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Macroeconomic Modeling Technological Change in the Energy Sector of the Russian Far East

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Abstract— **The authors evaluate the effects generated in the economy of the Russian Far East by the new gas processing and petrochemical industries. The calculations are based on the regional social accounting matrix for 2015 augmented with data on gas processing technologies and consumption of their products. According to the calculation results, if the output of new industries reaches 38 billion m3 of gas and 2 million tons of polyethylene, the region's GRP will increase by 13.9% compared to 2015. In terms of the concept of sequential interindustry modeling, the authors estimate the temporal distributions of the obtained integral effects. The researchers conclude that without lags in production and consumption, the integral increase in GRP will be obtained after 40 cycles, with lags – after 50 cycles. The maximum discrepancies between the two trajectories of the macro indicator (without and with lags) will be observed in the period up to 25th cycle.**

Keywords*— *Gas Processing, Petrochemistry, Social Accounting Matrix, Macroeconomic Effect, Technology, Russian Far East.

1. INTRODUCTION

Preserving the leading positions in the field of hydrocarbon production Russia is inferior to almost two dozen countries in terms of hydrocarbon deep processing (petrochemistry). One of the main structural problems of the petrochemical industry in Russia is the shortage of capacities for the production of basic monomers, especially ethylene. Domestic demand for polymers of ethylene exceeds by 40% the volume of their output [1]. In order to satisfy the demand for petrochemical products and to increase the share of these products in export it is planned to develop 6 petrochemical centers in Russia: West Siberian, Volga, Caspian, East Siberian, North-Western and Far Eastern. The relevant projects are developed so that to provide an additional capacity for the ethylene production. The capacity of the Far Eastern petrochemical center is 2 million tons, that corresponds to the current volume of polyethylene consumption in the country. Taking into account the parallel start of petrochemical production in other regions of the country, it can be concluded that the main direction of use of polyethylene produced in the Far East will be the external market.

A large-scale new production complex in the Far East will include all stages of the gas processing technology: from the extraction of raw materials to the creation of products with high added value. Its appearance will lead to the transformation of the network of structural links established in the region's economy. This transformation will take a certain period of time and its result in the form of a change in regional macro indicators can be assessed only in terms of the system forecast of the possible structural disproportions in the regional economy. Our work has two main goals. The first one is to assess the integral effects generated in the regional economy by new industries. And the second aim is to determine the trajectories of regional macro indicators that characterize the mechanism of integral effects formation.

Traditionally, the methods of balance modeling are applied to achieve these goals [2, p. 633-654; 3]. We will focus on those methods that allow us to obtain the parameters of adaptation of the regional economy to the new conditions of balanced development on the basis of iterative calculations, without involving complicated dynamic structures. These methods have been developed over the past 40 years, but only in 2014 researchers proposed the numerical method that is suitable for the situation considered in this article, when the new industries are oriented to the external market and don't change the base year regional technologies [4]. Two questions still remain open regarding this numerical method: 1) the correlation of its results with the results of the network model of the impulses propagation in the economy, and 2) its ability to take into account lags in production and consumption. An adequate assessment of the time distribution of integral effects from the development of petrochemical center in the region will be possible only after consideration of these operating questions.

2. BALANCE MODELLING THE TEMPORAL DISTRIBUTIONS OF THE NEW INDUSTRIES IMPACT ON THE REGIONAL ECONOMY

2.1.The Concept of Sequential Interindustry Modelling

Attempts to use balance models with a detailed representation of interindustry interactions to study the consequences of introducing new industries into an economy, especially actively began to be undertaken in the 1980s [5-8]. Romanoff and Levin proposed the concept of sequential interindustry modeling, which is based on the idea of combining engineering and economic calculations [9-11]. The researchers divided the industries into two groups (anticipatory and responsive industries) and specified the chronological features of production processes in industries by groups. The production in anticipatory industries is made in anticipation of future orders, responsive production takes place after the receipt of orders. Romanoff and Levine made the time factor the argument of the input-output flow coefficients and obtained a production function for the analysis of transient behavior. The described concept allowed to use balances to study the situations of non-homogeneous changes in output of different sectors and thus to receive answers not only to questions about the scales of real and potential economic imbalances and their effects, but also to questions about the temporal sequence of changes in industries' output carried out to eliminate these imbalances [12-14]. Similar imbalances arise in the economy of the Russian Far East when the petrochemical center establish. To determine how soon a complex of new productions will be integrated into the network of structural links of the region's economy, Romanoff and Levine's concept is used, but only its main idea described above. The reason for the need to use alternatives to the instrumental support of the concept of sequential interindustry modeling is information limitations.

2.2. Methods of Sequential Modeling of New Industries Effects with Unchanged Technologies of Base Year

When the production recipes of industries are kept constant, the integral effects generated by the petrochemical center in the regional economy can be calculated on the basis of multipliers of balance model augmented with rows and columns representing new gas processing and petrochemical industries. In this case, the distribution of the integral effects over time is provided by the numerical modified RAS-method [4]. The economic content of this method can be revealed on the basis of its comparison with the analytical method, also known as network model of impulse propagation [15, 16].

The network model is based on the representation of the impulse propagation process in the form of successive cycles. The effects of cycle n are given by

$$P_{\nu} = A_{\nu} P_0 = A P_{\nu-1}, \qquad (1)$$

where A is the input-output flow coefficients matrix, including similar coefficients for new industries; R_0 denotes the vector of external demand for products of new industries. The total increment in output and income caused by the integration of new industries into structural relations of the regional economy is defined as the sum of the effects of all cycles. To divide the industries into groups in accordance with Romanoff and Levin's concept, it is necessary to introduce lag operators in the formula (1):

$$P_{\nu} = \square_{\kappa} \Lambda_{\kappa-1} A P_{\nu-\kappa}, \qquad (2)$$

where L_k might be termed the lag operator on A for industries and economic agents with a response of k periods. In general, positive lags are applied for the anticipatory industries, negative lags are applied for the responsive industries.

The numerical method focuses on the entire output of new industries in a separate cycle independent of the directions of using it (external or regional market). The cycle n effects can be written as the difference between two vectors X_n and X_{n-1} that include data on output and income in the consecutive cycles. The elements of the vector X_n can be described by the following scheme:

$$\Xi_{\nu} = \varsigma_{\nu}\, 1^M + \Psi^{*},\ Z_{\nu} = (1^M)^T \varsigma_{\nu} + \Delta_{\nu},\ Z_{\nu} = \Xi_{\nu-1}, \qquad (3)$$

where V_n is the matrix containing the data on intermediate consumption, primary income and final demand for cycle n; Y^* the external demand vector incorporating the demand for products of new industries; D_n the import vector including interregional flows for cycle n; Z_n the expenditures vector for cycle n; M the dimension of V_n; 1^M M-sized column vector with ones, and where the superscript T denotes transposition.

The elements of the matrix V_n and vector D_n in cycle n are calculated, according to

$$\varpi_{\iota\varphi(\nu)} = \varpi_{\iota\varphi(\nu-1)}(\xi_{\varphi(\nu-1)} / \zeta_{\varphi(\nu-1)})),\ \delta_{\varphi(\nu)} = \delta_{\varphi(\nu-1)}(\xi_{\varphi(\nu-1)} / \zeta_{\varphi(\nu-1)}), \qquad (4)$$

where i and j are the indices of industries. Note that the analytical and numerical procedures only ever scale entire columns, and never rows. This mathematical feature ensures that production recipes of sectors remain unaltered during table balancing.

By analogy with the network model, the iterative calculations of the numerical method can incorporate the lag operators based on multiplying them by the matrix V. With similar lag structure, the convergence of numerical method calculations is faster than the convergence of the network model calculations. Differences in convergence depend on the share of intraregional consumption in the output of new industries: the greater this proportion, the greater the differences in results obtained by the two methods. Because we expect that the products of gas processing and petrochemical industries of the Russian Far East are mainly intended for the external market, the results of the network model and the numerical method will not differ significantly.

3. Modeling the Impact of Gas Processing and Petrochemical Industries on the Economy of the Russian Far East: Integral Effects and Their Temporal Distributions

In the calculations we use the social accounting matrix of the Russian Far East constructed for 2015. This matrix includes the prospective costs structures of gas processing and petrochemical industries. The integral change in macroeconomic indicators caused by the development of new industries is presented in the table.

Table. Change in macroeconomic indicators as a result of new industries development.

Indicator	Relative Change, %	Absolute change, bln rubles
Gross Regional Product	13.9	493.4
Gross Output		
Gas Production	36.4	116.8
Oil Production	0.5	2.9
Oil Processing	24.2	81.7
Gas Processing	-	905.5
Petrochemistry	-	158.8
Coal Mining	7.7	6.7
Heat Power Industry	11.1	20.4
Electric Power Industry	25.4	34.5
Other	10.5	368.0
Income of Households	11.2	278.5
Income of Regional Budgets	7.9	68.7

Taken together, the two new industries produce 1064.3 bln rubles. Their appearance in the region leads to an increase in GRP by 493.4 bln rubles or by 13.9% compared to 2015. New industries have the closest relations with other industries of the energy sector. The largest increases in gross output are planned in the gas production, oil refining and electric power industry. As expected, the temporal distributions of these integral effects estimated with analytical and numerical methods almost duplicate each other. It should be noted that under no-lag assumption, about 75% of GRP increments will occur within the three cycles of the initial impact. The changes are less than 0.01% after twenty cycles, and the process converges after about 40 iterations.

Based on the possibilities of industries to supply resources for gas processing and petrochemistry, we suppose the following lag structure of production in the region: industries of primary sector (gas, oil, coal productions): response to 5 cycles ago; industries of secondary sector (oil processing, gas processing, petrochemistry, heat and electric power industry): adjust production within a cycle; other industries of secondary sector and industries of tertiary sector, first of all transport: response to 1 cycle ago; income of the economic agents of the region: response to 1 cycle ago.

Therefore, we have just-in-time and responsive production modes. We should describe industries of primary sector as anticipatory, but we assume a 5 cycles response lag for them, which will be required for the development of additional Kovykta field along with the Chayandinskoye field. The introduction of the lag structure described above decelerates the convergence of macro indicators after the initial impact. In particular, 75% of total change in GRP will be received after 10 cycles. According to the calculation results, the fastest growth in output is observed in the gas production (the share of new industries in intraregional consumption of the resource accounts for more than 72%), and the slowest convergence of the output is typical for coal mining and heat power industry. In the case of coal mining, this is due to the lack of direct connections with new production facilities. The result for heat power industry is determined by a wide network of its structural links with the regional economy.

4. Concluding Remarks

In order to study the integral effects of new petrochemical center in the Russian Far East we augmented the regional social accounting matrix for 2015 by introducing in it the data on gas processing and petrochemical technologies. With the concept of sequential interindustry modeling we constructed the temporal distributions of these integral effects. Our results indicate that the analytical as well as the numerical methods can be used for the purposes of sequential interindustry modeling with assumption about the conservation of base year technologies. The economic content of two methods is the same, because it is given in accordance with the expenditures structure of industries and economic agents. But the convergence of their results is different due to the definition of the impulse. The analytical method considers as the impulse external demand for products of new industries, the numerical method assumes that this is gross output of new industries. In our case, with a high share of external demand in the gross output of the gas processing and petrochemical industries, the differences in the results of two methods are insignificant. We conclude that the integral increase in GRP generated by the appearance of gas processing and petrochemical industries in the region will be 13.9% (compared to 2015). This effect will be received after 40 cycles without taking into account the probability of the lags in production and consumption, and after 50 cycles with taking into account this probability. The maximum discrepancies between the two trajectories of the macro indicator (without lags and with lags) will be observed in the period up to 25th cycle.

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