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FLOW CORRELATIONS WITHIN TIME INTERVALS OF VARIABLE LENGTH: SPLINE ANALYSIS

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Abstract

The paper presents a new method for studying the mutual correlation of flows within short time intervals. The analysis of local correlations is necessary for the efficient management of flows in the economy – goods, transport, financial, labor, etc. It is known that switches can be observed in regressions of economic processes and divide correlation trajectories into temporal segments of various lengths. This causes the problem of quantifying the closeness and analytical representation of the correlation within sequential time intervals of variable length. Solving the problem will contribute to identification of possible regression switches and management of flows with regard to changes in market conditions. The sensitivity of conventional econometric methods to the length of the studied dynamics series does not allow identification of regression switches and estimation of the correlation closeness within short time intervals. Modeling of the dynamics of the investigated processes by cubic splines is effective. It is shown that the minimum curvature of cubic splines eliminates the criticality of the correlation method to the length of the studied dynamics series. Zero error of spline models at nodal points allows for more efficient identification of regression switches. The differentiability of splines allows movement from the study of the flow dynamics to the search for correlations between changes in the flow rate. The study is based on data on oil export flows. The proposed methodology for modeling flows and analyzing their correlation enabled identification of correlations between the rate of oil export flows to non-CIS and CIS countries.

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Keywords: Flows, correlation, regression switches, modeling, splines, analysis

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1. Introduction

In order to increase the efficiency of flow management in a modern economy, it is necessary to consider the impact of both long-term and short-term trends. Generalizing and smoothing procedures of classical econometrics are ineffective to identify local effects. Flows as dynamic part of economic systems can often and significantly change the reaction parameters, adapting to continuous changes in market conditions. Oil export flows are a striking example of the sensitivity of flows to changing market conditions. It is practically impossible to describe the local correlations between flows using conventional mono-models, which are more suitable for describing stable regressions. The presence of regression switches requires more accurate, flexible and 'fine' methods for modeling correlations.

2. Problem Statement

It is known that common econometric models provide a generalized picture of the correlation between processes. Generalization of changes in the correlation parameters hinders identification of regression switches. Additional restrictions are created by abstracting the method from the time sequence of process development. At the same time, the points of empirical processes are not always projected onto the model regression line while maintaining the time sequence of reactions. Thus, there is no possibility of observing changes in the correlation parameters a priory, and hence identification of regression switches.

To study sequential changes in the density and direction of correlations, it is necessary to use modeling and analysis methods to detect local correlations within time intervals of various lengths (Botasheva & Vintizenko, 2014; Ilyasov, 2018). To find a more effective alternative to conventional econometric methods, the analysis is carried out based on new econometric methods. Basic requirements are provided for the methods and models of the proposed new research platform, which are necessary for a more efficient analytical, quantitative and graphical study of the flow correlation (Hakeem, 2020; Hung, 2020; Uz Akdogan, 2020). For this, a description of the dynamic characteristics of flows in the economy is given. It is known that physical flows are analogous to economic flows, the most important characteristic of which is rate. It is physical flows that are mainly the object of study in the search for correlations (Bezverkhny, 2007; Koprov et al., 2009; Potapov et al., 2012). Analogues of dynamic characteristics and economic movement can be often found in physical processes. Flows, regardless of their nature, are more naturally represented in continuous time models. The continuity of the models allows the study of local flow correlations, which can also be found in the dynamics of physical flows. In addition, the dynamics of physical flows exhibits frequent mode switches, which can cause regression switches in models of flow correlation in economic systems.

3. Research Questions

The object of the study is spline approximation models of flows in the economy, and the methodology for identifying and analyzing the correlation between flows. The study aims to solve the following main tasks:

- Study of the advantages of modeling the dynamics of flows with preservation of all empirical values and rejection of smoothing procedures. Accurate working with flows is associated with accounting problems in the economy, for example, accounting for financial, commodity, labor and other flows.
- Modeling of the dynamics of flows using continuous models, which is necessary for transforming the models of flow dynamics into the models of flow rate. Flow correlations are often manifested in rate fluctuations.
- Evaluation of the efficiency of search for regression switching points while approximating flows by splines – piecewise continuous functions that adapt to a complex 'relief' of flow dynamics.

4. Purpose of the Study

The purpose of the study can be achieved by solving the following tasks: testing the efficiency of the spline function tool in modeling and analyzing the correlation of flows within short time intervals. The object of the study is the dynamics of oil exports to non-CIS and CIS countries. The graphic, quantitative and analytical implementation of the proposed platform is performed in the Maple 17 computer mathematics system. The Maple program is chosen due to calculations with zero error, and capabilities of quantitative, analytical and graphical presentation of solutions.

5. Research Methods

The proposed requirements for the analytical modeling of flow dynamics are best implemented through approximation by spline functions (Vygodchikova & Gusyatnikov, 2017). When approximating by splines, all the features of empirical dynamics are maintained, the model line passes through all 'nodal' points of the process without exception and preserves local accelerations and decelerations of growth with zero error. Cubic splines exhibit the best approximation properties and interpolation behavior (Giordani et al., 2014; Odoardi & Muratore, 2015; Ratto & Pagano, 2010). Continuity of splines allows automatic transformation of flow dynamics models into flow rate models through differentiation. An additional advantage of the spline approximation approach to describing flows is the ability to study correlations within short time intervals. Limitations to the length of the investigated time series are eliminated by additional points of the rate interpolation curve between the 'nodes'. This enables more accurate identification of possible switches of 'modes' in economic flows and the study of sequential changes in correlation parameters (Duarte et al., 2015; Idrisov & Érlikh, 2002; Lipton & Rennie, 2012).

6. Findings

To identify local features of correlation, continuous models of export flows are constructed using approximation by cubic splines to preserve the real values of the processes at all 'nodal' points (Fig. 1).

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Similar to physical movement, the rate of economic flow is defined as the first derivative of the function approximating its dynamics.

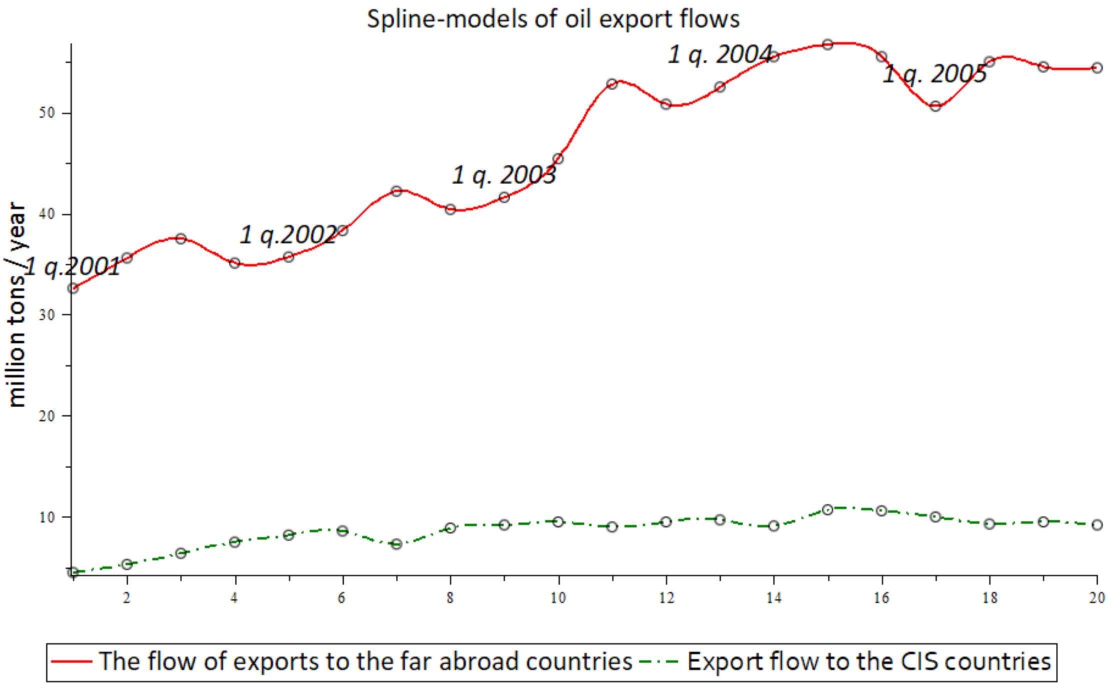

Figure 1. Spline approximation models of oil export flows to non-CIS and CIS countries, q. 1, 2001 – q. 4, 2005

Export flow correlations can be manifested in relatively short time intervals and masked by growing export volumes. Transformation of flows into the rate models illustrates the correlation features on the graph – the behavior of the rate curves can reveal the presence of a positive or negative correlation within different time intervals (Fig. 02). In the studied dynamics, asynchrony in the fluctuations of the flow rate curves can be observed on the graph from q. 3, 2001 to q. 2, 2004. The correlation coefficient of the flow rate within this interval is –0.75, which indicates a close negative correlation. The trajectories of the flow rate indicate the regression switches on the graph and enable calculation of the duration of the steady-state 'modes' of the mutual impact of flows.

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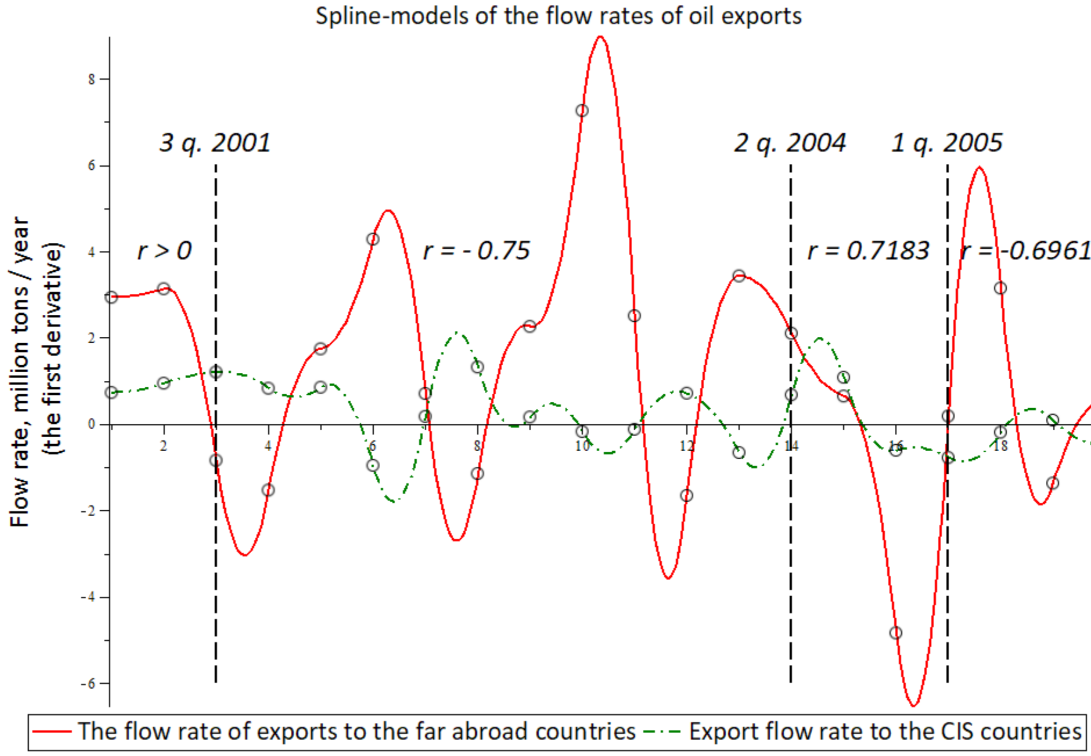

Figure 2. Latent correlations of the rate of oil export flows to non-CIS and CIS countries

In the next, relatively short time interval – from q. 2, 2004 to q. 1, 2005 – the rate curves show the synchronicity of fluctuations, which indicates that a positive correlation 'switch' in this time interval. From q. 1 to q. 4 in 2005, the behavior of the rate curves indicates a negative correlation of oil export flows. Within such short time intervals, a quantitative assessment of the correlation closeness is possible by interpolating additional points of the model curves. In contrast to classical regression, the correlations are found not by comparing discrete points in the correlation field, but by comparing continuous trajectories sequential in time.

7. Conclusion

Flow rate regression switches can occur for a variety of reasons. These include changes in oil export prices, which importers from non-CIS and CIS countries are willing to pay. It is known that the elasticity of demand for these two groups of countries is different during periods of relatively high or low world oil prices. OPEC restrictions on oil production often cause switches. The limitations in the volume of oil transportation through pipelines should be considered as well. The presence of factors with an unstable effect gives rise to instability in the correlation of flows, the parameters of which will differ in the context of a steady increase in total exports or a general decrease in oil demand. In particular, the studied time interval is characterized by a steady increase in the total volume of oil exports, when the acceleration of the export flows to one group of countries led to permanent deceleration in the growth of export volumes to another group of countries.

The analysis shows that averaging and smoothing of empirical data are acceptable in searching for long-term development trends, abstracting from local correlations and 'small responses'. In the accelerating economy, economic efficiency becomes possible when taking into account small changes in the market conditions, with flexible adaptation of the 'modes' of functioning of economic systems to growth deceleration and acceleration. 'Small responses' are best preserved in the models of the studied dynamics through approximation by cubic splines. The subsequent diagnostics of small responses is effectively performed by referring to the first derivative of the modeling function relative to the flow dynamics which is considered as the flow rate. The derivative becomes a tool that can detect a signal of a very small amplitude.

The transition from the models of the studied dynamics to derivatives is similar to the trend elimination. However, the elimination of the generalized trend in conventional econometric models results in residuals, the value of which at specific nodal points is not interpreted economically. On the contrary, differentiation of the modeling function of economic movement leads to rate models, which significantly expands the analytical capabilities of the method. First of all, the research potential of the derivative approaches economic processes to the dynamic characteristics of physical movement – rate, acceleration, impulses, force, etc.

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