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Climate Change and Variability in Designing Stable Markets of Agricultural Products

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Abstract

We propose a methodology of statistical analysis of food security as stability of national food supply system in a framework of extended reproduction. We suggest to ensure stability of production of main agricultural products based on synchronism and asynchronism of production fluctuations in the world, accounting for climate variability in space and time. We develop a system of statistical parameters for estimating stability of production levels and trends of different forms. We show that the parameters of trend stability may serve as characteristics of cycles' presence and stability.

Keywords: food security, production stability, asynchronism of production fluctuations, cycles.

1. Introduction

Food security should be treated as an element of national security, as it is one of the main goals of national agricultural and economic policies. In its general form, food security sets a direction of any national food system towards its ideal state. In this sense, the pursuit of food security is a continuous process. A variety of new mechanisms of agricultural policies support this process, but they should be based on the actual regional climate conditions and optimized additional investments providing employment opportunities.

According to the 2009 Declaration of the World Summit on Food Security, "food security exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life. The four pillars of food security are availability, access, utilization and stability. The nutritional dimension is integral to the concept of food security."

Thus, food security is a complex of solutions aimed to effectively solve the problems of not just producing, storing and processing of agricultural products, but also the problems of their fair distribution, issues of social and economic development in the rural areas.

Our research is mainly focused on the first two elements of the food security.

2. Climate Change and Variability in Designing Stable Markets of Agricultural Products

Our suggestions of taking into account synchronism of production fluctuations for creating a stable market of agricultural products are strongly associated with the climate change. Climate change requires change of national agricultural structure (crop production, cattle breeding, processing, and infrastructure). Note that each crop has unique vegetation conditions, including a recommended sowing time. Accordingly, the decision-making process of accounting for synchronism of fluctuations across the territories should also consider a possible shifts of regions with synchronous yield fluctuations due to the structural changes in planting. Thus, the importance of studying the climate change is undoubtable.

Nowadays, climate change studies are also demanded in the agricultural context due to the fact that there is no clear methodology available of quantifying climate change in a region. This restricts one from assessing the perspectives of agricultural production on a certain territory. Afanasiev & Kim (1998) earlier suggested to assess the climate change using the analysis of crops yield. At the same time, the influence of climatic factors can be classified into two categories: overall climate change over a region, and interannual volatility of weather conditions.

We define the dynamics of overall climate change accounting for the main yield factors (a reserve of productive moisture in the 1-meter soil layer in each month, snow water equivalent in January, monthly precipitation, etc.) that explain 96% of yield volatility. We use the time series characterizing the weather conditions to assess the dynamics of climate change in the region, that is also affected by multilevel cycles of sun activity. Afanasiev (2008) points out that aggregation of factors of production volatility caused by climate variability, in the framework of creating a stable market of agricultural products, can be considered as a formal statistical problem of signal (stability) to noise (volatility) ratio for a particular territory or the whole region. Any factor — yield, productivity, profitability (e.g., for creating agri corporations) — can be considered, as well as any population: states in a country and countries in the world, countries in the World Trade Organization (WTO), etc. Meanwhile, we do not narrow down the problem of production stability at a macro level (region, country) to a sole mathematical problem of balancing out the fluctuations due to data aggregation of organizations, regions, states (Afanasiev, 2008).

If we consider Russia, we should note that the long joint development of Russian regions led to a particular differentiation of labor and industrial specialization among them, within the general complex of national economy. Thus, a great portion of production from one specializing region is prepared for distribution to other, non-specializing, regions. In the last decades the traditional connections between regions have weakened, as regions were trying to establish individual international business connections to buy cheaper foreign products, but often of lower quality. In our opinion, a more appropriate way is to apply the research results of natural potential of Russian regions (invigorated with the study of climate change dynamics) to optimize domestic market first, then become competitive exporters in WTO, while providing job opportunities to Russian residents.

The variability of climate conditions among Russian regions allows the possibility of placing the production across the country in a particular way when low yields in a group of regions are compensated with higher yields in other regions. We found that the clusters of regions with synchronous fluctuations are stable for a large enough number of years. We study the 44-year dynamics and volatility of per capita wheat production in all regions of the Russian Federation. Wheat is not only the main crop in Russia, but also a fundamental factor for providing fodder for livestock defining the levels of meat and milk production. Moreover, unfavourable years for wheat production usually coincide with unfavourable years for pastures and haying, i.e., wheat production is an indicator of climate conditions.

3. System of Statistical Parameters in a Framework of Assessing Volatility and Stability of Production

Creating a stable market of agricultural products in the Russian Federation and worldwide requires statisticians to develop the parameters assessing the stability of the process in two aspects: stability of levels and stability of tendency (reproduction). For a time series of interest Y_t, $t = 1, .., T$ we suggest the following absolute and relative measures.

1. Absolute measures

(a) Volatility range: $R(Y_t) = \overline{Y}_{favourable} - \overline{Y}_{unfavourable}$;

(b) Mean linear deviation: $d(Y_t) = \frac{\sum_{t=1}^{T} |Y_t - \widetilde{Y}_t|}{T-k}$,

where $\widetilde{Y}_t$ are values smoothed with a parametric trend model with k parameters;

(c) Mean deviation from a moving average level: $m(Y_t) = \frac{\sum_{t=r+1}^{T-r} \frac{Y_t - \overline{Y}_t}{\overline{Y}_t}}{T+1-m}$,

where $r = 0.5(m - 1)$, m is a moving average period, $\overline{Y}_t = m^{-1} \sum_{i=t-r}^{t+r} Y_i$;

(d) Standard deviation: $s(Y_t) = \sqrt{\frac{\sum_{t=1}^{T} (Y_t - \widetilde{Y}_t)^2}{T-k}}$;

2. Relative measures

(a) Index of levels' stability: $I(Y_t) = \frac{\overline{Y}_{favourable}}{\overline{Y}_{unfavourable}}$;

(b) Percentage range: $PR(Y_t) = W_M - W_m$,

where $W_M = \max(W_2, \ldots W_{t-1}), W_m = \min(W_2, \ldots W_{t-1}), W_t = \frac{100|Y_t - Y_{t-1}|}{Y_{t-1}}$;

(c) Average percentage change: $APC(Y_t) = \frac{\sum_{t=2}^{T} \left(\frac{Y_t - Y_{t-1}}{\max(Y_t - Y_{t-1})} \right)^2}{T-1} \times 100$;

(d) Linear coefficient of volatility: $V^d(Y_t) = \frac{d(Y_t)}{\overline{Y}}$;

(e) Coefficient of volatility: $V(Y_t) = \frac{s(Y_t)}{\overline{Y}}$;

(f) Coefficient of growth stability: $K_p(Y_t) = \frac{12 \sum_{i=1}^{T} P_t P_Y}{T^3 - T} - \frac{3(T+1)}{T-1}$,

where P_Y and P_t are the ranks of the observations and time (years) in the period under study;

(g) Correlation index: $J(Y_t) = \sqrt{1 - \frac{\sum (Y_t - \widetilde{Y}_t)^2}{\sum (Y_t - \overline{Y})^2}}$;

(h) "Stability criterion" for a linear trend $\widetilde{Y}_t = a + bt : K = b / s(Y_t)$;

(i) Parameter of surpassing for exponential trend $\widetilde{Y}_t = ak^t : O_{ke} = \frac{\overline{k}}{k_{s(Y_t)}}$;

(j) Parameter of acceleration stability for parabolic trend $\widetilde{Y}_t = a + bt + ct^2 : O_2 = \frac{2c}{b_{s(Y_t)}}$;

(k) Parameter of stability for polynomial trend of third order $\widetilde{Y}_t = a_0 + a_1 t + a_2 t^2 + a_3 t^3 : O_3 = \frac{2\overline{a}_2}{b_{s(Y_t)}}$;

(l) Standardized sum of trend parameters: $\sum \beta = \frac{b}{s(b_t)} + \frac{c}{s(c_t)}$.

Note that the last four parameters can be calculated only after multiple analytical smoothing.

4. Conclusion

Our results of analysis of synchronism and asynchronism of per capita wheat production fluctuations can be employed in a system of governmental interventions into agricultural markets, to lower the fluctuations of the markets and ensure food security.

The methodology and results of identifying regions with synchronous and asynchronous fluctuations have a great potential for businesses in their search for new markets and sources of comparatively cheap raw materials. As a result, it can considerably impact people living in the regions with both deficit and surplus production.

The suggested system of statistical parameters of production stability defines national food supply system in a framework of extended reproduction, as well as its abilities to minimize the influence of climate and other factors on supplying food to all regions of a country.

The solutions impact trade optimization and transportation problems using the information on regions with synchronous production fluctuations.

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