Cross-Sectoral and Price Interactions: a Key to Development of Foresight and Management System in Agribusiness

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Abstract. Objectives: To research intersectoral interaction in agricultural production, considering price influence on the part of production and consumption. The object is the dynamic series of indices of production of crop products and livestock, along with indices of producer prices from agriculture and consumer price indices for food products in general for the Russian Federation. It was supposed to use the results of research in the process of management and Forsthy agribusiness at the federal and regional levels.

Methods: A general exploratory analysis of data was used as the essential tool for analysis, and the vector model of correction of errors (VECM) reveals the bidirectional influence of factors on each other with adjustment on long-term co-integration. A test on the Granger causality was also performed.

Results: Based on the received data, it is possible to conclude the extraordinary influence of livestock indices on the other ones that were possibly caused by economic and institutional peculiarities of the Russian agrarian-industrial complex and agricultural production. Accordingly, the authors proposed the main directions of the transformation of the agribusiness management system at the level of specific organizations and institutions of regional management. Adaptive and constructive approaches in the transformation of the control system will allow overcoming the trap of extensive development.

1. Introduction

1.1. National agrobusiness preconditions

1.1.1. Conjuncture

The Russian economy has been operating in recent years in the context of external geopolitical and internal institutional constraints. Meanwhile, the agricultural production sector has shown steady growth over the past few years. For example, since the beginning of the “sanctions” confrontation in 2014 to the present, the gross output of agricultural products has grown almost 1.5 times in real terms, while the GDP growth for this period remained in the negative or in an about zero zone [1]. This fact clearly defined good prospects for a successful solution to import substitution and food security problems. However, implying the relatively small part of agricultural production in national GDP, existing economic and institutional limitations formed the resistance boundary to further growth. Crop cultivation (grain production), which resulted in a noticeable export boom, has extensive and mainly raw-material character. On the other hand, there remains a relatively high level of food imports, even despite the induced countersanctions by the attitude of some developed countries. The agrarian industrial complex also depends on imports, starting with genetic material and finishing with agricultural techniques. Moreover, a long-time feature of the development of agricultural production in the Russian
Federation is a permanent disparity in the prices of factors of production (especially fuel and raw materials) and, of course, products. The devaluation of the ruble has greatly affected inflationary processes.

As for food security, the Ministry of Agriculture of the Russian Federation, in close cooperation with other departments, unions, associations, and the scientific community, is now developing a new draft doctrine. The current doctrine, approved in 2010 and operating until 2020, loses its relevance in some positions [2]. The main criterion for assessing the state of food security is the proportion of domestic food in total consumption. The planned values are achieved or exceeded for most products. However, economic barriers to access to food are increasing. Food price for the poor Russians from 2013 to 2016 rose from 48 to 54.4%, with the secured-from 22 to 26% [3]. Thus, the price factor in domestic agricultural production acquires a more complex character. In any case, the influence of consumer price dynamics should be considered in combination with the prices of producers both within the agroindustry complex and in the sectors directly or indirectly influencing agricultural production.

1.1.2. State program

The policy of stabilization and achievement of sustainable growth demanded the adoption of the state program of agricultural development of the regulation of markets of agricultural products, raw materials and food. It started functioning in 2013 and has already shown some results. Table 1 shows the implementation of the leading indicators of the program (see Table 1).

Table 1. Implementation of the main indicators of the state program of agricultural development and regulation of markets for agricultural products, raw materials, and food for the 2013-2020 yrs. in the Russian Federation [4]

| Indexes                                                                 | Summary of 2017 year   | Planning | Actual | Deviation | Rank of deviation |
|------------------------------------------------------------------------|------------------------|----------|--------|-----------|------------------|
| Index of agricultural production in farms of all categories (in comparable prices) by the previous year, % | 101.7                  | 102.4    | +0.7   | 4         |                   |
| Index of crop production in all categories of farms (in comparable prices) by the previous year, % | 101.5                  | 102.1    | +0.6   | 5         |                   |
| Index of livestock production of in all categories of households (in comparable prices) by the previous year, % | 101.9                  | 102.8    | +0.9   | 3         |                   |
| Index of physical volume of investments in the fixed capital of agriculture by the previous year, % | 100.6                  | 103.1    | +2.5   | 2         |                   |
| The profitability of agricultural organizations (considering subsidies), % | 14                     | 14.3     | +0.3   | 6         |                   |
| Average monthly accrued wages of employees in agriculture (for agricultural organizations not related to small business entities), rubles | 21 790                 | 26 280   | +20.6  | 1         |                   |
| Labor productivity index for the previous year, %                     | 104                    | 104      | 0      | 7         |                   |
| Number of high-performance jobs, thousand places                       | 304.3                  | 304.3    | 0      | 7         |                   |

The variance is ranked in descending order to illustrate the effect of target performance. One can observe the highest deviation on the average monthly wage, but it is fair to note that the deviation would be given smaller “real” wage indicators. Further, on ranks, there is an index of the physical volume of investments, the index of production of the crop, and animal husbandry.

During the whole period of 2005-2017 years, there is the fast substitution of labor by capital in agribusiness, and the action of the state program of support of agriculture accelerates this process. As an actual process for production, reducing the need for the workforce puts additional pressure on the pre-
vailing socio-economic situation in rural areas [5]. Gradual monopolization of production accompanies these processes.

1.2. Cross-sectoral and price interactions
The study of any interaction between industries that are closely related and simultaneously competing for state support is somewhat uneasy, referring us to the eternal philosophical problem of the "egg and chicken causality dilemma" (in our case, it is more likely the "chicken and grain"): what industry or sphere in an economic complex is primary or more important, and how are they related in dynamics? Another equally outstanding aspect is the availability of reliable tools with which to find answers to such calls.

The objects are a series of inter-annual percent changes that are suitable for analysis, without essential changes (Table 2). The first two rows show the dynamics of the cooperated and, at the same time, the competing branches of agriculture. On the other hand, it is always important to know about the topical problems of price disparity in agriculture. So, there are price indices – agricultural producers, and the consumer price indices of food products in the last rows.

Table 2. Indexes (interannual) in Russian Federation 1990-2018 yrs. [1]

| Data                          | 1996 | 2000 | 2005 | 2010 | 2015 | 2016 | 2017 | 2018 |
|-------------------------------|------|------|------|------|------|------|------|------|
| Crop production index (Crop PI), % | 100.3 | 110.9 | 102.7 | 76.2 | 103.1 | 107.8 | 103.5 | 97.6 |
| Livestock production index (Livestock PI), % | 89.0 | 101.1 | 100.4 | 100.9 | 102.2 | 101.6 | 102.6 | 101.3 |
| Food consumer price index (Food CPI), % | 117.7 | 117.9 | 109.6 | 112.9 | 114.0 | 104.6 | 101.1 | 104.7 |
| Agrarian producer price index (Agro PPI), % | 116.5 | 122.2 | 103.0 | 123.6 | 108.5 | 101.8 | 92.2 | 112.9 |

The Figure 1 shows the comparative dynamics of normalized indexes on the full dataset.

![Figure 1](image-url)
2. Methods

2.1. Exploratory analysis
As can be seen from the figure 1, there are rare outliers (Z-score analysis showed more than 3 standard deviations) in Food CPI in 1998, Agro PPI in 1999 and Crop PI in 2011 years respectively. These fluctuations correspond to the specific historical periods in the Russian economy. Leveling out is not necessary, besides they can contain important information to search for interactions. Table 3 shows the main descriptive statistics of the given data.

Table 3. Descriptive statistics of the given data.

| Data                        | Minimum | Maximum | Mean (geometric) | Median | Historical volatility | Stationary hypotheses (KPSS, p > 0.05) |
|-----------------------------|---------|---------|------------------|--------|-----------------------|---------------------------------------|
| Crop production index       | 75.7    | 146.9   | 102.6            | 103.1  | 66.1                  | rejected                              |
| (Crop PI), %                |         |         |                  |        |                       |                                       |
| Livestock production index  | 89.0    | 105.6   | 100.9            | 101.6  | 16.9                  | rejected                              |
| (Livestock PI), %           |         |         |                  |        |                       |                                       |
| Food consumer price index   | 101.1   | 196.0   | 114.3            | 111.0  | 90.9                  | rejected                              |
| (Food CPI), %               |         |         |                  |        |                       |                                       |
| Agrarian producer price index| 92.2    | 191.4   | 113.7            | 111.2  | 98.3                  | rejected                              |
| (Agro PPI), %               |         |         |                  |        |                       |                                       |

According to the data of 2 tables, the most exceptional minimum among indices is a crop production of 75.7%, and the highest maximum is at the consumer price 101.1%. The highest average level also has the price indices. Naturally, they have the most considerable historical volatility, which is easily explained by the fact that the production always has more inertia than prices, especially in the unstable Russian economy. Interestingly, the volatility in crop production is much higher than in livestock one (almost four times). One of the reasons, of course, can be called the instability of climatic conditions in various territories.

The hypothesis about the stationarity of the series according to the Kwiatkowski-Phillips-Schmidt-Shin criterion (KPSS) was not confirmed in any of the dynamic series. The paired Engle-Granger test and the total Johansen test showed the existence of mutual integration between variables. Due to the relatively small sample and therefore reduced the power of statistical tests, the significant threshold is set at 5%.

Thus, prerequisites exist for using the distinct data analysis model.

2.2. VEC model
Agribusiness is just a domain that can use numerous modern data analysis and machine learning techniques [6]. Factor interactions in agricultural production are quite numerous, and their study presents a real challenge for the researcher. They include industrial production figures, price factors, terms of trade, and others [7]. In this case vector family models are especially helpful. Borderline significance of cointegration raises the question of whether to use VAR (vector Autoregression) or VEC (vector error correction) models. Earlier authors [8] have already attempted to use VAR, of two time series of production indices in crop and animal husbandry. VAR is a modern model of the dynamics of multivariable time series in which the current values of these series depend on the past values of the same time series. It is an alternative to systems of simultaneous equations (structural models), with significant theoretical limitations. Also, the VAR model helps to see the mutual factors influence on each
other. VAR, as it is, ignores co-integration long-run terms, but its error correction representation form (VEC) does not [9][10]:

\[ \Delta Y_t = \alpha \beta' Y_{t-1} + \sum_{i=1}^{d} \Gamma_i \Delta Y_{t-1} + \eta_t \]  

(1)

Wherein:

\[ \alpha \beta' Y_{t-1} \quad \text{– error correction (cointegrations) part} \]  

(2)

\[ \sum_{i=1}^{d} \Gamma_i \Delta Y_{t-1} + \eta_t \quad \text{– VAR part} \]  

(3)

More clearly, interpretation is possible with investigating variables response to the impulse unit (IRF, impulse response function) and forecast error variance decomposition (FEVD). Another important methodological question brings up matching statistics and economics significance of results [11].

3. Results

3.1. VECM fitting

Fitting of VEC-model and selection of Hyperparameters was carried out using software environment R (library “tsDyn”) [12]. The information criteria were Akaike AIC and Bayes BIC. The best configuration described by the following hyperparameters: lag order – 2, co-integration rank – 3. Inside the co-integration equation, it is necessary to add the constant and trend, outside – only a constant.

Table 4. Outside the cointegration relation and lagged endogenous parameters for equations.

| Variables | Coefficients (* – significance, p-value < 0.05) | Lag order L\(^1\) | Lag order L\(^2\) |
|-----------|-----------------------------------------------|-------------------|-------------------|
| **Equation Crop PI** | | | |
| Crop PI | 1.04 | 0.37 |
| Livestock PI | -1.05 | 3.10* |
| CPI food | 1.00* | 0.37 |
| PPI agro | -0.82 | -0.23 |
| **Equation Livestock PI** | | | |
| Crop PI | 0.22 | 0.06 |
| Livestock PI | 0.11 | -0.22 |
| CPI food | 0.25* | 0.15* |
| PPI agro | -0.29* | -0.09* |
| **Equation Food CPI** | | | |
| Crop PI | -0.70* | -0.35* |
| Livestock PI | 1.02* | -1.15 |
| CPI food | -0.29 | -0.36* |
| PPI agro | 0.49* | 0.27* |
| **Equation Agro PPI** | | | |
| Crop PI | -1.08* | -0.52* |
| Livestock PI | 3.56* | -0.92 |
| CPI food | -1.87* | -1.18* |
| PPI agro | 2.12* | 0.85* |
On shifts in the crop production affects significantly changes in the consumer price index (coefficient equals 1) in first order lag margins and changes in livestock production of a second order lag with a high coefficient of 3.1.

On the index of livestock products significantly influences more factors, such as the lags of the first order: the producer price index with inverse proportionality (-0.29) and the consumer price index directly (0.25). On the second lag order, their influence slightly decreases – 0.09 and 0.15, respectively.

The response of the consumer price index to food causes a negative shift in the crop production index (the previous period -0.7 and before it -0.35), the livestock index only in the first order (1.02) and the producer price index 0.49 and 0.27 in both lags respectively. The autocorrelation is negative and observed in the second order lag as -0.36.

As for the producer price index in agriculture, it is mainly influenced by the dynamics of itself with the lags of the first and second order (2.12 and 0.85). Again, the negative impact of production indices in the crop growing (-1.08 and -0.52), livestock is significant only in the lag 1 (but with a relatively highest coefficient value of 3.56), while producer price indices relation is significant in the lags 1-2 (2.12 and 0.85 respectively).

| Table 5. Loading coefficients α for equation Crop PI. |
|------------------------------------------------------|
| Loading coefficients α for equation Crop PI (* – significance, p-value < 0.05) |
| α₁      | α₂      | α₃      |
| Equation P PI | -2.87*  | -2.06*  | -1.53*  |
| Equation Livestock PI | -0.40*  | -0.28   | -0.28*  |
| Equation CPI food | 1.03*   | 1.55*   | -0.37   |
| Equation PPI agro | 1.74*   | 0.47    | 2.89*   |

Loading coefficients α are short-run deviations around the long-run equilibrium. Rank to integration equal to 3 gives three equations. The biggest load has Equation of Crop PI; it speaks about the rapid return of short-term deviations to the general long-term equilibrium. Table 6 These are the parameters of the integration equations themselves.

| Table 6. Cointegrating vectors. |
|---------------------------------|
| №   | Crop PI | Livestock PI | Food CPI | Agro PPI | Trend | Constant |
|-----|---------|--------------|----------|----------|-------|----------|
| 1   | 1.00    | 0.00         | 5.55     | 0.06     | -0.14 | -109.26  |
| 2   | -1.79   | 1.00         | 0.00     | 0.21     | 0.17  | -127.40  |
| 3   | 6.37    | 0.00         | 1.00     | -1.09    | -0.37 | 12.89    |

Table 3 shows the long-run term parameters for 3 cointegration linear links. In two of them the trend has a negative inclination.

### 3.2. **FEVD**

As mentioned earlier, the models themselves are difficult to interpret directly. Variance decomposition or forecast error variance decomposition (FEVD) is used to help in the interpretation of VAR or VECM models once they have been fitted. The variance decomposition indicates the amount of information each variable contributes to the other variables in the autoregression. It determines how much of the forecast error variance of each of the variables can be explained by exogenous shocks to the other variables.
On figure 1, one can see how much of error appearance is coming from unexpected changes in other variables. The most prominent fluctuations in the index and crop production caused more by the dispersion of the index of livestock products and the index of crop production. Moreover, this influence grows with the expansion of the horizon. Indices of production and consumer prices are the least affected.

Figure 3. Livestock PI FEVD.

The "casual" magnitude of the livestock production index (fig.3) depends primarily on itself, and there is a lesser extent on other variables. The influence of fluctuations in crop production is relatively noticeable here. The effect of the prices is poorly expressed, like the previous example.
Regarding the consumer price index (fig.4), it is possible to assert that here the main influence is traced from the variability of the index in livestock products and to a lesser extent from crop production and the index itself. The influence of producer Price index is less expressed.

Finally, the producer price index of agricultural products (fig.5) primarily suffers from the influence of livestock production dynamics. Further on the force of influence, there is crop production and practically in equal shares price indices.

3.3. Granger causality
Also, according to the source data, it is possible to determine the presence of any significant causality between the time series (test causality of Granger). Fig. 6 presents a pair comparison of time series and statistically significant relationships (P-value < 0.05).
Figure 6. Significant Granger causalities (pairwise) and VECM coefficients. Lag order – 1, 2.

The scheme on the figure 6 shows the most expressed causality which bears variable Livestock PI about Crop PI, Agro PPI and Food CPI (moreover Livestock production index cause CPI in both lag orders). All other interactions are hidden due to a lack of statistical significance. The coefficients from VEC model is coming along with arrows of causality directions. Not all significant causality is accompanied by significant coefficients.

4. Discussion and conclusion

When comparing all the received models of time series interactions, a discussion question is that the dynamic range of the livestock production index is the most influential about other rows, as in the case of causality and of the size of the coefficients. This effect extends throughout not less than two time-lags both in statistics and economics aspects.

The most probable explanation of this phenomenon is the considerable unevenness in the directions and the features of the agricultural sector support. There is a noticeable trend towards monopolizing agroindustry complex. Thus, most of the Russian market is already controlled by a few companies (holding), which in turn rely more on the development of livestock and its processing. Underdeveloped small business in agricultural production (in 2018, the ratio of farms amounted to 11.9%, which is even less than the previous year by 0.5%) [13]. The part of private subsidiary farms is also decreasing. In the crop industry, for the most part, there was positive but extensive growth, and it was due to the export of unprocessed products. The weak influence of crop production depends on lack of domestic raw material processing. The weak influence of the consumer price index can be explained by the shrinkage of demand and the high ratio of food imports in Russia. At the same time, the dynamic of producer prices, which is associated with inflation costs, negatively affects almost all variables. One exception can be found in the first lag of animal husbandry index (state support talks), but in the second lag, the connection also becomes negative.

The important specificity of Russia is that its main territorial arrays include the opportunities of agrarian management [14]. At the regional level, the issues of infrastructure, the spatial distribution of producers, and an insufficient quantity of wholesale and logistic centers in the regions are of importance [15].
The vital functions of management in agribusiness are marketing management, financial management, supply chain management, and human resources management [16]. The authors would like to add “foresight” to the list. It must contain a synergetic mix of planning, prediction, and decision-making. Modern agribusiness is not conceivable without technical and technological modernization and innovative development. Thus, it indicates that the modernization potential laid down in the state program is realized enough [5]. However, in the absence of growth of the small business, the release of the workforce can lead to social tensions in rural areas and increased labor migration. People are the most critical asset of any agribusiness. Of course, and the competition also reduced in the markets.

The institutional and cross-industry approach in long-term planning and forecasting will allow the form a strategic management guideline for the development of the agroindustry complex [17]. It implies the development of a set of institutions that provide innovative processes and commercialization of scientific research, the creation of digital platforms as a set of interconnected and inter-dependent economic mechanisms of functioning based on digital technologies, the formation of new areas of activity and new markets. Penetration of digital and innovative technologies into regions is comparatively steady, and their fuller use will help to keep the profitability of production in challenging economic conditions for all categories of agribusiness [18].

As a conclusion, authors should set out the main directions on which to improve the development of a system of management and foresight both on the national and the regional levels considering the data obtained in the research. Overall transformation of the management system parts into adaptive and constructive components. The adaptation component is initially concerned with the internal environment of the enterprise and implemented as an aspect of more flexible foresight and management systems of specific agricultural production. The different influence of digital transformation can render on a business foresight. More efficient production will help to equalize inter-sectoral, cross-sectoral, spatial proportions, as well as proportions of the main categories of farms. Closer interaction with the academic environment will contribute to the development of human capital.

Adaptation processes link to structural changes in the industry. The construction leaving component is, primarily, the improvement of the external environment of business. It concerns the state administration of the agroindustry complex at the federal and regional levels and includes a set of measures relating to the development of competition, the reduction of price disparities, the limitation of inflation, and the provision of equal access to financial resources in government support programs. The balance between the formal and informal institutional environment has always been of great importance for the Russian economy and in the agroindustry complex particularly.

So, the exploration of complex interactions has many degrees of freedom and requires much effort to parse all possible options. The use of modern methods of machine learning becomes support in such situations. As for the specific case mentioned above, the further development of the idea for research is to increase the number of factors involved, testing other models and methods. It is necessary to study in detail the degree of penetration of the digital economy into the regional agroindustry complex to form a methodology in data analysis in this aspect. It may be necessary to explore deeper relationships and processes, including in other related industries and areas. The stimulation of modernization and upgrading of the material-technical and technological base of agrarian production would be exciting.

However, there are still enough problems that hinder the intensive and permanent growth of agribusiness. The formation of a sustainable institutional environment, especially in the regions, is complicated and contradictory due to the lack of a comprehensive strategic approach in the management system and of a modern foresight skill.

5. References
[1] Russian Federation Federal State statistics service homepage http://www.gks.ru
[2] Xenophontov M Yu, Polzikov D A, Goldenberg I A, Sitnikov P V 2018 Metodological problems of forming the food security concept in Russia In: Forecasting problems 5(170) 127-136
[3] RANEPA Institute of Applied Economic Research (IPEI) https://ipei.ranepa.ru/ru/cap

[4] National report on the implementation progress and results in 2017 of the state program for Agricultural Development and regulation of markets for agricultural products, raw materials and foodstuffs for the years 2013-2020 Ministry of Agriculture of the Russian Federation http://mcx.ru

[5] Shestakov R B, Alpatov A V, Lovchikova E I, Hashir B O 2018 Production function analysis of the regional agriculture within the framework of the state development program implementation In: Economics, labor, management in agriculture 10(43) 42-48

[6] Liakos K G, Busato P, Moshou D, Pearson S and Bochtis D 2019 Machine Learning in Agriculture: A Review MDPI Sensor in agriculture https://www.mdpi.com/journal/sensors/special_issues/Agi2018#published

[7] Usman M, Fatin D, Yusuf M, Barusman S, Faiz A M and others 2017 Application of Vector Error Correction Model (VECM) and Impulse Response Function for Analysis Data Index of Farmers’ Terms of Trade Indian Journal of Science and Technology vol 10(19) DOI: 10.17485/ijst/2017/v10i19/112258

[8] To the question of interbranch interaction in agricultural production: analysis and forecast based on VAR-model In: Economic aspects of management of innovative development of agrarian sector of Russia in regional aspects, CONFERENCE 2019, Komi (republican) Scientific Center of the Ural Branch of the Russian Academy of Science 334-339

[9] Nastansky A, Mehnert A, Strohe H G A 2017 Analysis of the agrarian production dynamics in conditions of total economy restriction In: Economics, labor, management in agriculture 4(33) 65-73

[10] Muller C A 2019 Note on the Interpretation of Error Correction Coefficients In: https://ru.scribd.com/document/207752006/Note-on-Interpreting-Error-Correction-Coefficient

[11] Marc F 2019 Bellemare, Agricultural and Applied Economics—Without Apology Metrics Monday: Statistical vs Economic Significance http://marchbellemare.com/wordpress/

[12] Package “tsDyn” homepage https://cran.r-project.org/web/packages/tsDyn/tsDyn.pdf

[13] Shestakov R B, Lovchikova E I 2017 Analysis of the agrarian production dynamics in conditions of total economy restriction In: Economics, labor, management in agriculture 4(33) 65-73

[14] Gizatullin Kh N, Garipov F N & Garipova Z F 2018 Management of the Structural Transformation of Regional Economy Ekonomika regiona 14(1) 43-52

[15] Goncharov V D, Rau V V Export potential of the Russia food complex In: Forecasting problems 5(170) 119-126

[16] Barnard F 2016 Agribusiness Management Taylor&Francis 484

[17] Solodovnik A I, Lovchikov E I, Fedotenkova O A, Hashir A A 2019 Strategic guidelines for the management of the agroindustry complex within the framework of the implementation of state development programs In: Economics, labor, management in agriculture 2(47) 79-87

[18] Alpatov A V, Shestakov R B 2018 Development of management systems in the Orel region agroindustry at the municipal level in the digital economy space In: Economics, labor, management in agriculture 2 35 46-54