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Application of modern models of economic growth

To determine the state of the country on the example of Ukraine

Content

Statistical material on such indicators of Ukraine's development as gross domestic product, population growth, investments, inflation, national debt of the state for the last 10 years is collected. The economic deflator of economic development and the savings ratio are determined.

Comparisons were made with China, the United States, Germany, Poland, Romania, the Czech Republic, Hungary, and Moldova.

The models of economic growth of R. Harrod, Harrod-domar, Solow-Swan, Cobb-Douglas-Tinbergen, Lucas and Romer are used.

According to all these models, it is determined that the actual growth rate of the economy is also lower than guaranteed in 2020 and prolongs the sharp decline; equilibrium investments differ significantly from actual ones in the negative direction, which leads to further stagnation of investment activity; from 2010-2011, technical progress has decreased significantly; reduction of funding for science and education in the country leads to a lack of interest in working in scientific institutes of the country, which entails a lack of scientific discoveries, innovations, development of new technologies.

The author's team of professors and masters performs macroeconomic issues using modern economic and mathematical models. Also develops the use of macromodels for micro-economic objects.
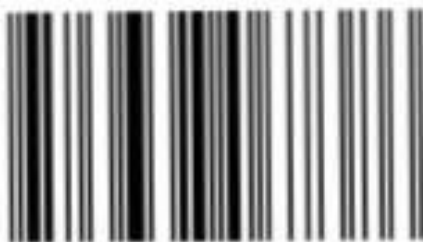
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Chapter 3.

Design and development of information system

Introduction

Almost every day we come across words like "economic indicators" and "economy". These terms are heard on TV screens, published in the headlines of official periodicals, sounded in the reports of officials and in the conclusions of economic experts, used by the Government and the Ministry of Economic Development in assessing the state of the economy, are generalized concepts of forecasting macroeconomic benchmarks. The International Monetary Fund constantly emphasizes the importance of these concepts, shows interest in their dynamics and explains all the problems in the socio-economic environment of our country.

Most citizens attribute the deterioration of living standards, unemployment and the need to go abroad to earn money by the deteriorating economy of Ukraine. But the word "economy" hides a deeper and ambiguous phenomenon. Yes, the economy itself is a rather complex but comprehensive organism. It is this organism that allows each person, country or society as a whole to function successfully. A successful economy is the key to stability and prosperity, but it depends on many factors, both internal and external. So, today, the challenge of time for the economies of all countries is the rapid spread of coronavirus COVID-19. And Ukraine is no exception. The economy of our country is experiencing a unique combination of two shocks - falling demand due to quarantine measures introduced in March 2020 due to an outbreak in the world and Ukraine caused by coronavirus SARS-CoV-2i and declining supply due to shutdowns, business restrictions, temporary closure. and logistics violations. And all this is superimposed on the huge problems and debts accumulated before the crisis.

Therefore, determining the prospects of Ukraine's economy in terms of economic growth models is not only interesting but also quite important

and important topic, as one of the most important long-term goals of economic policy of any government is to stimulate economic growth, maintain its pace at stable and optimal levels. . It is necessary to have a clear idea of what economic growth is, what factors stimulate it, and which, on the contrary, constrain it.

Recently, more and more attention is paid to the study of the possibility of predicting sustainable economic development of the country, the study of world experience in managing economic processes and more. Thus, in particular, economic theory develops dynamic models of economic growth, which help to explore the conditions for achieving the optimal (equilibrium) rate of economic growth for each country and to develop effective long-term economic policy. Despite the significant amount of scientific work and significant achievements in the theory and practice of state regulation of the economic process, there is no single solution to overcome this problem.

One of the interesting and useful opportunities provided by modern automated information systems is the ability to model the prospects of economic processes in order to most effectively influence them. Modeling is one of the ways to improve the analysis of economic phenomena in the future, which organically combines mathematical methods with real financial results to solve economic problems, which allows you to choose the best option for sound policy, ie, optimizes management decisions.

The purpose of this work is an in-depth study of the peculiarities of the formation and prospects of Ukraine's economy. At the same time, starting work on a particular topic, it should be noted that this is a very multifaceted, complex and large topic. Therefore, to achieve this goal it is necessary to solve the following tasks: to investigate the main determinants of economic growth and their measurement, to justify the use of certain definitions and on the basis of empirical research to select the necessary

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determinants for further use in economic growth models. transition economy, show the most famous models of economic growth.

The object of research is the economy of Ukraine and its factors.

The subject of the study is the determinants of economic growth and their impact on the economy of Ukraine and the main models of economic growth.

The relevance of the topic is that the prospects for development and the dynamics and nature of economic development of Ukraine, especially in a pandemic, are the subject of the strongest attention of economists and politicians. Much in the life of the country and its prospects depends on the processes taking place in the dynamics and the structural changes in the national economy. So, today, the state of our country's economy and prospects for its development is the most discussed topic in the country. The above indicates the relevance of this topic.

The scientific novelty of this research work is a comprehensive approach to studying the prospects of Ukraine's economy, ie, the application in one study of several models of economic growth with different conceptual and correlation components, which will better consider the object of study and draw more sound conclusions.

Methodology: the main conclusions of the study are based on confirmed provisions and conclusions, as well as on the research of leading domestic and foreign economists on the problems of economic growth. To achieve this goal, methods of general scientific, statistical and empirical analysis were used.

Various sources of information were involved in writing the work, including: textbooks, reference statistical materials, textbooks for economic specialties of higher education, educational literature, periodicals, open scientific articles, the Internet, etc.

The structure of the work includes an introduction, three sections, which are divided into several paragraphs, a conclusion and a list of sources used.

Chapter 1
Theoretical bases of modeling of processes of economic growth

1.1 Definition of the role and place of Ukraine in the modern world economy, including in Europe

Before embarking on modeling the prospects of Ukraine's development in transition, I consider it necessary to define the concept of the object under study, ie to consider the current state of the economy in general, to define the role and place of Ukraine in the world economy, including Europe , as well as to determine the general and specific features of the socio-economic situation in the transition economy. The urgency of this issue in modern conditions is determined by the need to clarify the nature, root causes and levers that affect the economic situation, its features and key macroeconomic indicators that characterize the level of the economy of any country, including Ukraine.

The role and place of any country in the world economy depends on many factors. Among the main are: the dynamics of the national economy, the degree of its openness and involvement in the international division of labor, its ability to adapt to external conditions of economic life. Being in the center of Europe, next to the states that are actively transforming their economies, Ukraine lags behind and does not keep up with the processes taking place in neighboring countries, although it has always been and will be at the intersection of geopolitical interests. Taking into account the resources and geographical location of Ukraine, as well as the specific conditions created by the world economy for each country, Ukraine must find its way in accelerating structural change in order to strengthen its role in the world economy.

The world economy (or "World Economy" or "world economy") is the current system of economies of all countries, the holistic nature and functioning of which are determined by the objective laws of human society and is a complex, dynamic system that is constantly changing [1] .

At the present stage of social development, the world economy plays a significant role in the economy of each individual country and the world as a whole, as it connects national economies that are connected and interact with each other. The relationship is the specialization of countries in the production of certain goods and services and trade in these products in world markets [2].

If we consider the role and place of Ukraine in Europe and in the world economy as a whole, the statistics and data show that we have something to be proud of. Ukraine is the largest country in Europe, and in terms of population it ranks fifth and brings 0.1113% of world gross national product. The basis of natural resource potential (RDP) of Ukraine are land resources, the share of which in the total natural complex of the state exceeds 44%. Part of the world's chernozems, the most fertile soils on Earth, are concentrated in the country. Mineral resources (iron, manganese, uranium ore, coal, rock salt, raw materials for building materials, etc.) also occupy a prominent place, the share of which in the national RDP exceeds 28% [3, 319]. Our country is also one of the three largest suppliers of barley, one of the seven most powerful producers of vegetable oil, pork, sugar, potatoes, grain and together with France, Germany and the United States is one of the largest producers of sugar beet, and hundreds of prominent Ukrainians - those who created in Ukraine or abroad, emigrants or their descendants are behind a good third of the world's greatest achievements and inventions, from the World Forum in Davos to Google and Apple.

Despite such a strong demographic and geographical potential, Ukraine's economy (by the end of 2019) ranks 62nd among 174 countries in nominal GDP ($ 153.8 billion), 49th in the world and penultimate among European countries (ahead of only Moldova) in GDP at purchasing power parity ($ 409.8 billion (IMF data for 2019)) (see Table 1.1), 113th place out of 169 countries in terms of GDP per capita ($ 3224.9). , according to intermediate data, Ukraine ranks 38th among 65 countries in terms of public debt ($ 30.5 billion), 55th place among 114 countries in terms of gold and foreign exchange reserves ($ 26.53 billion), 60th place among 171 countries in terms of unemployment (9.9%), 66th place among 82 countries in terms of wages ($ 404.0 / month), 70th place in terms of ease of doing business.In terms of the world economy, Ukraine, unfortunately, has stagnated since 1992 [4].

As we can see, our country does not show very high ratings of the state of the economy among the countries of the world. And although Ukraine, according to the UN classification on the grouping of countries in terms of their level of economic development belongs to countries with economies in transition (the group consists of about 30 states of the former Soviet Union, Central and Eastern Europe and Asia, which includes Ukraine) [5] improve their results in the ranking and take a proper place among the wealthy countries of Europe and the world.

Definition of the role and place of Ukraine in the modern world economy, including in Europe. In the framework of this study and in order to fully disclose the topic of this unit, as well as to clearly demonstrate the level of Ukraine's economy and its place in the world economy, below, on the example of one of the main economic indicators (GDP at purchasing power parity) level of nominal GDP of Ukraine and individual countries of the world at purchasing power parity (PPS), for the last ten years.

It should be noted that such macroeconomic indicators as gross domestic product and other important macroeconomic indicators, on the example of which we will study the prospects of Ukraine's economy in terms of economic growth models, are really important and indicative elements that characterize the dynamics and general state of the economy. . For example, knowing the GDP of different countries, we can conditionally determine which of them is the richest and so on.

A full analysis of the state of the world economy and its components, the level of the world economy on these and other indicators is made by experts from international organizations such as the UN, IMF and World Bank, which are official reports. However, it can be seen that their assessment is slightly different, because international organizations monitor the economies of only their member countries, and the number of member countries of these organizations is different (IMF - 182, World Bank - 181, UN - 185 countries) and so on.

Yes, we see that Ukraine has not yet reached the level of our neighbor - Poland, but is ahead of Hungary and Moldova. In addition to the general characteristics, the data show that in 2014 the GDP indicator for PKS of Ukraine tended to decrease (by 4.8% compared to 2013 and by 8.8% compared to 2014), and only in 2019 it caught up with 2013 year. If we turn to archival data, we find information that leading economists link the crisis of 2014-2015 not only with the beginning of hostilities in 2014 in the east of the country, but also with the incomplete recovery of the world economy after the crisis of 2009, which could not not to affect the economy and our country. In addition, in June 2015, the process of falling oil prices began, which was due to the slowdown in the world economy and the difficulties with its recovery in Europe.

Table 1.1 - Components of the world economy and their nominal GDP on PKS for 2010-2019 billion dollars.

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
China	12353,7	13809,9	15186,6	16658,4	18205,3	19664,1	21228,4	23130,7	25293,6	27307,0
USA	14992,1	15542,6	16197,1	16784,8	17527,3	18224,8	18715,1	19519,4	20580,3	21420,7
Germany	3261,2	3459,6	3541,0	3618,6	3767,3	3872,9	4000,2	4176,0	4342,9	4443,6
Poland	801,5	859,3	889,8	918	966,1	1013,6	1055,5	1128,4	1215,4	1287,3
Romania	332,6	346,4	360,3	379,5	399,7	419,5	444,2	484,8	518,6	549,2
Czech Republic	288,3	299,5	302,8	306,6	320,8	340,3	355,8	375,6	395,7	413,0
Ukraine	351,6	378,5	386,7	393,4	374,4	341,3	353,3	369,0	390,4	409,8
Hungary	220,7	229,4	230,4	239,0	253,7	266,2	274,9	292,1	314,5	335,8
Moldova	16,5	17,8	18,1	20,1	21,5	21,6	22,8	24,3	25,9	27,3
TOTAL gross world product on PKS	89646,8	95270,3	100154,9	105367,7	111065,6	115998,7	121089,8	128046,9	135762,1	142005,7

The table was compiled personally by the developers according to [6], [7]

Finally, due to the new challenges for the economy in 2020 due to the global spread of coronavirus disease, it can be stated that a new economic crisis has begun in the world economy, which will certainly affect Ukraine. The unprecedented quarantine measures applied by

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countries due to the COVID-19 outbreak in the late first and early second quarters led to a significant narrowing of demand and a drop in world trade. As a result, in the second quarter of 2020, the economies of almost all countries of the world experienced the deepest decline since World War II. Since May, against the background of the gradual lifting of quarantine restrictions, the country's economies have gradually recovered, sometimes even faster than expected, but despite the projected further recovery in 2021, they generally will not reach pre-crisis levels [8]. For example, the Organization for Economic Co-operation and Development predicts that the global economy will decline by 6% in 2020, or by all 7.6%, if "the second wave of coronavirus outbreaks occurs in most countries by the end of this year." According to the results of the second quarter of 2020, the actual fall in GDP of Ukraine has already reached a negative value of 11.4%. In addition, a new round of disease growth in some countries since late June has heightened the risks of a longer exit from the crisis. However, the rate of decline of Ukraine's economy was comparable to other countries, both developed and emerging markets.

The IMF said that by early June, governments around the world had spent about $ 10 trillion from the state budget to counter the economic consequences of the pandemic. "For the first time since the Great Depression, countries with both developed economies and emerging markets will be in recession," warns the International Monetary Fund.

The economic picture is bleak even for the world's richest, as governments and politicians struggling with a devastating health crisis and deaths have already spent trillions of dollars, leaving entire sectors of the economy in doubt.

As we can see, the development of the world economy and the events that take place in it have a significant impact on every component of the world economy. And Ukraine is no exception. Therefore, it is very

important that every country in the world, as an important component of the world economy, strives for economic growth and has a certain margin of safety to be able to meet external challenges.

Thus, using various means of defining the role and place of Ukraine in the world economy, the unit identified in a concise and generalized form Ukraine's capabilities, its importance in the world economy, ranking in the world and Europe by important indicators, highlights major crisis periods and current challenges. which we still have to overcome.

Therefore, before considering the prospects of Ukraine's economy in terms of economic growth models, it will be appropriate to refer to the statistical macroeconomic indicators of Ukraine's development over the past 10 years and consider the main determinants of the economic situation in our country.

1.2 Statistical assessment of the main determinants of the national economy of Ukraine during the years of independence

Achieving a high and stable rate of economic growth is one of the main goals of macroeconomic policy. The meaning of the prospects for economic growth lies in its contribution to the economic well-being of society. But the study of the prospects of Ukraine's economy is impossible without the analysis of national statistical information of the country, which, incidentally, is the main basis for further construction of mathematical models.

Monitoring the current state of the economy is quite multifaceted and large in scope of research, the analysis of which would go beyond the required scope of this work. It should be noted that the purpose of this study is to attempt to model the prospects of Ukraine's economy in the near future in terms of economic growth models, so in this section, considering

the current state of the economy, we did not focus on assessing socio-economic development countries on all known indicators, which, incidentally, for the relevant years for any country have already been calculated and are in the relevant statistical databases.

We decided to assess the quality of economic, monetary, budgetary, social and public debt management, as well as the risks they pose to the country in the future, using 11 of the most important indicators for the period of Ukraine's independence.

It is interesting to see where modern Ukraine began and where it has reached in the last 29 years. Having studied a certain amount of economic literature and summarized information on this issue, below we provide a comparative analysis of the main economic determinants in the economy of our country since the formation of an independent state. It should be noted that the analysis of important determinants in this study is based on available macroeconomic data at the date of its preparation, so the analysis period for individual indicators may be different. The last date for updating most of the data in this report is as of November 1, 2020, and for some data, as of October 1, 2020, incl. statistical information is entirely for 2020 at the time of development of the work - is missing and will be available in the World and / or national statistical database only in 2021.

The main determinant in assessing the economic condition of the market at the global level or a single country is a universal indicator of GDP - gross domestic product. It shows how many goods and services are produced in the country per year, ie allows you to measure the economy in money [10].

By the way, GDP and GDP per capita are used to characterize economic growth, but for different purposes. If you want to compare the economic and military-political potential of different countries, then use the 1st indicator. To compare the living standards of the population (in

different countries or in the same country, but at different times) use the second indicator.

We will analyze (Table 1.2) by three main types of GDP: nominal, real and GDP at purchasing power parity (PPS).

Nominal is the total volume of products and services produced, measured in current prices, ie in prices that are relevant today [11].

A clearer answer is given by the analysis of real GDP, which is measured in constant (constant, basic) prices, ie the value of this indicator is affected only by changes in production volumes and is not affected by possible inflation and devaluation processes.

GDP per capita generally takes into account the ratio of currencies - hryvnia and dollar - based on prices for a standard set of goods and services. Therefore, this indicator is one of the most suitable for comparing and measuring the uneven development.

It is important to note that the calculation of GDP according to world practices began in Ukraine only in the late 1990s. Preliminary data are quite conditional estimates, which can lead to significant artificial distortions in the data [12].

According to the table, we see that in 1991, at the time of the formation of independent Ukraine, the nominal GDP of our country was $ 77.4 billion (according to the World Bank). For comparison: it was more than Israel ($ 59.1 billion) and Singapore ($ 45.5 billion) [12]. During the period of independence, our country's economy grew only 1.9 times - to $ 153.8 billion in 2019 year. This is a very low growth rate. For example, over the same period, Israel's GDP increased 9.7 times and in 2019 amounted to $ 395.1 billion, Singapore - 8.2 times ($ 372.1 billion). The low growth rate of Ukraine's economy during the years of independence is associated in archival data with the significant crisis in the country in the

first half of the 1990-s, as well as with the impact of the global crises of 2008-2009 and 2014-2015.

Table 1.2 – Comparative analysis of the determinants of economic development of Ukraine by types of gross domestic product from 1991 to 2019

№	GDP indicator	1991	2019	Rate grows of GDP, %
1.	In actual prices (nominal), billion $*	77,4	153,8	198,0%
2.	At constant 2010 prices (real), billion. $*	188,4	135,5	71,9%
3.	GDP for PKS, billion. $*	332,1	409,8	123,4%
4.	In actual prices (nominal), UAH billion. **	299,0 billion carb.	3974,6	-
5.	At constant 2010 prices (real), UAH billion.	152,4 billion carb.	1077,1	-

*The table was compiled personally by the developers according to [13] *, [14] ***

Thus, the question arises: in Ukraine as a whole, the economic potential is growing or is it still falling? As noted above, the economy is measured not only in current period prices (nominal GDP), but also in fixed-date prices (real GDP), for example, the World Bank calculates in 2010 prices. From the data of table 1.2. we see that this figure is sadder for Ukraine: during the years of independence (since 1991) as of January 1, 2020, the economy fell by almost a third - to $ 135.5 billion, or 28.1%.

When analyzing GDP by PKS, the Ukrainian economy shows a slight increase over 28 years - by 23.4%, while in other countries this figure has increased several times.

The GDP forecast for 2020 remains unchanged - the fall in GDP will be about 5-6% (including the resolution of the Cabinet of Ministers of 27.05.2020 №534 and the NBU Inflation Report for October 2020). The contraction of the economy at the end of the year is primarily the result of a difficult business for the second quarter, which applied the most severe quarantine restrictions aimed at overcoming coronavirus disease. The main factor in the deepening GDP decline was expected to be a decline in domestic demand, which was due to both the direct impact of strict quarantine restrictions on economic activity and indirect - due to uncertainty about the further development of the pandemic situation. As a result, consumer behavior of citizens has changed in the direction of reducing the purchase of non-essential goods and investment behavior and investment behavior of enterprises – in the direction of postponing business projects [15], closing and suspending certain industries and slowing real wages. In contrast to previous crises, the service sector was the most affected, rather than manufacturing, catering establishments, sports and cultural institutions, and passenger transport. At the same time, since the beginning of the third quarter, business activity has noticeably revived in the context of a gradual easing of restrictions, due to which a gradual economic recovery is expected. This will be facilitated not only by milder quarantine conditions, but also by a revival of external demand and an increase in domestic consumption. However, economic activity will be constrained by the persistence of certain restrictions in the conditions of adaptive quarantine, as well as increasing the risks of further increase in the incidence of coronavirus [16].

Along with the GDP indicator, such an economically important indicator as inflation is considered – an excessive, against the needs of trade, increase in the amount of paper money, followed by their rapid depreciation (Table 1.3). Manifested by an increase in the general level of

prices and a decrease in the purchasing power of money. The main negative consequences of inflation are falling living standards and deteriorating expectations about the macroeconomic situation in the future, which leads, in particular, to a decrease in business activity [17].

Inflation rates are defined as the magnitude of changes in price indices, which, in turn, is an expression of the value of a set of goods (services) in each period of time, %.

Table 1.3 – Generalized data on the inflation index of Ukraine since 1991

Indicator	1991*	1996**	2019	As of 01.11.2020
Consumer price index, or inflation index, or Laspeyres index, %***	390,0	139,7	104,1	102,7

* the national currency was the so-called rubles - reusable coupons;

** the national currency hryvnia was put into circulation

The table was compiled personally by the developers according to [18] **

We can clearly see the fluctuations of this important indicator of the country's economic stability on the basis of generalized statistics for the last 10 years on such indicators as the consumer price index, inflation rate and inflation rate.

The inflation rate shows how many monetary units or percentages of the money supply are greater than the commodity. The inflation rate is calculated using price indices (consumer price index, GDP deflator, etc.) as the difference between the value of this index for a certain period (in percent) and 100%. The prices of the base period are taken as 100%, and the prices of the current years are estimated to these 100% [19]. Thus, if the price index for consumer goods in 2018 was 109.8%, and the base year

2017 was taken as 100%, then prices for this period increased by 9.8% (109.8-100).

The inflation rate shows how many percent the prices of the current year have changed from the prices of the previous one over a certain period of time. It shows how inflation has changed over a period of time (accelerated or slowed down). The inflation rate is equal to the difference between the consumer price indices of the current period and the base (previous) period, divided by the price index of the base (previous) period, and all this is multiplied by 100 [20]. These indicators for Ukraine for the last 10 years are calculated and summarized in Table 1.4.

Assume that in 2015 in Ukraine the CPI was 143.3%, and in 2014 - 124.9%. Using the formula, calculate the inflation rate for 2015, it will be equal to 14.7% (143.3-124.9) / 124.9x100%). This does not mean that prices in 2015 increased by 14.7% (they increased by 43.3% (143.3-100.0) but means that they increased by 14.7% more than in 2014.

Based on the above data, we see that the "leader" in inflation in Ukraine is 2014-2015, which was influenced by the global crisis and the beginning of hostilities in the east of our country. There is no inflation in 2012-2013, and the dynamics of decline is demonstrated in 2018-2019. As of November 1, 2020, the inflation rate according to IFIs is 102.7%, which is allegedly, from a scientific point of view, interpreted as a positive phenomenon.

Table 1.4 – Information on the inflation rate of Ukraine for the latter ten years, %

Indexes	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Consumer price index, or inflation index *	109,1	104,6	99,8	100,5	124,9	143,3	112,4	113,7	109,8	104,1
Inflation rate **	9,1	4,6	-0,2	0,5	24,9	43,3	12,4	13,7	9,8	4,1
Inflation temp**	-2,8	-4,1	-4,6	0,7	24,3	14,7	-21,6	1,1	-3,4	-5,2

*The table was created by the developers themselves according to [21] ***

*** calculated independently on the basis of data of the first row*
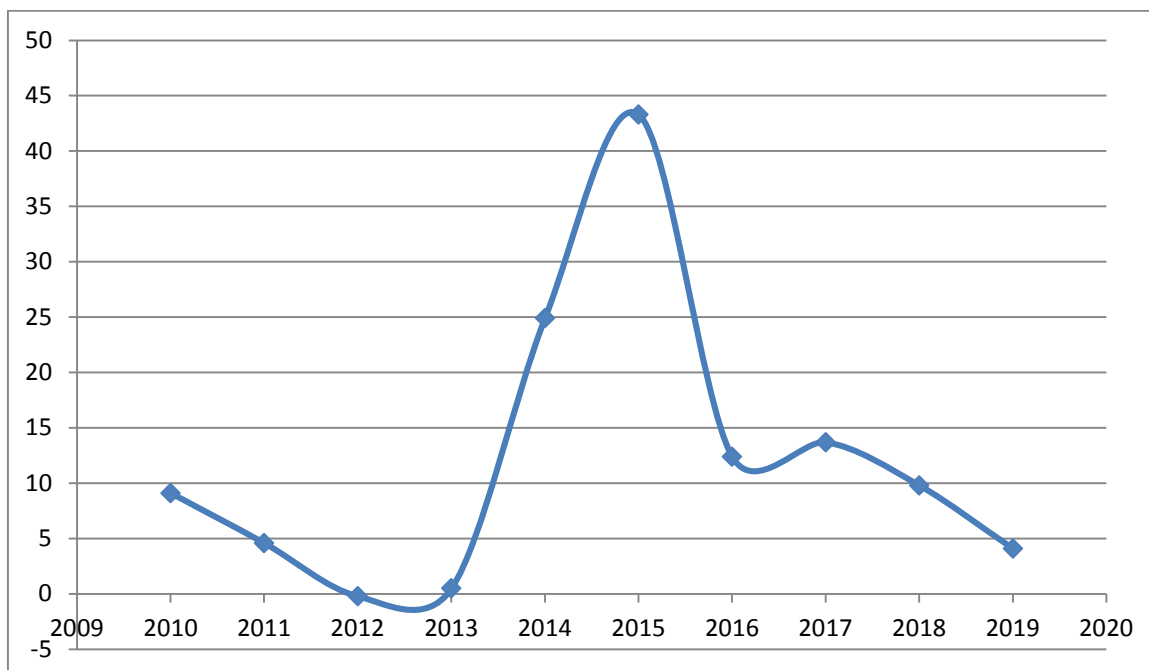
Figure 1.1 – Inflation rate in Ukraine 2010 - 2020

But given the economic situation in the world due to the COVID-19 pandemic, the situation in the country, the spread of coronavirus infection, the introduction of the picture and the introduction of restrictions (including logistics), reducing inflation is linked by leading experts with some reduction in demand. Against the background of increasing food supply in the consumer market, it neutralizes the backward pressure on prices from other factors, such as the weakening of the hryvnia, rising energy prices, recovery of economic activity and consumer demand, etc. and virtually prevents a significant acceleration of inflation.

In addition to this indicator, a special tool is also used - a deflator, which will be appropriate to declare, because it is an important determinant used to assess the dynamics of the state economy. The GDP deflator (Paasche index) is an indicator that characterizes the general level of prices in the economy. An analogue of the consumer price index, only much more honestly: it covers not only the goods selected in the basket for comparison, but all goods produced in the economy. It is calculated as the ratio of nominal GDP to real [22].

Some analysts see the GDP deflator as a key characteristic of inflation. The tool has been used by economists relatively recently, when it became necessary to compare GDP over several years, so data on the deflator for 1991 - are missing. This indicator is regularly displayed by statistical services in all countries of the world. The decrease in the indicator indicates the positive dynamics in the country's economy, as well as the fact that real GDP is growing relative to nominal, and the price level has decreased. Conversely, the growth of the deflator is due to rising prices for fuel and a set of common goods.

Below, with the help of a graph (Fig. 1.2), we showed exactly how this indicator changed in 2010-2020.
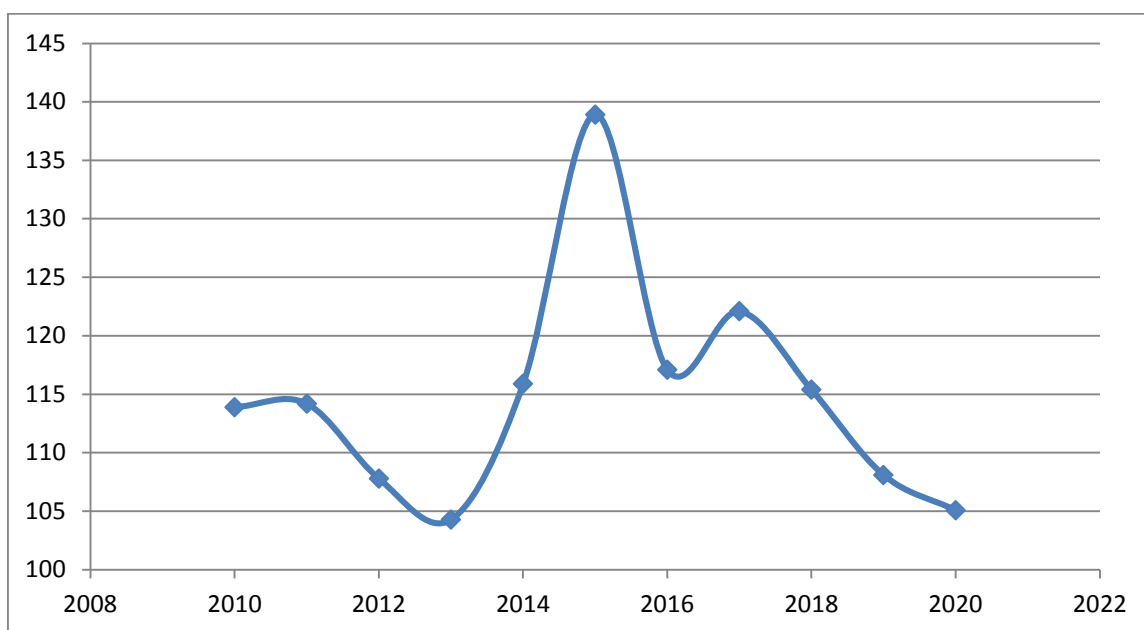
Figure 1.2 – GDP deflator in Ukraine

Over the past 10 years, the highest value of this indicator reached in 2015 and amounted to 138.9%. According to MFI forecasts, by the end of 2020 this figure will be 105.5%. Since the GDP deflator indicator in this paper is taken to compile a mathematical model for the prospects of Ukraine's economy in terms of economic growth models.

Another of the most important for understanding the quality of life and the level of any country's economy is GDP per capita. It reflects the amount of consumption per capita and is very closely correlated with the level of welfare in the country. GDP growth per capita signals the presence of economic growth, as well as productivity growth.

Below (Table 1.5.) Are data on changes in GDP per capita of Ukraine during the period of independence.

Table 1.5 – Comparative analysis of the level of welfare in Ukraine in terms of GDP per capita from 1991 to 2019.

	Indicator	1991	2019	GDP growth rate,%
1 *	GDP per capita (at current prices), $	1489,7	3659,0	2.4 times
2. * *	GDP per capita (at constant 2010 prices), $	3624,3	3224,9	88,9%
3 * * * *	GDP per capita for PKS, (at current international prices, $)	6356,7	13341,2	2.4 times

*The table was created by developers independently according to [23] *, [24] **,*
*[25] ****

As we can see, the nominal GDP per capita has grown 2.4 times since the independence of our state, but during this period it is a small growth of the economy. For example, our neighbors' growth rates over the same period are more significant: in Serbia, the GDP growth rate per capita is more than 3.3 times (up to $ 7,402.3), in Georgia - 3.6 times (up to $ 4,769.2) , in Poland - 7.0 times (up to $ 15,595.2). It should also be noted that in 2019 our country did not reach the parameters of pre-crisis 2013 ($ 3659.0 vs. $ 4035.0), ranking 122nd in the world ranking of the World

Bank. By the way, according to this parameter, Ukraine is inferior even to Moldova ($ 4498). GDP per capita in Poland in 2019, according to the World Bank, amounted to $ 15,595.2, Hungary - $ 16,476.0, Romania - $ 12,919, Bulgaria - $ 9,737, Belarus - $ 6,663.

The real income per capita of Ukraine is much worse - the income of every Ukrainian is $ 3224.9 per year and since independence has decreased by 11.1%, or almost $ 400.0 per year. According to this indicator, Ukraine ranks 113th. At purchasing power parity, GDP has grown more than 2.1 times in nominal terms over the past 28 years. This is a little, for example, in Poland over the same period, this figure increased 5.8 times (to $ 34,217.7), in Serbia and Moldova - 2.3 times (to 18,989.0 and $ 13,574.1, respectively). Ukraine ranks 98th in the world [20] on this indicator, among the neighbors it is the worst result.

Summarizing the analysis of this indicator, we note that GDP per capita for PKS can be both in current prices and in fixed (in the World Bank, these are the prices in 2017). The analysis of the data shows that in current prices from 1991 to 2019 the gross national income per capita increased from $ 6,356.7 to $ 13,341.2 (see Table 1.5), and in constant (real) - decreased (was 14396.6 $, and became 12810.3 $) It should be borne in mind that GDP per capita per PKS may increase due to population decline.

Therefore, the next important economic determinants should consider the dynamics of the population of our state since 1991 and the population of retirement age (Table 1.6).

Modern problems of the population are constantly talked about and written about a lot, because the current state and development of the country directly depends on the demographic processes taking place in society. Understanding the role and analysis of demographic processes and their impact on the country's economy is especially important in a market

economy - because the population is the basis for the formation of labor resources, and hence the economic potential of the country.

Table 1.6 – Analysis of the dynamics of the population of Ukraine and the number of retirees from 1991 to 2020

Indicator	1991	2019*	Growth rate (+,-)	As on 01.09.2020
Population of Ukraine, thousand persons **	51944,4	41902,4	-10042,0	41724,0
Population of retirement age (60 years and older), thousand persons ***	9631,1	9827,1	+196,0	9978,2
Population of retirement age (60 years and older) in the total population, %	18,5%	23,5%	+5,0%	23,9%

excluding the occupied territories (Crimea, Sevastopol, parts of Donbass)
*The table was created by the developers themselves according to [26] **, [27] ****

Data from the State Statistics in this form tell us about a slight increase in the number of retirees since 1991 - by 196.0 thousand people with a total population decrease of 10042.0 thousand people, or 19.3%. But all is not so good - the share of pensioners in the population of Ukraine today has increased from 18.5% to 23.9%, which clearly indicates a reduction in the working population under the age of 60 and the general aging of the nation.

Ukraine, according to the World Bank, has the highest rate of depopulation in Europe. Official data from the State Statistics Service say that as of September 1, 2020, 41,724.0 thousand people live in Ukraine. Thus, for 29 years of independence (according to the latest data as of the

reporting date), the population of Ukraine has decreased by 10,220.4 thousand people. The State Statistics Service usually considers the population by the number of births, deaths and records of changes in residence. Ukraine is one of the 30 countries in the world with a significant proportion of people aged 60 and older. Thus, the Ukrainian state is one of the "oldest" countries in the world. According to the national demographic forecast, by 2025 the share of people over 60 will be 25.0% of the total population, in 2030 - people over 60 will be over 26%. This is associated not only with the deterioration of the quality of life in the country, the collapse of the medical sector, etc., but also with the intention of a third of Ukrainians to emigrate, 55% of them - young people.

Interestingly, the Cabinet of Ministers of Ukraine together with the Institute of Demography and the State Statistics Committee presented the results of the assessment of the current population of Ukraine, conducted in late 2019. According to the results of the so-called "electronic census", the population of Ukraine at the end of 2019 is a total of 37,289.0 thousand people [28], which is 4613.4 thousand people or 11% less than the State Statistics Service.

Three methods were used for the census: a combined method of estimating the number of available population (data of mobile operators, data from statistical surveys of households and registers), the use of gender and age structure of the population together with data from registers, and the register method [29].

Below, Figure 1.3, shows the current distribution of Ukraine's population by age.
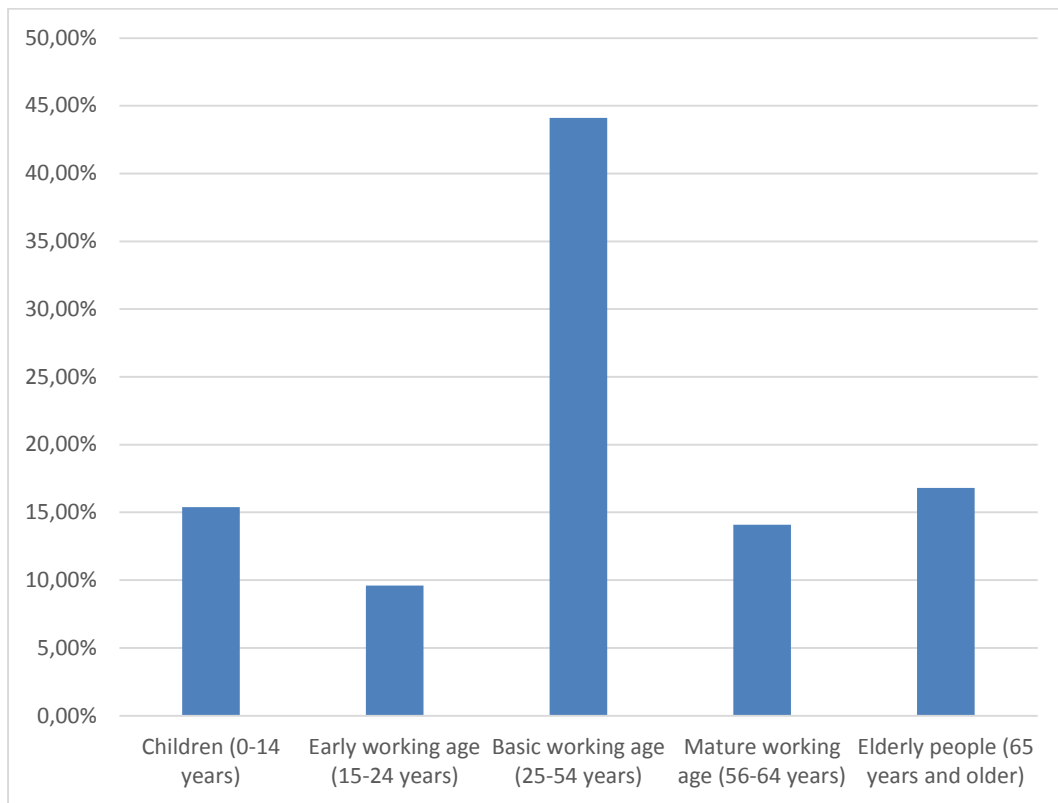
Figure 1.3 – Age distribution of the population in Ukraine [30]

As we can see, 25798.0 thousand people of working age (from 15 to 54 years old) live in Ukraine. This is 69.2% of the country's population in this calculation, ie almost a third of the population - people of retirement age. According to forecasts, in ten years the working population aged 25-54, which may be involved in the creation of the country's GDP, is declining. This is a challenge for the Ukrainian economy, because it is already experiencing a shortage of manpower. The main reason for depopulation in Ukraine today is the negative trends of high mortality and low birth rates, to which the Ukrainian reality was added by widespread migration due to rather unfavorable socio-economic conditions, such as the conflict in Donbass and declining living standards. In addition, after the introduction of the visa-free regime, millions of able-bodied people left the EU to earn money. In general, an average of 7 to 9 million Ukrainians take part in the migration process every year.

But despite the fact that human capital is one of the decisive factors in the development of any economy, the study of the effective functioning of the labor market, an important feature of which is the unemployment rate in the country, unfortunately today is a very important and acute issue.

Unfortunately, this indicator of our country has a negative trend (see table 1.7).

Table 1.7 – Monitoring of unemployment in Ukraine from 1991 to 2019

Indicator	1991	2019*	As of 01.11.2020 *
Unemployment rate,%	0,25%	8,6%	9,4%

* data of the State Statistics Service without taking into account the temporarily occupied territory of the Autonomous Republic of Crimea, the city of Sevastopol and part of the anti-terrorist operation zone.

The table was created by the developers themselves according to [8]

If we analyze only these data, it seems that the unemployment rate in our country has increased almost 34 times. Thus, the yearbook of the State Statistics Service for 1991 reports that at that time the unemployment rate was 0.25%. But it should be emphasized that at that time the Soviet calculation methodology was used. It should be emphasized that in the USSR there was criminal liability for parasitism, so it was dangerous to be unemployed. Thus, in 2019, unemployment was 8.6%, which is more than the generalized figure for the EU (7.4% in 2019), but lower than the unemployment rate in Greece (16.6%) and Spain (13.7 %) and more than in

the Czech Republic (2.0%) or in Germany and the Netherlands (both 3.2%) [31].

It should be noted that quarantine measures in 2020 aimed at overcoming the coronavirus disease COVID-19 had a very negative impact on the unemployment rate in Ukraine. There are no final annual data yet, but it is already said that during the quarantine the number of registered with the State Employment Service increased by 27% (401.0 thousand people). As for unofficial unemployment, the number of those who lost their jobs but did not join the labor exchange for various reasons (transport and infrastructure restrictions, the need to care for children, etc.) is estimated at up to 3 million people! And, most likely, these figures are not final. Today, the NBU's expectations for 2020 are 9.4%, and the National Bank assumes that this year's unemployment rate will be measured by double-digit "percentages", which has not been the case in Ukraine since 2002. The rapid rise in unemployment and, consequently, the impoverishment of the population threatens significant social upheavals [32].

The financial condition and welfare of the state are influenced by the level, trends and content of public debt. Therefore, the next macroeconomic indicator by which countries' economies are monitored and which we will consider is public debt. In fact, public debt arises as a result of financial borrowing of the state, contracts and agreements on the provision of loans and borrowings, prolongation and restructuring of debt obligations of previous years. It is important for analysts to identify potential risks associated with public debt so that current debt policy can be adjusted in a timely manner so as not to harm the economy and protect it from negative financial impacts, as well as to predict the possibility of timely repayment and servicing of public debt in the future. [33].

In the vast majority of countries around the world, public debt and its ratio to GDP are in the main group of indicators of economic development [34]. Our country is dependent on external financing, so every year the level of external public debt increases, which, as a consequence, increases the pressure on Ukraine's economy. At the same time, it is interesting to note that after the collapse of the Soviet Union, Russia, as the successor to the USSR, took on all debts and foreign assets, so Ukraine became independent with a zero balance of debts. In table 1.8. general data on the public debt of Ukraine for the years of independence are given.

Table 1.8 – Public debt of Ukraine from 1991 to 2020

Indicator	1991	2019	As of 01.11.2020 *
Public debt of Ukraine, UAH million *	zero balance	1 998 275,4	2 345 608,1

* The table was compiled personally by the developers according to [35]

However, as we can see, the amount of public debt alone does not give a comprehensive picture of the state of Ukraine's economy. In practice, the analysis of the ratio of various budgetary and economic indicators, including the comparison of the obtained results with the generally accepted criteria in this area. A number of indicators can be used for such analysis [33]. As part of our study, given that Ukraine has entered independence with a zero balance, it will be interesting and revealing to conduct an analysis over the past 10 years on two groups of indicators such as a comparative analysis of public debt to Ukraine's GDP and the ratio of external public debt and its gold and foreign exchange reserves (see table 1.7).

Table 1.9 – Dynamics of state and state-guaranteed debt, GDP and international reserves of Ukraine since 2010

Year	State and state-guaranteed debt, UAH million *	Debt growth rate to the previous year, %	of GDP in actual prices, UAH million *	State ratio. debt to GDP, %	Public and state-guaranteed external debt, million $	International reserves, million $ ***	The ratio of international reserves to external state. debt, %
2010	432235,0	+36,4	1079346,0	40,0	34759,6	34576,0	99,5
2011	473122,0	+9,5	1299991,0	36,4	37474,5	31794,6	84,8
2012	515511,0	+9,0	1404669,0	36,7	38658,8	24546,2	63,5
2013	584114,0	+13,3	1465198,0	39,9	37536,0	20415,7	54,4
2014	1100564,0	+88,4	1586915,0	69,4	38792,2	7533,3	19,4
2015	1572180,0	+42,9	1988544,0	79,1	43445,4	13300,0	30,6
2016	1929759,0	+22,7	2385367,0	81,0	45604,6	15539,3	34,1
2017	2141674,0	+11,0	2983882,0	71,8	48989,4	18808,5	38,4
2018	2168627,0	+1,3	3560596,0	60,9	50462,5	20820,4	41,3
2019	1998275,0	-7,9	3974564,0	50,3	48940,8	25302,2	51,7
On 01.10.2020	2345608,0	+17,4	3925000,0	59,8	50995,5	26525,8	52,0

*The table was compiled personally by the developers according to [35] *, [36] ****

Public debt to GDP is a key indicator that reveals the relationship between debt and productive activity of the economy. According to

domestic and foreign studies, the economically secure level of public and state-guaranteed debt for Ukraine is currently about 35% of GDP. This conclusion is based on the statistics of default in countries with emerging markets (studied by the IMF) and on Ukraine's own experience [37].
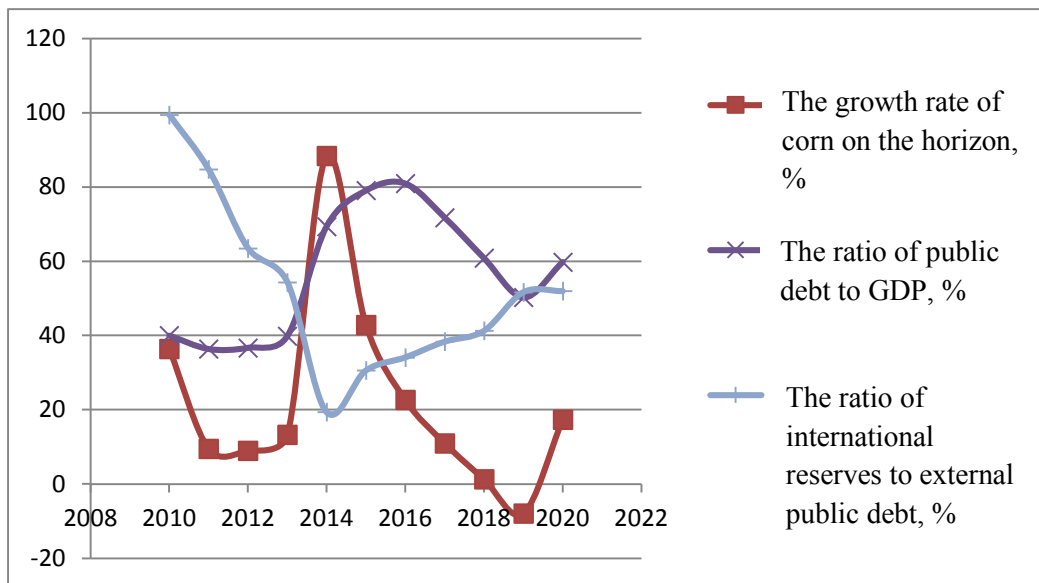
Figure 1.4 – Dynamics of debt and reserves

For 29 years, the state has borrowed a lot in the country and abroad, especially after 2008, and by the end of 2020 the wine to creditors 2345.6 billion UAH. (data from the Ministry of Finance of Ukraine), which is much higher than the safe level (59.8% of GDP versus the safe 35% of GDP). This is a lot, although compared to 2014-2016 it is a better result (in 2014 this figure reached 69.4% of GDP, in 2015 - 79.1%, in 2016 - 81.0%.). For comparison, most countries at a similar stage of development have a debt of 40-50% of GDP. In 2020, the debt-to-GDP ratio of Ukraine deteriorated to almost 60%. According to IFI forecasts for 2020, public and state-guaranteed debt will grow to 68% of GDP due to growing budget deficits, falling nominal GDP, and a weaker hryvnia exchange rate than at the end of last year. The high rate of growth of the debt-to-GDP ratio is

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evidence of an approaching crisis, and if the state is unable to stabilize the debt burden, then over time a significant part of the budget will be spent on debt service, and the tax burden may reach insurmountable heights for taxpayers [34]. The Law of Ukraine "On the State Budget of Ukraine for 2021" provides for a reduction in public debt next year by 3.4% - up to 64.6% of GDP.

A comparison of Ukraine's external public debt and its gold and foreign exchange reserves also gives a sad picture. External public debt in recent years is chronically ahead of Ukraine's foreign exchange reserves, and, as we see, as of 01.10.2020 it is overlapped by only 52.0%, although this is the best figure since 2014, when Ukraine's gold and foreign exchange reserves fell to catastrophically low levels. and covered only 19.4% of the debt. Then, against the background of financial and economic chaos and the apparent collapse of the country, a huge amount of foreign currency was withdrawn from the banking system by non-residents, households and domestic businesses. In December 2019, Ukraine's gold and foreign exchange reserves increased sharply, reaching an eight-year high to date. The reason is Gazprom's transfer of $ 2.9 billion to Naftogaz to enforce the decision to the Stockholm Arbitration Court. In 2020, against the background of significant payments on external liabilities on the financial account, the outflow of capital persisted. This led to a decrease in gross reserves compared to the end of the second quarter, however, they continued to increase compared to the beginning of the year - up to $ 26.5 billion.

The current level of Ukraine's international reserves ($ 26.5 billion) can be considered enough, but not stable, on the verge of sufficiency. As for external debt, it is clearly insufficient. Ukraine's foreign debt is a major threat to its international reserves. Therefore, the issue of attracting external loans, at least for refinancing, will be relevant for a long time [38].

Therefore, the stable development of the national economy of Ukraine depends on the search for investment resources. An important factor in investment growth is to determine the amount of savings that can be effectively further transformed into investment. So, the next indicator of our state's economy that we will consider is savings. By the way, savings are a part of the income of economic entities, not used for consumption, payment of taxes and fees and intended to meet future needs. In other words, gross national savings reflect the part of GDP that is directed to the reproduction of the economy and its future development. Therefore, at the state level, this potential of the national economy is constantly assessed. It depends on many factors, in particular on the political situation, primarily due to the direction of savings for the development of the national economy. The negative political situation leads to instability and reduced savings potential. This indicator is also influenced by psychological factors: the ability to manage psychological factors is limited and is realized mainly in the long run (increasing confidence, etc.) [39].

Table 1.10 – Gross savings from 1991 to 2020

Indicator	1991	2019	Expected for 2020 (IFIs)
Gross capital savings, % of GDP	26%	12,6%	10,5%

The table was compiled personally by the developers according to [40]

In Ukraine, according to the results of 2019 (World Bank data), gross savings, ie savings of individuals, businesses and the state, amounted to 12.6% of GDP, expected for 2020 and even less - 10.5% of GDP. It is

believed that sustainable economic growth requires financial resources of at least 27-35% of GDP, for example, EU countries since 2010 had a savings rate of 20-22% of GDP. Thus, at the end of 2019, gross savings in China amounted to 47% of GDP, Nepal and the Philippines - 44%, Mauritania - 38%, Bangladesh - 36%. Kyrgyzstan, Indonesia, India and Sri Lanka saved more than 30% of GDP. Worse in African countries. Thus, since 2010 in this region the level of savings was 4-18%: Benin - 11-18%, Kenya - 10-15%, Gambia - 4-12%. Unfortunately, in 2020 the forecast for this indicator is much worse - as we see from the table, today it is 10.5% of GDP, which is catastrophically low even against the background of African indicators and almost three times lower than necessary. The reduction of Ukrainians' savings was significantly affected by the pandemic in Ukraine and the world, which reduced, in particular, migrant remittances and income from individual entrepreneurship, although the government's income was supported by social assistance to the government. It is necessary to realize that a low level of savings preserves the poverty of the country forever and that only domestic savings can overcome poverty. The problem of savings in Ukraine is not related to the forms of their maintenance or redistribution of available scarce resources, but to the achievement of an acceptable level of savings themselves, as a result of expanding economic activity and increasing the amount of income of economic entities. This means that Ukraine's strategic priority should be the creation of effective institutions and economic mechanisms for growth and development, rather than trying to further compress and reduce "excess" demand, "excess" liquidity, "excess" budget expenditures [41]. This indicator was chosen to compile a model of Ukraine's development.

And therefore, the next determinant of the economic condition of the country, which needs to be enlightened, is the rate of savings. The situation in the economy, when current incomes do not cover the necessary

consumer spending, undermines the normal process of formation of national savings. Not to mention the problems of transforming savings into loans (but that's another story).

Figure 1.5 – Savings of the population as a percentage of disposable income for 1992-2020

From the above data, we see that since 2014, the process of formation of national savings has progressively deteriorated. In 2014-2018, the savings rate of the population fell to the level of 3-4% of disposable income (corresponds to the level of the middle 90-s), and from 2019 it became generally negative (in 2019 – 1.4%").

That is, long before the beginning of the crown crisis, the population literally "ate" the accumulated savings, and the current crisis only multiplied this process (as of 01.10.2020, this figure is "-6.0%"). In the last 1.5 years, the financial assets of the population have decreased by about UAH 150 billion.

Thus, given that the main fundamental task of the Ukrainian economy is the formation of savings and their transformation into investment, and savings in a healthy economy - the main component of national savings, gross savings and savings rates used in studying the prospects of Ukraine's economy in terms of economic growth models .

Economic power and welfare of countries is determined not only by the involvement in the process of economic activity of human capital and / or GDP per capita, but increasingly - by increasing production efficiency and competitiveness, which is reproduced through the formation of fixed (productive) capital, which is the most important part national wealth of the country, its technical base. Capital is the property that is used to make a profit, ie in the reproduction of GDP.

Therefore, the next important indicator that we will consider in this section of the work and which we choose to use in our mathematical econometric model is the value of fixed assets (fixed capital).

Capital exists in material and value forms. Capital in its material form is called funds. Valuation of funds is called funds. Thus, fixed assets are fixed assets expressed in value. Therefore, in the normative materials and practice of business communication, the terms "fixed assets" and "fixed assets" are used as synonyms [42].

Fixed assets have the largest share in the property of economic entities engaged in production activities and is directly related to the creation of GDP. By the way, fixed assets include buildings, structures, working and power machines and equipment, computers, vehicles, tools, production and household inventory and accessories, working and breeding cattle, perennials, domestic roads and other relevant facilities. The fixed assets also consider capital investments for radical land improvement (drainage, irrigation and other reclamation works); capital investments in

leased fixed assets; land plots, objects of nature use (water, subsoil and other natural resources) [42].

In our work, we have chosen to compile the model of the capital of Ukraine, expressed in value form - ie in the form of the value of fixed assets.

Due to the fact that from 1991 to 1994, official statistics provided data only on the percentage of capital accumulation and consumption, and these data did not reflect the real processes occurring in the economy, we analyzed the last 10 years, starting in 2010 year (table 1.11).

Table 1.11 – Change in the value of fixed assets, return on capital and capital intensity in general in the economy of Ukraine since 2010

Year	GDP in actual prices (nominal), UAH million.	GDP growth rate to the previous year, %	Cost of fixed assets (fixed capital), UAH million	Growth rate of value of fixed assets to the previous year, %	Capital productivity	
					Return on capital (GDP per hryvnia of fixed assets), UAH	Capital intensity of production, UAH
2010	1079346,0	118,1	6648861,0	100	0,16	6,16
2011	1299991,0	120,4	7396952,0	111,2	0,18	5,69
2012	1404669,0	108,0	9148017,0	123,7	0,15	6,51
2013	1465198,0	104,3	10401324,0	113,7	0,14	7,10
2014	1586915,0	108,3	13752117,0	132,2	0,12	8,67
2015	1988544,0	125,3	7641357,0	55,6	0,26	3,81
2016	2385367,0	120,0	8177408,0	107,0	0,29	3,42
2017	2983882,0	125,1	7733905,0	94,6	0,38	2,59
2018	3560596,0	119,3	9610000,0	124,3	0,37	2,70
2019	3974564,0	111,6	9574186,0	99,6	0,41	2,41

Note: since 2015, the data of the State Statistics Service without taking into account the temporarily occupied territory of the Autonomous Republic of Crimea, the city of Sevastopol and part of the anti-terrorist operation zone.

As already mentioned, economic progress is a complex and multifaceted process that requires a comprehensive assessment of its importance for the development of any country. The highest, fundamental criterion of economic, and hence social progress, is the level of development of productive forces, ie this criterion is used to assess the level of development of social production at this time.

As we can see, the ratio of total production (GDP) to the value of fixed capital in Ukraine was ambiguous. In general, in 2010-2019, GDP growth amounted to 72.8%, fixed assets growth - 30.6%, fixed capital productivity increased to UAH 0.41. per 1 hryvnia of fixed assets, and capital intensity decreased to UAH 2.41, or 2.5 times to the base year, 2010, respectively.

We analyzed the main parameters that characterize the level of development of productive forces of Ukraine on such indicators that reflect the effectiveness of material factors of production such as return on capital and capital intensity, because the ratio between GDP and fixed capital used is one of the leading in assessing economic performance. and forecasting economic growth, as fixed capital is the main material component of the reproduction process.

Return on capital shows the amount of gross output per 1 UAH. cost of fixed capital. This indicator characterizes the total return on the use of fixed capital, ie the efficiency of investment in fixed capital.

Under normal business conditions, the return on capital should tend to increase, as evidenced by the results of the analysis: this indicator for the first time since 2015, tended to increase and reached its largest size - 0.41 UAH. GDP per 1 hryvnia of fixed assets. But today, at the present stage of transformation of Ukraine's economy in the period of accelerated transformation of state capital into non-state, and then its redistribution - redistribution of property, the main thing for private capital is the

acquisition and consolidation of property and maximum one-time profit. Thus, the obtained data indicate that the growth of return on capital provides additional output without a corresponding increase in production capacity, as evidenced by the fall of this indicator compared to last year by 0.4% (growth rate - 99.6%). With this approach, we should continue to expect a decrease in capital in the form of fixed assets, although this figure in 2020 will also be affected by the laws adopted by deputies on 16.01.2020 Laws to increase the value threshold of fixed assets from UAH 6,000 to UAH 20,000. This means that if the value of tangible assets does not exceed UAH 20,000, they will not be considered fixed assets in tax accounting. This will lead to the fact that more assets can be classified as low-value and written off faster.

Capital intensity - shows what part of the value of fixed capital accounts for 1 UAH. value of gross output. This figure is inverse to return on capital. It characterizes the amount of fixed capital required for the production of gross output worth 1 UAH.

With constant capital intensity and other conditions of production, economic growth would be proportional to the increase in fixed capital. However, the country's economic growth is determined by both an increase in fixed capital and a decrease in capital intensity.

Capital intensity shows how "effective" new investments are for economic growth. Assume that the capital intensity is 6: 1 (as in 2010), then every six additional units of investment will lead to GDP growth per unit. If the capital intensity is equal to 2: 1 (as of today), then the increase in GDP per unit will be generated by only two additional units of investment.

Based on the analysis of the capital intensity indicator, certain regularities have been established. Thus, today, the fixed capital of Ukraine for 10 years has increased by 30.6%, capital intensity has decreased to

UAH 2.41. fixed capital for 1 UAH. products (services) produced in Ukraine, or 2.5 times, and since 2010 has the lowest value, which is a positive aspect and characterizes the provision of the country's economy with fixed capital and indicates an increase in gross output, the introduction of advanced technologies and productivity labor, because labor productivity is higher, the higher its capital adequacy and lower capital intensity of production [43].

However, not everything is so clear about the economy of our country. The value of the capital intensity indicator must be analyzed in a wider range, because its value, and thus the provision of the country's economy with fixed capital, is influenced by many factors, which complicates the formulation of unambiguous conclusions. Thus, one of a number of factors is the presence in the Ukrainian economy of capital-intensive industries, ie industries that use a large number of equipment with a long service life in relation to the products. Examples of such industries will be mining, oil, chemical, paper. Among the industries with low capital intensity are light, leather, furniture, and others. By the way, capital-intensive industries predominate in highly developed countries; in developing countries (including Ukraine) they can be found among the industries working for export. This explains the "phenomenon" of reducing capital intensity since 2015, which is associated with a decrease in output at capital-intensive enterprises in the country due to the lack of a market (which has a negative impact on government GDP), which is due to anti-terrorist operation in the East, severing economic ties with Russia as a major strategic partner in the market of Ukrainian metallurgical and chemical products, rising gas prices for industry in 2017-2018, which made the products of these industries less competitive, loss due to military actions of the mining industry of Donetsk and Luhansk regions, which, according to statistics, is about 20% of the country's industrial production.

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In general, the situation with fixed capital is complicated by the spread in 2020 of coronavirus disease. Thus, according to economic forecasts, by the end of the year is expected to reduce fixed capital in the form of fixed assets, associated with reduced capital contributions, including investment in fixed capital, and reduced productivity, weakening external and domestic demand due to the spread of COVID-19 etc. [15]. In addition, the introduction of strict quarantine restrictions has affected the reduction of investment activity and the decommissioning of some production facilities due to their underutilization due to reduced domestic demand [8].

That is, we still have to learn to manage the capital of the state with much greater efficiency. This requires a significant change in the parameters of development and the constant analysis and selection of this indicator for modeling for the successful long-term development of our country.

1.3 Modeling of economic growth in transition economies and its importance in modern conditions

At the present stage of socio-economic development of Ukraine of particular importance is a qualified analysis of macroeconomic indicators and parameters that characterize the economy as a whole, the main trends of its development and economic growth, as modeling economic growth, especially in transition economies. and Ukraine, are an important tool and tool that has not only conceptual and methodological, but also practical significance in solving pressing problems in modern conditions.

Analysis of a certain amount of scientific literature, statistics and practice of using economic growth models shows that there is a strong interest of experts in the possibilities of modeling economic growth in

transition economies and are a priority for research institutes and widely covered in both foreign and domestic scientific literature. Significant contribution to the formulation, understanding and development of general theoretical and methodological problems of creating and using macroeconomic models of economic growth was made by foreign researchers: Bruno M., Domar O., Kaldor N., Kupmans TK, Lewis A., Morishima M., Romer P., Solow R., Swan T., Stolera A., Tinberchen J., Uzawa X., Phelps E., Harrod R., Shell K. Arrow K., Eismont O. and others.

In the domestic scientific literature interesting and perspective results of researches in this area are presented in works of Alekseeva AA, Anchishkina AI, Barkalova NB, Vasilyk OD, Granberga AV, Dagaeva A, Zamkova O .O., Zvereva OA, Kostina NI, Kostoglodova DD, Nimchinova VS Plakunova MK, Raisky MM, Rivkina A., Sergienko YV, Smirnova AD, Sokolovskaya GA Trofimova G., Fedorenko NP, Fedotova Yu.V., Feldmana GA, Kharisova LM, Shtoffa VA, Yaremenko Yu.V. etc.

Most scientific publications pay great attention not only to identifying factors of economic growth, but also to substantiate forecasting models and methods of its regulation, study the world experience of applying mathematical models of economic growth, their efficiency and consequences for the economy and more. The tradition of retrospective study of economic growth with attempts to decompose into constituent elements to identify growth factors was continued in the works of Edward Denison (1915-1992) in the United States, Paul Berosch (1930-1999) and Angus Madison (1926-2010) in Europe and many others. authors.

Despite the large number of scientific publications and some achievements in the theory and practice of economic growth models, this problem continues to be the subject of scientific research and necessitates some correction of existing models and intensification of efforts to build

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such models of economic growth that more accurately reflect changing economic processes.

The processes of the transition economy are developing under the influence of heterogeneous disturbances, including the global spread of coronavirus infection COVID-19, which lead to deterioration at the micro and macro levels, and as a consequence lead to deterioration of the economy and, consequently, living standards. , which requires constant monitoring and regulation, as it has a significant impact on the processes taking place in the real sector of the economy. Thus, the importance of modeling economic growth in a transition economy is a very important area that is difficult to overestimate, and today is quite relevant.

In addition, the current level of socio-political relations, democratization and politicization of modern Ukrainian society, involvement in political life of various segments of the population, development of a multiparty system, changing personal priorities of individuals and individual social groups urgently require the development of statistical indicators to analyze economic life. at the state level. At the same time, the main sources of statistical data on the economic condition of the country and living standards are data from state reporting, in particular on population, labor, employed and unemployed in certain areas, the level of social security and social protection, quality of life and more. Therefore, the compilation of mathematical models by which these disparate indicators correlated, models that would take into account the growth rate of the economy on these indicators and which would objectively investigate economic challenges and their economic nature - and is the main prerogative in modern conditions.

That is why the modeling of economic growth plays a special role in the development and implementation of comprehensive measures, as ensuring a stable and high standard of living is an important prerequisite

for economic development of any country. This is especially relevant for Ukraine, because today, in a pandemic, when the pace of change in Ukraine's economy is almost daily, it is difficult to model economic growth, as evidenced by the constant deviations of government forecasts from the actual state of the economy. All this significantly complicates the planning and implementation of any economic activity and undermines public confidence in government. This once again objectively indicates the need to increase the efficiency of state regulation of economic processes both in countries with economies in transition and in particular in Ukraine, to improve and apply existing mathematical models to improve the country.

It should be noted that methodological approaches to modeling the prospects of Ukraine are diverse, as well as factors that affect the state of the economy.

1.4 Conclusions on the analysis and problem statement

According to the results of research identified in Chapter I of this paper, we saw that the economic development of the country is the most complex and multidimensional process, the effectiveness of which is measured by the same basic indicators for all. Thus, we considered the definition of the role and place of Ukraine in the modern world economy, including in Europe, got acquainted with the main economic indicators of our country and gave examples of Ukraine's place among other countries in the world and Europe. On the example of one of the main economic indicators (GDP at purchasing power parity (PPS) is a statistical analysis of the nominal GDP of Ukraine and some countries around the world at purchasing power parity (PKS) over the past ten years. In practice, when monitoring the state of any country's economy and comparisons between

countries, indicators are used, among which the most important are such macroeconomic indicators as gross domestic product (GDP), GDP per capita, population, etc.

Further, the work considered 11 main economic determinants of the national economy, made a thorough analysis of Ukraine's independence to date, compiled a brief rating of Ukraine along with other countries, including the EU, on such indicators as GDP , GDP per capita, unemployment rate and savings rate; the expediency of using separate definitions is substantiated and on the basis of empirical researches 6 main determinants are chosen for further use in models of economic growth, 4 of which are connected with physical possibilities of economy to growth: quantity of capital goods (fixed capital) in the form of cost of fixed assets. labor force, the determinant of productivity - real GDP, gross savings, as well as the Paasche index and the rate of productivity of capital. In addition, in practice (based on statistical data) considered the above economic concepts, used the skills of scheduling available data, improved the ability to work with world statistics, in which data are indicated in English.

Also, special attention is paid to the issue of increasing the importance and significance of modeling economic growth in transition economies, as an important tool and tool that has not only conceptual and methodological, but also practical significance in solving current problems in modern conditions. Foreign and domestic researchers who have made a significant contribution to the understanding and development of general theoretical and methodological problems of creating and using macroeconomic models of economic growth and briefly outlined the concept and main characteristics of the most famous models of economic growth, including R. Harrod, Harrod-Doman, Solow etc.

In Chapter II, as part of this work, to solve the problem of modeling and forecasting the prospects of Ukraine's development in terms of economic growth models, the study of the object will be based on the main selected indicators of Ukraine's economy, which will meet the requirements of the task, because Ukraine, according to the classification of groups of countries from the standpoint of their level of economic development, belongs to the countries with economies in transition.

In this paper we will consider the prospects of Ukraine's economy with the help of economic growth models. Namely, the models of Harrod, Harrod-Domar, Solow-Swan, Cobb-Douglas-Tinbergen, which are the most famous among the models of economic growth.

It should be noted that the main risk for the implementation of the forecast is a possible significant deterioration of the epidemic situation due to the coronavirus pandemic and return to strict quarantine measures in Ukraine and in the world, which could lead to more significant and lasting cooling of the global and Ukrainian economy. Other risks also remain relevant, such as the escalation of the military conflict in the east of the country or its borders, rising world food prices due to global climate change, labor migration abroad, etc.

Chapter 2
Problem statement and algorithm development

2.1 Theoretical foundations of basic mathematical models of economic growth

One of the points of achievement of the purpose of this work for research of prospects of development of Ukraine from the point of view of models of economic development is consideration of the most known models of economic growth. So what are these models, their concept and main characteristics, we will try to briefly explore in this section of the work.

Having processed a significant amount of scientific literature on models of economic growth, it can be noted that in modern economics, several scientific trends are active and competing. These are: Keynesians, whose characteristic feature is the emphasis on the problems of state regulation of the market; neoclassicists, who basically adhere to the principle of minimizing state intervention in a market economy; monetarists who believe that the main regulatory factor of the economy is the monetary apparatus; institutionalists who analyze the economic system through the prism of its main institutions, ie formal (regulatory and legislative) and informal (traditions, customs of business, etc.) rules of economic and social behavior.

Below, based on the research, we present generalized data on the main aspects, advantages and differences of the known models of economic growth with their practical application to achieve the goal of this work.

2.1.1 R. Harrod's model

PHarrod focused on analyzing the dynamic processes of equality between savings and investment. Based on this identity, such concepts as actual, guaranteed (equilibrium) and natural (maximum possible) rates of economic growth were substantiated [44].

In his concept, the scientist relies on a fundamentally new, introduced by him the concept of "guaranteed growth rate", meaning the rate of economic growth, which ensures the full use of capital in the economy (production capacity is used in full). Suppose to begin with that the number of labor resources is not limited, so economic growth depends only on the size of capital.

The actual rate of economic growth is calculated by the formula:

$$G = \frac{\Delta Y_t}{Y_{t-1}} = \frac{Y_t - Y_{t-1}}{Y_{t-1}}$$

(2.1)

where G – the actual rate of economic growth, Y_t and T_{t-1} – income for the current and previous periods, respectively.

The guaranteed rate of economic growth is calculated by the formula:

$$G_w = \rho \cdot \sigma$$

(2.2)

where G_w – guaranteed rate of economic growth, ρ – marginal productivity of capital, σ – the share of savings in income Y.

The natural rate of economic growth is calculated by the formula:

$$G_n = \frac{L_t - L_{t-1}}{L_{t-1}}$$

(2.3)

where G_n – natural rate of economic growth, L_t and L_{t-1} – the number of labor resources for the current and previous periods, respectively.

2.1.2 Harrod-Domar model

The Harrod-Domar model describes the dynamics of income, which is considered as the sum of consumption and investment. The economy is considered closed, so net exports are zero, and government spending in the model does not differ. The main premise of the growth model is the formula of the relationship between investment and income growth rate. It is assumed that the rate of income growth is proportional to investment [44].

The model has a number of prerequisites: first, the ratio of capital to product (capital intensity) is constant. The rate of productivity growth and supply expansion is exogenous and constant. With increasing income, GDP on the amount of savings will increase proportionally and will be equal. Investment equals savings, ie the growth of savings in connection with the growth of income leads to an increase in investment, increasing capital, GDP, which is used for production. Additional capital adds GDP income to the rate of capital productivity, and then GDP growth again increases the amount of savings, etc. Output depends on capital. And the investment lag is equal [45].

According to the Harrod-Domar model, it can be concluded that economic growth is possible as a result of increased savings in national income or increased efficiency of capital use [46, 56]:

$$I_t = (n \frac{Y_{t-1} - Y_{t-2}}{Y_{t-2}}) \frac{s_t}{1 - s_t}$$

(2.4)

where Y_{t-1}, Y_{t-2} – national income, respectively, in years t -1, t - 2; s_t – marginal propensity to save; $(1 - s_t)$ – marginal propensity to consume; – is the acceleration factor; I_t – autonomous investment in the year t.

Economic growth can be calculated by the formulas:

$$E3 = \frac{s_t}{k}, \quad k = \frac{\Delta K}{\Delta Y}.$$

(2.5)

Using data on the main economic parameters, we can predict the expected rate of economic growth in the future. Actual growth rates will differ from the estimated ones, but the differences will not be so significant if for the forecast period there is a constant share of savings in national income S and a constant capital intensity ratio k. At high rates of economic growth, the capital intensity ratio will stimulate this growth. Under conditions of depression, when economic growth slows, there will be a lack of investment to support the desired economic growth.

2.1.3 Solow-Swan model

The Solow-Swan model is the basic neoclassical model of economic growth. This model considers a closed economy without state participation.

The Solow-Swan model (Fig. 2.1) considers the dependence of production on labor and capital.

Production is partly directed to consumption and partly to investment. The model shows that with constant storage and productivity, the economy has a steady state in which investment in capital per capita will be equal to the rate of its disposal. Thus, there will be no economic growth per capita, and overall economic growth will be equal to population growth [46, 67].
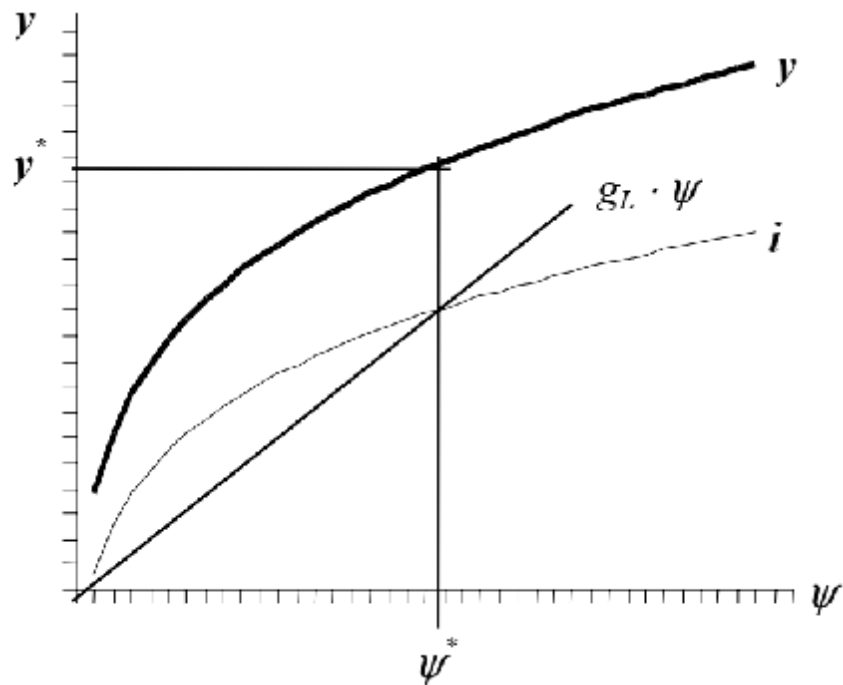
Figure 2.1 – Solow-Swan model

In the Solow-Swan model in fig. 2.1 equilibrium values of capital armament ψ^* and performance y^* obtained by crossing the curve of actual investment i and line g_L multiplied by capital adequacy. For all values $\psi < \psi^*$ (ie to the left of the point ψ^*) curve i passes above the savings curve gL multiplied by capital adequacy, ie the found equilibrium value of capital adequacy of labor (ψ^*) allows you to find the equilibrium value of income (y^*), per employee.

In all models of economic growth, it is assumed that the growth of the number of labor factors in the economy, due to natural population growth, is subject to the law:

$$L_t = (1 + g_l)^t \cdot L_0 = e^{t \cdot g_l} \cdot L_0$$.

$$(2.6)$$

where L_0 – population in the initial period, L_t – its number in the calculation period t, g_L – population growth rate.

The model uses capital, which is calculated by the formula:

$$\psi = \frac{K}{L}$$.

$$(2.7)$$

Income per employee (y) determined by the formula:

$$y = \frac{Y}{L}$$.

$$(2.8)$$

The amount of investment per worker is determined by:

$$i = \frac{I}{L} = \frac{\sigma \cdot Y}{L}$$.

$$(2.9)$$

2.1.4 Cobb-Douglas-Tinbergen model

The Cobb-Douglas-Tinbergen model is a modification of the classical Cobb-Douglas production function, which is associated with taking into account the impact of scientific and technological progress. In

this model, J. Tinbergen removed the restriction on the value of degree indicators for factors of production, which had to be equal to one.

The scientist also studied the impact of scientific and technological progress and other qualitative changes in production on the volume of social product, developed his own model of economic growth, so later the model was called the production function of Cobb - Douglas - Tinbergen [46, 62]:

$$Y = AK^{\alpha}L^{\beta}e^{\lambda t}$$

(2.10)

where Y – the volume of social product; K and L – accordingly, the amount of capital and labor used; α, β i λ – coefficients of elasticity of the social product by factors: capital, labor and technical progress; $e^{\lambda t}$ – a factor that reflects the impact of qualitative changes in production, including technical progress; t – the time factor in the sense of regression, the attenuation of technical progress under the influence of moral aging; A - coefficient of proportionality, scale.

2.1.5 Lucas model

This model estimates the contribution of human capital to economic development, as well as examines the stock and efficiency of human capital through the production function [46, 79]:

$$Y = K_y^{1-\alpha}[uh_t L_t]^{1-\alpha}h_{\alpha t}^{\delta}$$

(2.11)

where u – the share of labor costs to create human capital; h_t, $h_{\alpha t}$ – respectively, the stock of human capital and its average level in the economy as a whole at the time t; α, δ – parameters.

There are two conditions for the accumulation of capital:

- for human capital:

$$h' = \psi h(1 - u)$$,
$$\tag{2.12}$$

where ψ – learning efficiency;

– for physical capital:

$$k' = sk^{\alpha} h^{1-\alpha+\delta} u^{1-\alpha} - nk$$.
$$\tag{2.13}$$

2.1.6 Romer's model

Another effective model of economic growth is the model of exogenous growth, namely Mancue - Romero - Weil. This is a neoclassical model of exogenous economic growth using human capital.

Romer's research "reversed" the approach to macroeconomic analysis, as the American economist proposed the theory that technological innovation and knowledge are an additional factor in production, and the accumulation of this knowledge has a positive effect on productivity and capital. To drive such growth, he suggested stimulating innovation through economic policy. This has given other economists and practitioners a huge new set of tools.

In the Mancue-Romer-Weyl models, human capital acts as a factor of production and the process of its accumulation is completely similar to physical capital. The production function has the following form [47, 92]:

$$Y = K_y^{1-\alpha} H_t^{\beta} [A_t L_t]^{1-\alpha-\beta}$$

(2.14)

Where Y – output; K – physical capital; H – human capital; L – labor; α, β – parameters of the production function.

Physical capital is described by formula (2.15), and human capital is described by formula (2.16)

$$k' = s_K y_t - (n - g_A) k_t$$

(2.15)

$$h' = s_H y_t - (n - g_A) h_t$$

(2.16)

where s_K, s_H – norms of preservation of physical and human capital, respectively; n – growth rate of economically active population, g_A – the sum of the growth rate of technical progress and the rate of disposal of capital (usually this parameter has an approximate and constant value, which is 0.05).

The production function of Romer (2.14) is given in linear form:

$$\ln(\frac{Y}{L}) = \ln A - \frac{\alpha - \beta}{1 - \alpha - \beta} \ln(n + g_A) + \frac{\alpha}{1 - \alpha - \beta} \ln s_K + \frac{\beta}{1 - \alpha - \beta} \ln s_K$$

. (2.17)

The extended model is important for the analysis of convergence problems, because the insufficient development of physical capital can be compensated by the development of human capital, and vice versa. This model assumes not absolute but relative convergence. Absolute convergence would be achieved in the case of absolute mobility of technology, capital and labor without obstacles in their movement. However, in reality there are restrictions on the movement of these factors of production, so the convergence in the Solow model, even taking into account human capital, is conditional [46, 80].

2.2 Economic and mathematical models and problem solving

As mentioned above, today there are a huge number of models of economic growth, but in this aspect of the work we will consider the main ones that can be applied to the Ukrainian reality.

The main purpose of building such models is to determine the conditions necessary for equilibrium growth, which implies such economic development, when volumes of supply and demand, increasing from period to period in macroeconomic markets, are always equal to each other with full use of labor and capital. .

Also, these models are designed to determine the conditions of equilibrium growth of real output (income), ie they study the dynamics of the real sector of the economy over time. The condition of equilibrium in the real sector is the equality of aggregate demand and aggregate supply.

By the way, mathematical models of economic growth consider a closed economy without the participation of the state, ie the economic behavior of only two macro-entities is taken into account: households and the business sector.

2.2.1 R. Harrod's model for the economy of Ukraine

We calculate the actual, guaranteed and natural (potential) rates of economic growth for the economy of Ukraine for the period 2010-2020. The calculation was performed using 6 main determinants of the Ukrainian economy, selected on the basis of empirical research in Section I of this paper. These indicators, as well as the data calculated on their basis, are given in table 2.1.

Table 2.1 – Calculated economic growth rates according to the Harrod model

Year	Working population, thousand people	GDP in 2010 prices UAH., mln.	Shafts savings, UAH mln.	The cost of the main funds, UAH million	Productivity capital (ρ), %	Savings rate (σ), %	G_w (%)	G_n (%)	G
2010	32 130,2	1 079 346	225 583,3	6 648 861	16,23	20,90	3,39	0,00	0,00
2011	32 137,0	1 138 338	291 197,9	7 396 952	15,39	25,58	3,94	0,02	5,47
2012	31 993,3	1 141 055	304 813,1	9 148 017	12,47	26,71	3,33	-0,45	0,24
2013	31 846,8	1 140 750	271 061,6	10 401 324	10,97	23,76	2,61	-0,46	-0,03
2014	31 606,4	1 066 001	212 646,6	13 752 117	7,75	19,95	1,55	-0,75	-6,55
2015	29 634,7	961 698	316 178,5	7 641 357	12,59	32,88	4,14	-6,24	-9,78
2016	29 327,7	984 779	517 624,6	8 177 408	12,04	52,56	6,33	-1,04	2,40
2017	29 011,9	1 009 398	593 792,5	7 733 905	13,05	58,83	7,68	-1,08	2,50
2018	28 719,0	1 043 718	662 270,8	9 610 000	10,86	63,45	6,89	-1,01	3,40
2019	28 468,0	1 077 117	500 795,0	9 574 186	11,25	46,49	5,23	-0,87	3,20
2020	28 199,5	1 012 490	416 220,0	9 538 372	10,61	41,11	4,36	-0,94	-6,00

By the way, in order to carry out a balanced analysis and conclusions on the prospects of Ukraine's development according to R. Harrod's model, as well as without going into theoretical evidence on the relevant initial equations (which is not the purpose of the work), we consider it appropriate to note that Harrod's growth rate is guaranteed G_w – it is a fundamentally new category that he has introduced into scientific circulation, and is a generalized, macroeconomic, predictable quantity to which entrepreneurs

are set, but at the same time it represents a rate "at which producers will be satisfied with what they do." Harrod argues that the guaranteed pace is the axis of dynamic equilibrium and means a line of entrepreneurial equilibrium with full employment of available capital and technical improvements.

The indicator of the actual rate of economic growth G speaks for itself, and because it reflects the actual events, according to the results of consolidated economic indicators, they belong to the past period, and, consequently, do not require special conditions for their implementation.

Potential growth rate G_n on the contrary - reflects the maximum possible rate of economic movement at a given population growth and technical capabilities.

Based on the data in table 2.1. Below is a clear graph of the actual, guaranteed and natural (potential) rates of economic growth for the economy of Ukraine for the period 2010-2020 according to the Harrod model.

If the actual growth rate (G) coincided with the potential (Gn) and guaranteed (Gw) within a capitalist market economy, there would be sustainable continuous development. But in a transition economy there is no stability, as we see in Figure 2.2.

Figure 2.2 – Harrod's model for the economy of Ukraine

Thus, the application of Harrod's model for the analysis of Ukraine's economy (Table 2.1, Fig.2.2) shows that the guaranteed growth rate of Ukraine's economy (G_w), which is equal to the product of the productivity of capital and the rate of savings, much higher than the actual (G) and potential (G_n) growth rate. The graphical curve of the guaranteed growth rate of our country with full employment of available capital and technical improvements is far from the actual state of affairs. At the same time, the actual growth rate of the state's economy is almost always ahead of the potential exponent, having the maximum value in 2011, when the country's economy, like the rest of the world, revived after the economic crisis of 2008-2009. economic growth rate and had the lowest indicators in the crisis for the country and the world in 2014-2015.

Today, the actual economic growth rate is also lower than guaranteed ($G < G_w$) and, as the model shows, is absent in 2020 and prolongs the sharp decline. This leads to a reduction in investment in the country, as entrepreneurs will consider stocks of raw materials, equipment and materials excessive, thereby reducing procurement, which will ultimately

reduce the actual rate of economic growth compared to the dynamic equilibrium line, expressed in a guaranteed growth rate. consequence, leads to economic stagnation.

Further since $G_w > G_n$, then according to Harrod's model, it means that for the guaranteed growth rate in the country's economy there is not enough manpower, as a result, there is an underutilization of production capacity, which means that the actual productivity of capital is below the guaranteed value. The above, along with the actually lower, relatively inflated forecasts of development, regulatory capital intensity is a condition of prolonged depression.

Thus, according to Harrod, state and relationship G_w and G_n is crucial for the analysis of the country's development prospects in terms of determining whether recovery or depression will prevail in economic life for several years. For Ukraine, the prospects for economic development in terms of the Harrod model, unfortunately, are not positive: stagnation, prolonged depression and so on.

The problem is multifaceted. Therefore, in the short term, government regulatory policy should be aimed at converging the actual growth rate (G) with guaranteed (G_w) in particular by state inventories (reserves) of goods and raw materials, which do not deteriorate, and which are replenished during the recession through mass public procurement and sold during the "boom". This will stabilize market prices at a certain level.

In the long run, given that the productive sector of Ukraine's economy has operated under a constant capital deficit, the concentration of which has shifted to extractive industries, and as a result there has been a reduction in investment in the real economy and outflow of labor abroad, government regulatory policy should converge. guaranteed growth rate (G_w) with potential (G_n) by applying measures to create conditions for attracting labor to work in the country by creating new jobs, paying real

wages, etc. and by easing monetary policy and encouraging banks to direct their resources to expand lending to highly productive sectors of the economy in particular in part regulation of the interest rate on the loan (by reducing its value), which, according to Harrod, should stimulate investment and reduce the rate of savings.

2.2.2 R. Harrod - Domar model for the economy of Ukraine

According to the model of the British economist R. Harrod and the American economist of Russian origin E. Domar, we will determine the level of Ukraine's economy and the amount of necessary investments.

Due to the fact that the main prerequisite for this model is the relationship between investment and the growth rate of income (savings), we will compile a table of initial data (table 2.2) with the necessary indicators from 2010 to 2020, determined on the basis of statistical information.

Table 2.2 – Input data for the calculation of the Harrod - Domar model

Year	Savings rate (σ)	Investments (*I*) UAH mln	ΔY	ΔK
2010	0,24	51 536,31	-	-
2011	0,26	57 327,06	188 719,00	70 871,00
2012	0,23	67 133,48	165 726,00	33 760,00
2013	0,19	35 960,51	106 545,00	-25 964,00
2014	0,16	4 874,86	-45 486,00	-48 308,10
2015	0,22	64 715,92	65 167,00	53 696,50
2016	0,25	83 916,59	604 140,00	86 099,70
2017	0,24	58 609,91	411 157,00	89 245,40

Year	Savings rate (σ)	Investments (I) UAH mln	ΔY	ΔK
2018	0,21	64 066,31	637 822,00	130 264,90
2019	0,14	81 392,57	592 319,00	45 252,54
2020	0,12	-8 085,00	-176 435,00	-187 193,68

To determine the level of Ukraine's economy and the amount of required investment, using the data in table 2.2, calculate the acceleration factor (n), check the dependence of the savings rate and the accelerator ratio ($\sigma + n$), determine the equilibrium acceleration factor ($n*$), share of capital and the amount of economic growth (EG).

Розраховані показники знаходяться в зведеній таблиці 2.3.

Acceleration factor (n) – this is the ratio of investment growth to income or volume of finished products obtained from these investments, etc. The principle of acceleration is that investment growth is accelerated compared to the growth of national income and consumer demand. Each increase in income generates a larger increase in new investment.

In 2011, from one unit of investment received 0.3 units. GDP growth, the following year this figure increased by 33%, in 2013 the figure decreased to 0.34 units, and in 2014 it became negative, which indicates that the country's economy is unstable, there is a crisis, there is a decline GDP and investment outflow. Indeed, during this period, the country's economy was significantly affected by the war in the East, the annexation of Crimea, the separation of Luhansk and Donetsk regions. Then, against the background of financial and economic chaos and the apparent collapse of the country, a huge amount of foreign currency was withdrawn from the banking system by non-residents, households and domestic businesses.

Calculations have shown that since 2015, the state has been trying to regulate the state of the economy: the acceleration rate is stabilizing, although it never reaches the level of 2012-2013.

Table 2.3 – R. Harrod - Domar model for the economy of Ukraine

Year	n	$\sigma + n$	n^*	k	EG
2011	0,30	0,56	0,74	0,38	0,68
2012	0,41	0,64	0,77	0,20	1,15
2013	0,34	0,53	0,81	-0,24	-0,79
2014	-0,11	0,05	0,84	1,06	0,15
2015	0,99	1,21	0,78	0,82	0,27
2016	0,14	0,39	0,75	0,14	1,79
2017	0,14	0,39	0,76	0,22	1,12
2018	0,10	0,32	0,79	0,20	1,05
2019	0,14	0,27	0,86	0,08	1,78
2020	0,05	0,16	0,88	1,06	0,11

The equilibrium acceleration factor is calculated (n^*) for a country with full use of national income as a source of effective demand, ranges from 0.74 to 0.88 units. Our research showed that in 2020 the acceleration coefficient acquired a value close to zero, ie much less than the equilibrium value (0.88). This means that the economy is in crisis, there is an outflow of investment, which negatively affects the prospects for Ukraine's development.

Regarding the dependence of the savings rate and the accelerator ratio ($n - \sigma$), it should be recalled that a valuable feature of the model is the recognition of the fact that investments should grow faster than the income

that generates the growth of savings. In Ukraine, such a positive state of affairs was typical of 2011-2013. Since 2014, the situation has significantly deteriorated - savings rates have exceeded investments. Indeed, after the events on the Maidan and the beginning of Russia's aggression: the confrontation in Crimea and Donbas in 2014, investment in the Ukrainian economy declined significantly - from $ 4.5 billion in 2013 to $ 410 million in 2014. Undoubtedly, the main reason for the fall was the military conflict with Russia and its deepening political and economic crisis in the country. The model showed that despite the growth of investment in 2015 (a positive indicator of 0.77 units (Table 2.3)), which is largely due to the recapitalization of banks with foreign capital, since 2016, the dependence of savings and accelerator ratio not only does not reach 2013 and moreover in 2012, but also has a negative value, indicating investor distrust and unwillingness to invest in long-term projects, which is a direct consequence of the deteriorating political situation and economic uncertainty. Although in 2019, against the background of the change of the head of state, we see for the first time a balance between investment and savings, but in 2020, due to the global pandemic and uncertainty caused by quarantine measures, the model shows deteriorating estimates of these coefficients.

Share of capital (investments) (k) fixed capital is a difficult indicator, it is one of the main ones that should accelerate the country's economy to a stable 3.5-4% growth. Modeling the state of affairs regarding the size of the share of capital (share of investments in fixed capital or investment capital) in the GDP of Ukraine shows a changing picture in the period under study: yes, after a fairly positive period 2011-2012, when the share of capital in GDP was 0.38 -0.20, respectively, in 2013 the figure deteriorated significantly and even became negative (-0.24), which indicates the outflow of capital (investment), because real GDP in 2013, although not growing,

but all remained at the level of 2012. Therefore, it is clear that the share of capital can increase only if GDP does not fall and investments increase.

Unfortunately, today the picture of the share of capital in the Ukrainian economy is quite sad: according to the calculations of the model, at the end of 2020, we have the worst share of capital in the last 10 years (-0.02). There are many reasons for this, but as we noted in Part I of this paper, the decrease in the share of capital, in particular investment in fixed capital, is associated with deteriorating not only the political situation, lack of confidence in investing in long-term investment projects. introduction of strict quarantine restrictions due to the spread of COVID-19 incidence, which affected the reduction of investment activity and decommissioning of some production facilities due to underutilization due to reduced domestic demand, which also negatively affects the country's GDP, falling real volume, according to IFI at the end of 2020 is projected at 6.0%.

Therefore, one of the long-term goals of the macroeconomic policy of the government of any country is to stimulate economic growth (EU), maintaining its pace at a stable level. Under economic growth means long-term sustainable economic development, ie the process of progressive increase in GDP in the long run without disturbing the equilibrium in the short term. It will be recalled that the R. Harrod-Domar model takes into account only capital as the only growth factor. This factor seems to synthesize the functioning of all other factors. It is assumed that all factors are involved. The model helps to imagine what the economic growth curve will look like not in the short but in the long run. Based on the data in Table 2.3, the economic growth curve is constructed below, which is shown in Fig. 2.3.
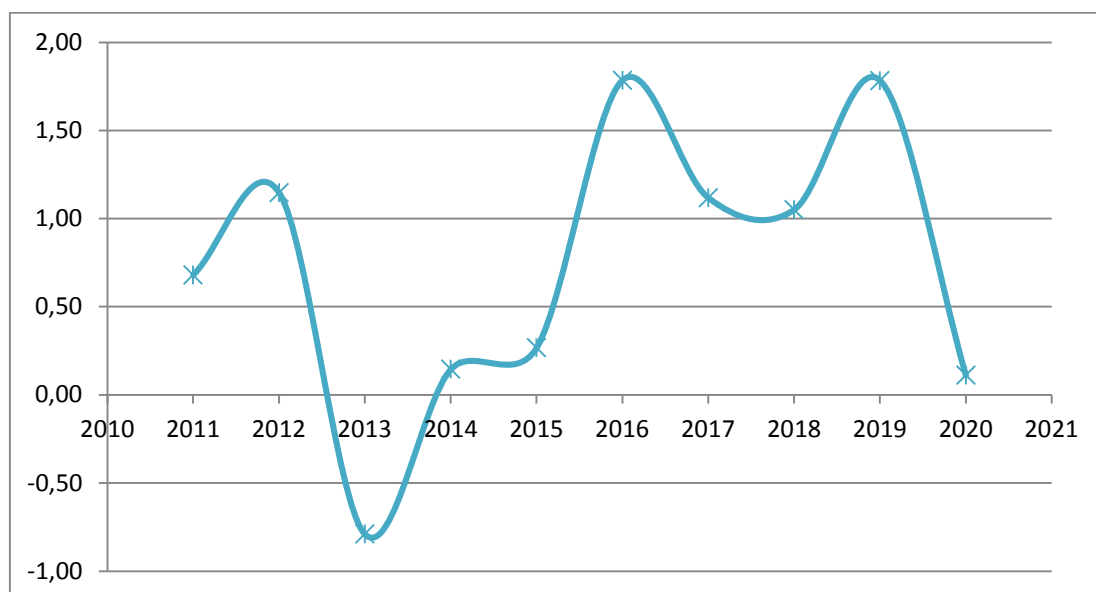
Figure 2.3 – Economic growth in Ukraine

Yes, we see that the larger the share of savings, the greater the size of investment, and hence the higher growth rate (2011-2012, 2015-2016 and 2018-2019). In 2013, 2017 and 2020, there is no economic growth in the country due to the high ratio of such an exponent of the model as capital intensity, which is a consequence of declining GDP, capital investment and fluctuations in the savings rate. In other years, the country's economy is trying to emerge from the crisis and ensure gradual economic growth. But the global crisis related to the coronavirus pandemic has had a severe impact on all parts of our country's economy, so the Harrod-Domar model curve shows us that Ukraine's economy will tend to a deep recession in the near future. It should be noted that it is very difficult to predict a recession. Even in retrospect, it is difficult to say whether certain changes in the economy were a recession or whether they were simply local fluctuations. However, there is a general statement that if GDP, ie total production in the economy, falls for two consecutive quarters, it indicates a recession, which we are currently witnessing from the above calculations based on statistics.

According to the Harrod-Domar model, we calculate the equilibrium value of investment for the country. The calculations are given in table 2.4.

Comparison of actual and equilibrium investments for Ukraine is shown in Fig.2.4.

The multiplier and accelerator effects were integrated into the model for the first time. Any deviation of investments from the equilibrium value brings the system out of balance, which is typical of the state of affairs in Ukraine. To balance the economy, the country needs investment, but equilibrium investments are significantly different from actual, and in the short term it is difficult for the country to provide such a level of investment, despite the fact that investors do not have confidence to implement long-term investment projects in our country. Therefore, the lack of stable sources for investment leads to further stagnation of investment activity in the economy of Ukraine.

Table 2.4 – Equilibrium investments according to the model of R. Harrod - Domar

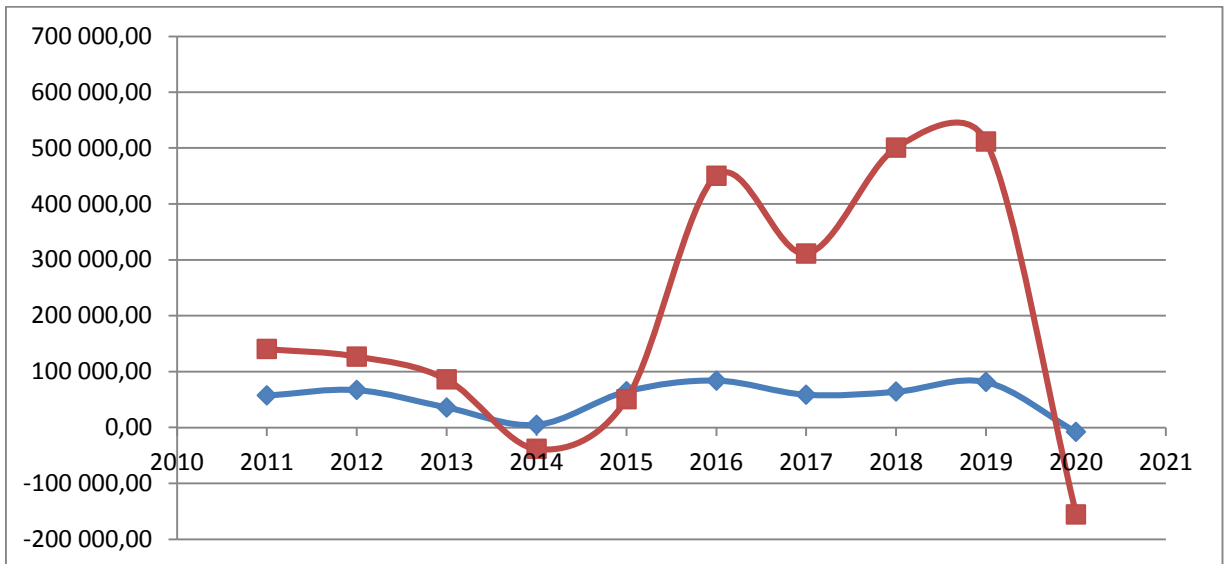| Рік	I	$I_{рівн}$	ΔI
2011	57 327,06	140 442,84	83 115,78
2012	67 133,48	126 989,05	59 855,57
2013	35 960,51	86 071,39	50 110,88
2014	4 874,86	-38 400,60	-43 275,46
2015	64 715,92	50 761,25	-13 954,67
2016	83 916,59	450 427,29	366 510,70
2017	58 609,91	311 327,41	252 717,50
2018	64 066,31	500 827,23	436 760,91
2019	81 392,57	511 619,22	430 226,65
2020	-8 085,00	-155 449,11	-147 364,11

Figure 2.4 – Actual (blue) and equilibrium (red) investments in Ukraine

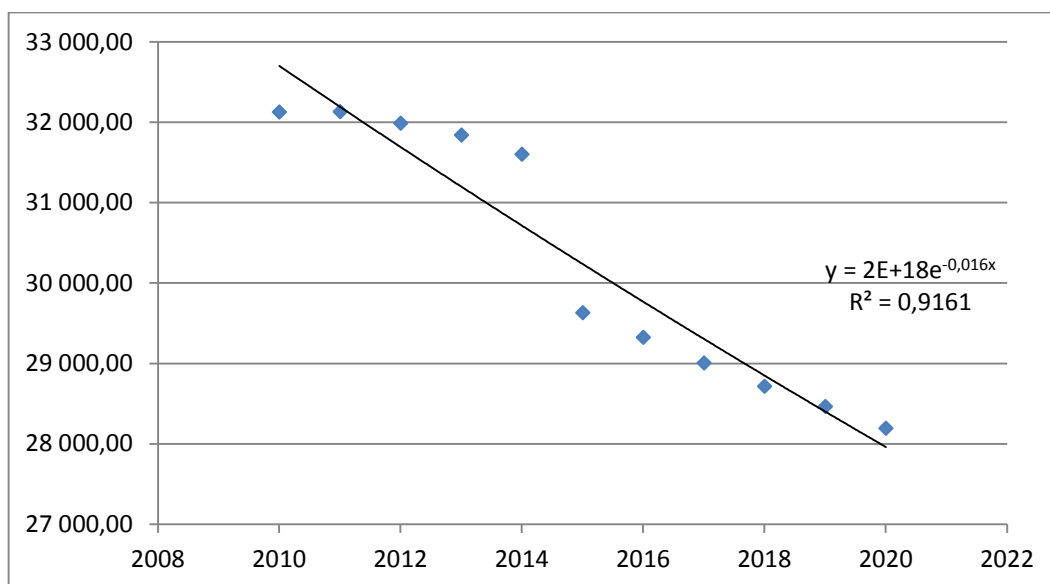### 2.2.3 Solow-Swan model for the economy of Ukraine

To build the Solow-Swan model, it is necessary to calculate the rate of population growth, capital adequacy, income per worker, the amount of investment per worker.

According to the working population aged 15 to 65 years with the help of MS Excel we will build a graph (Fig. 2.5), in which we will build an exponential trend to get the value of the growth rate of the working population of Ukraine.

The natural increase in Ukraine can be described by model 2.18, in which the coefficient of determination is 0.91, which indicates the high accuracy of the compiled model.

$$L_t = 2E + 18 \cdot e^{-0.016t}$$

(2.18)

From this we get that the growth rate of the working population in the country is -0.016. It should be noted that the population growth rate for 2010-2020 is negative, which indicates that against the background of reducing the total population of the country decreases and the working age population, ie the population that can be involved in creating GDP . As already mentioned in Chapter I, this is a challenge for the Ukrainian economy, because it is already experiencing a shortage of manpower. By the way, the Polish economy, which is willing to provide jobs for able-bodied Ukrainians, shows steady and planned GDP growth, and ie economic growth in general. The main reason for depopulation in Ukraine today is the negative trends in high mortality and low birth rates, to which the Ukrainian reality has been added by widespread migration due to rather unfavorable socio-economic conditions. In addition, after the introduction of the visa-free regime, millions of able-bodied people left the EU to earn money.

The chart shows a scatter plot with a declining trend line. The equation displayed is:

$$y = 2E{+}18e^{-0,016x}$$
$$R^2 = 0{,}9161$$

Figure 2.5 - Model of natural population growth in Ukraine

Calculated values of capital adequacy (ψ), income (y) and the amount of investment per worker (i) and the share of savings in income Y (σ), savings curve ($g_L \cdot \psi$) calculated as capital adequacy multiplied and population growth rate (g_L), to build the Solow-Swan model are given in table. 2.5.

Of course, in favorable economic conditions, businesses need to improve the quality of employees, and in unfavorable conditions, increased investment in staff by increasing productivity and labor intensity with a general reduction in staff. From the obvious results of the Solow-Swan mathematical model, we see that the income curve of one employee in Ukraine tends to grow at a faster pace than the curve of the volume of investment in one such employee. From this we can draw the following conclusions about the prospects of Ukraine's development.

Table 2.5 – Calculated values for the construction of the Solow-Swan model

ψ	y	i	σ	$g_L \cdot \psi$	g_L
5,88	29,56	7,02	0,24	-0,09	-0,016
8,09	35,42	9,06	0,26	-0,13	
9,18	40,76	9,53	0,23	-0,15	
8,41	44,29	8,51	0,19	-0,13	
6,94	43,19	6,73	0,16	-0,11	
9,22	48,26	10,67	0,22	-0,15	
12,25	69,37	17,65	0,25	-0,20	
15,46	84,30	20,47	0,24	-0,25	
20,15	107,36	23,06	0,21	-0,32	
21,92	129,12	17,59	0,14	-0,35	
15,49	124,09	14,76	0,12	-0,25	

Yes, "human capital" has always been considered an important asset of any economy. Therefore, the costs of it, such as the cost of medical care, preschool, school, higher education, investment in wages, training, etc. should be considered as long-term investments in the long run, which always result in high returns.

Unfortunately, the analysis of the obtained curves is not comforting: with the steady growth of income per employee (the model does not take into account such a factor as the level of income to living standards in the country), we see a disappointing trend of slower investment growth per employee. As the Solow-Swan model shows that the growth rate of the working-age population in the country is -0.016 (as evidenced by the Penn World Table, version 9.1), wages may increase as the number of employees decreases. Today, and we have already emphasized in this study the existence of this problem, there is an outflow of "brains" from our country abroad (including through reduced investment per employee), where employees can "sell" their skills and abilities in the labor market for a higher wage, comparable to a higher standard of living. In this case, usually the most valuable employees are laid off, in which the most significant costs were invested: experienced, skilled, healthy, enterprising. As a result, the quality of "human capital" is seriously deteriorating, and the country's economy is suffering large long-term losses, as investment in this resource has not paid off and continues to decline in the future.

Let's build curves y, i and $g_L \cdot \psi$ for the economy of Ukraine (Fig. 2.6 (a, b)).

There is a relationship between the amount of savings and the amount of capital used in the investment process (investment). These volumes are equal only in the conditions of equilibrium of the economic system of the country, which is determined by the corresponding level of income. The Solow-Swan model shows that the smaller the difference

between investment and savings, the higher the country's GDP. This rule sets the government the task of stimulating investment activity in the population. From the constructed graph 2.6 (b) we see that the difference between investments (graph 2.6 (a) and savings) (savings curve, graph 2.6 (a)) is large, so the GDP of the country is less, ie the economy does not tend to growth.
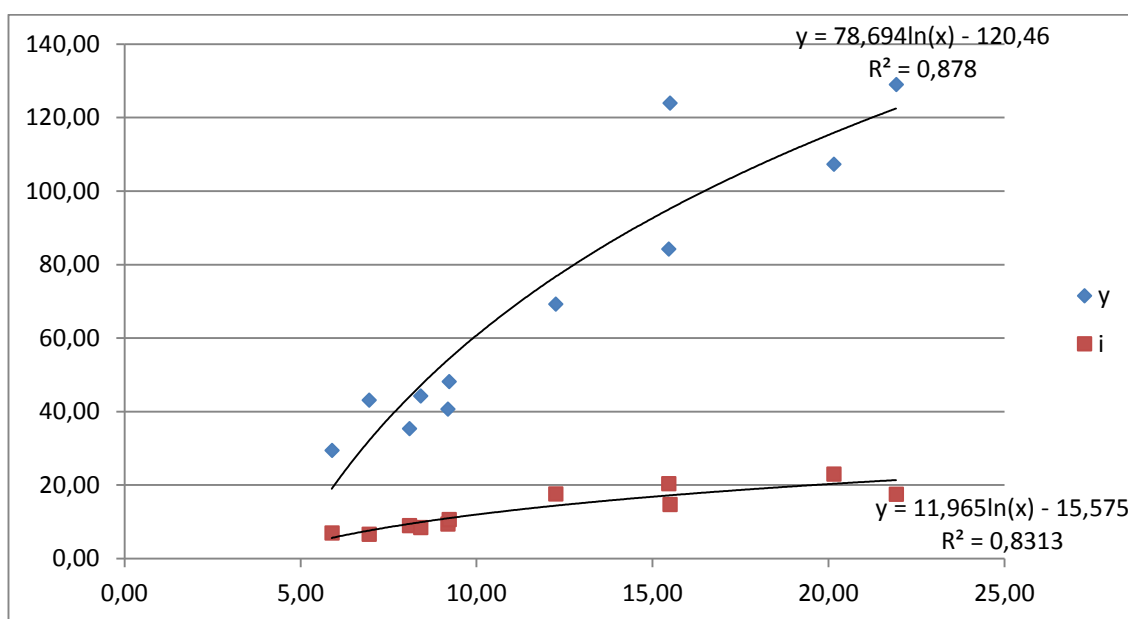

Figure 2.6 (a) – Curves of income (*y*) and volume of investment (*i*) per worker *i* in the model Solow -Swan

Thus, according to the Solow-Swan model (Fig. 2.6 (a, b)), reconstructed on the basis of statistical data on Ukraine, it is impossible to find the equilibrium value of capital and equilibrium value of income per worker, because the curve gL · ψ has from ' capacious slope, because it can not cross the curves y and i to find the equilibrium values. That is, from two graphs, we can conclude that the main obstacle to the economic development of the country is the reduction of Ukraine's population, and what is worst - able-bodied, because of which the country's economy suffers large long-term losses in the long run. It should also be noted that

the constructed curves in the Solow-Swan model have a high coefficient of determination, which ranges from 0.83 to 1 for the curves found. This indicates a high dependence of variables.
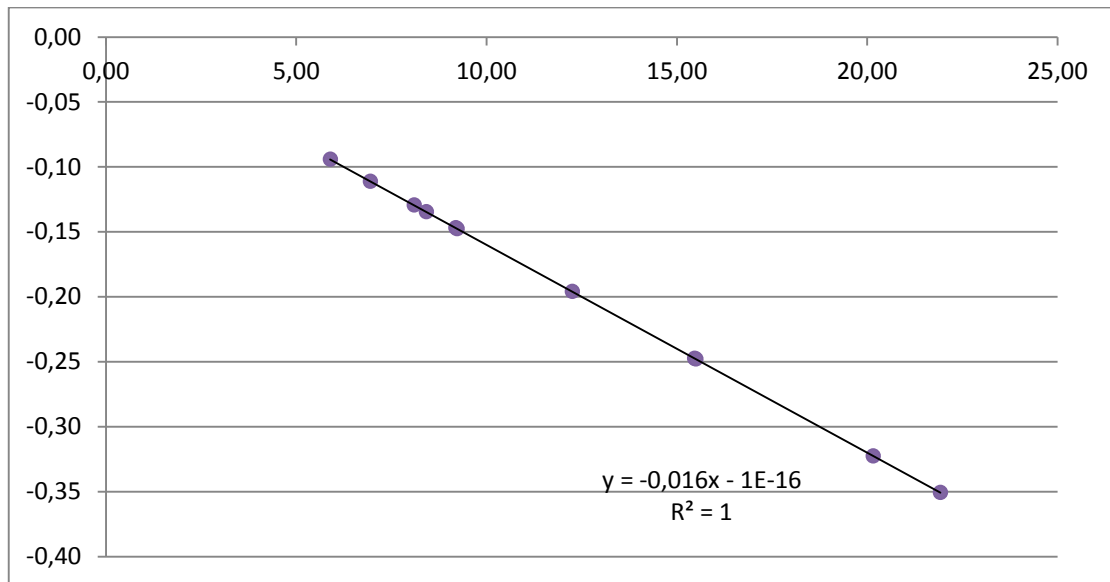

Figure 2.6 (b) – Savings curve in the Solow-Swan model

Using the neoclassical model of exogenous economic growth of Solow-Swan, we can conclude that this model is not correct to apply in the presence of a negative value of at least one correlation component. The purpose of the study in this case according to this model is not achieved in full. This is confirmed by the modeling of the prospects of Ukraine's economy, when the natural rate of population growth is negative, which makes it impossible to find equilibrium values to improve the growth of Ukraine's economy, although the model provides a general idea of the state of influencing factors.

2.2.4 Cobb-Douglas-Tinbergen model for the economy of Ukraine

The Cobb-Douglas-Tinbergen model of economic growth reveals a functional relationship between the social product (volume of production) and two independent but interrelated variable costs of capital and labor.

To calculate this model, turn it into a linear form:

$$\ln Y = \ln A + \alpha \ln K + \beta \ln L + nt \quad (2.19)$$

After logarithm of the input data for 2010-2020, we obtain a summary table:

Table 2.6 – Input data for the construction of the Cobb-Douglas-Tinbergen model

Year	Y'	K'	L'	t
2010	13,76	12,15	10,38	1
2011	13,95	12,47	10,38	2
2012	14,08	12,59	10,37	3
2013	14,16	12,50	10,37	4
2014	14,13	12,30	10,36	5
2015	14,17	12,52	10,30	6
2016	14,53	12,79	10,29	7
2017	14,71	13,01	10,28	8
2018	14,94	13,27	10,27	9
2019	15,12	13,34	10,26	10
2020	15,07	12,99	10,25	11

At the same time, it should be remembered that we are not dealing with abstract functions, but with a statistical dependence, rigidly tied to a specific reality. In this case, it is a question of the possibility of increasing the output of the social product by increasing either capital, or the number of workers, or through technical progress.

Using the tool "Regression" from the analysis package MS Excel, the coefficients of elasticity of the social product by the factors of capital, labor and technical progress were found.

According to the data of 2010-2020. The Cobb-Douglas-Tinbergen model for Ukraine looks like this:

$$Y = 7,31E - 05 \ K^{0,54} L^{1,59} e^{0,11t}$$
. (2.20)

The coefficient of determination is equal to 0.98, which indicates the high quality of the constructed model. Based on the model, we can say that with the growth of capital by 1%, the social product will increase by 0.54 units, with the growth of labor by 1%, the social product will increase by 1.59 units, and due to technical progress - by 0.11 units.

Now we build a Cobb-Douglas-Tinbergen model for two intervals and compare the results found.

In the first period (analysis for 2010-2015) the model has the following form:

$$Y = 2,14E - 18 \ K^{0,32} L^{4,89} e^{0,10t}$$
. (2.21)

The coefficient of determination is equal to 0.98, which indicates the high quality of the constructed model. Based on the model, we can say that

with the growth of capital by 1%, the social product will increase by 0.32 units, with the growth of labor - will change by 4.89 units, and due to technical progress - by 0.10 units. At the same time, there is a lack of human capital in the country.

In the second period (analysis for 2016-2020) the model has the following form:

$$Y = 1,22E - 05 \ K^{0,51}L^{1,78}e^{0,14t}.$$

(2.22)

The coefficient of determination is equal to 0.99, which indicates the high quality of the constructed model. Based on the model, we can say that with an increase in capital by 1%, the social product will increase by 0.51 units, with an increase in labor - will change by 1.78 units, and due to technical progress - by 0.14 units.

Comparing these intervals we can say that the amount of capital used in the period 2016-2020 increased by 59%, technical progress increased by 40%, which is a positive consequence, as such a change is due to the use of more modern technologies, partial upgrades of technical equipment, modern management methods, which has a positive effect on the competitiveness of products and, consequently, on the prospects of the economy as a whole.

But now it is interesting to compare how technical progress has changed by comparing the models for 2 years (formulas 2.4-2.8):

$$Y_{2010-2011} = 7,92E + 05 \ K^{0}L^{0}e^{0,18t}$$

(2.23)

$$Y_{2012-2013} = 1,03E + 06 \ K^{0}L^{0}e^{0,08t}$$

(2.24)

$$Y_{2014-2015} = 1,08E + 06 \ K^{0}L^{0}e^{0,05t}$$

(2.25)

$$Y_{2016-2017} = 5,61E+05 \ K^0 L^0 e^{0,18t}$$

(2.26)

$$Y_{2018-2019} = 6,34E+05 \ K^0 L^0 e^{0,18t}$$

(2.27)

For the convenience of tracking, we will build a graph of changes in technical progress according to models 2.23-2.27.
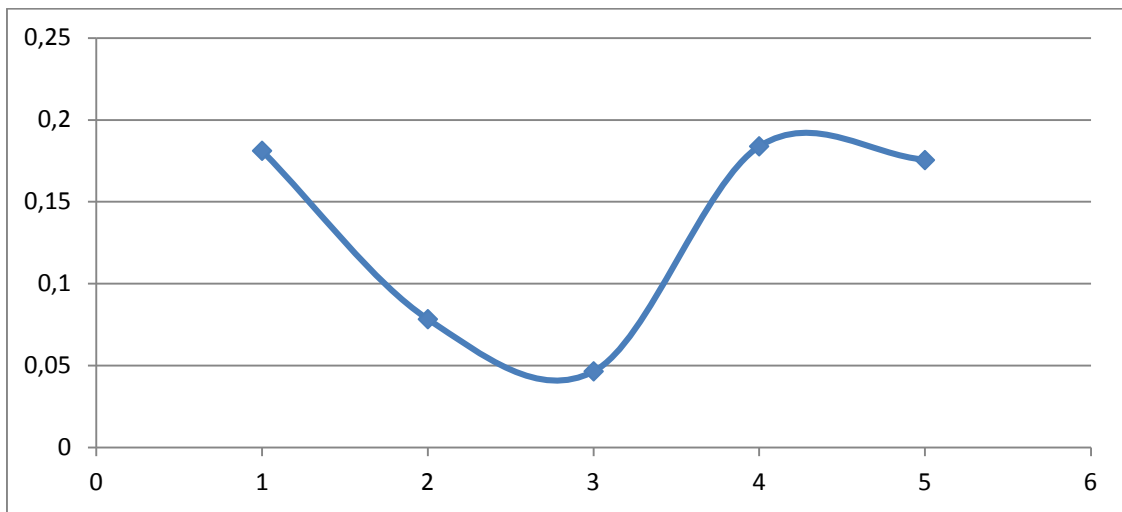

Figure 2.7 – Graph of changes in technical progress

For fig. 2.7 we see that in 2010-2011 technical progress was 0.18 units, in the next 4 years this figure decreased significantly due to the crisis and the unstable political situation. Although there has been a rapid growth of technical progress in the country since 2016, which has had a positive impact on the country's economic growth, and over the next 2 years the country has been able to maintain progress, on the one hand it is a positive moment. indicator that it is necessary to implement technical progress for economic growth. But in 2020, the figure is expected to decline, due to a pandemic, as the country is not currently focused on increasing technological progress to improve the country's economy.

2.2.5 Lucas model for the economy of Ukraine

When studying this model for the economy of Ukraine and conducting preliminary calculations, it was found that to apply this model to analyze the prospects of Ukraine is ineffective. This model uses data such as the share of labor costs to create human capital, training efficiency, the share of time spent on training. Therefore, it was concluded that the Lucas model can provide very interesting data for conclusions, but given the specifics of the chosen topic of this study, the Lucas model, in our opinion, should be used in the analysis of a particular sector of economy, production and / or enterprise. labor and training costs for a particular industry, as for each link these data are separate and significantly different.

2.2.5 Romer's model for the economy of Ukraine

Previous macroeconomic studies have emphasized that technological innovation is the main means of economic growth, but have not modeled how economic decisions and market conditions determine the development of new technologies.

In order to have a general idea of how science and research are subsidized in countries around the world, consider the statistics on expenditure (in% of GDP) for individual developed countries and countries with economies in transition, including and Ukraine (Table 2.7).

Thus, we see that the cost of research and development (including basic and applied research, experimental development, etc.) in developed countries is much higher than in developing economies, including in Ukraine. Indeed, cuts in science spending in our country have led to a critical situation in Ukraine's research organizations that continues to

deteriorate: budget funding for science is shrinking, the salaries of institutions are declining, staff cuts have begun, there is no money for utilities, there is a real threat of power outages. money to pay property taxes, etc.

Table 2.7 – Expenditures on research and development in individual countries in% to GDP

Country	2010	2011	2012	2013	2014	2015	2016	2017	2018
Israel	3,9	4,0	4,2	4,1	4,2	4,3	4,5	4,8	5,0
Sweden	3,2	3,2	3,3	3,3	3,1	3,3	3,3	3,4	3,3
Japan	3,1	3,2	3,2	3,3	3,4	3,3	3,2	3,2	3,3
USA	2,7	2,8	2,7	2,7	2,7	2,7	2,8	2,8	2,8
Czech Republic	1,3	1,6	1,8	1,9	2,0	1,9	1,7	1,8	1,9
Hungary	1,1	1,2	1,3	1,4	1,4	1,4	1,2	1,3	1,6
Estonia	1,6	2,3	2,1	1,7	1,4	1,5	1,2	1,3	1,4
Poland	0,7	0,7	0,9	0,9	0,9	1,0	1,0	1,0	1,2
Lithuania	0,8	0,9	0,,9	1,0	1,0	1,0	0,8	0,9	0,9
Bulgaria	0,6	0,5	0,6	0,6	0,8	1,0	0,8	0,8	0,8
Belarus	0,7	0,7	0,6	0,7	0,5	0,5	0,5	0,6	0,6
Romania	0,5	0,5	0,5	0,4	0,4	0,5	0,5	0,5	0,5
Ukraine	**0,8**	**0,7**	**0,8**	**0,8**	**0,7**	**0,6**	**0,5**	**0,4**	**0,5**
Moldova	0,4	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,3

The table was created personally by the developers on the basis of data [48].

Basic science has suffered particularly badly: due to the fall of the hryvnia exchange rate, most of the modern equipment, necessary reagents and consumables produced abroad, as well as participation in international projects and conferences, subscriptions to necessary scientific journals have

doubled. There is another important feature that officials do not consider when reducing the cost of science. Basic science is an international field of activity, there is a global market for scientific work. And if it is difficult to imagine a mass outflow of officials or law enforcement officers abroad, then in science "brain drain" from a country where conditions for scientific work are getting worse, to countries where normal conditions are created for researchers – a natural and continuous process.

Therefore, the problem of human capital, its use in reproducing the country's GDP is always and will be a topical issue, as evidenced by the findings of American economist Paul Romer, who always argued that knowledge can drive long-term economic growth and that economic growth can be increased by supporting education and science, the allocation of subsidies for research and development, as well as by increasing incentives for innovation.

Thus, Romer's models, published in 1990, marked the beginning of the theory of endogenous economic growth, according to which knowledge, innovation and investment in human capital are important factors in economic growth. The theory suggests that economic growth can be increased by supporting education, allocating subsidies for research and development, and by increasing incentives to innovate [49].

However, most empirical research by scientists refutes the effect of a direct proportional dependence of economic growth on the scale of funds allocated for research and invention. Therefore, we are interested in the possibilities provided by the Romer model, namely the ability to calculate the state and impact of human capital on the economy, disagreeing with the above conclusions of scientists and having the opposite opinion, for personal research and proof of Paul Romer's theory of the effect of direct proportional dependence economic growth from the scale of funds allocated for the financing of research and inventions, in the framework of

the work, a significant amount of literature on this issue has been developed. Thus, in one of the English-language sources of the National Science Foundation for Statistics of Scientific Resources [50], we found graphs created to prove Romer's theory of R&D spending (in% of GDP) in the United States, Japan, and the Organization for Economic Co-operation and Development (OECD).) in 1981-2006, compared with the GDP growth rate of these countries in this period, which clearly confirms the conclusions of Romer. Therefore, we tried to make appropriate schedules for our country and for completeness of the study to compare with individual neighboring countries, EU countries (including the Czech Republic, Hungary, Poland) and Moldova (by the way, Ukraine and Moldova are not members of the EU).

For this purpose, on the basis of information from the World Data Atlas (Table 2.7) as well as data on GDP per capita (Table 1.1 of Section I), two visual graphs were created (Figs. 2.8 - 2.9) and the obtained interesting, in our opinion, data were studied.
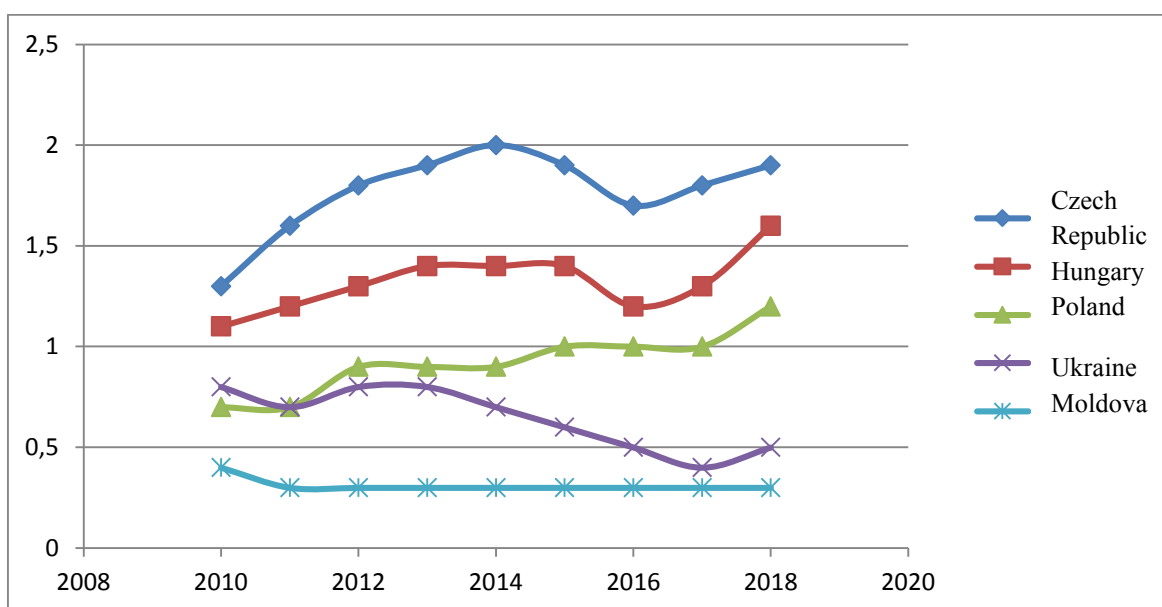
Figure 2.8 – Expenditures on research and development in individual countries, in% of GDP

As we can see from Figure 2.8, although it is very conditional and graphical, and aware of the existence of other factors affecting the economy of each country, that for the period from 2010 to 2015 there was a significant increase in research and development spending in selected EU countries; since 2015, due to the global crisis, research expenditures have been reduced, but by 2018 funding for this important area has been restored. Ukraine and Moldova, on the other hand, have reduced spending on science, especially our country (almost twice: from 0.8% of GDP in 2010 to 0.4-0.5% in 2017-2018).
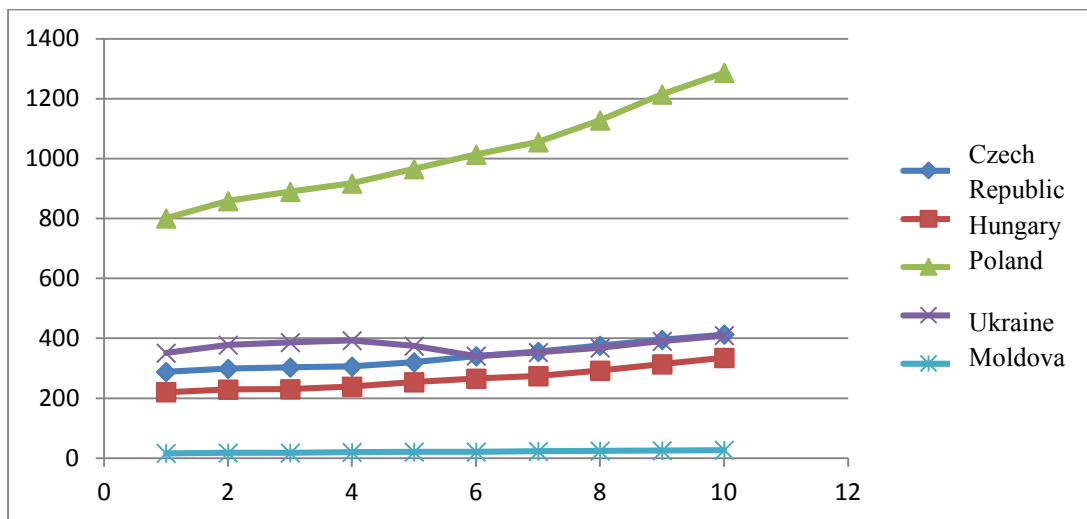
Figure 2.9 - Growth of economies in terms of GDP at purchasing power parity in individual countries in 2010-2018, in billion dollars

Interesting results were obtained when creating the data of graphs 2.8 and 2.9. Thus, it can be argued that scientific progress (continuous process of introduction of new equipment and technology, organization of production and labor based on achievements and implementation of scientific knowledge, inventions and research, reproduced by human capital) still has a direct impact on economic development.

Thus, the growth chart of the countries selected for analysis by GDP per capita shows the presence of a directly proportional dependence of the increase in economic growth on the number of resources involved in research and development. Proof of this is the growth rate of the economies of Poland, Hungary and the Czech Republic, directly proportional to the level and growth rate of state funds allocated for research for this period. At the same time, Hungary has increased the share of contributions to science, but the country's GDP does not show a rapid response, which can only reflect the non-competitive nature of scientific ideas and research. The same dependence is inherent in the economies of Moldova and Ukraine. But negative. In the absence of Moldova's growth rate of contributions to science, the country's economy has the same dynamics. Our state, ignoring scientific progress, having reduced almost 2 times expenses for development and researches (fig. 2.8), has received the same negative tendency of development of economy of Ukraine (fig. 2.9).

According to Romer's model, the assessment of the contribution of human capital to Ukraine's economic growth was carried out in three ways, the difference between which lies in the different interpretation of human capital: in the first way in the second method, human capital means the share of personnel engaged in research and development in the total economically active population (s_{H2}); in the third method, the amount of human capital is identified with the sum of the costs of research, development and technological innovation costs per employee engaged in research and development (s_{H3}).

Using MS Excel, the linear regression method was used to estimate the array of initial data (Table 2.8) by the above equation (2.17).

The results of the study based on the Romer model were obtained, which were obtained by regression analysis for the parameters A, s_K, s_H and

$(n+g_A)$ are given in table 2.9. Coefficients α and β were found taking into account their dependence on the above equation (2.17).

In the interpretation that human capital consists of graduates of higher education institutions in the total number of economically active population, we obtained a qualitative model because the coefficient of determination (R^2) is 0.98. The coefficients of the equations were determined from the found regression parameters $α$ and $β$ to determine the contribution of physical and human capital.

Table 2.8 - Input data for the calculation of the Romer model

Year	Y	$(n + g_A)$	s_K	s_{H1}	s_{H2}	s_{H3}
2010	29,56	0,0433	16,92	16,92	5,68	0,25
2011	35,42	0,0502	16,49	16,49	5,46	0,45
2012	40,76	0,0455	16,28	16,28	5,14	0,36
2013	44,29	0,0454	15,23	15,23	4,88	0,30
2014	43,19	0,0425	12,83	12,83	4,31	0,24
2015	48,26	0,0000	12,62	12,62	4,13	0,47
2016	69,37	0,0396	10,87	10,87	3,34	0,79
2017	84,30	0,0392	12,41	12,41	3,25	0,31
2018	107,36	0,0399	12,44	12,44	3,07	0,42
2019	129,12	0,0413	11,72	11,72	2,78	0,50

Thus, the contribution of physical capital to the growth of per capita income is 71%, and the contribution of human capital is negative and is -58%. Why did the contribution of human capital turn out to be negative? First, this indicator is affected by the fact that every year the number of higher education graduates decreases, this is due to the fact that the active population and Ukrainian students studying abroad are decreasing, which

means that confidence in the quality of education in Ukraine is declining. It is also difficult for graduates to find a job, because to get a job in the specialty requires work experience of one year. Entrepreneurs are not interested in university graduates because they do not want to spend time on employee training. Therefore, students are not interested in obtaining higher education, as further difficulties will arise with employment. Therefore, at this stage there is a devaluation of human capital, namely human intelligence. It follows that it is necessary to re-evaluate the contribution of university graduates to the growth of economic development of the country.

Table 2.9 – Estimation of human capital according to Romer's model

Parameters	Assessment of graduates of higher educational institutions (s_{H1})	Evaluation of employees involved in research and development (s_{H2})	Estimation of the results of research and innovation costs (s_{H3})
R^2	0,98	0,99	0,96
A	14,23	4,05	1,31
s_K	0,81	0,57	1,11
s_H	-0,67	-0,95	-0,07
$(n+g_A)$	0,01	0,01	0,00
α	0,71	0,93	0,55

In interpreting the fact that human capital means the share of personnel engaged in research and development in the total number of economically active population, a qualitative model was also obtained because the coefficient of determination is 0.99. According to the found regression parameters, it was determined that the contribution of physical

capital is 93%, and the contribution of human capital is negative and is -155%. From the obtained results we can say about the negative assessment of employees involved in research and development. This means that this type of human capital is depreciating in Ukraine. The number of employees in this area is rapidly declining, the country cannot ensure the development of this human capital. But this type of human capital is very important for the country's economic growth.

The third method determined that the contribution of physical capital is 55%, and the contribution of human capital is negative and is -4%. From the obtained results we can say that in the country there are low costs for research, development and costs for technological innovation. This suggests that the country needs to pay attention to developments and technological innovations for a positive impact on the country's economy.

The general conclusions based on the results of the research are disappointing. Calculations of Ukraine's prospects based on Romer's model showed a negative result, which is confirmed by the current state of affairs: reduced funding for science and education in the country leads to a lack of interest in working in scientific institutes, which entails a lack of scientific findings, innovations, development of new technologies and , as a consequence, leads to an outflow of young professionals abroad, uncompetitive technology and products and a general decline in Ukraine's economy.

And if the state's policy on science remains unchanged and / or worsens, ignoring the peculiarities of science will cost our country dearly, because talented young scientists will go where they can count on normal working conditions and salaries, which is already a general trend. , which is confirmed by research on the model of economic growth of Romer.

2.3 Conclusion of prospects for Ukraine's development in terms of economic growth models

In Chapter II of this research work, we, based on the analysis of the economic situation of the country in Chapter I, in order to achieve the goal of our work, we used the most well-known models of economic growth. According to the results obtained, aimed at identifying prospects for Ukraine's development, we can conclude that the country's economy is unstable.

In this paper, studies of the prospects of Ukraine's development were conducted using such economic and mathematical models as R. Harrod's model, Harrod-Domar model, Solow-Swan model, Cobb-Douglas-Tinbergen model, Lucas model and Romer's model and considered their concept and main characteristics and features.

An important conclusion from the theoretical and practical aspects of the work is that by using in practice the knowledge of mathematical modeling, it can be argued that the application and interpretation of the results of economic growth models goes beyond the usual narrow normative, dogmatic understanding of the basics of a model and requires mastery of a wide range of knowledge - from socio-economic, economic, cybernetic to mathematical, used in the application of selected models and in describing the results. In addition, it should be remembered that we were not dealing with abstract functions, but with a statistical dependence rigidly tied to a specific reality, although in almost all cases almost qualitative models were obtained, because the coefficient of determination (R^2) was 0,98-0.99. In our opinion, this is the main practical proof of the need to use mathematical forecasting methods for government officials to take prudent measures to improve the economic situation in Ukraine in the future.

On the basis of the conducted empirical research it is possible to draw the following most important conclusions of our research concerning a current condition of economy of the country and prospects of its development from the point of view of models of economic growth.

Thus, according to the calculated model of Harrod, it is found that today the actual growth rate of the economy at the end of 2020 and the beginning of 2021 - is absent and prolongs the rapid decline. This leads to a reduction in investment in the country, which will ultimately reduce the actual rate of economic growth and lead to economic stagnation. Also, this model revealed a shortage of manpower, which leads to underutilization of production capacity, so capital is used inefficiently, which creates conditions for prolonged depression. To improve the situation, it is necessary to pursue state policy in terms of creating conditions for attracting labor to work in the country by creating new jobs, providing appropriate conditions for labor, overcoming the demographic decline, labor migration outside Ukraine and youth migration, taking measures to help improving monetary policy and stimulating banks to direct their resources to expand lending (investment) in highly productive sectors of the economy.

Thus, the prospects for the development of Ukraine's economy in terms of the Harrod model, unfortunately, are not positive: stagnation and prolonged depression, and so on.

According to the Harrod-Domar model, to determine the level of Ukraine's economy and the amount of necessary investments, the acceleration coefficient was calculated, the dependence of the savings rate and the accelerator coefficient was checked, the equilibrium acceleration coefficient, capital share and economic growth were determined. Calculations have shown that the country lacks investment for economic growth: since 2015, the state has been trying to regulate the state of the

economy - the acceleration rate is stabilizing - but never (as of the end of 2020) reaches the level of 2012-2013. The equilibrium acceleration coefficient and the dependence of the savings rate and the accelerator coefficient also show that the country's economy is in crisis, there is an outflow of investment, which negatively affects the prospects for Ukraine's development. Unfortunately, today the picture of the share of capital (investment) in Ukraine's GDP is also quite sad: according to the model, at the end of 2020, we have the worst share of investment in the country's economy over the past 10 years (-0.02). Also, the modeling allowed to obtain data that as of January-November 2020 there is no economic growth in the country due to the high coefficient of such an exponent of the model as capital intensity, which is a consequence of declining GDP, capital investment and savings.

Therefore, the modeling showed that today it is difficult for the country to ensure the appropriate level of investment, due to the distrust of investors in the country. The decline in investor confidence is significantly influenced by the following factors: high levels of corruption, a weak judiciary and a high level of the shadow economy. But in addition to the most important factors mentioned above, which negatively affect the business climate, new ones have been added. In particular, constant rotations in the government, political and economic instability, increasing tax pressure and changes in tax legislation, temporary suspension of reforms, implementation of restrictive measures related to coronavirus disease. Therefore, to improve economic growth, state policy should be aimed at improving the investment climate by, in particular, restoring investor confidence, including by fighting corruption as the basis of all foundations and changes in the country, restoring a fair judiciary, because the rule of law still has to find a place in our country, and through the use

of effective methods and measures that will help to effectively combat the shadow economy.

The above, as well as the global crisis associated with the coronavirus pandemic, has had a severe impact on all parts of our economy, so the Harrod-Domar model curve shows us that Ukraine's economy will tend to a deep recession in the near future.

According to the neoclassical model of Solow-Swan's exogenous economic growth, we are convinced that the working-age population of Ukraine, which can be involved in the reproduction of GDP, is declining, which is a negative challenge for the country's economy. Due to the low rate of population growth, which has a negative value, it is impossible to find the equilibrium value of capital and the equilibrium value of income per worker. That is, we can conclude that the main obstacle to the economic development of the country is the reduction of the working population of Ukraine, due to which the country's economy suffers large long-term losses in the long run. Therefore, to trace equilibrium values for economic growth, it is necessary to promote an increase in the economically active population. And one of the reasons for the decline is the outflow of the working population abroad.

Therefore, it is concluded that the Solow-Swan model is not correct to apply in the presence of a negative value of at least one correlation component. The purpose of the study in this case according to this model is not achieved in full. This is confirmed by the modeling of the prospects of Ukraine's economy, when the natural rate of population growth is negative, which makes it impossible to find equilibrium values to improve the growth of Ukraine's economy, although the model provides a general idea of the impact factors.

According to the Cobb-Douglas-Tinbergen model, the coefficients of elasticity of the social product by the factors of capital, labor and technical

progress were found and it was found that there is a lack of human capital in the country, which has a significant impact on social product and technical progress. innovation and development of knowledge-intensive industries, which, ultimately, is the most important factor in overcoming the economic crisis and providing conditions for economic growth. In addition, the simulation results revealed that with an increase in capital by 1%, the social product will increase by 0.51 units, with an increase in labor - will change by 1.78 units, and due to technical progress - by 0.14 units. It is also estimated that the amount of capital used in the period 2016-2020 increased by 59%, technical progress increased by 40%, which is a positive consequence, as such a change is due to the use of more modern technologies, partial upgrades of technical equipment, modern management methods. has a positive effect on the competitiveness of products and, consequently, on the prospects of the economy as a whole. But the curve of technological progress at the end of the period under study and the beginning of 2021 shows a decline, primarily due to the pandemic, as the country is not currently focused on increasing technological progress to improve the country's economy.

As part of achieving the goals of this work, an interesting experience was also the application of the Lucas model to identify prospects for the development of Ukraine's economy.

This model uses data such as the share of labor costs to create human capital, training efficiency, the share of time spent on training. When studying this model and conducting preliminary calculations, it was found that applying this model to analyze the prospects of Ukraine is ineffective. Therefore, it was concluded that the Lucas model can provide very interesting data for conclusions, but given the specifics of the chosen topic of this study, the Lucas model, in our opinion, should be used in the analysis of a particular sector of economy, production and / or enterprise.

labor and training costs for a particular industry, as for each link these data are separate and significantly different.

Previous macroeconomic studies on selected models of economic growth, such as the Cobb-Douglas-Tinbergen model, have emphasized that technological innovation is the main means of economic growth, but have not modeled how economic decisions and market conditions determine the development of new technologies. Therefore, the Romer model was chosen to analyze the state of affairs and prospects of Ukraine's development in terms of supporting Ukrainian education, allocating subsidies for research and development, etc. The results of modeling endogenous economic growth, in which knowledge, innovation and investment in human capital are important factors of economic growth, showed a negative result, which is confirmed by the current state of affairs: reduced funding for science and education in the country leads to lack of interest in research institutes , which entails a lack of scientific findings, innovations, development of new technologies, and, as a consequence, leads to an outflow of young professionals abroad, uncompetitive technology and products and a general decline in Ukraine's economy. Therefore, the state needs to comprehensively create an environment to stimulate education (scholarships, dormitories, budget places, competitions, Olympiads, scientific exhibitions and much more). Stimulate development and technological innovations for a positive impact on the country's economy. Thus, human capital will be highly valued, which will improve the country's development prospects.

Section 3

Design and development of information system and safety measures

3.1 Information support

Automated Information System (AIS) is a set of software and hardware designed to automate activities related to the storage, transmission and processing of information.

Automated systems are characterized by the fact that part of the functions of control or data processing is performed automatically, and part - by man.

In this work, an automated system based on the Microsoft Office Excel application was developed. The primary purpose of the developed AIS is the implementation of an automated process of calculating economic growth models for Ukraine.

To perform calculations on a personal computer, you must have Windows 10 or a later version of Windows, as well as Microsoft Excel from MS Office version 2010 or later.

The mechanism of automation of the calculation process is implemented using macros and MS Excel functions. The system is controlled by using the objects of the "Shapes" panel (mainly buttons, as well as switches, various auto shapes, mostly arrows), as well as the "Figure" panel (inserting images).

The buttons are used to navigate the pages, as well as some other more complex functions (conversion of data into other units of measurement, calculation of the optimization problem, etc.).

However, shapes and autoshapes are only a means of performing a certain function (going to another page, etc.). Instead, the mechanism for

implementing these functions was set using macros. Macros were written in two ways:

• directly from the Excel workbook by selecting "Tools" - "Macro" - "Start recording" and sequentially perform actions that will be performed automatically in the future;

• by software macro recording by opening "Tools" - "Macro" - "Visual Basic Editor".

After writing the macro, a certain form is created, to which this macro is assigned.

The built AIS has 8 letters: screensaver, main menu, information about EU models, statistical data on Ukraine 2010-2020, models of Harrod, Harrod-Domar, Solow-Swan, Cobb-Douglas-Tinbergen and Romer.

The screen saver contains 3 buttons:

• Main menu;

• About the author;

• Entrance;

The "About the author" button is assigned a macro, using the user form, which in the Visual Basic editor looks like this:

```
Sub ПА()
UserForm1.Show (зображено на рисунку 3.2)
End Sub
```

The macro of the information system exit ("Exit" button) looks like this:

```
Sub Output ()
ActiveWorkbook.Close
End Sub
```

In this case, the login is implemented only from this book (ActiveWorkbook.Close function). If desired, you can easily change this option to exit the entire MS Excel application. To do this, just write Application.Quit instead of ActiveWorkbook.Close.

The "Main Menu" button launches a macro to go to another page (in this case - to the main menu page). This macro looks like this in the VBA editor:

```
Sub Menu ()
Sheets("Menu").Select
End Sub
```

All other buttons to go to other pages are based on similar macros indicating the page to be accessed (in this case Sheets ("Menu"). Select).

On the main menu page there are buttons with macros that allow you to go to other pages - to quickly get information about EU models, statistics on Ukraine 2010-2020, return to the screen saver, calculate the models of Harrod, Harrod-Domar, Solow-Swan , Cobb-Douglas-Tinbergen and Romer.

The page with information about economic growth models has general information about the used models, from this page you can easily return to the main menu. The page of statistical data contains a table taking into account the main economic determinants of the country.

The block diagram of the information system is shown in Fig. 3.1.
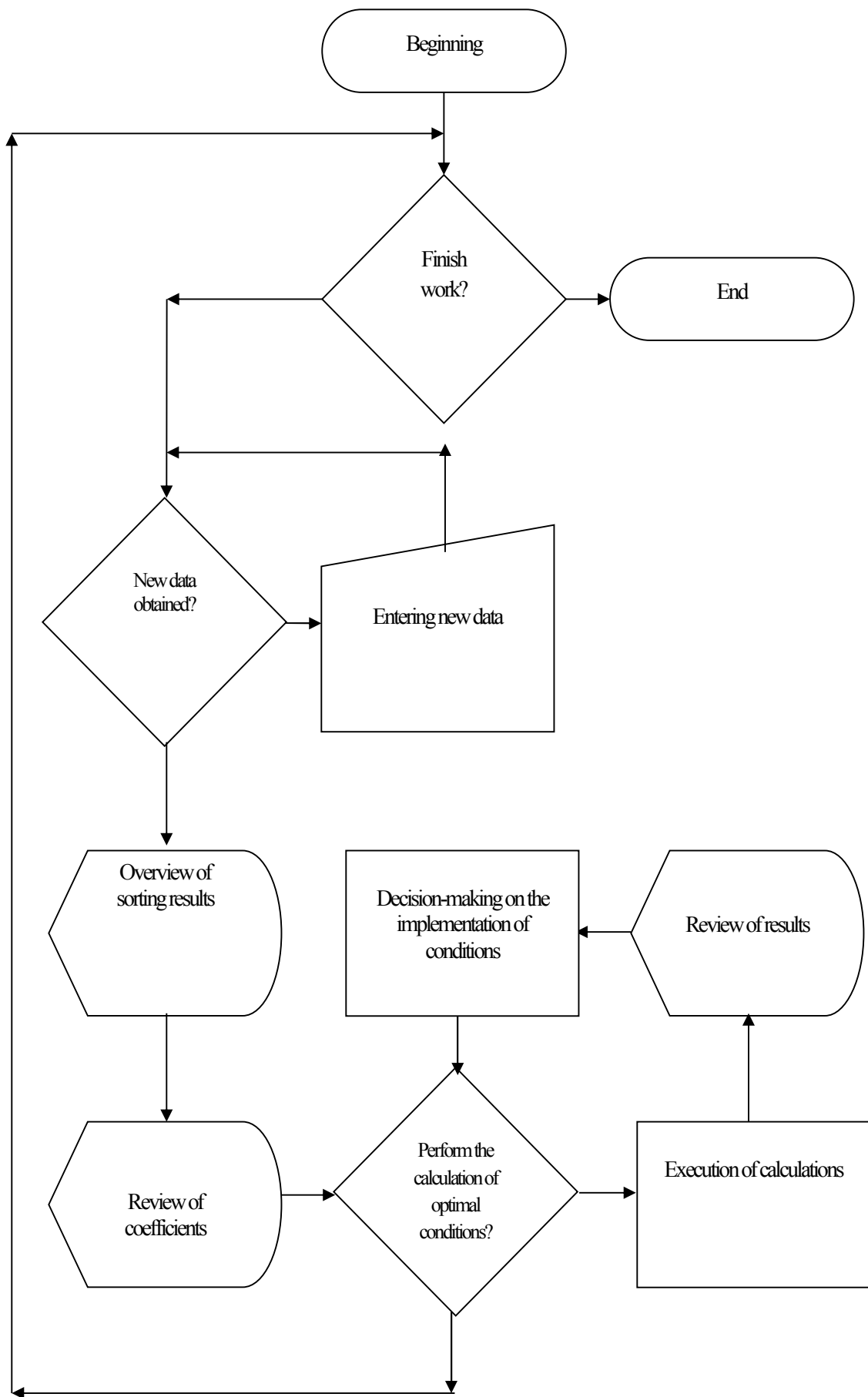
Рисунок 3.1 – Структурна блок схема інформаційної системи

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3.2 Safety measures

Given that the topic of this work on modeling the development prospects of the whole of Ukraine is quite huge, as well as realizing the huge number of industries, activities, industrial, chemical, agricultural industries, etc., to develop safety measures for all participants in the reproduction of our GDP states within the scope of work - unrealistic. However, it should be noted that the issue of safety has always been a priority and the main direction for all legal entities and individuals who, in accordance with the laws of Ukraine, use hired labor and for all employees in our country as a whole.

The state has developed and operates a system of legal, socio-economic, organizational and technical, sanitary and hygienic and preventive measures and safety measures aimed at preserving human life, health and ability to work in working conditions.

Safety measures on the territory of Ukraine are regulated by the legislation on labor protection, Labor codes of Ukraine, the Law of Ukraine "On compulsory state social insurance against accidents at work and occupational diseases that caused disability" and adopted in accordance with their regulations. legal acts such as regulations on labor protection, instructions, classifiers, recommendations, instructions, explanations, state sanitary rules and regulations, regulations on fire and man-made safety, etc. By the way, in 2020, the State Labor Service of Ukraine approved a new Handbook of regulations on labor protection, which should be used in the formation of the database of documents on labor protection.

The state policy in the field of labor protection is determined in accordance with the Constitution of Ukraine by the Verkhovna Rada of Ukraine and is aimed at creating appropriate, safe and healthy working conditions, prevention of accidents and occupational diseases. In particular,

a new version of the basic Law on Safety in Ukraine "On labor protection" was developed and adopted in 2020 in order to harmonize national legislation on labor protection with the EU framework directive.

Therefore, the state policy of the country in the field of occupational safety is based on the following principles:

- priority of life and health of employees, full responsibility of the employer for the creation of appropriate, safe and healthy working conditions;

- increasing the level of industrial safety by ensuring continuous technical control over the state of production, technology and products;

- comprehensive solution of labor protection problems on the basis of national, sectoral, regional programs on this issue and taking into account other areas of economic and social policy, achievements in science and technology and environmental protection;

- social protection of workers, full compensation for damage to persons who have suffered from accidents at work and occupational diseases;

- establishment of uniform requirements for labor protection for all enterprises and business entities, regardless of ownership and activities in Ukraine;

- use of economic methods of labor protection management, state participation in financing labor protection measures;

- informing the population, conducting training, professional training and advanced training of workers on health and safety;

- ensuring coordination of the activities of public authorities, institutions, organizations, associations of citizens that solve problems of health, hygiene and occupational safety, as well as cooperation and consultation between employers and employees (their representatives),

between all social groups when making decisions on labor protection at the local and state level;

- use of world experience of work organization on improvement of conditions and increase of labor safety on the basis of international cooperation.

Висновки

Today, against the background of the global crisis caused by the spread of coronavirus infection, the economic situation in Ukraine continues to be difficult. Thus, according to the latest statistics at the time of its creation, the decline in Ukraine's GDP in the second quarter of 2020 was 11.4%, the decline in industrial production in January-July - 7.7%. Inflationary dynamics both in the consumer market and in the manufacturing sector confirms the depth of the crisis phenomena associated with a steady decline in demand in the economy.

Therefore, determining the prospects of Ukraine's economy in terms of economic growth models is not only interesting but also quite important and important topic, as one of the most important long-term goals of economic policy of any government is to stimulate economic growth, maintain its pace at stable and optimal levels. . It is necessary to have a clear idea of what economic growth is, what factors stimulate it, and what, on the contrary, constrain it, which became the main goal of the study.

In the first part of the work, in order to achieve this goal, the main trends of economic development of Ukraine were analyzed and the definition of the role and place of Ukraine in the modern world economy, including Europe, identified the main economic indicators of our country and gave examples of Ukraine's place among other countries of the world and Europe, considered 11 main economic determinants of the national economy, made a thorough analysis of their independence since Ukraine and to date, compiled a concise rating of Ukraine along with other countries, including the EU, on such indicators as GDP, GDP per capita, unemployment rate and savings rate. The expediency of using separate definitions was also substantiated and on the basis of empirical researches 6 main determinants were selected for further use in models of economic

growth. In addition, they highlighted the issues of increasing the importance and significance of modeling economic growth in transition economies, singled out foreign and domestic researchers who have made significant contributions to the understanding and development of general theoretical and methodological problems of creating and using macroeconomic models of economic growth.

The second part considers the theoretical concepts, main aspects and advantages and possibilities of the most famous economic models of economic growth selected for further study, such as the R. Harrod model, Harrod-Domar model, Solow-Swan model, Cobb-Douglas-Tinbergen model, Lucas and Romer's model. Also, this part of the work was devoted to the practical consideration and application of these mathematical models. The application of these models allowed to practically identify the problems of Ukraine's economy by modeling and forecasting the prospects of Ukraine's development.

The third part of the section presents the created information system for calculating economic growth for Ukraine according to the used models.

The relevance of this research is a comprehensive approach to studying the prospects of Ukraine's economy, ie, the application in one study of several models of economic growth with different conceptual and correlation components, which allowed to better consider the object of study and draw more sound conclusions.

Thus, the results of this work are to determine the prospects for the development of Ukraine's economy in terms of selected models of economic development, which today, unfortunately, are not positive. The modeling revealed the deterioration of Ukraine's economy due to the outflow of investments and fluctuations in the savings rate, reduction of the working population, lack of labor resources, reduction of capital in GDP, declining curve of technical progress and falling economic growth. The

results of modeling endogenous economic growth, according to which knowledge, innovation and investment in human capital are important factors of economic growth, also showed a negative result, which entails a lack of scientific findings, innovations, development of new technologies. All this will lead to the country's economy in the near future to large long-term losses and is proof that the country's economy is heading for a deep recession, which creates conditions for prolonged depression, economic crisis, which causes prolonged economic stagnation and more. Based on the obtained modeling results, the main vectors for taking the necessary measures to improve the economic situation in the country were identified.

Also in the work, on the basis of the calculations, the technique of application of separate models is improved, in our opinion. Thus, it was concluded that the Solow-Swan model is not correct to apply in the presence of a negative value of at least one correlation component, which makes it impossible to find equilibrium values, and found that the use of the Lucas model to analyze Ukraine's prospects is ineffective; it is suggested that this model should be used in the analysis of certain sectors of the economy, production and / or enterprise, where it is realistic to determine the share of labor costs and time for training for a particular industry, as for each link these data are separate and significantly different.

It should be noted that in almost all cases, almost high-quality models were obtained, as the coefficient of determination (R^2) was 0.98-0.99. In our opinion, this is the main practical proof of the need to use mathematical forecasting methods for government officials to take prudent measures to improve the economic situation in Ukraine in the future.

Given the above, the purpose of this study is considered achieved and disclosed in full.

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