Development of an Agro-Food complex on the basis of economic integration

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ABSTRACT

The agro-food complex combines agriculture, food-processing industry and agricultural trade. It has been established that integration is an effective tool for formation and functioning of this complex. However, due to the unstable political and economic situation in recent years, there is a decrease in production of certain types of food in Ukraine. A vertically integrated structure which looks like a two-tier hierarchical structure has been studied. The purpose of its functioning is profit maximization at the expense of the synergetic effect, resource saving, etc. Under strict vertical integration, profit distribution can be made on the basis of distribution mechanisms of scarce resources, using priorities where expenses of enterprises can be considered a priority. The problem of formation of an effective vertically integrated structure can be brought to solving the issue of the smallest covering of a set. It has been proved that a boundary value of an index of vertical integration is determined by a share of energy resources in the process of production and the potential of their production. In Ukraine, the use of biogas complexes can provide growth of the mentioned index to 0.25. This corresponds to the ratio of energy resources in the crop production cost structure.

Keywords: development, agro-food complex, intergration, model, biogas.

1. Introduction

The agro-food complex combines agriculture, food-processing industry and agricultural trade. Therefore, the role of this complex in life sustenance of people is unique. In addition to the economic function (food production and distribution, forming a share of the state and local budgets), the agro-food complex also plays a social function (development of rural territories, formation of ecologically safe 'green' energy, etc.).

Formation and functioning of the agro-food complex is carried out on the basis of integration and cooperation. In other words, by means of vertical integration, there is combination of efforts put forth by, firstly, producers of agricultural raw materials (grains, seeds of oilplants, sugar beets, etc.), secondly, their processors (in particular, grain processing, oil and fat, sugar industries, food production), thirdly, food product wholesalers and retailers. Consequently, an agro-food chain is formed: from an agricultural raw materials producer (agrarian enterprises, farm enterprises and peasant farms) to a specific consumer.

It should be noted that due to biological properties of agricultural waste, plant remains, animal and poultry keeping, products can be used for biogas production on the integration basis.

The article aims at justifying the directions of economic development of the agro-food complex on the basis of integration. In particular, the authors clarify the trends of social and economic development of the Ukrainian agro-food complex, as well as highlight methodological approaches to modelling of agro-industrial integration and economic integration in the „green" energy sector.

2. Literature review and problem statement

The essence of agroindustrial integration determines its potentials as a tool for improving efficiency of agroindustrial production (Kovalenko 2012).

A vertical integration is considered as an extension of activities and/or control of a company along its technological distributional marketing chain: at the preliminary stage (up to raw materials production) or at the next one (up to sales of products to an ultimate consumer). The vertical integration is intended to replace market transactions with other forms of contacts (internal operations and processes, long-term contracts, etc.) (Kuts 2012).

The vertical integration is also defined as a set of enterprises interconnected and integrated on the technological basis in order to achieve common goals. We propose to interpret a vertically integrated structure as a complex, dynamic organizational form of business that is a result of the vertical integration. Such a structure is an officially registered (or established on the basis of contracts and agreements) association of business units (enterprises, firms, companies, organizations and institutions) or technologically independent stages of production. As a rule, they form a complete cycle. Their task is joint activities in order to obtain a synergistic effect (Nusinov, Kolesnikov 2013; Pająk, et al., 2016, 214-217; Lakhno et al. 2018, 1802–1812).

Such an association takes place around a central production line including raw materials processing and end production (Shumeiko 2008), and independent enterprises are its structural elements (Bespalov 2006).

Agro-industrial integration combining agricultural and industrial production, including agricultural service cooperatives dealing with processing, procuring, marketing, distribution or supply activities, is quite common (Ivanov, Rohoza, Verhal 2016).

It is proved that the logistic concept of food supply involves formation of an agro-food complex which has four blocks: resource support and technological maintenance; agricultural production; storage and processing of agricultural products; food trade (Perebyynis V., Perebyynis O. 2006, p. 116).

Both cooperation and integration in the agrarian sector of the economy create benefits of such approaches to others through: accumulation of labour, financial and other resources; shortening production lead time; economies of scale; synergistic effect; possibility of access to new knowledge; wider dissemination of knowledge and information; streamlining information flows; greater opportunities for social development of a region; creating new jobs; increase in revenues to the local budget; creating better conditions for combining their members' personal interests with interests of all participants in the production process; protection of an association members from monopolistic manifestations of suppliers, sales, banking and other structures (Skopenko 2010).

Development of the agro-food complex implies improving production relations on the basis of cooperation and vertical integration of agricultural and processing enterprises (Ivanov, Perebyynis, Oleksenko, Svitlychna 2016), development of internal and external markets of food products (Rohoza, Verhal 2015), as well as rural territories (Ivanov, Rohoza , Perebyynis 2016).

Issues of integration in a 'green' energy sector, as well as in biogas production and use, are analyzed, in particular, in publications (Perebyynis V., Havrysh, Perebyynis Y. 2016), (Kalinichenko, Havrysh, Perebyynis 2016, 2017).

Thus, increasing the efficiency of functioning of the agro-food complex, being interested in the formation of inter-farm associations, we need to clarify the existing models and mechanisms of functioning of vertically-integrated structures, development of "green" energy production on the basis of economic integration.

3. Economic integration as the basis for development of an agro-food complex

3.1. Tendencies of social and economic development of the agro-food complex of Ukraine

The agro-food complex plays a leading role in forming the state's food security. Thus, in Ukraine in 2016, the level of self-sufficiency with the main types of food (production for domestic consumption within the state) amounted to: grain – 290.5%; eggs – 114.0%; meat and meat products – 105.4%; milk and dairy products – 103.6%; potatoes, vegetables and food gourds – 101.6%; berries and grapes - 84.6% (Agriculture of Ukraine – 2016, p.220).

According to the Ministry of Agrarian Policy and Food, in 2015, Ukrainian commodity producers turned to Asia ($7.4 billion), the EU ($5.9 billion) and Africa ($2.2 billion). The main types of exported food are crops ($13.8 billion) including cereals, as well as sunflower oil, oilseeds, sugar and tobacco. Exports of livestock products amounted to $1.0 billion (meat and by-products, dairy products, ready-to-eat or canned meat products, etc.). However, the food industry development is characterized with unstable tendencies (Table 1).

Table 1: Production of some types of food in Ukraine, million tons

Production	2014	2015	2016
Oil	4.4	3.7	4.4
Sugar	2.1	1.5	2.0
Milk	1.1	1.0	1.0

Source: (Ukraine in figures – 2016, p. 112).

Development of plant growing is also characterized with multi-vector tendencies. During 2014-2016, production of sunflower seeds increased by 34.7%, grain – by 3.4%, but there was a decrease in production of sugar beets, potatoes and vegetables (Table 2).

The period under analysis was characterized with a certain increase in crop yields (except for 2015 with worse weather and climatic conditions). This was promoted, in particular,

by the high efficiency of production and commercial activity of large agrarian enterprises developing modern agrotechnologies (Table 3).

Low paying capacity of the public in Ukraine limits development of the internal food market. Certain difficulties in selling livestock products on foreign markets and other reasons led to a decrease in production of meat, milk and eggs (Table 4).

Table 2: Production of plant products in Ukraine, million tons

Production	2014	2015	2016
Cereals	63.9	60.0	66.1
Sugar beets (industrial)	15.7	10.3	14.0
Sunflower seeds	10.1	11.2	13.6
Potatoes	23.7	20.8	21.7
Vegetables	9.6	9.2	9.4

Source: (Agriculture of Ukraine – 2016, p. 94).

Table 3: Crop yields in Ukraine, c/ha

Production	2014	2015	2016
Crops	43.7	41.1	46.1
Sugar beets (industrial)	476.5	433.8	481.5
Sunflowers	19.4	21.6	22.4
Potatoes	176.4	161.4	165.8
Vegetables	207.8	206.1	210.5

Source: (Agriculture of Ukraine – 2016, p. 102).

Table 4: Production of the main types of livestock products in Ukraine

Production	2014	2015	2016
Meat (slaughter weight), mln. t	2.4	2.3	2.3
Milk, mln. t	11.1	10.6	10.4
Eggs, bln.	19.6	16.8	15.1

Source: (Ukraine in figures – 2016, p. 150).

The developed world under the influence of urbanization is characterized with a tendency to dwindling rural population. Ukraine also did not avoid it. As of January 1, 2017, the country's rural population was 13.2 million people (31.1% of the total population). In agriculture, forestry and fisheries, in 2016, 2.8 million people were employed (17.6% of the total employed population). The world-wide pattern of a decrease in agricultural employment is observed, which has been shown in the reduction of this category of employees by 7.3% in comparison with 2014 and decrease in the number of employees from 530.9 thousand to

509.5 thousand people (Agriculture of Ukraine – 2016, pp. 19-20). There is a positive tendency in the growth of labour productivity (output per one agricultural worker, at constant prices in 2010) from 227.8 thousand UAH in 2014 up to 277.3 thousand UAH in 2016 (by 21.7%).

Another positive tendency (for agricultural commodity producers) is the growth of average sales prices of one ton of products for the period under analysis. In particular, during this period, purchasing prices of crops at agricultural enterprises increased from 1,801 to 3,414 UAH (in 1.9 times), oilseeds seeds - from 4,063 to 8,656 UAH (in 2.1 times), industrial sugar

beet - from 494 to 849 UAH (in 1.7 times), farm animals (in live weight) - from 15,737 UAH to 22,468 UAH (in 1.4 times), milk - from 3,588 to 5,462 UAH (in 1.5 times) (Agriculture of Ukraine – 2016, p. 58, 186).

Along with the increase in the volume of food sales, the indicated tendencies have become the basis for increasing the wage fund. Therefore, it is no coincidence that in the agriculture during 2014-2016, average monthly nominal wages of full-time employees increased from 2,476 to 3,916 UAH (by 58.2%) (Agriculture of Ukraine – 2016, p. 22).

For modern Ukraine, a gap in wages between peasants and those working in cities is a tradition derived from the former Soviet Union and the Russian Empire. In this context, in recent years, there is a positive tendency of reducing a pay gap between rural and urban workers. Thus, whereas in 2014 the wages of workers employed in agriculture, hunting, forestry amounted to 71.2% of the average wage in Ukraine, in 2016 it grew to 75.6% (Agriculture of Ukraine – 2016, p. 22).

However, a share of labour costs in the structure of the cost of agricultural production in Ukraine (as opposed to economically developed countries) remains low and even decreases. In particular, whereas this indicator made up 7.1% in agricultural enterprises in 2014, it was only 5.4% in 2016, including agricultural enterprises where it decreased from 5.6% to 4.0%. Accordingly, in agricultural enterprises, deductions for social measures declined from 2.7% to 1.2%, and in agricultural enterprises – from 2.1% to 0.9% (Agriculture of Ukraine – 2016, pp. 183-184).

In spite of the complex socio-political situation, during the last years housing construction in rural areas continues. In particular, 3,096 thousand m² of the total area of housing were commissioned in 2014, 3,579 thousand m² in 2015, 2,864 thousand m² in 2016. The number of built apartments was respectively 28,000 m², 31,000 m² and 28,000 m². However, according to these indicators, rural areas lag behind urban ones, where 222 m² of housing per 1,000 inhabitants (in rural areas – 217 m²), 2.9 apartments (in rural areas – 2.1) were constructed in 2016 (Agriculture of Ukraine – 2016, p. 159).

In addition to housing, social and cultural facilities are commissioned in rural areas. Thus, pre-school educational establishments for 1,918 seats, general educational institutions for 1.3 thousand pupils' seats, hospitals for 100 seats, outpatient clinics for 342 visits per shift, club facilities for 850 seats were commissioned in 2016. However, commissioning of residential homes for elderly people has been stopped since 2014, (Ukraine in figures – 2016, p. 163).

Consequently, integration is an effective tool for formation and functioning of the agro-food complex. However, due to the unstable political and economic situation in recent years, there is a decrease in production of certain types of food in Ukraine. One of the methodological tools for development of the agro-food complex is the modelling of vertically-integrated structures.

3.2. Modeling agro-industrial integration

In the simplest version, a vertically-integrated structure is a two-level hierarchical structure consisting of n functionally dependent subsystems and Pm business processes, the input of which results from the previous parts of the hierarchy. At the same time, all subsystems have the right to make decisions concerning the organization of relevant business processes within the limits defined by the managing system. The hierarchical location of subsystems (a multi-tiered structure) is determined by the fact that some processes are influenced or directed (partially/completely) by the managing system.

Let us consider a vertically integrated system consisting of one coordinating subsystem (a higher level of the hierarchy B_0) and n managing subsystems of a lower level being subordinate to a subsystem of a higher level (Fig. 1).

At the first level, the subsystem B_0, which acts as a management center for united enterprises, is represented. At the second level, there are functionally dependent subsystems represented by a finite aggregate of heterogeneous agents $B_1, ... B_n$, where $n \geq 2$ is an aggregate of enterprises that are a part of the integrated association and interact with the management center. In addition to that, each agent is responsible for separate stages of the production and sales process vertical and can be represented both as one enterprise or a group of independent enterprises.

Given that a vertically integrated organization is formed on the basis of the subordination of the adjacent links of commodity promotion to one of the channel participants (Bespalov 2006) prevailing in it, a role of the coordinating subsystem is performed by one of the enterprises with the greatest economic potential.
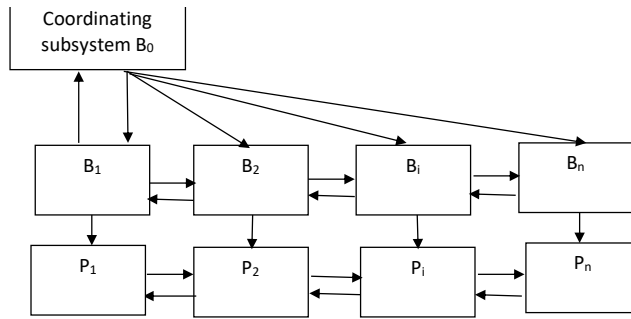
Figure 1. A vertically integrated structure as a hierarchical structure
Source: own study

That is, for a set of agents $B = (B_1, B_2, ..., B_n)$ included in the vertically integrated structure, the necessary condition for a managing subsystem selection can be described as follows:

$$\forall B_i \in B, \exists B_0, B_0 = \left\{ B_i \in B : R_{B_i} = \max_n \left(R_{B_1}, R_{B_2}, ..., R_{B_n} \right), i = 1, .., n \right\} \quad (1)$$

where R is the potential of individual enterprises being part of the integrated structure, B_0 is the coordinating subsystem of the vertically integrated structure, n is the number of enterprises being a part of the integrated structure.

Taking into account that functioning of the vertically integrated structure is mainly aimed at profit maximization due to the synergistic effect, resource savings, etc., it is important to outline mechanisms of profit distribution by the coordinating system among the subsystems of the second level. Under the strict vertical integration, profit distribution can be made on the basis of mechanisms for scarce resources allocation using priorities, where expenses of enterprises can be considered a priority (Burkov 1997; Veres 2010):

$$p_i(s) = \begin{cases} s_i, if \sum_{j=1}^{n} s_j \leq P \\ \min\{s_i, \gamma\eta_i(s_i)\}, if \sum_{j=1}^{n} s_j > P^{'} \end{cases} \quad (2)$$

where n is the number of enterprises being a part of the integrated structure, s_i is their claims for the expected profit, x_i is the distributed profit of a separate enterprise, P is the profit of the integrated structure to be distributed, $\eta_i(s_i)$ is the function of a distribution priority, $\min\{s_i, \gamma\eta_i(s_i)\}$ indicates that an enterprise receives a resource in an amount not bigger than the declared value, γ is the parameter that plays a rate

setting role and is selected given budget constraints, i.e. profit P is fully distributed given claims and priority functions:

$$\sum_{i=1}^{n} \min\{s_i, \gamma\eta_i(s_i)\} = P \quad (3)$$

Let us consider the features of interaction of a couple of agents of the vertically integrated structure (Fig. 2).

Such interaction is based on satisfying the needs of integration participants, forming goals of integration of enterprises as well as their interconnection, in which an output of one system is an input for another one (outputs of one enterprise create resource conditions for the functioning of another enterprise). Meeting other needs may result in the involvement of intermediaries or expansion of the integrated structure by involving other integration participants. Therefore, the condition for expansion of the integrated structure due to external agents is the following dependence:

$$B^* = B \cup A_i \left\{ f(B, A_i) < f(B^*) | \forall A_i \in A, i = 1, ..., n \right\} \quad (4)$$

where $f(B, A_i)$ is the function of an enterprise's effectiveness in cooperation with an intermediary, $f(B^*)$ is the function of an enterprise's efficiency when involving an intermediary into the integrated structure, A is an external agent.

Obviously, the problem of forming an effective vertically integrated structure can be reduced to solving the problem of the smallest covering of a set (Christofides 1978, pp. 53-54), which provides maximum efficiency of the integrated structure and determines expediency of the association expansion due to integration of an intermediary agent.

Let's assume that $R = \{r_1, ..., r_m\}$ is a set of requirements imposed to an enterprise being

a part of the vertically integrated structure, $B = \{B_1, ..., B_m\}$ are enterprises of the vertically integrated structures. Herewith, there is fulfillment of a condition where each enterprise B_i from a set of B is assigned a subset of requirements $Rj \subseteq R$ where $j = 1, ..., m$. Herewith, an enterprise B_i either fully meets the requirements of a coordinating subsystem, or does it partially, fulfilling a function of the set R_j with a certain quality being a cover set R, if $R_i \cup R_j = R$.

Let's assume that c_j are expenses related to the functioning of an enterprise being a part of the vertically integrated structure. Therefore, a problem of the optimally vertically integrated structure is of the form:

$$F(x) \rightarrow \sum_{j=1}^{n} c_j x_j \rightarrow \min \qquad (5)$$

$$\sum_{j=1}^{n} a_{ij} x_j \geq 1 \qquad (6)$$

$$a_{ij} = \begin{cases} 1, \text{if an enterprise } x_i \text{ is able to meet requirements} \\ \qquad \text{with certain efficiency } R_j \\ 0, \text{otherwise.} \end{cases} \qquad (7)$$
$$x \in 0,1$$

Thus, the analysed vertically integrated structure looks like a two-tier hierarchical structure. Its functioning is aimed at profit maximization at the expense of the synergetic effect, resource saving, etc. In response to the unstable energy supply and ecological crisis on the planet, the issue of using the opportunities of the agro-food complex for energy production is pressing.

3.3. Integration in the 'green' energy sector

Global energy consumption is constantly increasing. It leads to a reduction in stocks of fossil carbohydrate fuels. Therefore, in recent decades, the issue of utilization of renewable energy sources has become even more urgent. Biogas takes a proud place among them. It is used for production of thermal and electrical energy, as well as substitution of natural gas and traditional motor fuel. Business practice has proved that the success of production and commercial activity largely depends on the effectiveness of vertical coordination. In this context, the question that has to be answered concerns the role of biogas complexes in the formation of vertically integrated structures. Biogas complexes perform the following functions: processing and disinfection of industrial and municipal waste, bioconversion of plant material, production of energy resources (biogas, biomethane, electric and thermal energy),

production of biofertilizers and other products (e.g., carbon dioxide). A vertically integrated structure including a biogas complex enjoys such advantages: expenses of integrated production are reduced, its competitiveness increases (Eriksson, Olsson 2007; Nolm-Nielsen 2000). Vertical integration can be directed both 'up' and 'down'. If biomethane, electric and/or thermal energy is sold to external consumers (in grid system or in main pipelines), there is integration that is directed 'up. Such a scheme is widely used, for example, in Germany. In this case, electrical energy is sold at a 'green' rate (Schulz, Coop, Hohhi, Fulton, Parson, Rebok, Ilchuk 2012). Having its own biogas plant, an agrarian or processing enterprise can fully or partially meet its own needs for motor fuel, electrical and thermal energy, biofertilizers. This will reduce the use of external flows of material resources. Introduction of a biogas complex by an agrarian enterprise allows to change an index of vertical integration. It is measured as a proportion of monetary (material) flows between structural divisions of a firm to the total flow (Bhuyan 2005; Caves, Bradburd 1988; Davies, Morris 1995). This index varies from 0 to 1.

The value of the index of vertical integration should be determined by the following formula:

$$FVI = \frac{Ee + Et + Ef + Eb + Ec}{MRN} \qquad (8)$$

where *FVI* is the index of vertical integration, *Ee* is the cost of electrical energy produced by a biogas complex, *Et* is the cost of thermal energy produced by a biogas complex, *Ef* is the cost of motor fuel substituted by biogas produced by a biogas complex, *Eb* is the cost of biofertilizers produced by a biogas complex, *Ec* is the cost of carbon dioxide (by-product of biogas upgrading), *BMP* is the cost of material resources necessary for operating an agrarian enterprise (fuel, electrical and thermal energy, mineral and organic fertilizers, seeds and planting material, plant protection products, etc.).

The existing processing enterprises of Ukraine have already had similar experiences. Thus, at Hlobyne Sugar Refinery, biogas covers 50% of energy requirements; as for its oil extraction plant – 100 % (ASTARTA 2017). Boundary value of the index of vertical integration is determined by a share of energy resources in the production process and potential of their production. According to estimates (Havrysh, Perebyynis 2015), the use of biogas complexes in Ukraine can provide an increase of this index to 0.25. This corresponds to the share of energy resources in the crop production cost structure.

4. Conclusions

The agro-food complex combines agriculture, food-processing industry and agricultural trade. It is established that integration is an effective tool for the formation and functioning of this complex. However, due to the unstable political and economic situation in recent years, there is a decrease in production of certain types of food in Ukraine. In comparison with Poland, other EU countries, the wage remains low, causing intensive labor migration.

The analysed vertically integrated structure looks like a two-tier hierarchical structure. Its functioning aims at profit maximization at the expense of the synergetic effect, resource saving, etc. Under strict vertical integration, profit distribution can be made on the basis of scarce resources distribution mechanisms using priorities, where the expenses of enterprises can be considered a priority. The problem of formation of an effective vertically integrated structure can be brought to solving the issue of the smallest covering of a set.

In response to the unstable energy supply and ecological crisis on the planet, the issue of using the opportunities of the agro-food complex for energy production is pressing. It is proved that a boundary value of an index of vertical integration is determined by a share of energy resources in the process of production and the potential of their production. In Ukraine, the use of biogas complexes can provide growth of the mentioned index to 0.25. This corresponds to the ratio of energy resources in the crop production cost structure.

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