Forecasting the tendencies of the Russian vegetables market development

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Vegetables market and its infrastructure, imitation model, scenario forecast, production and consumption of vegetable production in Russia.

Abstract

The article is devoted to studying the alternatives of development of the Russian vegetables market from the point of view of change of the level and structure of production and consumption of vegetables. The main objectives of the research are to collect and analyze data of the Russian market of vegetable production, modeling and scenario forecasting vegetables market, a substantiation of directions of development of the market under study. The methodological basis of the research is developing the combined economic & mathematical imitation model that is based on creation of the differential equations system. As any qualitative and quantitative changes of market factors lead to shifts in consumer behavior and the structure of consumed products, the scenario variants of development of the situation at the Russian vegetables market was analyzed depending on foreign trade limitations, level of development of infrastructure, and pricing factors of the market. As a result of the research, the volume of consumption of various types of vegetables is predicted for the variants of the forecasts, as well as consequences of the change of the situation for the Russian vegetable sphere on the whole.

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Introduction

Vegetables perform an important role in the food ration of modern humans. They are a source of vitamins and minerals, necessary for correct functioning of the organism. Increase of the world population and development of technologies lead to the sustainable tendency of growth of the world production of vegetables. The world growth of consumption of vegetables is stimulated by increase of the living standards of population of the developed countries and the information campaigns on healthy food. The global market of vegetable products is characterized as highly dynamic: a double increase of production has been observed since 1993 by means of application of intensive technologies and high-quality seed material. The character of vegetable trade was changed in the part of enlargement of the trade flow through wholesale prices.

The Russian market of vegetables is peculiar for stable growth of production and investment activity in the vegetable sector, aimed at improvement of infrastructure: construction of greenhouses, vegetable storages, wholesale distribution centers, and selection and seed centers. However, the volumes of production are insufficient for year-round provision of the country's population with vegetables according to the norms of consumption (124 kg per capita), as dependence on import is not yet solved, and the infrastructure and logistics of the sub-complex is not yet developed. With foreign trade limitations (food embargo) in 2014, Russia received a unique possibility to replace part of the imported products with domestic vegetables. On the other hand, there has been reduction of Russian population's income since 2014. These factors form a tendency for reduction of quality of consumed vegetables, which takes the form of consumption of cheaper products and reduction of consumption of these food products. The situation

in the Russian economy does not allow counting on quick restoration of demand at food markets, which could be the basis for further shift of demand in favor of cheaper segment and restoration of large non-commodity production in population's economies for personal consumption (Food embargo: results of 2015. Analytical report, 2015). Such changes of the market situation lead to the necessity for evaluating the influence of the embargo regime on the state and further development of market vegetables, changes of the structure of consumption, and the forecast in part of improvement of infrastructure. The research of the Russian vegetable market is useful because of combination of economic, political, social and other factors. The study of this situation is useful both from the point of view of the theory of functioning of food markets, and from the point of view of developing practical recommendations.

The issues of vegetables markets are studied in a lot of works. The market of vegetable products is a complex system of interconnection between manufacturers and consumers of agricultural products. The researchers note the common peculiarities of vegetables market in various countries: asynchronous character of production and consumption (Yang and Hu, 2013), importance of ecological aspects of production in vegetable growing (Subić and Jeločnik, M. 2013), (My et al., 2017), labor intensity of the sphere, high dependence on imported products, incomplete information provision and low level of elaboration of the issues of consumption, capital-output ratio, importance of investments assessment (Nzaku and Houston, 2009), (Subić, Jeločnik and Ivanović, 2011), perishable character of vegetable products, special mechanism of trade and high volatility of prices (Shukla and Jharkharia, 2011), (Xu and Liu, 2013) and (Rajkumar, 2014). The scientific society agrees on the decisive influence of the level of development of infrastructure on the state of the market and effectiveness of work in the sphere of vegetable production (Rachmina D. et al., 2014), (Shukla and Jharkharia, 2011). Besides, an important factor of effective work of vegetable growers is usage of marketing approaches (Singh, Jha and Singh, 2011), (Popkova et al., 2013), (Kosorukov, 2012) (Soboleva and Parshutina, 2015) for filling the most perspective market niches.

In this research, we will try to evaluate the structural shifts in consumption of vegetables in Russia depending on the influence of exogenous factors, according to the market specifics. Specifics of the Russian vegetables market is related to concentration (67% of gross production of all vegetables) of production in secondary husbandries of the population, insufficient level of development of infrastructure, active expansion of imported products, and limited assortment of vegetables consumption vegetables. These factors, which influence the processes of production, processing, and storage of vegetable products and its movement to consumer, also influence the character of consumption of vegetable products.

The purpose of the research is to evaluate the variants of development of Russian market of vegetable products, to analyze the structure, tendencies, and perspectives of consumption of vegetable products in various conditions. In the context of forecasting, some limitations of the study should be noted. Thus, an important characteristic of the development of the vegetable market is the assortment of their consumption, the detailed study of which is difficult due to the lack of detailed data. Therefore, the study identified only 8 groups of vegetables. The results could be useful for manufacturers for making timely and justified decisions as to expedience of investing into development of company's infrastructure, planning the assortment of grown products, etc.

Methodology

The overview of scientific literature, which contains studies in the sphere of forecasting the parameters of market of vegetable products, allows for the conclusion on certain one-sided character of the research. Most of them are concentrated on forecasting of prices (Yoo, 2015), (Xu and Liu, 2013), (Yang and Hu, 2013), and (Lagi et al., 2015) or forecasting of demand at the total level (Shukla and Jharkharia, 2011). Besides, the researchers usually study all vegetables as a single commodity without typological division (Mutuc et al., 2007). The dominating part of the researchers focused on creation of economic and mathematical models of the market class Auto Regressive Integrated Moving (ARIMA) (Shukla and Jharkharia, 2011), (Yang and Hu, 2013). The ARIMA model is linear (Robledo, 2002), and complexity of market vegetables as an object of research and forecasting requires using more complex methods. These methods include the models of systemic dynamics (Dynamic Simultaneous Equations Models), which allow modeling complex systems with hundreds of endogenous variables with dozens of feedbacks at the

long-term horizon of planning. Dynamic models are widely used for forecasting of parameters of complex and strategically significant agri-food markets: grain market in the USA (Robledo, 2002), rice market in Japan (Sakurai et al., 2017), meat market in Europe (Põldaru et al., 2008) and (Jarkko and Niemi, 2011).
The methods of systemic dynamics for modeling the vegetables market were used in the works (Nzaku and Houston, 2009) in part of demand for imported vegetables in the USA (Rajkumar, 2014) and in part of analyzing the sales of vegetables in India. The issues of consumption in view of the typological structure of vegetables are not studied sufficiently.

The PowerSim Studio 7 platform was selected as a program product for conducting this research. The PowerSim Studio package was created and distributed by Powersim Software AS (Norway). The used methodology is based on classic methods of systemic dynamics, created by J. Forrester. The package has certain advantages over its analogs (AnyLogic, iTHINK, and GPSS World), which include: blocks of analysis of risks and optimization of business processes, accounting of time lags, accounting of probabilities and risks, automatized accounting of limitations, presence of cross references, possibilities of simulation run various scenarios, and response to external factors.

The dynamic model, which is implemented in the PowerSim system, is a system of differential equations in the Cauchy form of first degree, which describe the processes of the real world. The Powersim model operates in the so-called "compressed" time mode, allowing the user to "instantly" conduct a rapid analysis of the system's response to certain scenario conditions and external influences (Akopov, 2014).

The stages of creation of the systemic and dynamic model were conducted in several stages.
1.Analysis of statistical data. Identification of causal connections.
2.Cognitive modeling – development of the map of causal connections.
3.Development of the mathematical model presented in the form of the dynamic system of simultaneous equations. Calculation of the model's coefficients with the usage of statistical packages.
4.Implementation of the mathematical model on the platform of imitation modeling, which supports the methods of systemic dynamic.
5.Integration of the imitation model with the sources of data (MS Excel, data bases).
6. Conducting numerical experiments. Calibration of the model. Verification of the model for historical data (confirming the model's adequacy) (Akopov, 2014).

The model used the statistical data from the sources of the Federal State Statistics Service (https://www.fedstat.ru/, http://cbsd.gks.ru/), the Ministry of Agriculture of the RF (http://mcx.ru/), and foreign trade statistics of the FAO (http://comtrade.un.org/).

The research was performed with the typological structure of vegetables, namely eight types of vegetables: cucumbers, tomatoes, beet, carrot, cabbage, bulb onion, garlic, and other vegetables (marrow, eggplant, pepper, radish, green cultures). We grouped these types of vegetables, distinguishing the group of "seasonal" (cucumbers, tomatoes, and other vegetables) and "traditional" (beet, carrot, cabbage, bulb onion, and garlic), which are in large demand in Russia. Consumption of seasonal vegetables in Russia is insufficient (-35% of the norm), while consumption of traditional vegetables exceeds the norm's threshold (+22%). Thus, we developed eight systems of differential equations for each type of vegetable. In the general form, the system of differential equations, which described the level of consumption of vegetable products, is presented in the following form:

$$\begin{cases} \frac{dy_i}{dt} = -a_{i1}y_i + b_{i1}x_{i1} + b_{i2}x_{i2} - b_{i3}x_{i3} - b_{i4}x_{i4} + b_{i7}x_{i7} + b_{i8}x_{i8} + b_{i9}x_{i9} + c_i, & (1) \\ y_i|_{t=0} = y_i^0 \\ \frac{dx_{i4}}{dt} = -d_{i1}x_{i1} - d_{i2}x_{i2} + d_{i3}x_{i3} - d_{i4}x_{i4} + d_{i5}x_{i5} + d_{i6}x_{i6} + e_i, & (2) \\ x_{i4}|_{t=0} = x_{i4}^0 \end{cases}$$

where,
i – numbers corresponding to each type of vegetable products;
y_i – resulting variable for the i-th function (consumption of the i-th type of vegetables);

$\frac{dy_i}{dt}$ speed of change of consumption of the i-th type of vegetable;

t – time;

y_i^0 – value of i-th resulting variable for i-th function of development in the initial moment of time t = 0;

$b_{i1}, \ldots b_{i9}, d_{i1} \ldots d_{i6}$ – coefficients during factor variables;

x_{i1} – production of i-th type of vegetable;

x_{i2} – import of i-th type of vegetable;

x_{i3} – export of i-th type of vegetable;

x_{i4} – domestic price of i-th type of vegetable;

x_{i5} – import price of i-th type of vegetable;

x_{i6} – export price of i-th type of vegetable;

x_{i7} – storage capacities of vegetables;

x_{i8} – area of greenhouses;

x_{i9} – Russian population's income per capita.

Equations (1) of each of 8 systems of differential equations create a mathematical model of consumption of vegetable products on the whole and are presented in formula (3)

$$\frac{dy_i}{dt} = -a_{i1}y_i + b_{i1}x_{i1} + b_{i2}x_{i2} - b_{i3}x_{i3} - b_{i4}x_{i4} + b_{i7}x_{i7} + b_{i8}x_{i8} + b_{i9}x_{i9} + c_i, \quad (3)$$

The second block, which consists of equations (2) of each system of differential equations, characterizes the pricing component and contains eight differential equations which are presented by formula (4)

$$\frac{dx_{i4}}{dt} = -d_{i1}x_{i1} - d_{i2}x_{i2} + d_{i3}x_{i3} - d_{i4}x_{i4} + d_{i5}x_{i5} + d_{i6}x_{i6} + e_i, \quad (4)$$

In the process of mathematical modeling each indicator that characterizes the situation in the market of vegetable products was described in dynamics for the period of 2005 – 2015, for which the dynamic rows were built, presented in Appendix 1. The obtained mathematically described trends allow to draw a conclusion about the positive dynamics of development of production, foreign trade indicators in the context of the investigated types of vegetables (with the exception of the onion imports due to its internal overproduction), as well as infrastructure indicators.

For implementation of the model in the PowerSim Studio system, quantitative and qualitative interconnections of variables were set. PowerSim Studio allows modeling various variants of development of the system depending on the set parameters. For the purpose of modeling the alternatives of development of market, the conditions of further development of the situations were set and imitation experiments for 3 scenarios of market development were performed.

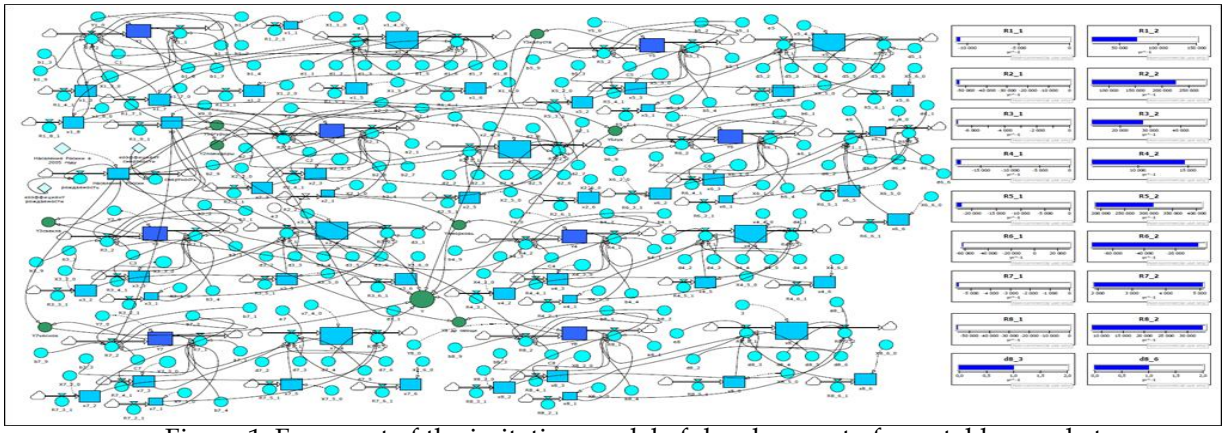

Figure 1. Fragment of the imitation model of development of vegetables market

Scenario I (scenario "removal of limitations for competition") has the following conditions: decision on removal of all foreign trade limitations for vegetable products will lead to mass return to the Russian market of cheap imported products, which may negatively influence the competitiveness of domestic vegetables and profitability of infrastructure development.

Scenario II (scenario "development on the basis of limiting the internal market") is based on the idea of preservation of embargo with the EU countries and with the key supplier – Turkey – and usage of this period for a large leap in development of the infrastructure, and, therefore, creation of possibilities for growth of internal production.

Scenario III (scenario "unused possibilities") supposes preservation of existing tendencies, determined during creation of trend models. In the conditions of preservation of the embargo, but with lack of assets for development of infrastructure, and, therefore, limited internal production (as to assortment, quantity, and other characteristics).

Results

With execution of the conditions of Scenario I (scenario "removal of limitations on competition"), the growth of the level of consumption of vegetable products is predicted, as well as qualitative and quantitative change of the structure of consumption in favor of increase of the share of seasonal vegetables, which will diversify the ration and will allow a part of husbandries to refuse from growing vegetables on their backyards.

Scenario I supposes improvement of the situation for consumers, which is a positive tendency – however, this scenario is negative for domestic vegetable growing, if the existing possibilities for quick development of infrastructure and technological restoration are not used in full, and further development of the sphere takes place in more complex conditions.

Within Scenario II (scenario "development on the basis of limiting internal market"), insignificant structural changes of consumption of vegetable products are expected with large growth of the level of consumption of vegetables on the whole. Scenario II could be considered more "protectionist" that the first one and more preferable – from the point of view of domestic manufacturers. Development of the situation with Scenario III (scenario "unused possibilities") will ensure the tendency for growth of prices for imported, all-season vegetables. There will be certain reduction of the level of consumption and the change of its structure in the part of growth of the share of traditional vegetables. This scenario could be determined as pessimistic, as negative influence on consumption of vegetable products and development of the domestic market of vegetable products is expected.

The quickest growth of consumption of vegetables on the whole and of seasonal vegetables, for which the largest underrun from the physiological norm is observed, is seen during removal of foreign trade limitations within scenario I (scenario "removal of limitations on competition"). However, slowdown of the growth rates of own production is expected (on average, by 1.3% per year), which will negatively influence the level of food security.

According to scenario II (scenario "development on the basis of limitation of internal market"), despite small underrun in the level of consumption, development of domestic vegetable production is expected (growth by 4.7 % per year). In case of increase of the population's income, this growth could be even higher, as well as strengthening of positions of the Russian agricultural products' manufacturers. According to our calculations, this scenario supposes execution of the indicators of the National program of development of vegetable production of closed soil (1,208 hectares).

Scenario III (scenario "unused possibilities") shows that lost possibilities negatively influence all participants of the market – manufacturers and consumers. Growth of domestic production is established at the level of 2.6% per year.

Table 1. Forecasting scenarios of change of consumption of vegetables in Russia

Indicators, kg per capita	2017	2018	2019	2020	2021	2022
Scenario I - "Removal of limitations on competition"						
Consumption of all types of vegetables, including	125.6	128.9	132.5	136.2	140.1	145.1
consumption of seasonal vegetables, including	71.3	73.1	74.9	76.9	79.1	81.6
consumption of cucumbers	9.3	9.5	9.8	10.2	10.5	10.9
consumption of tomatoes	24.3	25.7	27.1	28.6	30.2	31.9
consumption of other vegetables	37.7	37.9	38.0	38.2	38.5	38.8
consumption of "traditional" vegetables including	54.3	55.9	57.5	59.3	61.3	63.5

consumption of beet	7.0	7.1	7.3	7.4	7.6	7.8
consumption of carrot	8.6	8.7	8.7	8.8	8.9	9.1
consumption of cabbage	29.9	31.3	32.9	34.4	36.1	37.8
consumption of bulb onion	7.2	7.0	6.9	6.8	6.8	7.0
consumption of garlic	1.7	1.7	1.8	1.8	1.8	1.9
Scenario II - "Development on the basis of limiting the domestic market"						
Consumption of all types of vegetables, including	119.4	122.0	124.8	127.7	130.9	134.4
consumption of seasonal vegetables, including	65.9	67.0	68.2	69.6	71.0	72.6
consumption of cucumbers	8.9	9.2	9.4	9.7	10.0	10.4
consumption of tomatoes	19.7	20.5	21.4	22.4	23.4	24.4
consumption of other vegetables	37.2	37.3	37.4	37.5	37.6	37.8
consumption of "traditional" vegetables including	53.5	55.0	56.6	58.2	59.9	61.8
consumption of beet	6.5	6.6	6.7	6.8	6.9	7.0
consumption of carrot	8.4	8.4	8.5	8.5	8.6	8.7
consumption of cabbage	28.4	29.9	31.5	32.9	34.5	36.1
consumption of bulb onion	8.6	8.5	8.3	8.2	8.2	8.2
consumption of garlic	1.6	1.7	1.7	1.7	1.8	1.8
Scenario III - "Unused possibilities"						
Consumption of all types of vegetables, including	116.1	118.2	120.4	122.9	125.6	128.9
consumption of seasonal vegetables, including	63.8	64.6	65.5	66.5	67.6	69.0
consumption of cucumbers	8.5	8.7	8.9	9.1	9.3	9.6
consumption of tomatoes	18.2	18.8	19.4	20.1	20.9	21.7
consumption of other vegetables	37.1	37.2	37.2	37.3	37.5	37.7
consumption of "traditional" vegetables including	52.3	53.6	54.9	56.4	58.0	59.9
consumption of beet	6.4	6.4	6.5	6.6	6.7	6.8
consumption of carrot	8.4	8.4	8.5	8.5	8.6	8.7
consumption of cabbage	27.5	28.7	30.0	31.4	32.7	34.2
consumption of bulb onion	8.5	8.3	8.3	8.2	8.2	8.4
consumption of garlic	1.6	1.7	1.7	1.7	1.7	1.8

Conclusions/Recommendations

The results of the research show a small difference in the level of consumption with different scenarios. This fact is explained by several reasons. In particular, there are various violations of the embargo regime (e.g., import of vegetables of Turkish origin with documents of other countries, etc.), which reduces its protectionism effect. Besides, authenticity of the research is determined by the character of the data used, so it is necessary to increase the precision of statistical studies of the indicators of vegetable products market and to expand the list of tracked indicators.

A large difference is observed as to scenarios for the indicator of production – while in Scenario I we see decline of production, Scenarios II and II predict growth of vegetables production in Russia. Thus, the results of imitation modeling confirm the thesis that one of the key factors of development of vegetable products market is creation of a powerful infrastructural basis inside the country. In other words, manufacturers' investing into construction of greenhouse complexes and wholesale distribution centers in the short-term and long-term will perform a decisive influence on competitiveness and profitability of production of vegetables. Stimulation of development of infrastructure is necessary for overcoming the existing inertia tendencies of vegetable market in Russia at present and in future, increase of own production, and reduction of the share of import of in domestic consumption. Further one, with positive development of the situation, it is possible for domestic vegetable growers to enter the world market, as the policy of export orientation is viewed as one of the perspective goals of the Russian economy (Popkova and Sukhodolov, 2017).

In our opinion, there's necessity for additional research in the sphere of seasonality of consumption of the typological structure of vegetables and evaluation of the influence of the country of origin of imported products on the level and structure of vegetables consumption for full study of the factors that determine the consumption structure.

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Appendix 1: Trends of factor variables

production of cucumbers tons	x1 = 54.061t + 1,099
production of tomatoes, tons	x2 = 89.687t + 1,990.2
production of beet, tons	x3 = 27.693t + 785.4
production of carrot, tons	x4 = 43.206t + 1,258.1
production of cabbage, tons	x5 = 85.383t + 2,649.2
production of bulb onion, tons	x6 = 97.397t + 1,134
production of garlic, tons	x7 = 0.9848t + 232.01
production of other vegetables, tons	x8 =64.765t + 916.97
import of cucumbers, tons	x11 = 13,456t + 79,264
import of tomatoes, tons	x12 = 40.960t + 416.074
import of beet, tons	x13 = 1.613.6t + 48,203
import of carrot, tons	x14 = 10,288t + 131,520
import of cabbage, tons	x15 = 3,056.4t + 175,302
import of bulb onion, tons	x16 = -30,730t + 597,273
import of garlic, tons	x17 = 1,542.1t + 37,131
import of other vegetables, tons	x18 = 25,641t + 165,634
export of cucumbers, tons	x19 = 319.94t – 1,174.7
export of tomatoes, tons	x20 = 19.159t – 7.8678
export of beet, tons	x21 = 142.31t – 22.83
export of carrot, tons	x22 = 372.12t – 1,274.5
export of cabbage, tons	x23 = -131.53t + 1,508.8
export of bulb onion, tons	x24 = 689.47t + 4,863.6
export of garlic, tons	x25 = 21.269t – 33.317
export of other vegetables, tons	x26 = 83,770t – 104.152
import price of cucumbers, RUB/kg	x27 = 4.4987t + 5.3254
import price of tomatoes, RUB/kg	x28 = 3.7192t + 10.991
import price of beet, RUB/kg	x29 = 3.1472t + 0.9257
import price of carrot, RUB/kg	x30 = 1.5634t + 4.947
import price of cabbage, RUB/kg	x31 = 1.4777t + 4.2184
import price of bulb onion	x32 = 1.7731t + 2.1287
import price of garlic, RUB/kg	x33 = 5.9303t – 4.0923
import price of other vegetables, RUB/kg	x34 = 3.3392 t + 15.203
export price of cucumbers, RUB/kg	x35 = 2.4107t + 22.44
export price of tomatoes, RUB/kg	x36= 1.0761t + 39.785
export price of beet, RUB/kg	x37 = 2.0275t – 1.0969
export price of carrot, RUB/kg	x38 = 0.6588t + 20.977
export price of cabbage, RUB/kg	x39 = 1.4139t + 1.0507
export price of bulb onion, RUB/kg	x40 = 1.5213t – 0.6736
export price of garlic, RUB/kg	x41 = 3.9529t + 4.6282
export price of other vegetables, RUB/kg	x42 = 0.8361 t + 7.5652
domestic price of cucumbers, RUB/kg	x43 = 5.3267t + 44.999
domestic price of tomatoes, RUB/kg	x44 = 5.3913t + 57.028
domestic price of beet, RUB/kg	x45 = 1.4566t + 13.279
domestic price of carrot, RUB/kg	x46= 2.0437t + 14.404
domestic price of cabbage, RUB/kg	x47 = 1.3028t + 11.92
domestic price of bulb onion, RUB/kg	x48 = 1.3762t + 13.887
domestic price of garlic, RUB/kg	x49 = 10.195t + 34.401
domestic price of other vegetables, RUB/kg	x50=4.0643t + 35.334
number of population, million people	x51 = 0.1464t + 142.5
income per capita, RUB	x52 = 3,001.3t – 4,062.8
expenditures per capita, RUB	x53 = 1,124.7t + 3,242.4
capacities of vegetables storage, thousand tons	x54 = 18.885t + 2,552.6
area of greenhouses, hectares	x55 = 81.064t + 6,652.5