. F(3,20)	0.1035

*White test shows that for all equations we accept the null hypothesis about the presence of homoskedasticity.

Multicollinearity Test: VIF**

Variables	**Coefficient Variance**	**Centered VIF**
	for equation of GDP_kz	
HH	0.008983	4.816800
GCF	0.000887	2.735482
EX	0.003178	4.614205
IM	0.000955	2.435046
FS	0.034962	1.748405
	for equation of HH	
NI/CPI KZ*100	0.017174	1.000000
	for equation of GCF	
INV_TOT	0.014086	1.000000
	for equation of EX	
OIL_PROD/OIL_PROD(-1)*100	0.085994	1.010592
W_GDP	0.365920	1.010592
	for equation of IM	
HH	0.040319	1.050694
GCF	0.038920	1.020593
	for equation of CPI_KZ	
NI(-1)/CPI_KZ(-1)*100	0.006844	1.249051
(USD_RUB*RUB_KZT)/(USD_RUB(-1)*RUB_KZT(-1))*100	0.001394	2.238866
(CPI_RU*RUB_KZT/RUB_KZT(-1)*100)/100	0.001556	1.365515
FAO	0.002303	2.125275

**VIF calculation was not used for the NI equation since the VIF requires at least two variables including an intercept. Centered VIF turned out to be less than 5 for all cases, which shows there is no multicollinearity between groups of variables.

Appendix B: Heteroskedasticity and multicollinearity diagnostics for equations of the supply-side model

Heteroskedasticity Test: White*

	for equation of mining		
F-statistic	0.189726	Prob. F(14, 8)	0.9966
	for equation of manufacturing industry		
F-statistic	0.571077	Prob. F(4, 19)	0.6868
	for equation of trade		
F-statistic	2.303509	Prob. F(4, 19)	0.1054
	for equation of construction		
F-statistic	0.602378	Prob. F(9, 12)	0.7735
	for equation of agriculture		
F-statistic	0.985412	Prob. F(9, 10)	0.5042
	for equation of transport		
F-statistic	0.357811	Prob. F(14, 9)	0.9586

*The White test shows that for all equations we accept the null hypothesis about the presence of homoskedasticity.

Multicollinearity Test: VIF**

Variables	Coefficient Variance	Centered VIF
	for equation of mining	
DELTA_LOG_K_MINING	0.002175	1.351134
DELTA_LOG_L_MINING	0.007803	1.487896
DELTA_LOG_BRENT	0.002796	2.156522
ECM_TERMS_MINING(-1)	0.014101	1.819366
	for equation of manufacturing industry	
DELTA_LOG_K_MANUF	0.007547	1.602852
DELTA_LOG_L_MANUF	0.034699	1.495957
DELTA_LOG_ALUM	0.003943	1.320129
ECM_TERMS_MANUF (-1)	0.018378	1.186177
	for equation of trade	
DELTA_LOG_K_TRADE	0.000420	1.235363
DELTA_LOG_L_TRADE	0.007268	1.065352
DELTA_LOG_NOM	0.004076	1.074304
ECM_TERMS_TRADE(-1)	0.036907	1.193596
	for equation of construction	
DELTA_LOG_K_CONSTR	0.020077	1.356213
DELTA_LOG_L_CONSTR	0.441617	4.192307
ECM_TERMS_CONSTR	0.053071	4.775961
	for equation of agriculture	
DELTA_LOG_K_AGRICUL	0.002969	1.929394
DELTA_LOG_L_AGRICUL	0.014135	1.872845
ECM_TERMS_AGRICUL(-1)	0.047453	1.046770
	for equation of transport	
DELTA_LOG_K_TRANSPORT	0.000937	1.229790
DELTA_LOG_L_TRANSPORT	0.005813	1.180565
DELTA_LOG_BRENT_PRICE	0.000695	1.141004
ECM_TERMS_TRANSP(-1)	0.034711	1.136807

**Centered VIF turned out to be less than 5 for all cases, which shows there is no multicollinearity between groups of variables.

Appendix C: Test for restrictions of the coefficients

Test for restrictions of the coefficients of the Cobb-Douglas equations for consistent returns to scale.

A restriction test for coefficients of the Cobb-Douglas equations was carried to verify the null hypothesis of constant returns to scale. Testing was carried out using Wald's test based on the Restricted Least Squares approach and Student's t-test.

Null hypothesis: $0 = 1 - \alpha - \beta$

	Mining	Manufacturing	Agriculture	Transport	Trade	Construction
t-statistic	-8.907492	-2.950620	-3.881654	-12.81094	- 10.57423	-2.495709
Probability	0.0000	0.0082	0.0013	0.0000	0.0000	0.0214
F-statistic	79.34341	8.706157	15.06724	164.1202	111.8144	6.228565
Probability	0.0000	0.0082	0.0013	0.0000	0.0000	0.0214

The null hypothesis is rejected in all cases.

Appendix D: Assumptions on capital and labor growth rates for the supply-side model.

Mining and quarrying

The mining industry has been impacted by the COVID-19 pandemic primarily through a decline in global energy prices, in particular oil prices. According to OPEC+ estimates, prices for Brent crude by the end of 2020 will be at USD 45 a barrel. Consequently, it is assumed that the book value of fixed assets in real terms will grow less than in 2019 by only 4%, ensuring simple reproduction against last year's 6%. At the same time, the introduction of quarantine measures in the country simultaneously with the drop in oil prices affects the labor force in 2020. For example, in May 2020, KazMunayGas announced the dismissal of 249 people. In total, the mining workforce is projected to decline by 2% in 2020. However, already in 2021, according to the OPEC+ forecast, oil prices will recover to USD 47 a barrel. Against this background, investment activity is expected to recover in 2021 and the growth rate of the book value of fixed assets in the mining industry will be 7% and the growth in the number of employees will be 3%.

Nevertheless, the coefficient for the number of employees turned out to be insignificant in the mining industry model, and a negative sign for the coefficient (-0.02) may indicate an overabundance of labor in this industry, which is reflected in a decrease in the marginal product of labor.

Manufacturing industry

In the manufacturing industry, investments in fixed assets decreased in annual terms by 20.8% in 2019. The current crisis is not conducive to the growth of investment in fixed assets. As a result, it is assumed that in 2020 the book value of fixed assets in the manufacturing industry in real terms will decrease by 5% compared to 2019. At the same time, the decrease in employment in this industry will be 1.4% in 2020 compared to 2019 amid the COVID-19 pandemic. Nevertheless, in 2021, considering state support for the manufacturing industry within the framework of the Business Roadmap 2025 program and the Enbek program, the book value of fixed assets of the manufacturing industry is expected to increase by 3% in real terms, and at the same time an increase of 1% in the number of employed is expected.

The coefficient of capital change was found to be insignificant in the manufacturing model.

Agriculture, forestry, and fisheries

Due to state support for agriculture, it is assumed that the COVID-19 pandemic will not have a strong impact on investment in fixed assets in 2020. As a result, in 2020 it is expected that the growth rate of the real book value of agricultural fixed assets will remain positive at 5%. However, this figure is lower than in 2019 when the growth rate of the book value was 6%. Due to the quarantine measures, employment in the agricultural sector is expected to decrease by 1% in 2020. In 2021, against the background of the provision of the agro-industrial complex and in addition to direct subsidies and concessional lending opportunities, it is assumed that the real book value of agricultural fixed assets will increase by 8%. Also, considering the development of new directions for the processing of agricultural products, employment in the agricultural sector is expected to grow by 3% in 2021.[1]

Wholesale and retail trade; repair of cars and motorcycles

The largest impact of the COVID-19 pandemic was in the trade sector through the depreciation of the USD/KZT nominal exchange rate.

It is assumed that the book value of fixed assets in the trading sector in 2020 will increase by 7%, which is lower than in 2019. The slowdown in the growth rate of the book value of fixed assets is associated with a decrease in investments in fixed assets in this sector. The growth rate of the number of employed in 2020 will remain at the 2019 level of 2%. This is due to the premise that despite the restriction of trading platform activities, the intensification of online trading will ensure an influx of self-employed people into this area.

In 2021, a sharp increase in the growth rate of employment in the trade sector is expected to reach 9.5% due to the inflow of self-employed from other sectors of the economy. In particular, the transfer of some workers to remote work, which may remain in 2021, will allow them the opportunity to additionally engage in online trading as self-employed. In 2021, a further slowdown in the growth rate of fixed assets in the trade sector is expected to be 5% due to the delayed impact of the decrease in investments of the previous year. However, the fall in the value of fixed assets is not expected due to the State Trade Development Program 2021–2025.
The corresponding estimates of the coefficients in the trading model turned out to be insignificant. This result is consistent with the empirical results for other developing countries.[2]

Construction

The construction sector has not been directly affected by the COVID-19 pandemic. Moreover, the industry was supported by an increase in investment in residential construction. Against this background, the assumption for 2020 is made that the book value of fixed assets will increase by 8% compared to the previous year, with an increase in the number of employees by 5%. The latter assumption is based on data from the Electronic Labor Exchange Enbek.kz, according to which construction has become the main industry where new vacancies are created in 2020. In 2021, further growth in the book value of fixed assets in the construction sector is expected due to the intensification of demand for housing amid the possibility of withdrawing some savings from the pension fund. The growth rate of the book value will be 14% in 2021

[1] Official information resource of the Prime Minister of the Republic of Kazakhstan: https://primeminister.kz/ru/news/reviews/itogi-apk-za-4-mesyaca-2020-goda-sozdanie-novyh-moshchnostey-uvelichenie-ploshchadi-selhozkultur-i-cifrovizaciya-352342
[2] Jansen M., Peters R., Salazar-Xirinachs J. M. (2011). Trade and employment: from myths to facts. International Labour Office. Geneva: ILO. ISBN: 978-92-2-125321-1

compared to 2020. The number of employed will remain at the 2020 level due to high employment growth rates in 2020 at 5% due to government support.

The construction sector, according to the simulation results, turned out to be labor-intensive rather than capital-intensive. The coefficient at the rate of employment growth turned out to be significant, while the coefficient at the rate of capital change was insignificant.

Transport and storage

This sector has been directly affected by the restrictive measures introduced because of the COVID-19 pandemic. Investments in fixed assets of the transport and warehousing sector showed negative dynamics in 2019, having decreased by 16.9% compared to the previous year.[3]

As a consequence, it is expected that the growth rate of the book value in 2020 of this sector will decrease by 1% compared to the previous year. At the same time, given the complete suspension of the movement of air and rail transport during the state of emergency and the persistence of restrictions on the operation of transport as part of the subsequent relaxation of quarantine measures, it is expected that the number of people employed in this sector will decrease by 50% in 2020.

However, with government support for employment projected in 2021, employment in this sector is expected to recover, increasing by 40% in 2021 compared to 2020.

[3] Data of the Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan

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