Direct investment and costs of production: empirical results of modelling costs structure applied to Russian industry in 2005–2009

Eugenia Nazrullaeva[1]

In the applied theory of exogenous or endogenous economic growth it is usually assumed that investment leads to capital accumulation with no influence on technological progress. On the other hand, at the firm level investment is aimed at developing innovative technologies (process innovations) which lower firms' production costs per unit of output. However, when a firm decides to make an investment it may consider other reasons besides improving production process. Firms may also invest in expanding the range of goods produced, i.e. invest in product innovations associated with the extensive growth. The question arises: do investments matter?

In our study we analyze a relationship between investment processes and the dynamics of production costs. We discuss the influence of different types of investment, including fixed investment, R&D investment, and foreign direct investment, on the structure of production costs (costs of raw materials, wages, etc.). The aim we pursued was to find out whether higher investments lower costs of production per unit of output controlling for the dynamics of relative prices. If our hypothesis of investment significance for production process and technological progress is not rejected, it means investments are efficient.

We base our study on the official statistics on seventeen key industries in Russian mining and manufacturing sectors, electricity, gas, and water supply sector. The data is taken from the Federal State Statistics Service (Rosstat), and it covers the period from 1st quarter of 2005 to 3rd quarter of 2009. Until 2005 Russian industrial statistics was based on the OKONKh industrial classification. Starting from 2005 the OKVED classification (harmonized with NACE European Classification of economic activities) has been introduced. Unfortunately, the continuity of official industrial statistics failed after 2004. Econometric modelling encounters serious limitations due to the small sample problem. Our previous empirical results suggest that there is the statistically significant relationship in several manufacturing industries. To verify our hypothesis of investment efficiency we assume that the long-run equilibrium found in 1995–2004 remains after 2005, as it takes time to develop and use innovative technologies which lower production costs. We test for cointegration between costs per ruble of output and investment, taking into account the possibility of structural breaks in the data which covers the beginning of the current crisis. Our results suggest that the effect of investment on costs varies across the industries, and the overall efficiency of investment can be seriously questioned. No investment efficiency found

[1] Eugenia Nazrullaeva, PhD student, State University – Higher School of Economics, Economics Department. Moscow, Russia

in mining sector of energy producing materials which accounts for nearly half of total investment in Russian industry.

Keywords: costs per unit of output, technological progress, direct investment, Russian industry, cointegration, structural break

JEL Classification: C22, E22, E23, O30

1. Introduction

In the applied theory of exogenous or endogenous economic growth it is usually assumed that investment leads to capital accumulation with no influence on technological progress. On the other hand, at the firm level investment is aimed at developing innovative technologies (process innovations) which lower firms' production costs per unit of output. However, investment behavior motives go far beyond securing technological progress. Firms may also invest in expanding the range of goods produced, i.e. invest in product innovations associated with the extensive growth instead of the intensive growth. So economic growth accompanied by the growth of private investment may lack the so-called investment nature. According to the Federal State Statistics Service (Rosstat) in the mid-2000s industry accounted for around 80 per cent of total investment in Russian economy. About 40 per cent was invested into fuel industry, particularly into oil industry[2].

So a question arises: do investments matter? For example, if we consider the Cobb – Douglas production function, widely used in theoretical and empirical analysis of economic growth and technological progress, output elasticities of factors used in production are assumed to be constant. If investments matter this no longer holds. The idea is as follows. Suppose the production function determined by capital (K) and labor (L):

$$Y = AK^{\alpha}L^{1-\alpha},$$

The assumption that investments have an effect on the production function may be formalized in the following way:

$$\dot{\alpha} = \gamma I,$$

where I - investment, and $0 \le \gamma \le 1$. Elasticities change proportionally to investments. This framework was introduced in Peretto & Seater (2007) as a model of endogenous growth.

The next question which arises is: what kind of investment processes may influence technological progress? Peretto & Setter (2007) consider cost-reducing R&D investment. We discuss the influence of different types of investment, including R&D

[2] «Investment in Russia», 2005. Source: Rosstat.

investment, fixed capital investment, and foreign direct investment on the structure of production costs.

The empirical analysis of the dynamics of the costs structure together with investment in fixed capital at the disaggregated economic activity level may reveal the nature of economic growth. In this paper a simple framework for this phenomenon is developed and tested. The main hypothesis of the paper can be stated as follows: higher investment leads to lower production costs per ruble of output as a result of technological progress. Its verification assumes modelling the costs structure as a function of investment.

This paper is probably one the first, based on Russian statistics, to look at the investment efficiency and technological progress from the point of view of the costs structure. There is literature that looks at the related but rather distinct theoretical and empirical questions concerning growth, technological progress, investment volatility, and costs of production.

Theory of exogenous economic growth considers the effect of capital accumulation and technological progress on growth. Endogenous growth theory, in turn, questions the nature of technological progress. Aghion et al. (2004) analyze the effects of productivity shocks on output growth in the presence of credit constraints. The transmission channel is the composition of investment: long-term and short-term investment. Short-term investment takes relatively little time and does not have a substantial effect on productivity. Long-term investment, in turn, has a direct effect on productivity. Short-term investment, according to Aghion et al., concerns maintenance of the existing equipment, while long-term investment is connected with investment in R&D and adopting new technologies of production. It can be inferred from the results of their research that under complete financial markets long-term investment and productivity are countercyclical and short-term investment are procyclical. In the presence of financial constraints long-term investment turns to become more procyclical and more sensitive to the exogenous productivity shocks.
Costs of production are analyzed in investment theory in terms of adjustment costs, i.e. costs of changing the capital stock. The nature of adjustment costs is rather close to the ideas proposed in this paper concerning the effect of investment on the costs structure dynamics. Higher short-term investment may bring higher costs per ruble of output because this type of investment is associated with maintenance costs and costs of new equipment installation. Long-term investment, in turn, is associated with developing new technologies of production. In other words, in long-term period higher investment is expected to stipulate technological progress.

Nadiri and Mamuneas (1994) analyze the effect of public sector investment on costs of production structure at the industry level. Public sector capital is being disaggregated at two components: infrastructure and R&D. Private sector costs are modeled as a function of relative factor prices, output produced, and public capital. The main hypothesis of the paper is that higher public investment in infrastructure and R&D leads to lower costs per unit of production. The cost function is estimated for panel data for twelve two-digit US industries (by Standard Industrial Classification, SIC) during the period 1956–1986. The results obtained by the authors suggest that in case of investment in R&D public capital has a direct impact on the costs structure: it lowers the costs of production per unit of output and leads to higher productivity.

We base our study on the official statistics on seventeen aggregated and disaggregated economic activities in Russian mining and manufacturing sectors, electricity, gas, and water supply sector.

1. Mining and quarrying (C)
2. Mining and quarrying of energy producing materials (CA)
3. Mining and quarrying, except of energy producing materials, i.e. stone, sand, chemical and fertilizer minerals, etc. (CB)
4. Manufacturing (D)
5. Manufacture of food products, beverages and tobacco (DA)
6. Manufacture of textiles and textile products (DB)
7. Manufacture of leather and leather products (DC)
8. Manufacture of wood and wood products (DD)
9. Manufacture of pulp, paper and paper products; publishing and printing (DE)
10. Manufacture of chemicals, chemical products and man-made fibre (DG)
11. Manufacture of rubber and plastic products (DH)
12. Manufacture of other non-metallic mineral products (DI)
13. Manufacture of basic metals and fabricated metal products (DJ)
14. Manufacture of electrical and optical equipment (DL)
15. Manufacture of transport equipment (DM)
16. Manufacturing not elsewhere classified (DN)
17. Electricity, gas and water supply (E)

The data is taken from the Federal State Statistics Service (Rosstat), and it covers the period from 1st quarter of 2005 to 3rd quarter of 2009. Until 2005 Russian industrial statistics was based on the OKONKh industrial classification. Starting from 2005 the OKVED classification (harmonized with NACE European Classification of economic activities) has been introduced. Unfortunately, the continuity of official industrial statistics failed after 2004. We discuss a possible way of recalculating industrial time series in 1995-2004 retrospectively using tables of correspondence; however, the results do not seem to be very fruitful.

According to our hypothesis improvement in technologies as a result of higher investment implies lower costs per ruble of output. In order to measure the effect of investment on the costs structure cointegrating equations are estimated at the disaggregated economic activity level.

The rest of the paper is organized as follows. Section 2 describes the main problems offered by the data and its drawbacks. Section 3 outlines the model, the main results and their economic interpretation. Section 4 draws conclusions.

2. The data

2.1 The data: methodology

The data used is the official statistics borrowed from Rosstat (www.gks.ru). The statistics analyzed in the paper is the following:

- production costs, quarterly data, 2005–2009, in current purchaser prices[3];
- fixed capital investment, quarterly data, 2005–2009, in current prices;
- output produced (turnover from the supply of goods and services as a proxy), quarterly data 2005–2009, in current producer prices;
- R&D investment, quarterly data, 2005–2009, in current prices;
- producer price index (PPI), quarterly data, 2005–2009;
- investment deflators, quarterly data, 2005–2009;
- foreign direct investment (in USD), quarterly data, 2005–2009;
- RUR/USD exchange rate, average, quarterly data, 2005–2009.

According to the methodology of Rosstat investment in fixed capital is aimed at creation and reproduction of fixed capital stock, reconstruction and technical reequipment, acquiring machines, etc. So fixed capital investment is closely connected with a firm's level of technology.

Investment in R&D is a part of investment in non-financial assets not included in fixed capital investment. Unlike fixed capital investment this type of investment represents costs of developing and testing new prototypes of machinery and equipment, i.e. describes a firm's level of technological innovativeness.

Foreign direct investment (FDI) is defined as the accumulation of tangible and intangible assets, cash, capital lease, and credits from foreign co-owners of a firm. We suppose that motivation behind FDI should be more transparent than motivation behind domestic investment. The advantage of using FDI over domestic investment when modelling the costs structure is that we do not need to construct investment deflators. It was discussed in Bessonov & Voskoboynikov (2006) that official investment deflators published by Rosstat are biased and do not reveal the actual dynamics of the prices of fixed assets. Foreign direct investment does not need to be deflated because the dynamics of prices is eliminated by converting investment in rubles using quarterly average ruble exchange rate.

[3] i.e. prices which exist at the moment when goods and services are used in production process

Finally, costs of production constitute an item which includes all expenditures excluded from investment. Therefore, the differences between costs and investment in statistics are rather subtle and depend on how carefully accounting principles are abided by a firm. Costs of production include several components: material costs, wages, depreciation, and other costs. The dynamics of production costs is determined mostly by the dynamics of its main component: material costs. The composition of material costs includes:

- costs of acquiring raw materials, intermediates, and accessories for production process, including costs of acquiring import raw materials;
- transportation costs;
- fuel and energy consumption.

According to our hypothesis technological progress involving higher investment in development of less resource-consuming technologies should result in lower costs per ruble of output due to lower costs of acquiring raw materials used in production. Wages are excluded from the analysis of the costs structure. According to real business cycles theory positive technology shock leads to an increase in wages and labor supply (Romer, 2006). This fact contradicts our hypothesis of lower costs as a sign of technological progress.

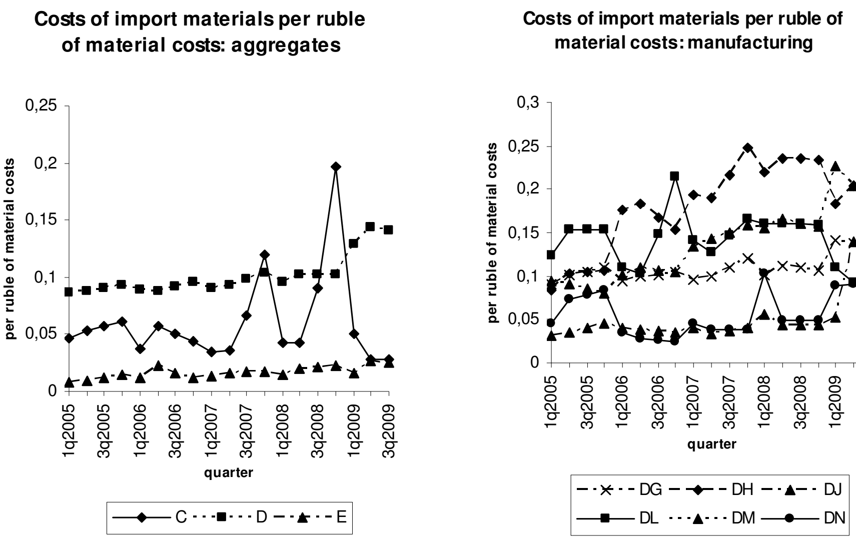
The main problem which arises when working with Russian industrial statistics is that until 2005 Russian industrial statistics was based on the OKONKh industrial classification, but starting from 2005 the OKVED classification (harmonized with NACE European Classification of economic activities) has been introduced. In the OKONKh classification an industry is an aggregate of firms according to their main economic activity. The object of classification is a firm. The drawback of such classification is that a firm has non-core activities that may constitute a large share of its profit. So in OKVED the object of classification is an economic activity. OKVED was officially introduced in 2003, transition period lasted for 2003–2004. So the continuity of official industrial statistics failed after 2004. Nevertheless, there is a possible way of recalculating industrial time series retrospectively for the period 1995–2004 using tables of correspondence published by Rosstat. These correspondence tables allow converting data from the OKONKh classification to the OKVED classification, and based on the principle that an institutional industry may be represented as a weighted aggregate of several economic activities. This approach produces estimates for the main production and financial indicators, though the quality of these estimates remains unknown and thus may be questioned. The weighting matrices used for recalculation are given exogenously. As a rule, the weights are obtained using the data of the transition period 2003–2004: the hypothesis of constant exogenous weights lies behind recalculation. We limited our analysis to the period 2005–2009 because our estimates obtained for the earlier period based on the approach discussed appear to be biased and thereby numerically incomparable, i.e. the approach itself requires further refinement.

2.2. The data: 2005-2009 dynamics and crisis

Because of methodological problems with official industrial statistics time series analyzed in this paper are rather short. Period from the 1st quarter of 2005 to the 3rd quarter of 2009 covers 19 observations. The impact of crisis hit Russian industry in autumn 2008 is supposed to be revealed through the dynamics of costs of production per ruble of output and the dynamics of real investments.

From Figure 1 it may be inferred that wages per ruble of output in mining and manufacturing industries witnessed substantial growth at the end of 2008. Unlike mining and manufacturing electricity, gas, and water supply sector faced a decrease of wages in the first half of 2009. From the figures it also can be seen that the level of wages per ruble of output is higher in manufacturing than in mining. The proportion between costs of labor in manufacturing and costs of labor in mining remains unchanged during 2006–2009 and accounts approximately 4 to 1, i.e. total costs of labor in manufacturing are four times higher.

Figure 1. Costs of production: wages and costs of acquiring import raw materials



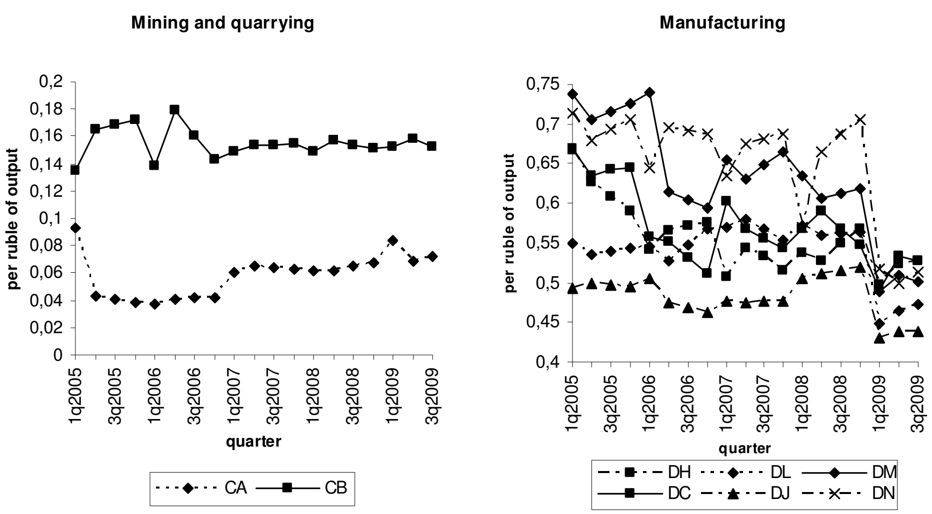
Source: Rosstat

Another factor which should be taken into account in the analysis of the costs structure is the share of import materials used in production process. Costs of import raw materials per ruble of total costs of materials are higher in manufacturing as it can be seen from Figure 1. The autumn crisis of 2008 led to the fall in the percentage of import materials used for production in manufacturing industries. The activities excluded are manufacture of transport equipment (DM) and manufacture of fabricated metal products (DJ).

One of the first conclusions is that manufacturing industries seem to face severe problems during 2008: real output decreased, import raw materials used in production are substituted for domestic ones.

The dynamics of costs of raw materials per ruble of output (fuel and energy consumption and transport costs eliminated) that we believe being an indicator of the level of technology is shown in Figure 2. Dynamics of costs per ruble of output in mining does not suggest any changes occurred after the crisis. Once again manufacturing industries appear to suffer more from the consequences of the crisis. It can be observed from Figure 2 that material costs per ruble of output in manufacturing plummeted after the 3rd quarter of 2008. So there is a clear structural break in mean. If we compare the effect of the 2008 crisis on material costs with the effect of the 1998 crisis, we see that the situation is quite different. As it was shown in Kantorovich & Nazrullaeva (2009) structural breaks in the dynamics of material costs per ruble of output occurred with a substantial lag at the beginning of the 2000-s. So the crisis of 1998 appears to have no immediate effect on the dynamics of costs, its influence was accumulated by real output and relative producer prices dynamics.

Figure 2. Costs of acquiring raw materials per ruble of output

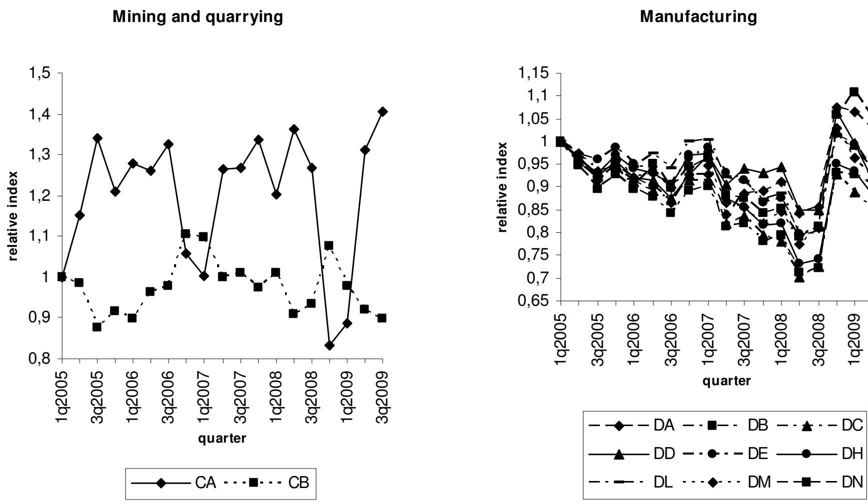


Source: Rosstat

Costs per ruble of output analyzed above are calculated in nominal terms, therefore, when modelling the relationship between investments and the costs structure this indicator should be adjusted for the dynamics of relative prices, i.e. prices entering into costs relative to prices of output. No deflator of costs is being officially published by Rosstat. In our paper we suggest aggregate producer price index as a proxy for purchaser prices in which costs are measured. Then the proxy which accounts for the dynamics of relative prices in the dynamics of costs per ruble of output is relative PPI index: PPI of an economic activity relative to the aggregate PPI. In the previous version of Russian industrial classification the aggregate PPI was the PPI for industry as a whole. With the introduction of OKVED the aggregate PPI is the PPI which accounts for the dynamics of prices for three aggregate economic activities: mining (C), manufacturing (D), and electricity, gas, and water supply (E). This aggregate is calculated by Rosstat.

Figure 3 represents the dynamics of relative PPI in 2005–2009. As we can infer from Figure 3 there was a sharp reduction of relative prices in mining of energy producing materials at the end of 2008 followed after the fall in oil prices. Manufacturing appears to respond to the crisis faster than mining: a decline for manufacturing activities is witnessed in the 2nd quarter of 2008 followed by an increase after the 3rd quarter. At the end of 2008 we see that prices in manufacturing grew higher than average prices for industrial activities (C, D, E), i.e. relative PPI index exceeds 1. In mining of energy producing materials relative price index is high during the whole period 2005–2009. And the situation seems to remain unchanged if we compare it to the earlier data for 1995–2004. In mining the crisis of 2008 led to the same changes in relative prices as the crisis of 1998: a sharp decline followed by a gradual rise in relative PPI. However, most of institutional industries now aggregated into manufacturing economic activities showed another pattern of dynamics. For machinery, chemicals, food, and light industry relative PPI increased immediately during the crisis of 1998. So current crisis brings some new patterns which suggest that unstable situation in manufacturing industries is quite alarming. After the 3rd quarter of 2008 relative PPI in manufacturing exceeded its level before the crisis. During the year 2009 we observe a gradual decline in relative prices which appear to be a positive sign.

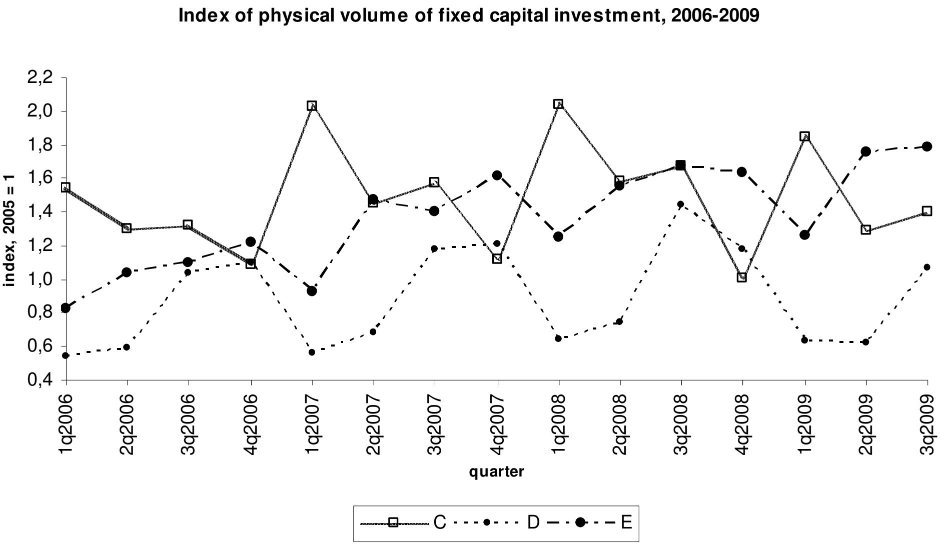
Figure 3. PPI by economic activities relative to aggregate PPI (C, D, E)



Source: Rosstat

Finally, the dynamics of investment and output should be analyzed. From Figure 4 we may see the dynamics of physical volume of production aggregated at the level of manufacturing and mining during 1995–2009 when Russian industry faced the two crises of 1998 and 2008 (the value in 1st quarter 1995 as 1). For the period 1995–2005 the indices of physical volume of production for economic activities are calculated retrospectively by Eduard Baranov and Vladimir Bessonov (SU – HSE) [Baranov, Bessonov (1999)]. The conclusion which may be inferred is that the negative consequences of the 2008 crisis for Russian industry are quite severe: the worst situation is in manufacturing where physical volume of output in the second half of 2008 plummeted more than in mid-1998. The effect of the crisis of 2008 on mining is roughly the same as in 1998, and the dynamics of physical volume of output in electricity, gas and water supply sector seems to be almost unaffected by the both crises.

Figure 4. Indices of physical volume: production and fixed capital investment.



Source: Rosstat.

The situation with investment is rather puzzling. During the period from the 2000-s Russian industry was characterized by stable growth of investment. Observing this growth the hypothesis that higher investment leads to lower costs per ruble of output was proposed. However, it is clear now that after the last year's crisis the situation has changed. Figure 4 suggests that in terms of physical volume of fixed capital investment the growth we witnessed does not exist anymore. The physical volume of investment seems to be rather stable during the last three years (the data officially published by Rosstat) if we neglect the seasonal component.

3. Empirical modelling of the costs structure

3.1 The model framework

Before we proceed to discuss modelling the costs structure the hypothesis we test should be formalized. The key assumption of our paper states that if higher investment leads to lower costs per ruble of output (relative prices dynamics eliminated) we may estimate the degree of technological progress in an industry.
The dynamics of costs per ruble of output is determined by the following components:

$$\frac{C_t}{Y_t} = A\frac{P_t^C}{P_t^Y},$$

where $\frac{C_t}{Y_t}$ is the share of costs in output in nominal terms, $\frac{P_t^C}{P_t^Y}$ is price index of costs relative to price index of output, and A stands for the real costs structure which is referred to as a technology component.

The initial approach applied for the data 1995–2004 was to verify the hypothesis by estimating autoregressive distributed lag models $ADL(p,q,r)$ at an industry level ($\forall m = \overline{1,M}$ industries):

$$\alpha_p(L)smc_t^m = \theta + \beta_q(L)inv_t^m + \gamma_r(L)rppi_t^m + \sum_{i=2}^{4}\delta_i d_{it} + \varepsilon_t^m, \text{ where}$$

- smc_t^m is the logarithm of costs of raw materials per ruble of output;
- inv_t^m is the logarithm of investment, deflated;
- $rppi_t^m$ is the logarithm of relative PPI index;
- d_{it}, $i = \overline{2,4}$ - seasonal dummy variables: 1 in quarter i, and 0 otherwise.

When the processes analyzed are integrated of order 1, $I(1)$, the ADL model allows for error correction model representation which is more informative from the point of view of economic interpretation in terms of short-run fluctuations and the long-run equilibrium. Therefore, first, formal tests for unit roots are needed to be applied; second, cointegration should be tested.

For the period 1995–2004 short-term fluctuations around long-term equilibrium described by cointergration were proved to be insignificant, except for chemical industry, i.e. investment influence the costs structure in the long-run only. Small sample does not allow adopting the same approach for the period 2005–2009. Previous results from Kantorovich & Nazrullaeva (2009) suggest that in this case the analysis may be limited to estimation of possible relationship between the costs structure and investments using cointegration approach. It should be mentioned, though, that cointegration phenomenon being approached in econometric literature as a long-term equilibrium requires longer time intervals. The applicability of cointeration concept may be doubted for the period which account for 4 years. Additional assumptions are required. We assume that the long-run equilibrium found 1995–2004 remains after 2005, as it takes time to develop and use innovative technologies which lower production costs, however the parameters of the equilibrium change.

Modelling empirical relationship between costs and investments controlling for relative prices requires the following steps.

1. Stationarity: unit root tests
   - Dickey – Fuller test (1979)
   - Zivot – Andrews test (1992) ("univariate") for an endogenous structural break
2. Cointegration tests:
   - Two-stage Engle – Granger procedure (1987)
   - Gregory – Hansen test (1996) ("multivariate") for an endogenous structural break in cointegrating equation
3. Statistical inference: asymptotic inference which, however, faces small sample problem (bootstrap inference was proved to be no better in this case).

3.2 Unit roots and structural change

The data first tested for a unit root using the augmented version of the Dickey – Fuller test (1979). The choice of lagged differences in the test is exogenous and aims at finding the trade-off between the power of the test and small sample problem. The results of the Dickey – Fuller test suggest that there is a unit root in $\left\{smc_t^m\right\}_{t=1}^T$, $\left\{inv_t^m\right\}_{t=1}^T$, and $\left\{rppi_t^m\right\}_{t=1}^T$ $\forall m = \overline{1,M}$, $M = 17$ economic activities.

However, as the period analyzed in the paper covers 1st quarter 2005 to 3rd quarter 2009 there may exist structural break in the series on $\left\{smc_t^m\right\}_{t=1}^T$, $\left\{inv_t^m\right\}_{t=1}^T$, and $\left\{rppi_t^m\right\}_{t=1}^T$ $\forall m = \overline{1,M}$ caused by exogenous shocks. In our case the crisis which hit Russian economy in the autumn of 2008 may be treated as such an exogenous shock. Therefore, formal procedure which allows testing for stationarity in case of a structural break is necessary: the Andrews – Zivot (Zivot – Andrews1992) test is applied. This test suggests three different types of structural breaks: level shift, shift in trend, and regime shift (both shift in level and in trend). Under the null hypothesis of stationarity with an endogenous structural break the Andrews – Zivot test has three specifications (see Table 2).

Table 2. The Andrews – Zivot (1992) test for an endogenous structural break: hypothesis specification

Alternative hypothesis $H_1 : \alpha < 1$	$y_t = \mu + \alpha y_{t-1} + \beta t + \theta DU_t(\tau_B) + \gamma DT_t(\tau_B) + \varepsilon_t$	**Null hypotheses**
Level shift	(A) $y_t = \mu + \alpha y_{t-1} + \theta DU_t(\tau_B) + \varepsilon_t$	$H_0 : \theta = \beta = 0$, $\alpha = 1$
Trend shift	(B) $y_t = \mu + \alpha y_{t-1} + \beta t + \gamma DT_t(\tau_B) + \varepsilon_t$	$H_0 : \beta = \gamma = 0$, $\alpha = 1$
Regime shift	(C) $y_t = \mu + \alpha y_{t-1} + \beta t + \theta DU_t(\tau_B) + \gamma DT_t(\tau_B) + \varepsilon_t$	$H_0 : \theta = \beta = \gamma = 0$, $\alpha = 1$

Source: own creation

Where $DU_t(\tau_B) = \begin{cases} 1, t > \tau_B; \\ 0, t \le \tau_B. \end{cases}$ and $DT_t(\tau_B) = \begin{cases} t - \tau_B, t > \tau_B; \\ 0, t \le \tau_B. \end{cases}$ are dummies for additive shift in level and shift in trend, τ_B – break moment.

The results of the Andrews – Zivot test for endogenous structural change with the specifications of the alternative hypothesis A, B, C are presented in Table 3 below.

Table 3. Endogenous structural break: results of the Andrews – Zivot test (1992), min t-statistics

Economic activity	Costs of materials per ruble of output (SMC) (break moment, year: quarter)			Relative PPI index (RPPI) (break moment, year: quarter)			Fixed capital investment, in 2004 prices (INV) (break moment, year: quarter)			R&D investment, in 2004 prices (INV) (break moment, year: quarter)			Foreign direct investment (break moment, year: quarter)		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
1. C	-11.1*** 06:3	-7.53*** 05:2	-10.1*** 06:3	-3.50 08:2	-2.96 05:2	-5.11** 08:2	-4.29 06:1	-3.21 05:2	-4.56 08:3	-5.69*** 08:3	-4.31* 05:2	-5.29** 08:3	-4.45 07:4	-3.72 05:2	-6.66*** 07:2
2. CA	-11.3*** 06:3	-6.98*** 05:2	-9.48*** 06:3	-3.28 08:2	-2.95 05:2	-4.99* 08:2	-4.15 06:1	-3.10 05:2	-4.56 08:3	-6.00*** 08:3	-5.12*** 05:2	-5.30** 08:3	-4.44 07:4	-3.72 05:2	-6.58*** 07:2

3. CB	-7.47*** 06:2	-6.03*** 05:2	-6.99*** 06:2	-2.91 05:4	-2.34 05:2	-3.81 06:2	-5.12 06:1	-3.94 05:2	-5.62*** 05:3	-4.06 08:2	-2.63 05:2	-4.67 07:3	-5.80*** 08:4	-4.25* 05:2	-6.28*** 08:1
4. D	-3.09 08:3	-2.41 05:2	-6.23*** 07:3	-3.13 08:2	-2.95 05:2	-4.90* 08:2	-4.36 07:1	-4.03 05:2	-4.69 05:3	-6.59*** 06:3	-5.77*** 05:2	-6.58*** 05:2	-4.80** 05:4	-4.53** 05:2	-5.67*** 05:2
5. DA	-4.82** 08:1	-3.62 05:2	-8.50*** 07:3	-5.55*** 08:2	-2.48 05:2	-5.86*** 08:2	-5.30** 08:3	-4.64** 05:2	-5.45** 08:3	-4.40 05:3	-3.56 05:2	-4.31 05:3	-8.31*** 05:3	-6.26*** 05:2	-8.85*** 06:4
6. DB	-4.58* 08:3	-1.48 05:2	-4.67 08:2	-2.60 06:4	-2.05 05:2	-4.84* 08:2	-5.04** 08:4	-4.22* 05:2	-6.31*** 08:2				-6.42*** 05:3	-3.91 05:2	-6.51*** 05:3
7. DC	-3.59 05:3	-3.26 05:2	-4.75 06:3	-3.06 06:4	-2.27 05:2	-4.75 08:2	-4.65* 07:3	-4.14 05:2	-5.01* 05:4						
8. DD	-3.99 08:4	-3.26 05:2	-4.39 08:3	-3.77 08:2	-3.47 05:2	-5.34** 08:2	-3.97 07:1	-3.49 05:2	-4.04 07:1						
9. DE	-3.91 08:3	-1.45 05:2	-3.18 07:3	-2.88 06:4	-2.51 05:2	-4.00 08:2	-4.14 06:1	-3.84 05:2	-3.92 08:1	-4.48 06:2	-3.30 04:2	-4.30 07:2	-4.64* 07:4	-4.28* 05:2	-11.5*** 07:4
10. DG	-2.96 07:3	-1.83 05:2	-3.27 06:4	-2.83 07:3	-2.32 05:2	-3.62 08:1	-4.54 08:3	-3.56 05:2	-4.97* 08:3	-5.16** 08:1	-5.06*** 05:2	-5.19** 06:3			
11. DH	-4.20 08:3	-2.86 05:2	-3.31 07:3	-3.14 06:4	-2.23 05:2	-3.66 07:4	-3.72 05:4	-2.38 05:2	-5.07* 06:4	-2.11 06:2	-2.52 05:2	-4.70 07:3			
12. DI	-4.44 08:1	-3.40 05:2	-5.83*** 07:3	-3.59 06:2	-1.83 05:2	-4.10 08:2	-4.52 07:1	-3.44 05:2	-4.35 08:1	-3.51 06:2	-2.94 05:2	-5.01* 07:4	-4.97** 08:3	-4.65** 05:2	-6.06*** 08:1
13. DJ	-3.78 08:3	-2.01 05:2	-3.43 07:3	-2.40 06:1	-2.08 05:2	-2.64 07:1	-3.98 07:1	-3.69 05:2	-4.59 08:1	-4.37 08:3	-3.22 05:2	-4.28 05:2	-5.10** 08:1	-4.33* 05:2	-5.86*** 08:1
14. DL	-7.46*** 08:3	-1.68 05:2	-6.36*** 08:3	-3.13 06:4	-2.59 05:2	-3.46 07:4	-4.29 05:4	-3.80 05:2	-5.43*** 08:2	-4.05 05:3	-3.74 05:2	-4.21 06:3			

15. DM	-2.73 08:3	-1.72 05:2	-2.93 06:3	-2.96 06:4	-2.47 05:2	-5.05*** 08:2	-4.85** 07:1	-3.99 05:2	-5.18** 07:2	-5.56*** 06:3	-4.78** 05:2	-5.34** 05:2	-4.94** 08:4	-3.83 05:2	-5.38*** 08:3
16. DN	-6.00*** 08:3	-2.68 05:2	-4.77 08:1	-4.35 08:2	-2.06 05:2	-3.88 08:2	-5.48*** 08:3	-3.76 05:2	4.99* 08:3	-4.66* 08:1	-4.36* 05:2	-5.91*** 08:1	-4.65* 08:4	-4.31* 05:2	-3.66*** 07:2
17. E	-2.75 05:2	-2.01 05:2	-3.41 05:2	-5.05*** 08:2	-2.36 05:2	-4.34 07:4	-4.98** 07:1	-4.62** 05:2	-4.69 07:1	-4.05 05:3	-3.33 05:2	-4.17 08:1			

Notes

1. The null hypothesis of endogenous structural change is rejected ***, **, * at 1, 5 and 10 per cent significance levels respectively.
2. The Andrews – Zivot asymptotical critical values: 1 per cent significance level (A) –5.34, (B) –4.93, (C) –5.57; 5 per cent (A) –4.80, (B) –4.42, (C) –5.08; 10 per cent (A) –4.58, (B) –4.11, (C) –4.82.
3. Results obtained using Gauss 6.*0*.

Source: own creation

According to the results of the Andrews – Zivot test the moment of structural break varies across the economic activities analyzed and depends on the time interval for which the test is run. Nevertheless, we may infer from Table 3 that the formal test for an endogenous structural break for economic activities, especially in manufacturing, confirms that the break in costs and investments, as well as in relative PPI, occurred in the 3–4th quarters of 2008, i.e. when Russian industry finally faced the world economic crisis.

However, a univariate analysis for testing the hypothesis of relationship between costs and investments is not enough. As we see from the results of the Andews – Zivot test even if we assume that the series analyzed are stationary with structural breaks the moments of these breaks differ. So the empirical model we estimate should account for breaks. The approach which may solve this problem is using the results of the Dickey – Fuller test, i.e. assuming that the series are non-stationary (even if we know that structural breaks may lead to the biased results of the Dickey – Fuller test), and analyze cointegrating equations with a single structural break for the series. Instead of analyzing different moments of breaks we search for a single break for all the processes at once, i.e. the break which would describe the dynamics of costs, investments, and relative PPI in equilibrium.

3.3 Cointegration: costs of production and investments

Before discussing tests for cointegration it should be mentioned that the hypothesis we test in this paper implies the exogeneity of investment, i.e. technological progress assumes that the dynamics of investment determines the dynamics of the costs structure. The dynamics of investments (and relative PPI) is supposed to precede the costs dynamics.

In case of endogenous structural change standard tests for cointegration are replaced by the residual-based approach introduced in Gregory and Hansen (1996). The Gregory – Hansen test implies three possible specifications of cointegrating equations: level shift (C), level shift with trend (C/T) and regime shift (C/S). The specification of the Gregory – Hansen cointegrating equation is the following:

$$smc_t^m = \mu + \alpha inv_t^m + \phi rppi_t^m + \begin{bmatrix} \beta t + \theta DU_t(t_B) + \gamma DU_t(t_B) inv_t^m + \\ + \lambda DU_t(t_B) rppi_t^m \end{bmatrix} + \varepsilon_t, \qquad (1)$$

where

- t is time trend;
- $DU_t(\tau_B) = \begin{cases} 1, t > \tau_B; \\ 0, t \le \tau_B. \end{cases}$ and $DT_t(\tau_B) = \begin{cases} t - \tau_B, t > \tau_B; \\ 0, t \le \tau_B. \end{cases}$ are dummies for

level shift (C) and shift in trend for (C/T) and (C/S), τ_B – break moment.

Table 4 below contains the estimates of cointegrating equations from the residual-based Engle – Granger and Gregory – Hansen two-step procedures. As it was already mentioned we analyze different types of investment processes which may influence the dynamics of the costs structure.

Table 4. The results of tests for cointegration (CI): Engle – Granger (1987), Gregory – Hansen (1996)

Economic activity	1st step: Parameter estimates (t-statistics in parethesis)					2nd step
	const	inv_t^m	$rppi_t^m$	t_B (year: quarter)	DU_t	CADF t-statistics (2nd step)
inv_t^m : **Fixed capital investment, deflated, in 2004 prices**						
3. CB	-6.32^{***}	0.235^{***}	-0.259	2006:3	-0.0883^{**}	
	(-5.24)	(3.15)	(-1.27)		(-2.59)	-8.22^{***}
11. DH	0.263	-0.0971^{*}	-0.157		-0.113^{**}	
	(0.386)	(-2.08)	(-0.854)	2009:1	(-2.33)	-5.41^{**}
12. DI	0.0584	-0.101^{***}	0.181^{**}		-0.103^{***}	
	(0.284)	(-7.75)	(2.30)	2008:4	(-8.19)	-5.07^{**}
14. DL	-2.49^{***}	0.0848^{**}	0.0620		-0.149^{**}	
	(-4.80)	(2.47)	(0.394)	2008:3	(-5.71)	-5.65^{**}
16. DN	-3.51^{***}	0.178^{**}	-0.109		-0.164^{**}	
	(-3.91)	(2.82)	(-0.483)	2009:1	(-2.50)	-5.12^{**}
inv_t^m : **R&D investment, deflated, in 2004 prices**						
1. C	-1.36	-0.186^{**}	-0.318		0.301^{***}	
	(-1.68)	(-2.58)	(-1.13)	2006:4	(4.65)	-7.60^{***}
2. CA	-1.54	-0.190^{*}	-0.412		0.350^{***}	
	(-1.52)	(-2.09)	(-1.44)	2006:4	(4.22)	-7.15^{***}
11. DH	-0.545^{***}	-0.0814^{***}	-0.435^{**}			
	(-3.87)	(-4.43)	(-2.52)	-	-	-3.99^{**}
12. DI	-1.49	-0.00983^{*}	0.171		-0.0799^{***}	
	(-0.0799)	(-2.07)	(1.14)	2008:2	(-3.74)	-4.85^{*}

Notes:

1. ***, **, * – OLS parameter estimates are significant at 1, 5, and 10 per cent level respectively. Asymptotical critical values for t-statistics with 15 degrees of freedom: (10 per cent) 1.75, (5 per cent) 2.13, (1 per cent) 2.95. Critical values for t-statistics with 16 degrees of freedom: (10 per cent) 1.75, (5 per cent) 2.12, (10 per cent) 2.92.
2. ***, **, * - the CADF test (2nd step of the Engle – Granger and Gregory – Hansen procedures) suggests there is no unit root in the residuals of cointegrating equation at 1, 5, and 10 per cent level respectively. The MacKinnon asymptotical critical values for the CADF test for T=19: (10 per cent) -3.28, (5 per cent) -3.68, (1 per cent) -4.54. The Gregory – Hansen asymptotical critical values: (10 per cent) -4.69, (5 per cent) -4.92, (1 per cent) -5.44.
4. Results obtained using Gauss 6.0.

Source: own creation

It can be seen from Table 4 that cointegration between the costs structure and fixed capital investment exists at the aggregated level in mining except of energy producing materials and for several manufacturing industries (manufacture of rubber and plastic products; non-metallic mineral products; electrical and optical equipment). For manufacture of non-metallic mineral products (DH) and manufacture of electrical and optical equipment (DI) we observe a statistically significant negative relationship between the costs structure and investment. Moreover, the additive structural change occurred in these industries at the end of 2008 and lowered costs of materials per ruble of output. As we already inferred from Figure 2 costs per ruble of output did decline at the end of 2008. Several explanations besides technological efficiency may be mentioned in this case. First of all, firms began to cut costs during the crisis. Secondly, relative producer prices also decreased meaning that prices of final goods grew faster than prices of costs. In order to avoid losses firms were forced to increase their prices of final goods as a response to higher prices of raw materials.

Table 4 shows that R&D investment has a significant influence on the dynamics of the costs structure in the same activities in mining and manufacturing. The elasticity of the costs structure to R&D investment (as our model is specified in logarithms) is negative when the influence of additive endogenous structural break is controlled for in cointegrating equations. Relative prices seem to have no influence on costs, except for manufacture of non-metallic products (DH). Therefore, despite the crisis there are technological improvements in production process of several economic activities, i.e. more R&D investments lead to lower unit production costs. However, positive results in terms of production and investment efficiency for only three economic activities do not appear to be very fruitful. The situation with investments in Russian industry after 2005 has undoubtedly changed.

It should also be mentioned that no significant results were obtained for foreign direct investments. So our hypothesis that this type of investment may have more transparent motivation than domestic investment fails.

4. Conclusion

In this paper the relationship between unit costs of materials and different types of investments was analyzed. Decreasing costs per ruble of output were revealed for several economic activities after the crisis of 2008. Comparing the dynamics of costs with the dynamics of investments was supposed to help explaining how the situation in Russian industry changed in the second half of the 2000-s. Previous research suggests that before 2005 investment growth led to technological progress and consequent output growth, i.e. production and investment efficiency was observed. However, after 2005 the situation in Russian industry began to change: we observe the slowdown of investment growth and high costs of production per ruble of output. The crisis seems to redouble the problems Russian industry faces with almost no evident signs of recovery observed yet. Manufacturing appears to suffer most.

The analysis concerned modelling the costs structure at the disaggregated economic activity level for quarterly data 2005–2009 and its link to investments and relative prices (controlling for endogenous structural breaks). However, econometric modelling encounters serious limitations due to the small sample problem which is accounted for by the changes in official industrial statistics starting from 2005 with adoption of the OKVED industrial classification harmonized with NACE. The results suggest that if the effect of the crisis is eliminated there are a few economic activities which may be referred to as efficient: higher fixed capital investments and R&D investments lead to lower costs per ruble of output. However, for the majority of activities the hypothesis of investment and production efficiency is not verified. The effect of investment on costs appears to vary across the activities, and the overall efficiency of investment can be seriously questioned. The positive result, however, is that investment appears to have a partial effect on costs in mining sector: mining except of energy producing materials shows R&D investment efficiency. Our previous research suggests that during the transformation period in Russian economy and even at the beginning of the 2000-s no technological progress in mining existed. As it was mentioned mining in Russia accounts for more than a half of total investment, so the question whether these funds are spent efficiently is crucial for Russian industry.

The core result of this paper is that the relationship between investments and costs previously found in 1995–2004 appears to continue its existence meaning that there is a long-term equilibrium between costs and investments. Therefore, from a theoretical point of view investment is not simply a source of capital accumulation, it influences the level of technology in industry through production costs as endogenous growth theory predicts. From a practical point of view this result means that the worst fears of investments spent in the ways that fail to develop advanced technologies may be mitigated. Technological progress in 2005–2009 is still observed for several mining and manufacturing economic activities. Costs per ruble of output become lower with the rise in investment.

Future research in this field implies controlling the relation between investments, technological progress, and economic growth. A model framework that would allow capturing both the investment effect of lower costs as a technological component and the effect of higher output as a growth component should be developed and tested. Moreover, the analysis of technological progress and the level of innovativeness in industry requires working with the firm-level data together with the data at the economic activity level of aggregation.

References

Aghion, P. – Angeletos, G.-M. – Banerjee, A. – Manova, K. 2005: Volatility and Growth: Credit Constraints and Productivity Enhancing Investment. *NBER Working Paper Series*, 11349.

Anatolyev, S. 2003: Advanced Econometrics. NES Lecture Notes, New Economic School (NES).

Banerjee, A. – Lumsdaine, R.L. – Stock, J.H. 1992: Recursive and Sequential Test of the Unit Root and Trend Break Hypothesis: Theory and International Evidence. *Journal of Business and Economic Statistics*, 10, 3, 271–87.

Baranov, E. – Bessonov, V. 1999: Production intensity indices. *Promyshlennost v Rossii*, 3, 4–12. p.

Bessonov, V. A. – Voskoboynikov, I.B. 2006: Prakticheskij analiz. On Dynamics of Fixed Capital and Investments in the Russian Economy in Transition. *HSE Economic Journal*, 2, 193–228. p.

Cook, S. 2003: Spurious rejection by cointegration tests incorporating structural change in the cointegrating relationship. *Discussion paper series*, Swansea University, Department of Economics.

Dickey, D.A. – Fuller, W.A. 1979: Distribution of the Estimators for Autoregressive Time-Series with a Unit Root. *Journal of the American Statistical Assiciation*, 74, 366, 427–431. p.

Dickey, D.A. – Pantula, S.G. 1987: Determining the Order of Differencing in Autoregressive Processes. *Journal of Business and Economic Statistics*, 5, 4, 455–461. p.

DiNardo, J. – Johnston, J. 1997: Econometric methods. 4th ed., McGraw-Hill. New York.

Engle, R.F. – Granger, C.W.T. 1987: Co-Integration and Error Correction: Representation, Estimation and Testing. *Econometrica*, 55, 2, 251–276. p.

Gregory, A.W. – Hansen, B.E. 1996: Residual-based tests for cointegration in models with regime shifts. *Journal of Econometrics*, 70, 1, 99–126. p.

Kantorovich, G. 2002: Times Series Analysis. Lecture Notes. *HSE Economic Journal*, 1-5.

Kantorovich, G. – Nazrullaeva, E. 2009: The Reduction of Costs per Unit of Output in Russian Industry: Direct Investment as a Reason. *HSE Economic Journal*, 13, 1, 59–79. p.

Maddala, G.S. – Kim, I. M. 1998: Cointegration, Unit Roots and Structural Change. Themes in Modern Econometrics. Cambridge University Press, Cambridge.

Leybourne, S. – Newbold, P. 2003: Spurious Rejections by Cointegration Tests Induced by Structural Breaks. *Applied Economics*, 35, 9, 1117–1121. p.

MacKinnon, J.G. 1991: Critical Values for Cointegration Tests. In Engle R.F. and Granger C.W.J. (eds): Long-run Economic Relationships: Readings in Cintegration, Oxford University Press, Oxford, 267-276. p.

Nadiri, I.M. – Mamuneas, T.P. 1994: The Effects of public infrastructure and R&D capital on the costs structure and performance of U.S. manufacturing industries. *The Review of Economics and Statistics*, 76, 1, 22–37. p.

Peretto, P.F. – Seater, J.J. 2007: Factor-Eliminating Technical Change. Economic Research Initiatives at Duke (ERID) *Working Paper*, 17.

Pollok, D.S.G. 1994: A Handbook of Time Series Analysis. Princeton University Press, Princeton.

Romer, D. 2006: Advanced Macroeconomics. 3rd ed. McGraw-Hill, Berkeley.

Van Dijk, F. 2007: Advance Time Series Econometrics. Lecture Notes, State University – Higher School of Economics, Helsinki.

Zivot, E. – Andrews, D.W.K. 1992: Further Evidence on the Great Crash, the Oil-Price Shock, and the Unit-Root Hypothesis. *Journal of Business & Economic Statistics*, 10, 3, 251–270. p.