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TFP change, output gap and inflation in the Russian Federation (1994–2006)

Panayotis Michaelides*, John Milios

Laboratory of Theoretical and Applied Economics, Department of Humanities, Social Sciences and Law, School of Applied Mathematics and Physics, National Technical University of Athens, Greece

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ABSTRACT

The present paper estimates Total Factor Productivity (TFP) change for the Russian economy in the time period 1994–2006. It also calculates potential output and output gap using a Cobb-Douglas (CD) production function and a Hodrick–Prescott filter, as well as the Non-Accelerating Wage Rate of Unemployment (NAWRU), and the Non-Accelerating Inflation Rate of Capacity Utilization (NAICU) concepts. The results show that despite the severe economic crisis TFP has contributed to strong economic growth in the country after 1998, while the output gap, although negative between 1999 and 2003, has recently become positive. The relationship between output gap and inflation is examined and the results suggest that there is a strong (causal) relationship between output gap and inflation in the Russian economy.

1. Introduction

Russia's transition from a centrally planned to a Western-type capitalist economy was marked by a rapid decline in nearly all economic indices during most of the 1990s. Moreover, unlike in most former "socialist" countries in Europe, where the negative rates of change of GDP and of industrial output began to turn around to positive after 1994, in Russia the deterioration of the economic situation continued, lasting for several years more (Campos & Coricelli, 2002; IMF, 2001, 2002; Milios, 2001).

* Corresponding author. Tel.: +30 2107721624; fax: +30 2107721618.
E-mail address: pmichael@central.ntua.gr (P. Michaelides).

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The present paper first estimates Total Factor Productivity (TFP) change, a very important determinant for long-term economic growth, and then attempts to reach a better understanding of the supply side of the Russian economy, examining the concepts of potential output and output gap and linking them to inflation.

Economic policy has placed increasing emphasis on output gap despite the fact that it is a notion that cannot be observed directly and is difficult to measure. When total labour and total output are below the economy's potential (i.e. the so-called potential labour and potential output, respectively, both of which pertain to levels it would be desirable to achieve) then a negative gap exists. In simple terms, current labour (or output) is below what the economy could sustain, all things being equal. In this situation there is spare labour (or production) capacity in the economy. The implication is that the rate of inflation is likely to fall because inflationary pressure is falling. When actual labour (or output) is at a distinctly higher level than potential labour (or output), there is a positive labour (or output) gap, meaning that inflationary pressures will be intensifying. The labour gap is unlikely to persist in the long-run, the supposition being that when demand and supply are equal a wage and price adjustment process will tend to take place to restore equilibrium.

The present paper accordingly aims at measuring the labour and output gaps in the Russian economy with a view to assisting decision makers in effective implementation of their policies. An estimation, for example, of the level of potential labour could make it possible to acquire a more objective view of the country's unemployment problem and could assist with determining the most effective set of policy measures. A failure by the Russian Federation effectively to address labour market problems would obviously place additional strain upon the government, with broader economic and political implications.

The paper is organized as follows: Section 2 presents a brief analysis of Russia's economic performance; Section 3 outlines the methodological framework and Section 4 sets out the data and the variables; Section 5 presents and discusses the empirical results and, finally, Section 6 concludes the paper.

2. The Russian economy in the 1990s

Decentralization of the enterprise decision-making mechanisms and of accountability, price liberalization and, finally, the largest privatization in history, were the key economic reform elements in Russia's transition from a centrally planned economy to a Western-type economy (Boycko, Shleifer, & Vishny, 1995).[1] Following the breakup of the Union, state revenues were drastically cut, as were social benefits (e.g. education, etc.), which had been provided directly by the state and by large state enterprises to their employees. With the collapse of the COMECON commercial transactions among the FSU countries was transformed into "foreign trade". Income tax from non-state activities became a significant cost factor, fuelling tax evasion and leading to delays in tax payments by certain large enterprises (OECD, 1997). The money economy was therefore partly replaced during the 1990s by non-monetary transactions (Aukutsiovek, 1998), similarly encouraging the spread of tax evasion (Kaitila, 2003; OECD, 1997). The state was meanwhile unable to control many other fundamental variables, with the quality of state education, health and transport services undergoing considerable deterioration.

The first apparent result of the "transition" process was the dramatic decline in output, continuing until 1998, combined with very high rates of inflation. But the aggregate decline in output did not equally affect all branches of the Russian economy. Significant sectoral restructuring took place, benefiting the service sector at the expense of industry's share in the GDP (Milios, 2001). There was consequently a much greater decline in industrial output than there was in overall output (GDP). There was also a near-collapse in investment activity (IMF, 2002; Kaitila, 2003; OECD, 1995: 3 ff). The decline in output was accompanied by large reductions in Research and Development (R&D) expenditures (Goskomstat, 1997). Furthermore, the high rates of inflation prevented the national currency from

[1] For a political economy approach in modeling the transition process, see Marangos (2003). For an excellent attempt to model the privatization process in Transitional Economies, see Marangos (2004).

functioning as a means of storing value. For international transactions the rouble was abandoned in favour of the US dollar (IMF, 1994: 71).

Despite the dramatic decline in the GDP and in industrial production until 1998 (Maroudas, 2001: 62), the reported rate of unemployment in Russia continued to remain relatively low, i.e. below 10%, until the mid 1990s. More specifically, the rate of unemployment rose from 5.7% in 1993, to 8.9% in 1995. The fact that official figures underestimate real rates of unemployment and real reductions in employment opportunities for women with children and pensioners (Kapelyushnikov, 2001) does not seem to provide a satisfactory explanation for why the collapse of production did not result in more rapidly increasing unemployment. As is well known, one major explanation for the phenomenon is the idea that the job market response to recession was a reduction in real wages rather than reduction of employment. More precisely, in contrast to the situation in other transitional economies which implemented a wage-tax incomes policy, Russian policymakers opted for liberalization of the labour market. Real wages thus fell and the labour market was equilibrated without shedding labour. This policy was induced by the "soft" monetary policy of the Russian Central Bank (RCB), which led to hyperinflation in the early 1990s. Another possible explanation for the relatively low level of unemployment is the numerical contraction of the labour force. Between 1992 and 2001 there was a 6% fall in the numbers of people available for employment. Throughout the period under discussion the labour market in Russia has indeed been subject to complex influences from a very broad range of factors.

The dissolution of the Soviet Union led to a substantial decline in the living standards of the Russian population (OECD, 1995: 125, 128–129). Deterioration in living standards was accompanied by increasing social inequality among the population. The situation changed in the late nineties, with unemployment rates climbing to a high of 14% in 1999, in contrast to the rates of change in output and investment, which were positive.

It is important in this context for the economic authorities to be in the position to determine as precisely as possible at any given time the level of potential output, the level of actual output and the direction in which the economy is heading. The Russian authorities should in other words place increased emphasis on developing a range of relevant indicators to assess the degree of pressure on the economy's capacity. An investigation of the labour and output gap is of paramount importance for policy making in Russia.

3. The methodological framework

Potential GDP is an unobservable variable and cannot be measured directly. It can, however, be estimated with the aid of a number of theoretical and statistical procedures. Statistical methods eliminate cyclical fluctuations from the actual GDP time sequence. These statistical methods include the time trend and the Hodrick–Prescott (HP) filter approach. No additional variables other than actual GDP are needed for the application of the statistical methods, and this is one reason for the widespread acceptance these methods have received. The linear, two-sided HP-filter approach is a widely used method for obtaining the long-term trend of a series using only actual data. The trend is obtained by minimizing the fluctuations in the actual data around it, i.e. by minimizing the following function:

$$\sum [\ln y(t) - \ln y*(t)]^2 - \lambda \sum [[\ln y*(t+1) - \ln y*(t)] - [\ln y*(t) - \ln y*(t-1)]]^2$$

where y^* is the long-term trend of the variable y and the coefficient λ determines the smoothness of the long-term trend, expressing the potential output in this case.

Of course, statistical methods have some drawbacks, such as low levels of accuracy of the estimates when made in longer time-frames. They also require extensive time series. Meanwhile economic growth is affected by various potential sources of shock and substantial and accelerated changes in actual output do not necessarily signal either expansion or contraction of potential GDP Irrespective of what are to some extent drawbacks, the HP-filter approach is very widely employed because of its simplicity. Reliance on the HP-filter approach *alone* could in this connection lead to erroneous conclusions. In contrast to the theoretical approaches, it does not use information provided by the factors of production, such as labour, capital and technology. It therefore does not measure the influence of structural shocks on potential output. But the most essential drawback to this approach is that it fails to take into account certain substantial changes in the economic structure.[2] This is a noteworthy drawback in the case of Russia. The disadvantages of the statistical methods have led to the analysis based on the production function being used in conjunction with the HP-filter approach as an alternative method for measuring potential output.

The production function method estimates a production function when real GDP is a function of capital, labour and technology. Its most important practical advantage is its capacity for explaining different sources of growth. The production function is then estimated when the capital stock is being fully utilized and the labour force is fully employed. This method has been used by various researchers (e.g. Artus, 1997; Bolt & van Els, 2000; de Masi, 1997; Giorno, Richardson, Roseveare, & van der Noord, 1995; Senhadji, 2000, etc.). HP-filter smoothing techniques are used in the production-function approach to filter technology and potential labour (e.g. Bolt & van Els, 2000; Fagan, Henry, & Mestre, 2001; Giorno et al., 1995).

The most commonly used production function in empirical investigations using aggregate data is the Cobb-Douglas (CD) production function (Thirlwall, 2001: 181). Specifications of the functional form of the production function such as the *translog* provide the opportunity to characterize the data in a more flexible way, but with limited data it tends to be seriously over-parameterized. In other words, the translog estimates are likely to suffer from degrees of freedom and multicollinearity problems (Coelli, Prasada Rao, & Battese, 1998).[3] We accordingly assume a Cobb-Douglas production function with two inputs, capital and labour, and Hicks-neutral technological progress. Production at time t is thus given by:

$$\begin{aligned} &Y_t = A_t L_t^{\alpha} K_t^{\beta} \\ &Y_t > 0,\ L_t > 0,\ K_t > 0,\ A_t > 0,\ \alpha > 0,\ \beta > 0 \end{aligned} \tag{1}$$

The notation is standard: Y_t is output, L_t labour, K_t capital, A_t characterizes Total Factor Productivity, and α, β are the elasticities of labour and capital, respectively. Given that, typically, the sum of the values of α and β are set equal to unity (Billmeier, 2004; Thirlwall, 2001), Eq. (1) takes the form:

$$Y_t = A_t L_t^{\alpha} K_t^{1-\alpha} \tag{2}$$

Eq. (2) can be written as

$$\frac{Y_t}{L_t} = A_t \left(\frac{K_t}{L_t}\right)^{1-a} \tag{3}$$

Taking *logs* Eq. (3) yields a linearized form:

$$\ln\left(\frac{Y_t}{L_t}\right) = \ln A_t + (1-\alpha)\ln\left(\frac{K_t}{L_t}\right) \tag{4}$$

In general, this linearization reduces the number of coefficients to be estimated, eliminating the multicollinearity problem of the explanatory variables.[4] Alternatively, taking *logs*, Eq. (2) can be written

[2] For overviews of the HP filtering method shortcomings see Harvey and Jaeger (1993), King and Rebelo (1993), Cogley and Nason (1995) and Billmeier (2004).

[3] The CD function has drawbacks as well (Stikuts, 2003): first, it is a simplified reflection of reality. For instance, it considers as homogenous the production and labour expanded originating from different sectors and skills. Second, the data employed may result in a biased estimation, since the application of more accurate data is restricted by irregular availability (e.g. data concerning the utilization of capital are not accessible with adequately high frequency). Third, natural or optimal factor utilization capacity is difficult to define. Finally, the Solow residual is a substantial component of the production function, which is calculated as estimation residual and as such is freely interpretable. Irrespective of its drawbacks, the CD function is one of the methods, which along with the HP-filter is very widely used to estimate the potential output (Stikuts, 2003). For a brief review of the model's theoretical limitations see Thirlwall (2001, pp. 185–187), which are, however, of limited practical character, as the author himself implies see (Thirlwall, 2001, p. 187).

[4] As is well known, multicollinearity is a statistical phenomenon involving high correlation between two or more predictor variables in a multiple regression. In such a situation the coefficient estimates may change erratically in response to small changes in the model or the data. If variables are combined (i.e. dividing by L_t) there is only one variable left (K_t/L_t) and the multicollinearity problem is thus eliminated.

as

$$\ln Y_t = \ln A_t + \alpha \ln L_t + (1-\alpha)\ln K_t \tag{5}$$

The logarithm of the Total Factor Productivity ($\text{tfp}_t = \ln A_t$) is equal to:

$$\text{tfp}_t = \ln A_t = y_t - [\alpha l_t + (1-\alpha)k_t] \tag{6}$$

Using calculus, we get (Thirlwall, 2001: 181) Eq. (7) that allows us to estimate Total Factor Productivity change[5]:

$$\frac{\partial A_t}{\partial t}\frac{1}{A_t} = \frac{\partial Y_t}{\partial t}\frac{1}{Y_t} - \alpha\frac{\partial L_t}{\partial t}\frac{1}{L_t} - (1-\alpha)\frac{\partial K_t}{\partial t}\frac{1}{K_t} \tag{7}$$

Also, the growth rates of labour and capital productivity, respectively, are given by:

$$1 = \frac{\partial Y_t}{\partial t}\frac{1}{Y_t} - \frac{\partial L_t}{\partial t}\frac{1}{L_t} \tag{8}$$

$$k = \frac{\partial Y_t}{\partial t}\frac{1}{Y_t} - \frac{\partial K_t}{\partial t}\frac{1}{K_t} \tag{9}$$

Next, potential output Y_t^* is derived by substituting the potential values of the production factors:

$$\ln Y_t^* = \ln A_t^* + \alpha \ln L_t^* + (1-\alpha)\ln K_t^* \tag{10}$$

where * denotes the potential value of the production factor.

We are now required to measure the potential value of production factors. The actual value of capital stock is typically used as a substitution for its potential value, as capital stock cannot fluctuate substantially. It is thus assumed that the capital stock available is always used at its potential. But the traditional method for estimating the potential output is not appropriate for a transitional economy like Russia's, since it is not adjusted for capital utilization and assumes, artificially, that the output gap has been, on average, zero (see further Oomes & Dynnikova, 2006).

In this context we have that:

$$K_t = u_k K'_t \tag{11a}$$

where u_k denotes capital utilization and K'_t denotes the capital estimate *not* adjusted for capacity utilization.

Similarly, we measure supply-side constraints in Russia by estimating u_k^*, the so-called Non-Accelerating Inflation Rate of Capacity Utilization (NAICU) which was first introduced by McElhattan (1978).

This implies:

$$K_t^* = u_k^* K'_t \tag{11b}$$

Total Factor Productivity (A_t^*) is estimated as the residual of Eq. (4) and the potential level is determined by the HP-filter to obtain a smooth time series. Thus:

$$A_t^* = A_{s_t} \tag{12}$$

where A_{s_t} is the HP-filtered residuals of Eq. (4) characterizing TFP.

[5] The famous growth accounting approach is based on Eq. (7). It was pioneered by Abramovitz (1956) and Solow (1957) and is aimed at explaining the determinants of growth worldwide after World War II. As is well-known, in growth accounting, growth in a single country is broken down over time, using a production function, into a part explained by growth in factor inputs and another part (i.e. the Solow residual), which is attributed to technological change, and is called Total Factor Productivity (TFP). The basic framework can be extended in other ways (see, for example, Denison, 1967; Mankiw, Romer, & Weil, 1992), the most common of which is to consider different types of capital and labour. Growth accounting has been applied to numerous cases in the last two decades (see Griliches, 1988; Jorgenson, 1988; Page, 1994; Young, 1994, etc.). Young (1994), for instance, used the growth accounting methodology to argue that the rapid growth of Taiwan, Singapore, South Korea and Hong Kong was mainly due to increases in investment and in the size of the labour force, not to technological progress. Growth accounting has also been used extensively for studying the slowdown in productivity in the United States since the 1970s.

Potential labour input is estimated using the NAWRU concept. The NAWRU is the unemployment rate given constant wage inflation.[6] Elmeskov's (1993) method is used to construct a chronologically variable NAWRU.[7] It is based on an equation correlating unemployment with changes in wage inflation:

$$u_t - \text{NAWRU}_t = \lambda \Delta^2 w_t \tag{13}$$

where u_t is the actual unemployment rate, NAWRU_t is the (natural) unemployment rate, which has no effect on wage inflation and w_t is the average gross wage in the national economy. Δ, Δ^2, Δ^3 are the first, second and third difference operators, respectively.

It is typically assumed (e.g. Slevin, 2001) that the NAWRU changes only gradually over time, so that $\Delta\text{NAWRU}_t \approx 0$. In this context, taking the first differences in Eq. (13) to the left and right leads to an equation for λ:

$$\lambda = \frac{\Delta u_t}{\Delta^3 w_t}, \quad \Delta^3 w_t \neq 0 \tag{14}$$

when inserting the latter (14) into Eq. (13) we get:

$$\text{NAWRU}_t = u_t - \frac{\Delta u_t}{\Delta^3 w_t} \Delta^2 w_t \tag{15}$$

Eq. (15) implies that the NAWRU is equal to the actual unemployment rate, which is adjusted for changes in the rate of unemployment and the wage inflation relationship. The resulting series is then smoothed to eliminate erratic movements using the HP filter. Consequently, potential employment is calculated as follows:

$$L_t^* = L_{s_t}[1 - \text{NAWRU}_{s_t}] \tag{16}$$

where L_s is the HP-filtered labour time series and NAWRU_{s_t} is the HP-filtered NAWRU time series. Labour Gap is then calculated as follows:

$$L_{\text{gap}} = (L_t - L_t^*)/L_t^* \tag{17}$$

where L_t is the actual labour time series. Correspondingly, output gap is calculated as follows:

$$Q_{\text{gap}} = (Q_t - Q_t^*)/Q_t^* \tag{18}$$

where Q_t is the actual output time series.

Next, given that output gap is typically associated with inflationary pressures in the economy, we correlate the output gap with inflation. We further investigate whether the output gap has predictive power for inflation in the Granger sense. The concept of causality, introduced by Granger (1969), has been widely used in economics. In general we say that a variable X causes another variable Y if past changes in X help to explain current change in Y via past changes in Y. The empirical investigation of (Granger) causality is in other words based on the following general autoregressive model (Karasawoglou & Katrakilidis, 1993):

$$\Delta Y_t = a_0 + \sum_{i=1}^{m} a_{1i} \Delta Y_{t-i} + \sum_{i=0}^{n} a_{2i} \Delta X_{t-i} + \varepsilon_t \tag{19}$$

where Δ is the first difference operator and ε_t is the white noise error term with zero mean and constant variance. The null hypothesis that X does not Granger-cause Y is rejected if the coefficient α_{2i} is statistically significant.

In order to identify the optimal lag-length of Eq. (19), we use Hsiao's (1981) methodology as extended by Ahking and Miller (1985) according to which the lag length should be chosen in accordance with Akaike's Final Prediction Error (FPE) criterion. Also, an exhaustive study by Thornton and

[6] Several studies show that the equilibrium unemployment rate changes over time, but generally follows the actual unemployment rate (Layard, Nickell, & Jackman, 1991).

[7] For instance, this approach has also been used by Bolt and van Els (2000) to estimate the output gap in the European Union (E.U.).

Batten (1985) advocated using the FPE criterion for choosing lag lengths. This is more preferable than the usual practice of ad hoc lags since the results could be biased either because existing causalities are not detected, or because of spurious causalities. Of course, the general autoregressive model of Eq. (19) is appropriate for testing Granger causality only if the variables are not cointegrated. As is well known, cointegration implies that two or more variables have a long-run equilibrium relationship. Granger (1986) and Engle and Granger (1987) suggested a test based on cointegration and error-correction models. If cointegration is not detected, the autoregressive model of Eq. (19) is estimated. Otherwise, an error-correction model has to be estimated.

4. Data and variables

The estimation of the production function of the Russian economy is carried out using the available data from publications of the International Monetary Fund (IMF). The data, compiled each quarter, covers the 1994–2006 period.

We could have started with 1992 because it is the first year, after the major economic reform process in the early 1990s, that data are available. We decided, however, to remove 2 years from the initial period, when the data is clearly inappropriate (e.g. hidden unemployment not reported in the official unemployment figures). The survey terminates at 2006 because selection of the time series has been subject to data availability. The sample size for estimating a production function is quite satisfactory, enabling us to capture a full cycle and not stop, for instance, when the economic crisis ended in 1999.

Data on the capital stock (K_t') is not published but was able to be estimated by means of the popular *Perpetual Inventory* method. We restrict ourselves to factor utilization in industry, as data on other sectors is fragmentary. Following Oomes and Dynnikova (2006) we take the capacity utilization (u_k) and NAICU (u_k^*) measures estimated for industry as proxies for the economy-wide u_k and u_k^*, respectively. The estimates of u_k come from three institutions, namely: the Institute for the Economy in Transition (IET), the Russian Economic Barometer (REB), and the Center for Economic Analysis (CEA). In our calculations we use the arithmetical average of the three values published by the three institutions respectively (see, for instance, Bates & Granger, 1969; Granger, 1980; Granger & Newbold, 1986; Holden, Peel, & Thompson, 1990). In a similar vein, the estimates of u_k^* come from an application of the methodology in Oomes and Dynnikova (2006), where the final estimate of u_k^* that we use is equal to the average value of the three estimates obtained from the three respective institutions, i.e. IET, REB, and CEA. For a more detailed description of the methodology and characteristics of the surveys see Oomes and Dynnikova (2006).

5. Empirical analysis

As can be seen, the most widely used functional form of the production function is the linearized Cobb-Douglas specification (Thirlwall, 2001), which reduces the number of coefficients to be estimated and eliminates the multicolinearity problem of the explanatory variables. We use a time-series data set for the period 1994–2006, when data is available. The results of the regression through Ordinary Least Squares (OLS), which is used for the estimation of the linearized Cobb-Douglas production function

Table 1
Regression results for the production function.

Independent variables	Estimate
Intercept ($\ln A_t$)	3.17*
$1-a$	0.39*
Implied a	0.61
R^2	0.68
Mean absolute error	0.14

* Significance at the 10% level or higher.

Table 2
Average growth rates (1994–2006).

Growth rate in production	Growth rate in labour	Growth rate in capital	Labour productivity	Capital productivity	Total factor productivity
$[\mathrm{d}Y/\mathrm{d}t]/Y$	$[\mathrm{d}L/\mathrm{d}t]/L$	$[\mathrm{d}K/\mathrm{d}t]/K$	$[\mathrm{d}Y/\mathrm{d}t]/Y - [\mathrm{d}L/\mathrm{d}t]/L$	$[\mathrm{d}Y/\mathrm{d}t]/Y - [\mathrm{d}K/\mathrm{d}t]/K$	$[\mathrm{d}A/\mathrm{d}t]/A$
+0.066	−0.056	−0.125	+0.150	+0.192	+0.150

are presented in Table 1:

$$\ln\left(\frac{Y_t}{L_t}\right) = \ln A_t + (1-\alpha)\ln\left(\frac{K_t}{L_t}\right)$$

Table 1 presents the regression results for the dependent variables.

The signs of the estimated coefficients are consistent with the stated hypotheses and economic theory; the results are statistically significant for the independent variable, while the equation explains a considerable part of the variability of GDP. The results should be assessed as satisfactory given the various imperfections in this sort of country data (Mankiw et al., 1992: 408), not to mention the critical nature of the period under investigation and the various violent shocks that the Russian economy faced at the time.

There are no signs of serious violation of the basic assumptions concerning the residuals, as was easily confirmed with the aid of the relevant procedures (see Samouel et al., 1996: ch. 12): specifically, the normality of the errors was assessed through examination of the frequency distribution of the residuals as well as by reference to the Q–Q or P–P normality plot, which is a special type of plot for checking normality. As far as the assumption of homoscedasticity is concerned, compliance with this assumption was evaluated through examination of the scatter plot of the standardized residuals against the predicted values. Finally, as for the assumption that the residuals are independent of each other, investigation of the scatter plot of the standardized residuals against the time variable did not provide any evidence supporting the idea of dependence between successive values, i.e. autocorrelation effect.[8]

Labour elasticity derived is 0.61 and the value of capital stock elasticity is 0.39. These values are, in general terms, consistent with estimations produced by research on other countries. For instance, as is known, the majority of research papers indicate that the value of labour elasticity for the developed countries is around 2/3, while that of capital is 1/3 (labour elasticity estimates in the US are within the range of 0.59 and 0.87, and from 0.57 to 0.59 in Germany) (see Bolt & van Els, 2000; Dimitz, 2001). On these grounds, the estimation of labour and capital elasticity of Russia's production function may be regarded as credible.

Table 2 provides the calculated annual growth rates of production and inputs, labour productivity, capital productivity and TFP derived by Eqs. (7)–(9), respectively.

In the time period under survey, the growth rate in production was positive and equal to about 6.6%. However, there was a significant fall in capital stock, with a negative growth rate equal to about 12.5%, caused by the collapse of investments, while labour declined by "only" 5.6% and, given its higher share in production, managed to withstand the significant decline in production. Meanwhile, the growth rate in TFP in the time period 1994–2006 was positive, very significant, and equal to about 15%. We can thus see that technology was the "sheet-anchor" of the Russian economy during the period under survey, since it kept the negative annual growth rate of GDP to positive levels when a dramatic decline in the capital stock took place. Furthermore, the annual growth rate in the productivity of capital is high, this being attributable to the fact that capital declines faster than output. The annual growth rate of labour productivity is also (slightly) positive for to the same reason.

If we take a closer look at the results and try to isolate the crisis sub-period (1994–1997) from the "recovery" sub-period (1998–2006), two conclusions suggest themselves. First, all inputs, namely capital, labour and technology, experience a significant decline which goes hand-in-hand with the

[8] An alternative diagnostic is provided by the Durbin–Watson statistic which indicates the degree of autocorrelation in our dataset. However, given the value of this statistic in our dataset (1.92), the hypothesis that the residuals are autocorrelated cannot be accepted.

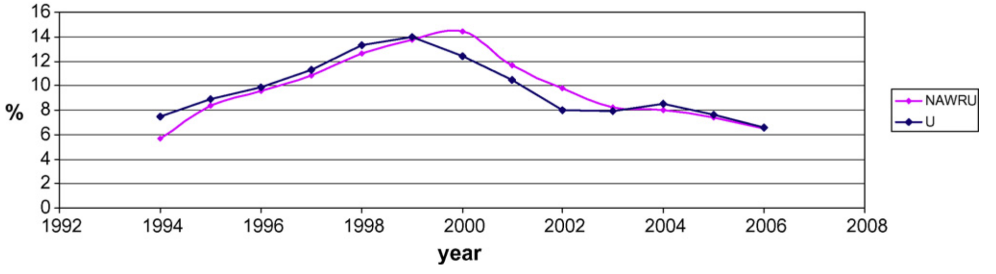

Fig. 1. NAWRU and actual unemployment rate (*U*) in the Russian Federation.

decline in output between 1994 and 1997. Second, there is a sub-period of recovery (1998–2006), where the technological level is significant and positive as shown in Fig. 4. We thus notice that a decline in output was averted because of the positive growth rate in technology in the Russian economy, as expressed through TFP in the time period 1998–2006.[9] Our results are, in general terms, consistent with the findings by Oomes and Dynnikova (2006), Kwon and Antonio (2005), and Andrienko and Guriev (2004) (see below).

But the critical situation as regards technology in the crisis sub-period (1994–1997) is related to cutbacks in research and development (R&D) expenditures. The R&D statistics for the crisis sub-period in Russia are overwhelming.[10] Moreover, from surveys in various productive branches it became evident that the machinery and equipment in Russian factories was technologically obsolescent.[11] The poor state of the production infrastructure also had a negative effect on exports (OECD, 1997).[12]

Fig. 1 illustrates the NAWRU and the actual unemployment rate (*U*).

Fig. 2 illustrates potential labour and the actual labour for each year.

The actual level of capital stock and its potential level, both adjusted for capacity utilization are illustrated in Fig. 3.

Fig. 4 illustrates the potential (TFP*) and actual (TFP) level of TFP, expressed by the residuals of the CD production function.

Substituting potential estimates for actual data and the technological variable for the estimated residual variable, Russia's potential GDP (Y^*) and actual GDP (Y) are calculated, respectively (Fig. 5). Fig. 5 summarizes its performance.

As far as the estimation of the potential output is concerned, this is associated with the supply side of the economy. The positive output gap should be expressing excess demand and the negative output gap excess supply. The positive output gap is associated with inflationary pressures in the economy, and policy makers are accordingly very concerned about it. Let us correlate the output gap with the consumer prices index for the case of Russia (Table 3).

[9] It is interesting to note that in a seminal article, Andreff (1978) applied, in general terms, a similar methodological framework to investigate the relation between the level of technology and economic slowdown in the Eastern European countries in the 1950s and early 1960s. For a brief survey of some important contributions to measuring the percentage of growth arising from an increase in TFP in the former USSR, see Andreff (1978: 50).

[10] In 1991 R&D expenditures amounted to approximately 1.85% of GDP but by 1997 they were had fallen to 0.5%. Between 1991 and 1997 a rapid decline in the expenditures for R&D is thus observed, amounting to 72.97%, which implies a decline of 19.59% annually. Until 1993 the capital funding allocated to the various scientific programs in Russia was reduced by a factor or 4–10 by comparison with the figures for 1990. More than 500 high-level scientists had meanwhile emigrated and over 17,000 departed "for long term employment abroad". Many of the 4500 research centers disappeared and 1100 were privatized (Milios, 2001).

[11] For instance, according to OECD (1997–1998: 37–38) about half of the existing oil pipes were more than 20 years old so that approximately 2% of oil production was being lost because of leakages and accidents (see Goskomstat, 1997; OECD, 1997; Pavlovich, 1996).

[12] Unsuccessful oil drillings, with oil constituting one Russia's basic export products (Analytis, 1999: 299; Kaitila, 2003: 8, 19), increased from 4000 to 32,000 in 1993, due to the shortage in appropriate capital and inadequate technical infrastructure. Technological inefficiency in general led to a situation where only half of the oil available for extraction was being pumped (Analytis, 1999: 298).

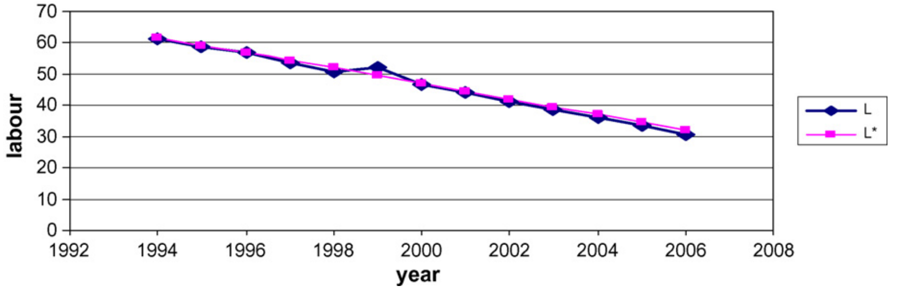

Fig. 2. Potential labour (L^*) and actual labour (L) in the Russian Federation.

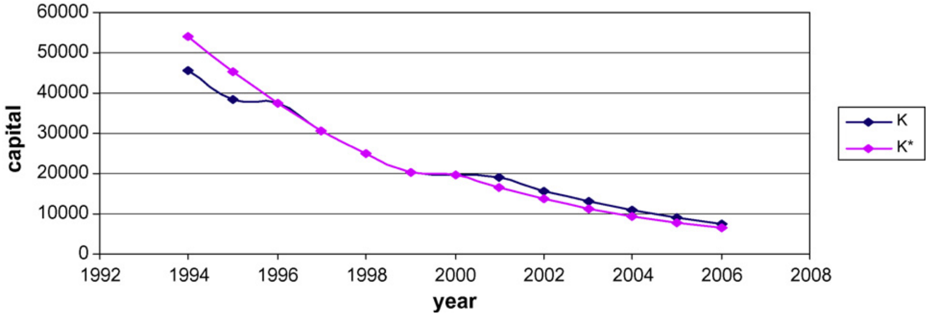

Fig. 3. Potential (K^*) and actual (K) capital in the Russian Federation adjusted for capacity utilization.

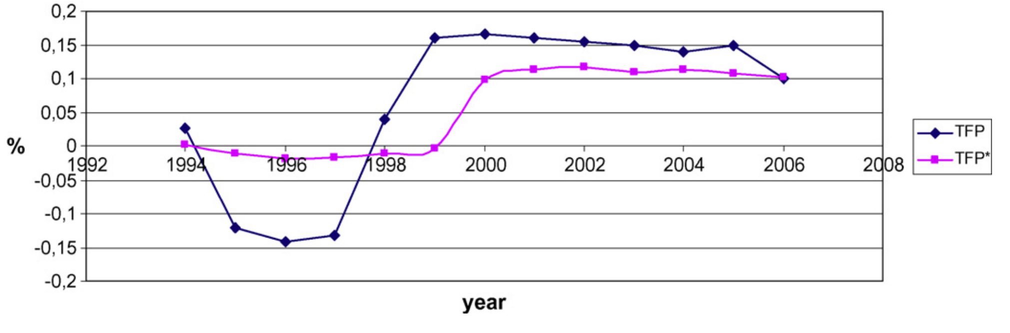

Fig. 4. Potential (TFP*) and actual (TFP) level of TFP in the Russian Federation.

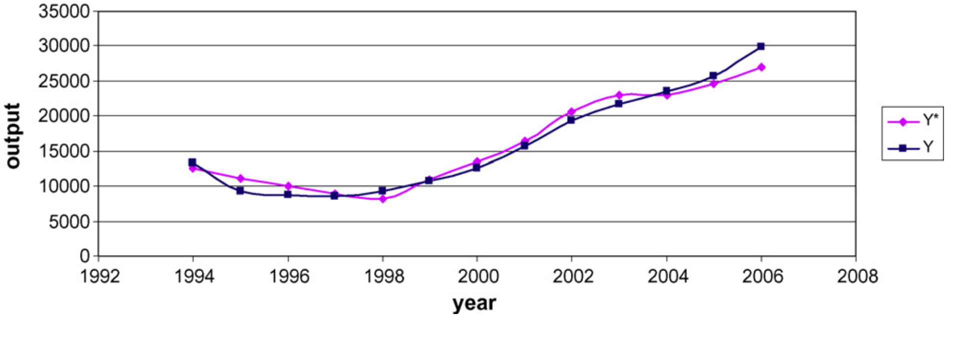

Fig. 5. Potential (Y^*) and actual (Y) output in the Russian Federation.

Table 3
Correlation of output gap with inflation.

Lags (years)	0	1	2	3
Consumer Price Index (CPI)	0.15	0.03	0.21	0.82
Wage inflation (WI)	0.16	0.06	0.09	0.59

Table 4
Granger causality test results.

Hypothesis	Lags	*F*-Statistic	Probability
Consumer Price Index does *not* Granger Cause Output Gap	0	2.83408*	0.09906
Consumer Price Index does *not* Granger Cause Output Gap	1	2.68126*	0.06244
Consumer Price Index does *not* Granger Cause Output Gap	2	5.99925*	0.01818
Consumer Price Index does *not* Granger Cause Output Gap	3	9.38100*	0.00366

* Significance at the 10% level or higher.

As shown in Table 3 the highest correlation is with lag 3, meaning that the output gap transforms into inflation after about 3 years. The correlation coefficient over this period of 0.82 indicates strong correlation. We note a roughly similar pattern when using the two different measures for inflation. This is attributable to the roughly similar pattern followed by the two inflation measures.

We next expand our investigation by seeking out the true explanatory power of empirical causality. In this context, we investigate whether the output gap has predictive power for inflation in the Granger-causal sense (Table 4).

As can be seen, the output gap seems to have considerable predictive power for inflation, in the Granger sense. In other words output gap (Granger) causes inflation. We also note that the results are consistent, in general terms, with our findings from simple correlation implying that the output gap in the Russian Federation transforms into inflation after approximately 3 years. The results therefore indicate that there is a strong correlation between the Consumer Price Index (CPI) and the output gap. The resulting inflationary pressures are also apparently caused by external factors such as depreciation of the currency, high oil prices, etc., since Russia is now an open economy.

Table 5 reports the optimum lag length and the corresponding FPE criterion. The FPE values have been calculated for lag lengths up to 4 years. The test for autocorrelation of the residuals is favourable to the hypothesis of white noise processes. Of course, before proceeding to the estimation of Eq. (19) we examined whether significant error-correction terms are erroneously excluded from the model. The empirical results, which are available upon request by the author, showed that the null non-cointegration hypothesis cannot be rejected at the 5% level. Thus, the autoregressive model of Eq. (19) has to be estimated.

The minimum FPE occurs when inflation is lagged 3 years. Again, the results are consistent with our finding that the output gap in the Russian Federation transforms into inflation after approximately 3 years.

As is well-known, after falling from about 25% in 2001 to approximately 10% in 2004 inflation in Russia has since begun to accelerate. This is consistent with our finding that the output gap in Russia was negative between 1999 and 2004 but has recently become positive. Our findings thus suggest that that rate of inflation may be explicable by the fact that the Russian economy is facing increasing supply-side constraints, creating excess demand and, hence, inflationary pressures (Oomes & Dynnikova, 2006). Furthermore, supply-side constraints in goods markets are likely to have arisen because of insufficient investment, given that gross fixed investment in Russia has been considerably

Table 5
Optimal lag length.

Time series	Opt. lag length (years)	FPE ($\times 10^{-3}$)
Δ (Consumer Price Index)	3	1.440

Note: Δ indicates the first difference operator.

less than in most other transition countries (Oomes & Dynnikova, 2006). On the other hand, supply-side constraints in labour markets appear to be the result of a lack of interregional labour mobility (Andrienko & Guriev, 2004; Kwon & Antonio, 2005).

6. Conclusions and policy implications

The present paper estimated TFP growth rate and output gap in the Russian Federation in the time period 1994–2006 using the production function approach and the HP-filter technique. According to our findings, TFP has made a significant contribution to the strong growth enjoyed by the country since 1998. The output gap in Russia was negative between 1999 and 2003 but has recently become positive. The paper furthermore examined the relationship between output gap and inflation. Where demand pressures on resources were present, a positive gap for a time lag of 3 years tended to be associated with increases in inflation. Of course, the overall inflation rate is subject to external factors such as the rate of depreciation of the euro, high oil prices, etc., and the output gap alone is not totally sufficient to explain inflation.

Our findings are in general terms consistent with the available theoretical and empirical literature. More specifically, the similar pattern followed by natural and actual rates of unemployment is consistent with the findings of the seminal paper by Layard, Nickell, and Jackman (1991), for example. Our results are also consistent with the findings by Oomes and Dynnikova (2006) suggesting that the output gap in Russia was negative between 1999 and 2003, but may have recently become positive. Finally, the fact that the output gap fuels inflation (or in other words the “domestic” character of the inflationary mechanism indicating an origin basically from inside the Russian social formation), is another example of the general consistency of our results with the relevant literature (see, for instance, Milios, 2001).

As we have seen earlier, economic policy has placed increasing emphasis on production gap. More precisely, when total output is below the potential of the economy then a negative gap exists. In simple terms, current production is below what the economy could normally sustain and there is spare production capacity in the economy. In contrast to this situation, lately in Russia there is a positive production gap, meaning that inflation pressures are rising.

This is an interesting result, as economic policy could focus predominantly on the monetary situation and prospects for inflation within the total economy. As is well known, the concept of output gap is an important link between the real economy and inflation. In this context, the output gap provides a useful way of thinking about inflationary pressure and has its largest role in the country’s policy-making process as an input into the Central Bank’s economic projections.

The results from this study provide us with useful insights in relation to Russia’s monetary and fiscal policies. First, as mentioned above, potential output and output gap measurements are an important part of monetary policy formulation. Indeed, in cases where the inflation targeting framework is used, the output gap is the most important determinant of how “loose” or “tight” the monetary policy should be in order for the inflation target to be obtained at maximum growth.

In the Russian case, this fact makes the estimation of the country’s output gap of great importance. This is because the interest rate should take into consideration the output gap in the economy and the difference between observed inflation and the targeted inflation, among other fundamentals. The estimated output gap in this study indicates that, currently, the actual output of the economy is over its potential. This means that in order to stimulate growth, there is practically no room to “relax” the monetary policy without creating inflationary pressures. Due to the increasing potential output growth of the economy over the last years, the extent to which the monetary policy can be loosened is restricted. As for the bank rate, the output gap that has been established in this study implies that interest rates need to be higher than where they have been in line with a loosened monetary policy.

The other important implication of the findings of this study has to do with the budget deficit. Just like in the case of monetary policy, the output gap estimated in this study suggests that there is no room for the government to run a budget deficit without inflationary pressures building up. The fiscal expansionary policy must bear in mind the increasing potential output growth that the economy has been experiencing implying that there is no higher limit to the extent to which the budget deficit can grow. And because of the increasing potential growth, it would be more appropriate if the fiscal expansion were aimed at those expenditures that would not lead to an increase in the economy's long-term growth potential.

As a final conclusion, we would say that it is clear that there is no room for the use of expansionary fiscal and monetary policies in the Russian economy. This being the case, the focus should be directed at structural issues that could reverse the positive output gap.

In closing we would like to stress that all estimates of output gap are subject to a margin of error. The production function estimate is contingent on an estimate of the NAWRU, the NAICU and other measures to calculate potential values and gaps. In other words, the methodology we used should be treated with caution since both the level of potential figures and the gap are estimates whose accuracy cannot be treated as altogether certain. For the case of the Russian Federation the uncertainty may indeed increase as the economy seems to have undergone some significant changes during the 1990s and a large proportion of income from salaries remains undeclared. It is moreover difficult to estimate cyclical demand pressures in a transition economy that has had only a limited experience with business cycles. It would clearly be of great interest for there to be further research on the subject. Obviously, extending the data to a longer period could also be a subject for future research.

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