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## ANALYSIS AND FORECASTING OF THE DYNAMICS OF PRODUCTION VOLUME BY THE HIGH-TECH SECTOR ENTERPRISES OF THE UKRAINIAN INDUSTRY

**Los V.O., Makarenko O.I., Stukalo K.S.**

*Zaporizhzhia National University*

*Ukraine, 69600, Zaporizhzhia, Zhykovsky str., 66*

vitalos.2704@gmail.com, olenamak@gmail.com, stukalo.katya26@gmail.com

ORCID: 0000-0002-7932-5232, 0000-0003-1009-5122, 0000-0003-2231-6295

### Key words:

autoregressive model,  
high-technology sector,  
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The article is devoted to the study of the dynamics of production volume by enterprises of the high-tech sector of Ukrainian industry: chemicals and chemical products; basic pharmaceutical products and preparations; computers, electronic and optical products; air and spacecraft and related machinery; medical and dental instruments and supplies, electric equipment. Theoretical and practical aspects of the development of high-tech sector of the economy are considered, the essence of this concept is analyzed. The structure of the high-tech sector of Ukrainian industry was analyzed and it was found that for the period from 2012 to 2019, the development of the studied industries has a positive trend: the highest growth rates are observed in the manufacture of medical and dental instruments and supplies (an increase by 2.2 times), and the lowest – in air and spacecraft, related machinery (growth of 3%). The analysis of the dynamics and structure of the development of high-tech sectors in Ukraine was carried out. A number of autoregressive models were built, their accuracy and quality were evaluated. The models were tested for autocorrelation of residuals by the Durbin-Watson and the von Neumann criteria. According to the results of the calculations, it was found that there is no autocorrelation in the models. On the basis of the models built, a forecast of the development of the high-tech sector of industry in Ukraine was made. The results of the forecasting indicate the preservation of existing trends in the sectors under study.

## АНАЛІЗ ТА ПРОГНОЗУВАННЯ ДИНАМІКИ ОБСЯГІВ ВИРОБНИЦТВА ПІДПРИЄМСТВАМИ ВИСОКОТЕХНОЛОГІЧНОГО СЕКТОРУ ПРОМИСЛОВОСТІ УКРАЇНИ

**Лось В.О., Макаренко О.І., Стукало К.С.**

*Запорізький національний університет*

*Україна, 69600, м. Запоріжжя, вул. Жуковського, 66*

### Ключові слова:

авторегресійна модель,  
високотехнологічний сектор,  
динаміка, прогноз, структура

Стаття присвячена дослідженню динаміки обсягів виробництва підприємствами високотехнологічного сектору промисловості України, з виробництва: хімічних речовин і хімічної продукції; основних фармацевтичних продуктів і препаратів; комп'ютерів, електронної та оптичної продукції; повітряних і космічних літальних апаратів, супутнього устаткування; медичних і стоматологічних інструментів та матеріалів, електричного устаткування. Розглянуто теоретичні та практичні аспекти розвитку високотехнологічного сектору економіки, проаналізовано сутність даного поняття. Проаналізовано структуру високотехнологічного сектору промисловості України та встановлено, що за період з 2012 р. по 2019 р. розвиток досліджуваних галузей має позитивну тенденцію: найбільші темпи зростання спостерігаються у галузі виробництва медичних і стоматологічних інструментів та матеріалів (збільшення у 2,2 рази), а найменші – у галузі виробництва повітряних і космічних літальних апаратів, супутнього устаткування (зростання на 3%). Проведено аналіз динаміки та структури розвитку високотехнологічних галузей промисловості України. Побудовано ряд авторегресійних моделей, оцінено їх точність та якість. Моделі перевірено на автокорельованість залишків за двома критеріями: Дарбіна-Уотсона та Неймана. За отриманими результатами розрахунків встановлено,

що автокореляція в моделях відсутня. На основі побудованих моделей розроблено прогноз розвитку високотехнологічного сектору промисловості України. Результати прогнозування свідчать про збереження існуючих тенденцій у досліджуваних галузях.

### Statement of the problem

The structure of a country's economic system determines the efficiency, dynamics and pace of its economic development. Ukraine's modern economy is characterized by the structural shifts: the share of productive industry decreased, and the non-productive increased [1]. According to the State Statistics Service of Ukraine [2] the industry share (mining, processing industry, electricity, gas, water, construction) in 2001 amounted to 33,7% of the country's GDP, services sector – 50,6%, agriculture – 15,7%. In 2020 the industry's share in the GDP structure amounted to 24,21%, services – 64,95%, agriculture – 10,84%. In addition, the structure of industry is changing towards a growing share of the high-tech sector, consisting of high-tech material manufacture and provision of high-tech services. The main high-tech sectors of the industry include: the manufacture of pharmaceutical products, biotechnology; manufacture of air and spacecraft equipment; manufacture of media equipment: for radio, television and communications; manufacture of medical equipment, measuring instruments, optical devices and equipment; production of office equipment and computer technology, software; management, development and use of Internet resources [3]. These industries influence the economic and social development of the country, contribute to the activation of a range of related industries that supply them with materials, components and technological equipment, research and development activities. So, one job in the high-tech industry creates 7–8 jobs in adjacent industries, and with the trade, service and recycling sectors, it creates up to 10 jobs. However, in Ukraine high-tech industries form only 6% of GDP and 5% of exports, and the science intensity of GDP is only 0.77% [4]. This indicates the ineffective functioning of high-tech sectors of the Ukrainian economy. The National Economic Strategy for the period up to 2030 [5] includes the promotion of innovation and modernization of sectors of the economy to improve their competitiveness, so the analysis and forecasting of the development of high-tech sector of Ukraine is an important scientific and practical task, the solution of which will make it possible to determine the status of achieving this goal.

### Analysis of recent studies and publications

The study of issues of structural adjustment of the national economy is reflected in the works of: V.M. Heyets, I.V. Kryuchkova, E.M. Libanova, L.N. Serhieieva and others.

The works of both domestic and foreign scientists are devoted to the study of the high-tech sector: O.B. Bilotserkivsky [6], I.I. Ivanova [7], E.V. Prushkivska [8], O.B. Salikhova [9], L.I. Fedulova [10] and others.

In particular, O.B. Bilotserkivsky, based on the analysis of the structure of the high-tech sector of Ukraine and the structure of the volume of industrial products realized by type

of activity, determined that Ukraine is approaching to the developing countries by the branch structure of industry [6].

Ivanova I.I. studied trends in the development of the high-tech sector of the economy [7]. Her work examines the modern transformation processes of the economy and their characteristic features, analyzes and presents the world volume of production of high-tech products. Ivanova I.I. determined that the USA is a leader in the world production of high-tech products. The author analyzed the specific weight of countries in the world production of high-tech products, as well as world exports of high-tech products. Ivanova I.I. believes that the general trend in the formation of the economic model in developed countries is its innovative orientation on the basis of intensive creation and use of knowledge of society, which is possible due to the appropriate scientific and technical policy, development of education system, information support.

Prushkivska E.V. scientific research analyzes the approaches to defining the concept of «high-tech industry of the economy»: industry, commodity, definition of a high-tech enterprise. It is proved that the industry approach is appropriate to use for macroeconomic analysis and international comparisons; the commodity approach – for the analysis of foreign economic activity, and to develop a system to support and stimulate the development of high-tech sector it is appropriate to use the approach based on the definition of high-tech enterprise [8].

The studies of methodological approaches to the assessment of the high-tech sector of the economy in Ukraine are devoted to the works of O.B. Salikhova [9]. Based on the analysis of the methodology of defining high-tech industries and goods, the author proposed adapting the classification for high-tech goods of the Organization for Economic Cooperation and Development (OECD) to the Ukrainian reality. Considering this, she conducted a comparative analysis of the development of the high-tech sector of Ukraine with other countries of the world.

Problems of economic development of Ukraine in the context of the analysis of markets for high-tech goods and services are studied in the works of L.I. Fedulova [10]. In her research, the author identified the characteristic trends and problems of development of the high-tech sector of the Ukrainian economy and examined the structure of exports and imports of high-tech services. In her work: the factors that determine the place of Ukraine in the world market of high-tech goods and services are analyzed; the forecasted directions of development of the market of Ukrainian high-tech goods are developed and the measures on their implementation are offered; the investment climate of the country and its characteristics are considered. According to L.I. Fedulova, the state of the market of high-tech goods in Ukraine is characterized by general instability of legislation, underdeveloped financial intermediation institutions, macroeconomic imbalances, high riskiness of economic activity, insufficient protection of investors' rights. The

author noted that «the high-tech sector is a complex systemic scientific and production structure, which occupies a certain place in the economy and resource provision is much more important and meaningful than it is interpreted in the literature and in the normative legal acts of Ukraine» [10].

However, despite the significant amount of scientific research analyzing structural changes in the economy, the issue of assessing trends in the development of high-tech sector of Ukraine on the basis of economic and mathematical modeling apparatus is not covered enough in the scientific literature, which makes the chosen topic of the study relevant.

### Objectives of the article

The objective of the article is to analyze the structure of the high-tech sector of the Ukrainian economy and forecasting of development indicators based on autoregressive models.

### The main material of the research

To analyze the dynamics and structure of the high-tech sector of the industrial sector of Ukraine the following types of industrial activity according to the OECD classification are taken into account [11]: Manufacture of chemicals and chemical products; manufacture of basic pharmaceutical products and pharmaceutical preparations; manufacture of computer, electronic and optical products; manufacture of air and spacecraft and related machinery; manufacture of medical and dental instruments and supplies, manufacture of electrical equipment. For these types of economic activity the analysis of structural components of high-tech industries in the industry of Ukraine based on the data of the State Statistics Service of Ukraine concerning the volume of products (goods, services) produced by enterprises by type of economic activity in 2012–2019 was carried out (Table 1) [12].

The analysis of the data in Table 1 showed that the ratios between the components of high-tech production change over time. In 2013 and 2014, there was a significant decrease in chemical production and chemical products by 9.4% and 8%, respectively. In general, this time series is characterized by significant volatility, namely in 2015 there was a sharp increase (by 33.8%), and in 2016 a decrease by 21% and since 2017 there has been a steady growing dynamics. The volume of chemical production

grew by an average of 2.6% annually. From 2012 to 2019, the output of chemicals and chemical products grew by 22.6%. The dynamics of the production volumes of basic pharmaceutical products and preparations is characterized by a steady growing dynamics. On average, each year the volume of production of basic pharmaceutical products grew by 16.5%. In 2019, production of pharmaceutical products increased by 7.4% relative to 2018 and by 3.4 times relative to 2012. The existing trend can be explained by preferential taxation of enterprises producing basic pharmaceutical products [13]. The time series characterizing the volume of production of computers, electronic and optical products also has a growing trend. It should be noted that from 2012 to 2015 the production volumes of the analyzed time series remained almost unchanged, and in 2016 there was a significant growth (almost by 50%). In general, during the analyzed period the volume of manufacture of computers, electronic and optical products grew on average by 9,9% annually. But in 2019 the volumes reached the value – 19134794.4 thousand UAH, which is 2 times more than in 2012. The volume of manufacture of computers, electronic and optical products grew on average by 9,9% annually. But in 2019 the volumes reached the value – 19134794.4 thousand UAH, which is 2 times more than in 2012. The volume of manufacture of aircraft and spacecraft, related machinery gradually grew by 2017, on average by 5.1% each year. And in 2018 and 2019 there is a decrease in manufacturing volumes by 17.8% and 7.2%, respectively. Overall, there was a 3% increase in the manufacture of aircraft and spacecraft and related machinery over the study period. The manufacture of medical and dental instruments and materials is characterized by a steady growing dynamics. Thus, in 2019 compared to 2018, the growth was 13.7%, and compared to 2012, the volume of production increased by 2.8 times. On average, the annual growth of medical and dental instruments production volumes was 13.5%. The dynamic series characterizing the production volumes of electrical equipment by 2014 tends to decrease. And from 2015 to 2018 there is a growing dynamics, but already in 2019 there was a significant decrease in production volumes – by 5.7%. Analysis of the dynamics of the series for the period from 2012 to 2019 shows an increase in the volume of production of electrical equipment by 68.3%. Having

Table 1 – The volume of industrial products manufactured by enterprises of the high-tech sector in Ukraine, 2012–2019, mln. UAH

Years	Manufacture of chemicals and chemical products	Manufacture of basic pharmaceutical products and pharmaceutical preparations	Manufacture of computer, electronic and optical products	Manufacture of air and spacecraft and related machinery	Manufacture of medical and dental instruments and supplies	Manufacture of electrical equipment
2012	68386,87	11422,78	9022,349	20016,13	878,0318	25874,53
2013	61970,24	13133,94	9856,357	19870,36	884,9882	24859,77
2014	57075,44	15879,72	9695,138	19909,91	1043,554	22643,47
2015	76379,55	21711,37	9597,708	24461,08	1594,237	26006,38
2016	60265,58	26963,63	14373,23	24547,42	1772,576	30379,14
2017	63467,38	31230,08	15097,22	27035,42	2022,68	37321,09
2018	77883,41	36060,76	19183,38	22233,57	2129,757	46160,79
2019	83846,96	38746,96	19134,79	20623,79	2420,664	43536,39

Source: built by the authors using [12]

analyzed the dynamics of indicators of production volumes of high-tech industries, we can assert that the studied time series have an increasing trend. So, high-tech industries in Ukraine are developing, although not at a significant pace.

In order to establish the degree of contribution of each component to the development of the high-tech sector of the domestic economy, let us analyze its structure in dynamics (Fig. 1).

The maximum share in the structure of the high-tech sector is occupied by the production of chemicals and chemical products, but this share decreased by 10.2% in 2019 compared to 2012. There is also a decrease in the share of manufacturing of aircraft and spacecraft and related equipment (from 14.8% to 9.9%). The share of manufacturing of basic pharmaceutical products and preparations increased

from 8.4% in 2012 to 18.6% in 2019, the manufacture of computers, electronic and optical products from 6.7% to 9.2%. The share of manufacture of medical and dental instruments remains practically constant. In general, the share of the high-tech industry sector during the analyzed period decreases from 10.2% to 7.2%. This tendency is connected with presence of various obstacles and threats, the main threat is unstable political and economic situation in the country, connected first of all with the armed conflict in the Donbass. Another important problem is insufficient financing and imperfection of state regulation of industrial development, especially in high-tech industries [14].

The authors propose to forecast the indicators of development of high-tech industry in Ukraine in six stages (Fig. 2).

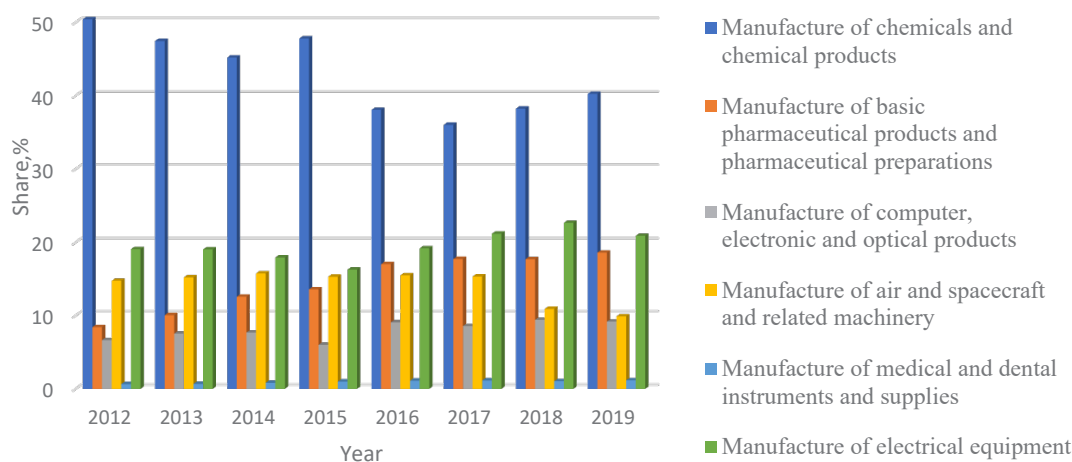


Fig. 1 – Dynamics of the structure of the high-tech sector of industry in Ukraine, 2012–2019, %.

Source: built by the authors using [12]

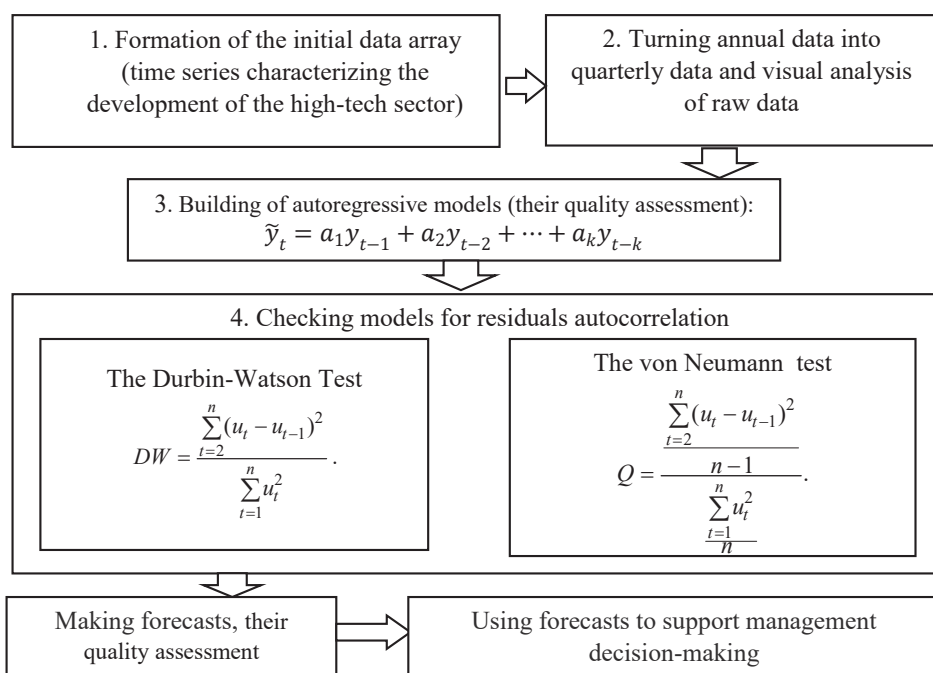


Fig. 2 – Stages of forecasting indicators of development of the high-tech industry sector

Source: made by the authors

The first stage is the formation of an array of initial data. The data of the State Statistics Service of Ukraine on the volume of industrial products produced by enterprises of the high-tech sector [12], which are presented in Table 1, are used as input data.

At the second stage, in order to increase the sample size, the annual data were transformed into quarterly data. For this purpose, coefficients characterizing the ratio of the number of days in the quarter to the number of days in the year were used, conditionally assuming that the volume of production in the relevant industry is constant every day of the year. As a result of the transformations, a time series of 32 values was obtained.

At the third stage, first-order autoregressive models were built, taking into account the results of the autocorrelation test (autocorrelation coefficients of the first order were the highest). The first 30 values of the considered time series were used to build autoregressive models, the last two values were used to assess the quality of forecasts determined by the models. The results of the estimation of parameters and quality of autoregressive models are shown in Table 2.

Models (1)-(6) are qualitative because the coefficient of determination is close to 1 and statistically significant.

At the next, fourth stage, models (1)-(6) were tested for residuals autocorrelation using two criteria: the Neumann and Durbin-Watson. The results are shown in Table 3.

The values of the criteria indicate that there is no correlation of the residuals in the models.

At the fifth stage the forecasts were built, the results of forecasting by models (1)-(6) are shown in Fig. 3.

To evaluate the quality of forecasts we used the mean absolute percentage error (MAPE) indicator, which is 0,55% for model (1), 0,55% for model (2), 1,9% for model (3), 0,64% for model (1) 4, 2,6% for model (5) and 1,26% for model (6). The forecasts are accurate, because the MAPE is less than 10%.

According to the results of the forecast, it can be concluded that in the 4th quarter of 2020 the volume

of manufacture of chemicals and chemical products is expected to increase by 1.7% as compared to the corresponding period of the previous year; the manufacture of basic pharmaceutical products and preparations by – 2.2%; computer, electronic and optical products will increase by – 10.2%; medical and dental instruments and supplies will increase by 13.2% and the manufacture of electrical and electronic equipment by 7,5%. The volume of manufacture of air and space aircraft and related machinery will decrease by 0.37%.

**Conclusions**

The authors made an analysis of the dynamics of the output volume of industrial products of the high-tech sector, which consists of the following types of economic activity: manufacture of chemicals and chemical products; manufacture of basic pharmaceutical products and preparations; manufacture of computers, electronic and optical products; manufacture of air and space aircraft, related machinery; manufacture of medical and dental instruments and materials; manufacture of electrical equipment. On the basis of the analysis, it was found that the production volumes of almost all of the above types of products are increasing insignificantly, while the manufacture of air and spacecrafts and related machinery, electrical and electronic equipment is decreasing.

The forecast of indicators of development of Ukrainian high-tech industry in six stages is proposed. As a result of the calculations a number of autoregressive models of the first order was obtained. All built models are qualitative and statistically significant. The built models were tested for autocorrelation of residuals according to two criteria: the Durbin-Watson and Neumann. According to the results of the calculations, it was found that there is no autocorrelation in the models. The forecasts based on models (1)-(6) are qualitative, because the mean absolute percentage error (MAPE) is less than 10%.

The forecasting results indicate the persistence of trends in the industries under study. The results of the study

Table 2 – Autoregressive models

Indicator name	Autoregressive model equation
Manufacture of chemicals and chemical products ( <i>MCP<sub>t</sub></i> )	$\widehat{MCP}_t = 1,01 \times MCP_{t-1} \quad R^2 = 0,993..(1)$
Manufacture of basic pharmaceutical products and pharmaceutical preparations ( <i>MPP<sub>t</sub></i> )	$\widehat{MPP}_t = 1,006 \times MPP_{t-1} \quad R^2 = 0,993 (2)$
Manufacture of computer, electronic and optical products ( <i>MCEOP<sub>t</sub></i> )	$\widehat{MCEOP}_t = 1,025 \times MCEOP_{t-1} \quad R^2 = 0,994 (3)$
Manufacture of air and spacecraft and related machinery ( <i>MSRM<sub>t</sub></i> )	$\widehat{MSRM}_t = 0,999 \times MSRM_{t-1} \quad R^2 = 0,996 (4)$
Manufacture of medical and dental instruments and supplies ( <i>MMDIS<sub>t</sub></i> )	$\widehat{MMDIS}_t = 1,032 \times MMDIS_{t-1} \quad R^2 = 0,996 (5)$
Manufacture of electrical equipment ( <i>MEE<sub>t</sub></i> )	$\widehat{MEE}_t = 1,018 \times MEE_{t-1} \quad R^2 = 0,995 (6)$

Source: built by the authors

Table 3 – Results of checking models (1) – (6) for residuals autocorrelation

Criterion	Model (1)	Model (2)	Model (3)	Model (4)	Model (5)	Model (6)
von Neumann	2,039	2,039	2,267	2,074	2,438	2,182
Durbin-Watson	1,964	1,964	2,183	1,997	2,347	2,101

Source: calculated by the authors

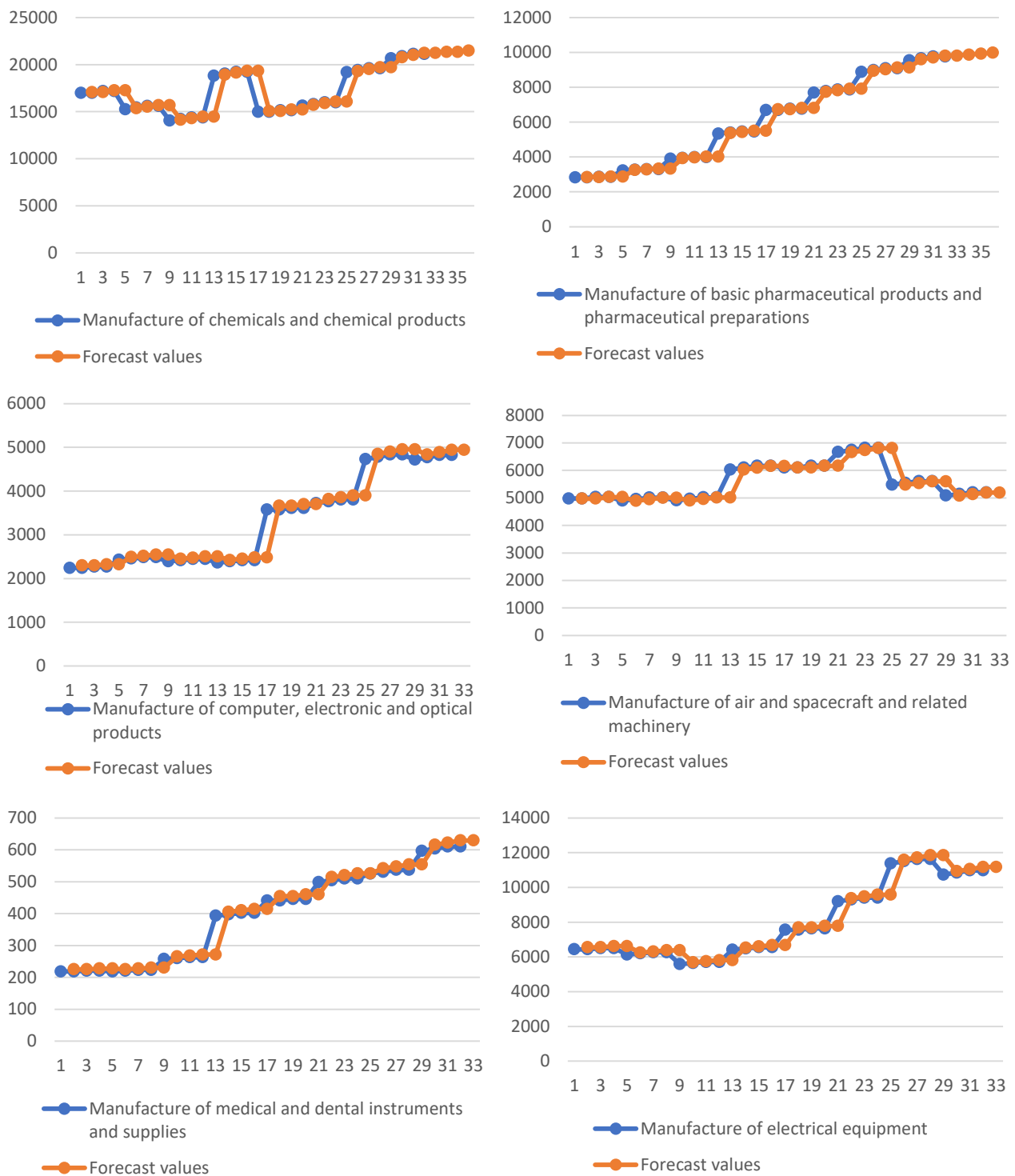


Fig. 3 – The results of forecasting the production volumes of industrial products by enterprises of high-tech sector in Ukraine

Source: calculated by the authors

can be used in the decision-making process to develop a strategy for the development of high-tech sector of the Ukrainian industry.

The prospect of further research of is to evaluate the effectiveness of government measures for supporting the development of high-tech sector of Ukraine.

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