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Abstract

This paper presents an unobserved component model for real GDP, real household consumption, and real investment of an oil-exporting economy. The model decomposes domestic variables' dynamics into permanent and transitory components, accounting for dependence on oil prices in the short and long-run, as well as for the common long-run economic growth and the common cyclical behavior. Estimated on the Russian macroeconomic variables, the model exhibits strong dependence on oil prices.

Key words: oil prices; GDP; consumption; investment; unobserved component model; common growth.

JEL codes: C13, C32, C51, E20

1. Introduction

There is a large body of evidence on the positive dependence of economic development of oil-exporting countries on oil prices (Esfahani et al., 2014; Korhonen, Ledyaeva, 2010; Kuboniwa, 2014; Sinelnikov-Murylev et al., 2014; Rautava, 2004). Other things being equal, an increase in the oil prices for such economies means an improvement in the terms of trade, a transfer of wealth from the foreign economies: for the same physical volume of exports, domestic economic agents can purchase more imported goods. Thus, as oil prices rise, welfare of domestic economic agents, their real income and consumption also rise, i.e. a positive long-term relationship between household consumption and oil prices can be expected to exist. Moreover, when oil prices grow, oil-exporting economy has additional sources for investment financing. Esfahani et al. (2014) proposed an extension of the Solow model, in which part of oil export revenues is invested in capital stock, which leads to a long-term positive dependence of investment, capital and output on oil prices. Authors identified cointegration relations between GDP and oil prices for major oil-exporting countries and estimated corresponding error-correction models. In this paper we propose an unobserved components model for an oil-exporting economy. Its advantage over standard error-correction models is that it allows for more flexible modeling of changes in long-term growth rates in the economy. This is especially relevant for the Russian economy, which has undergone a significant decline in long-term growth rates after the 2008-2009 crisis. In the paper we propose multivariate UC model for real GDP, real household consumption and real investment with common growth and cyclical components. The model is estimated on the Russian data from 1999 to 2019. In the context a widespread slowdown in economic growth, it may be relevant to use the model for other countries that are highly dependent on terms of trade.

2. Model

In constructing UC model we work with four key macroeconomic variables: the logarithm of real GDP y_t, the logarithm of real household consumption c_t, the logarithm of real investment i_t and the logarithm of real oil prices p_t. It is assumed that each variable $z_t \in \{y_t, c_t, i_t\}$ consists of an independent of oil prices permanent component $\bar{z}_t^{no}$, a permanent component determined by oil prices $\beta^z p_t$, an independent of oil prices transitory component $\tilde{z}_t^{no}$ and a transitory component determined by oil prices $\tilde{z}_t^{o}$:

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(1) $y_t = \bar{y}_t^{no} + \beta^y p_t + \tilde{y}_t^{no} + \tilde{y}_t^{o}$,

(2) $c_t = \bar{c}_t^{no} + \beta^c p_t + \tilde{c}_t^{no} + \tilde{c}_t^{o}$,

(3) $i_t = \bar{i}_t^{no} + \beta^i p_t + \tilde{i}_t^{no} + \tilde{i}_t^{o}$.

Parameter β^z is a long-run elasticity of the variable z_t with respect to oil prices. We assume that growth rates of the independent of oil prices permanent components share the common path:

(2) $\bar{y}_t^{no} = \mu_t + \bar{y}_{t-1}^{no}$,

(3) $\bar{c}_t^{no} = \lambda^c \mu_t + \bar{c}_{t-1}^{no}$,

(4) $\bar{i}_t^{no} = \lambda^i \mu_t + \bar{i}_{t-1}^{no}$,

where λ^c and λ^i are loading parameters for the common growth rate component. It is assumed that long-run growth rate μ_t is described by the random walk process:

(5) $\mu_t = \mu_{t-1} + u_t, u_t \sim N(0, \sigma_u^2)$.

We also considered a specification with stochastic disturbances in equations (2)-(4), but estimates of variances of these shocks turned out to be insignificant on the Russian data. It is assumed that the logarithm of real oil prices is also described by the random walk process due to poor predictability of oil prices (Alquist et al., 2013):

(6) $p_t = p_{t-1} + \eta_t, \eta_t \sim N(0, \sigma_\eta^2)$.

We assume that variables $\tilde{y}_t^{no}$, $\tilde{c}_t^{no}$ and $\tilde{i}_t^{no}$ share a common transitory component q_t, described by the AR(2) process:

(7) $q_t = \rho_1 q_{t-1} + \rho_2 q_{t-2} + \varepsilon_t, \varepsilon_t \sim N(0, \sigma_\varepsilon^2)$,

(8) $\tilde{y}_t^{no} = q_t + \tilde{y}_t^{noi}$,

(9) $\tilde{c}_t^{no} = \gamma^c q_t + \tilde{c}_t^{noi}$,

(10) $\tilde{i}_t^{no} = \gamma^i q_t + \tilde{i}_t^{noi}$,

where γ^c and γ^i are loading parameters for the common transitory component, $\tilde{y}_t^{noi}$, $\tilde{c}_t^{noi}$ and $\tilde{i}_t^{noi}$ are idiosyncratic transitory components for GDP, consumption and investment respectively, described by AR(1) processes (higher lags are insignificant):

(11) $\tilde{y}_t^{noi} = \varphi^y \tilde{y}_{t-1}^{noi} + \xi_t^y, \xi_t^y \sim N(0, \sigma_{\xi^y}^2)$,

(12) $\tilde{c}_t^{noi} = \varphi^c \tilde{c}_{t-1}^{noi} + \xi_t^c, \xi_t^c \sim N(0, \sigma_{\xi^c}^2)$,

(13) $\tilde{i}_t^{noi} = \varphi^i \tilde{i}_{t-1}^{noi} + \xi_t^i, \xi_t^i \sim N(0, \sigma_{\xi^i}^2)$.

The last three equations describe dynamics of the transitory components determined by oil prices:

(14) $\tilde{y}_t^{o} = \psi^y \tilde{y}_{t-1}^{o} + \theta^y \eta_t$,

(15) $\tilde{c}_t^{o} = \psi^c \tilde{c}_{t-1}^{o} + \theta^c \eta_t$,

(16) $\tilde{i}_t^{o} = \psi^i \tilde{i}_{t-1}^{o} + \theta^i \eta_t$.

It is expected that oil shock sensitivity parameters θ^y, θ^c and θ^i are negative, because it probably takes some time for actual levels of real GDP, consumption and investment to adapt to their permanent levels, instantaneously changed by oil price shock. Values $\beta^y + \theta^y$, $\beta^c + \theta^c$ and $\beta^i + \theta^i$ characterize short-run elasticities to the oil price shocks.

3. Empirical results

We use the Russian statistical agency Rosstat data on real GDP, real household consumption and real gross capital formation from the 1st quarter of 1999 to the 3rd quarter of 2019. Time series were seasonally adjusted with the ARIMA-X12 filter in Eviews. The real oil price variable was constructed as the ratio of the global Brent crude oil price to the US seasonally adjusted CPI. The corresponding data are obtained from the FRED.

The model was estimated by the maximum likelihood method using the Kalman filter in Matlab. To maximize the likelihood function, we used the 'fminunc' function, starting with 100 randomly generated initial values to obtain global optimum. The parameters estimates are shown in Table 1. All parameters estimates are highly statistically significant except the autoregressive coefficients ψ^y and φ^i for the GDP transitory component determined by oil prices and the investment idiosyncratic transitory component. The parameters estimates appear to be plausible. Estimates of the long-run elasticities of consumption and investment are similar and approximately equal to 0.26. This result can have the following interpretation: aggregate consumption and investment have similar shares of imported goods, and the aggregate import increase due to higher oil prices is distributed between consumption and investment uniformly.

The long-run oil price elasticity of output is lower (equals 0.094), and it is consistent with the capital channel of the oil prices long-run influence. If 1 percent oil price increase induces 0.26 percent increase in the level of investment and capital, and if the capital share in the production function is equal to 0.35, the 1 percent oil price increase will induce 0.091 percent increase in output, given constant levels of the labor and the total factor productivity. Estimates of the short-run elasticities of GDP $\beta^y+\theta^y$, consumption $\beta^c+\theta^c$ and investment $\beta^i+\theta^i$ are 0.043, 0.037 and 0.070 respectively. Thus, real household consumption demonstrates the smallest short-run reaction to the oil price shock. In addition, household consumption has the lowest speed of adjustment to its long-run level after the oil price shock, as ψ^c is greater than ψ^y and ψ^i. Investment demonstrates the highest sensitivity to the common transitory component γ^i, consistent with classical view that investment is the most volatile component. The values of loading parameters λ^c and λ^i for the common growth rate component are very close to each other. It means that real household consumption and real investment have the same growth rate in the long-run. The lower growth rate of GDP can be explained by the fact that GDP contains government spending, and government spending in constant prices varies slowly due to the methodology of construction of this variable. Primarily the change in the government spending at constant prices measured by the change in the employment in the government sector.

Table 1 – Parameters estimates

	β^y	β^c	β^i	θ^y	θ^c	θ^i	γ^c	γ^i
point est.	0.094	0.261	0.257	-0.051	-0.224	-0.187	1.042	2.633
std. err.	0.022	0.039	0.062	0.019	0.037	0.056	0.220	0.376
t-stat	4.184	6.644	4.158	-2.729	-6.071	-3.350	4.729	6.994
	φ^y	ψ^y	φ^c	ψ^c	φ^i	ψ^i	ρ_1	ρ_2
point est.	0.902	0.328	0.717	0.820	0.276	0.587	1.571	-0.652
std. err.	0.082	0.224	0.123	0.036	0.192	0.091	0.125	0.131
t-stat	11.041	1.466	5.833	22.722	1.437	6.458	12.524	-4.977
	σ_η	σ_ε	σ_{ξ^y}	σ_{ξ^c}	σ_{ξ^i}	λ^c	λ^i	σ_u^2
point est.	15.979	0.507	0.616	1.116	1.499	1.448	1.438	0.070
std. err.	1.290	0.109	0.072	0.104	0.194	0.078	0.091	0.033
t-stat	12.384	4.637	8.589	10.759	7.713	18.484	15.885	2.144

Figure 1 shows the estimate of the long-run growth component of GDP and a common transitory (cyclical) component, independent of oil prices. The long-run growth was quite high at the beginning of the sample period (5 percent per year), which can be explained by recovery from the transformational recession. By the crisis of 2008 the growth rate had declined to 2.5 percent per year, and after the crisis of 2014 the growth rate stabilized at the 2 percent per year level. Figures 2, 3 and 4 present permanent and transitory components for GDP, investment and household consumption.

The model estimates indicate that GDP and investment were substantially overheated right before the crisis of 2008 (due to overheating of the common transitory component). However, household consumption was below its permanent level: oil prices rose steadily for a long period of time, and consumption had not caught up to its new higher permanent level. Right after the sharp fall in oil prices in 2008 consumption was temporarily higher than its permanent level, which can be explained by slow adjustment and by high fiscal support of household income at that time. Before the 2014 crisis, oil prices were fairly stable and high, and all domestic variables stabilized at their permanent levels. After the sharp oil price drop in 2014 real GDP and real household consumption were temporarily higher than their permanent levels because of non-instant adjustment. In addition, sharp exchange rate devaluation could potentially temporarily stimulate output. In recent years, transitory components of the key Russian macroeconomic indicators, particularly the independent of oil prices common transitory (cyclical) component, were predominantly negative. This can be explained by sanctions and geopolitical tensions influence, as well as restrictive economic policies.

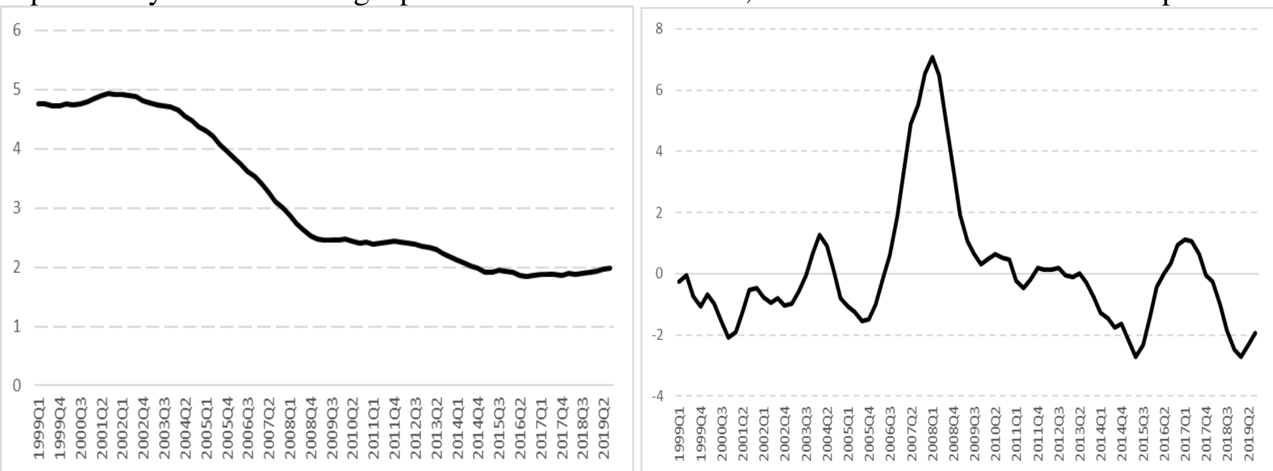

Figure 1. Long-run growth rate of real GDP, percent per year (left chart), common transitory (cyclical) component, independent of oil prices (right chart, percent deviation from the permanent level).

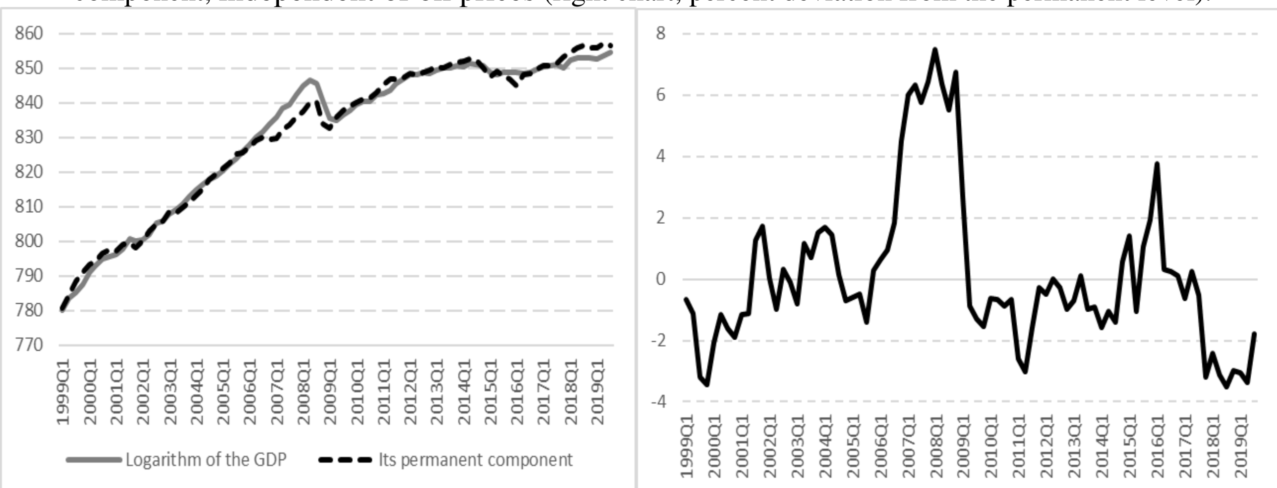

Figure 2. Logarithm of real GDP, its permanent level (left chart), transitory component of real GDP (right chart, percent deviation from the permanent level).

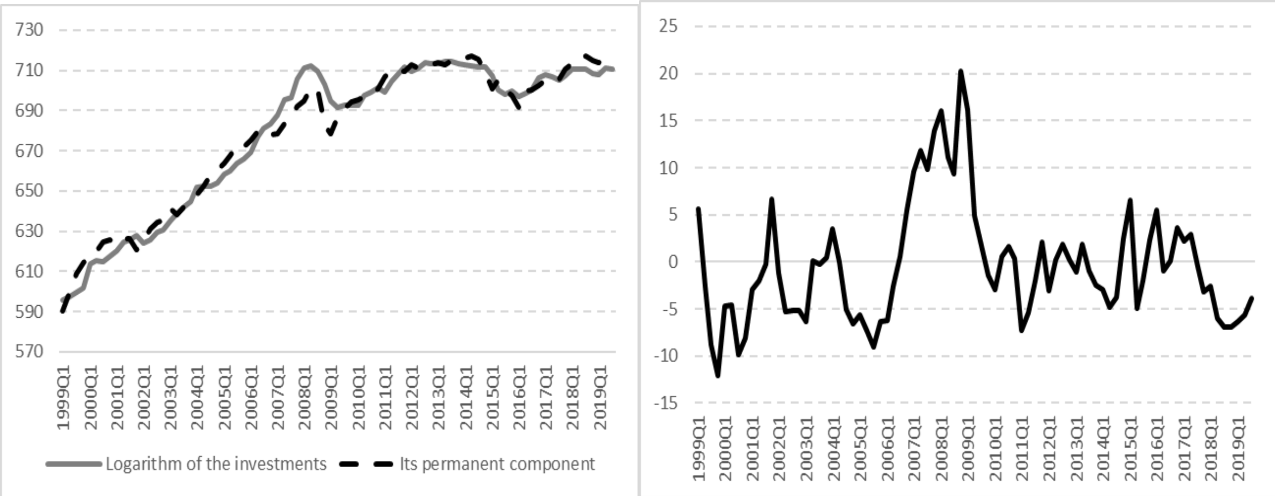

Figure 3. Logarithm of real investment, its permanent level (left chart), transitory component of real investment (right chart, percent deviation from the permanent level).

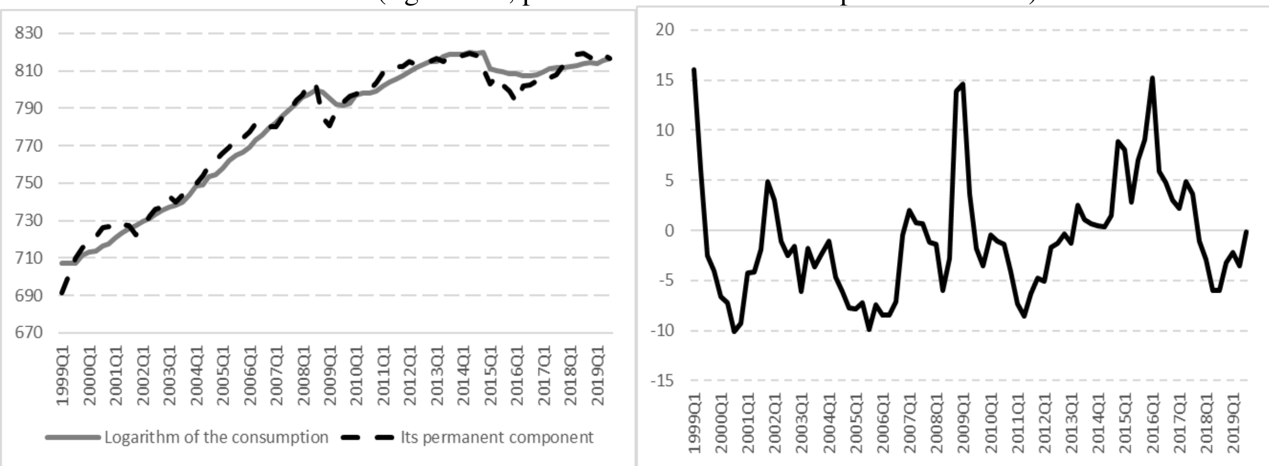

Figure 4. Logarithm of real household consumption, its permanent level (left chart), transitory component of real household consumption (right chart, percent deviation from the permanent level).

4. Conclusions

In this paper we describe dynamic dependence of key macroeconomic variables of an oil exporting economy on oil prices using multivariate unobserved component model. In contrast to standard error correction model, this setup allows for time variation in a long-run growth rate. The model is estimated on the real GDP, real consumption and real investment data of the Russian economy. Estimation results show quite a strong dependence on oil prices: estimated oil price elasticity for real GDP is 0.09, for real consumption and investment – 0.26. The model also exhibits a significant slowdown of the economic growth to 2 percent per year. Moreover, Russian macroeconomic variables were below their permanent levels in recent years. This fact can be explained by wedges generated by the current economic policy, sanctions pressure and high uncertainties about future economic development.

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