PHYSICS - ECONOMICS INTERDISCIPLINARY ANALOGIES IN MODELLING OF RUSSIAN FINANCIAL SYSTEM

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In Russia, there is still a great distrust in national currency, especially when external unfavorable factors arise. The public and banks at these times buy foreign currency either from a sense of survival, or with speculative purposes. The ruble liquidity required for this is partially borrowed from the Central Bank.

The purposes of this paper:

1. **to find out whether** the changes in the dollar rate that have already occurred are the cause of liquidity changes

or vice versa, the speculative play of banks in the foreign exchange market is driving the dollar rate?

2. **to build an adequate model** of this financial subsystem and work with it using a Kalman filter (KF).

As an indicator of fluctuations in the money supply, I choose the balance of the Bank of Russia's operations with the banking sector M^{t} (billion rubles) on day t for the provision and absorption of ruble liquidity (hereinafter referred to as **saldo**). The negative sign of the balance characterizes the absorption of funds by the Bank of Russia, the positive sign is the provision of liquidity to the banking sector. Data on saldo and on dollar/ruble rate S^t from 13.01.2015 to 28.04.2018 were used.

Answer to **question 1**: It was found that the change in the rate $\Delta S^t = S^t - S^{t-1}$ 6 days ago is the cause (according to Granger) of the saldo value.

Answer to **question 2**: **Model and Kalman filter**

Observed system’s output value is saldo $y^t = M^t = y0^t + v^t$. For the control value we choose pre- ceded 5 days earlier dollar exchange rate changes $u^t = \Delta S^{t-5}$. The nature of commercial banks' actions to create money supply: loan - lend - loan payment (for this, loan again), etc. is essentially periodical. So, we assume that the “true” value of the saldo $y0^t$ obeys the equation of a discrete oscillator with control and noise

$$y0^{t+1} = y0^{t} - \beta_0 (y0^{t} - y0^{t-1}) - \beta_1 (y0^{t-1} - y0^{t-2}) + \\ + \beta_2 (u^{t} - u^{t-1}) + w_0^{\,t}.$$

The oscillatory model is fruitfully used in the physics and electronics and well explored.

Introducing the state vector, we obtain model of the system in usual form

$$x^{t+1} = F^{t} x^{t} + G^{t} u^{t} + w^{t},$$

$$y^{t} = H^{t} x^{t} + v^{t},$$

where w^{t}, v^{t} – system and observation noises.

Estimation of the model parameters vector was carried out by minimizing the root-mean-square error of KF prediction of the saldo

$$RMSE(\theta) = \sqrt{\frac{1}{Tu-(Tl-1)}\sum_{t=Tl}^{Tu}(y^{t+1}-\hat{y}^{t+1|t})^2},$$

$$\hat{\theta}_{RMSE} = \arg\min_{\hat{\theta}} RMSE(\hat{\theta}).$$

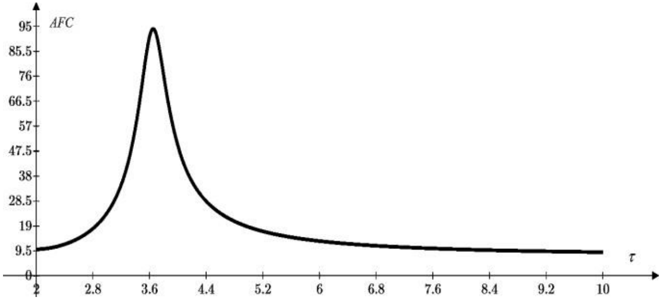
Here $\hat{y}^{t+1|t}$ is the forecast for saldo in moment $t+1$ by information up to the moment t.

The estimated model parameters $\hat{\theta}_{RMSE}$ can be used to build the system's transfer matrix $W(z) = H(zI - F)^{-1}G$ and its amplitude-frequency characteristic $AFC(\omega) = |W(e^{i\omega})|$, well-known in electronics.

Interpretation of results

Resulting estimates of oscillator parameters mean that the period of the saldo self-oscillations $2\pi / \arccos(-\hat{\beta}_0 / 2\sqrt{\hat{\beta}_1}) = 4.218$ days and the attenuation of the amplitude per day by $1/\sqrt{\hat{\beta}_1}$ = 2.179 times. $\hat{\beta}_2 = 24.442$ means that with the USD/RUB exchange rate growth in 1 RUB, after 6 days the money supply increases by about 20 billion rubles.

AFC as a function of the period of input oscillations $\tau = \frac{2\pi}{\omega}$, has the form:



Amplitude-frequency characteristic of the system “change in the dollar rate-liquidity saldo” as a function of the period τ (days) of rate changes oscillations.

It can be seen that the system of “change in the dollar rate-liquidity saldo” during this period has a high “quality factor”, i.e. control u^t (changes in the dollar rate), repeated with a period close to τ = 3.7 (for example, 4 days), can cause fluctuations in the saldo of large amplitude.

Conclusion

The proposed model affects only one fragment of the extensive system of country's money supply dynamics. In a crisis-free period, it can be used to predict to some extent changes in the ruble money supply by tracking changes in the dollar exchange rate. The research utilizes underlying physics - economics analogies. The possibility of unfavorable swaying of the ruble liquidity oscillations was discovered if a period of exchange rate changes would be close to the resonant one.