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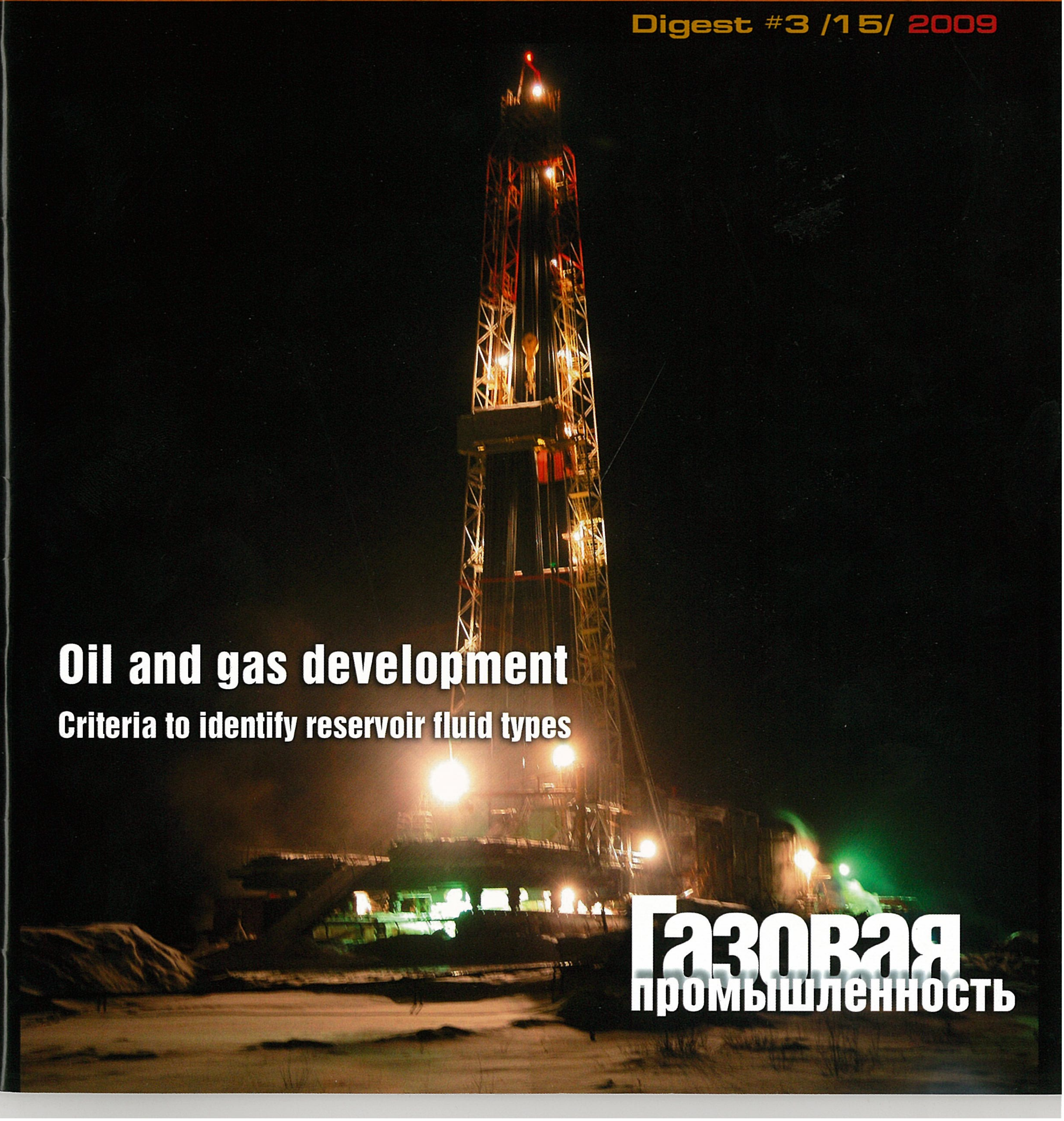
Digest #3 /15/ 2009



Oil and gas development

Criteria to identify reservoir fluid types

Газовая промышленность

Pareto-efficiency, cost minimisation, and innovations: the key Gazprom policies targeting gas production*

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Last year was remarkable in many ways: 16 years that Russia had switched from central planning to a market economy; 45 years of gas production in Tyumen region where Russia currently produces about 92% of its gas; and the 15th anniversary of Gazprom, the largest gas producer domestically and worldwide. Now it is believed critical to focus on econometric insights into Gazprom's operations in Tyumen to analyse, building on available results, the economic performance of company's production policy.

Econometric studies of Russian gas industry by the Central Economics & Mathematics Institute of the Russian Academy of Sciences (CEMI RAS) were initiated in the mid-1970s by L.E. Varshavsky.[1, 2] In the end of 1990s CEMI RAS director, academician V.L. Makarov, for the first time domestically, applied the Computable General Equilibrium Model-based approach to analysis of the Russian economy and developed his RUSEC model.[3] Building on RUSEC, two computable models were developed by the Experimental Economy Laboratory of CEMI RAS in association with the gas industry: RUSEC-GAZPROM, upon a Gazprom's request in 2002,[4] and the RUSEC-Natural Monopolies Model requested by the Russian Ministry of Economic Development and Trade in 2003.[5] Both models were used for analysis of growing natural gas price implications for efficiency of the Russian gas industry and for key macroeconomic indicators of this country.

The following two 2008 studies can be highlighted. First, L.V. Shamis's study[6] which addresses Gazprom gas production function with autonomous technical progress over 1990 – 2005 was studied, and on its basis, problems of labour and capital substitution applied to gas production were analysed. Next, two other studies were published[7, 8] to propose econometric models targeting production functions to enable gas production forecasting both in Tyumen region fields and in the entire Gazprom subsidiaries' operating area. This study is continuation to the above.

ECONOMETRIC STUDY AND ITS RESULTS

To assess consistency of these factors' elasticity estimates, two Cobb-Douglas production functions with constant returns to scale technology were chosen for this study:

- The Tinbergen function with time trend[9 (pp. 109–110)]

$$\Gamma_t = e^{\alpha_0}\bar{\Phi}_t^{\alpha_1} L_t^{1-\alpha_1} e^{\alpha_2 t}, \text{ and } \quad (1)$$

- The function with cumulative gas production

$$\Gamma_t = e^{\alpha_0}\bar{\Phi}_t^{\alpha_1} L_t^{1-\alpha_1} e^{\alpha_2 G_{1963,t-1}}, \quad (2)$$

Where: Γ_t = gross natural gas production over year t; L_t = average annual number of gas production personnel (employees) over year t; $\bar{\Phi}_t$ = average annual value of fixed industrial assets (FIA) in gas production (in constant 1990 prices) over year t; $G_{1963,t-1}$ = cumulative gas output from production start-up (1963) through year t–1; t = operating years; e = natural base for logarithms; and α_i = coefficients of production function (i = 0, 1, 2).

Now the production functions, (Eq. 1) and (Eq. 2), can be brought to a more convenient type for this econometric study by dividing them by L_t:

$$\frac{\Gamma_t}{L_t} = e^{\alpha_0}\left(\frac{\bar{\Phi}_t}{L_t}\right)^{\alpha_1} e^{\alpha_2 t}; \quad (1')$$

$$\frac{\Gamma_t}{L_t} = e^{\alpha_0}\left(\frac{\bar{\Phi}_t}{L_t}\right)^{\alpha_1} e^{\alpha_2 G_{1963,t-1}}, \quad (2')$$

Where: $\frac{\Gamma_t}{L_t}$ = labour productivity in the gas sector over year

* This study was supported by the Russian President Grant No. НШ-3890.2008.6 and by the Russian Foundation for Basic Research (project 08-06-00301-a). Summary of this study was reported at the VII International Workshop, "Multivariate statistical analysis and econometrics" (Tsakhkadzor), XXXI Acad. Shatalin's International Scientific Workshop, "Systemic modelling of socio-economic processes" (Voronezh), and at the International conference "Paths of innovation: new technologies for the gas industry (INNOTECH-2008)" (VNIIGAZ).

Table 1

Econometric study summary: one year-lagged production function of FIA for gas production by Gazprom subsidiaries in Tyumen region, 1965–1990

Production function	Coefficients (t-statistics)		R^2	DW	Breusch–Godfrey Lagrange multiplier test for the first-order autocorrelation of residuals
	α_0	α_1			
$\frac{\Gamma_t}{L_t} = e^{\alpha_0}\left(\frac{\bar{\Phi}_{t-1}}{L_t}\right)^{\alpha_1}$	–1.82	0.95	0.72	0.99	F-cm. = 0.70 [p = 0.41]
	[–2.75]	[8]			TR^2 = 0.76 [p = 0.38]

Note: In square brackets the p-value is sourced from;[10 (p. 68)] R^2 = coefficient of determination; DW = Durbin-Watson statistics; F-ст. = F-statistics; TR^2 = Breusch–Godfrey Lagrange multiplier test statistics.

t; $\frac{\bar{\Phi}_t}{L_t}$ = FIA per employee in gas production over year t.

1. The centrally planned economy, 1965 – 1990. These econometric studies of these production functions focus on Gazprom's output in Tyumen region (excluding Norilskgazprom), applied to centrally planned economy. Relevant statistics for gas production was derived from VNIIEGazprom yearbooks *Gas Industry in the USSR*[7, 8], summarising average annual value of FIA from the Form 11 (postage stamp) according to Russian Industry Classification (OKONKh 11231 "Natural gas production") for Tyumen region, and from average annual industry workforce statistics – from the Form 1-T (OKONKh 11231) regarding Tyumen.

As a result, it was found that for the 1965–1990 period, gas production can be adequately described by the one year-lagged production function of FIA

$$\frac{\Gamma_t}{L_t} = e^{-1{,}82}\left(\frac{\bar{\Phi}_{t-1}}{L_t}\right)^{0{,}95} \quad (3)$$

excluding time and cumulative production (see Table 1) which are statistically insignificant.

Statistical insignificance of time and cumulative production as well as low labour elasticity of gross gas production, $1 - \alpha_1$ at 0.05, point on the fact that during 1965-1990, growing gas production in Tyumen region was mostly supplied by rising FIA and progressive bringing new fields on stream.

2. Market economy, 1993–2007. In 2007 gas production by Gazprom subsidiaries in Tyumen (including Severneftegazprom) amounted to 507,698 m^3. The 1992–2006 statistics relating to gross and cumulative gas production as well as annual averages for FIA (in constant 1990 prices) was available in several sources.[7 (p. 20-21); 8 (p. 6-7)] Summaries for average annual employees in gas production for 1993–2004 were derived from Form 1-T OKONKh 11231, and for the 2005–2007 – (after the form 1-T was abolished) – from Form П-4 OKVED (Russian Classification of Economic Activities) 11.10.2, "Natural gas and gas condensate production."

The Gazprom subsidiaries' data for Tyumen region were summarised according to 2007 Gazprom Methodology Guidelines: the companies included Gazprom Dobycha Nadym, Gazprom Dobycha Urengoy, Gazprom Dobycha Noyabrsk, Gazprom Dobycha Yamburg, Tyumentransgaz, Purgaz (100%), Purgazdobycha, and Severneftegazprom. Since 1993, the annual averages for FIA and workforce for Tyumentransgaz (as its production in 1993–2007 fell only to about 0.1% of Gazprom's production overalls for the region) remain excluded from the totals. Gazprom's data regarding its gasfield employees at Purgazdobycha (according to OKVED 11.10.11, "Crude oil and petroleum gas production") over 2005–2006 were added to the summary data on employee numbers (OKVED 11.10.2) for the same years.

The econometric study of functions and for 1993–2007 is built around the least squares in Eviews 6.0 software package and statistics from Table 2.

The results showed that, in terms of classical econometric criteria and common economic vision, the 1993–2007 gas production by Gazprom subsidiaries in Tyumen would be likely best described by the following one year-lagged production functions of FIA (see Table 3):

- Function with time trend

$$\frac{\Gamma_t}{L_t} = e^{168}\left(\frac{\bar{\Phi}_{t-1}}{L_t}\right)^{0{,}89} e^{-0{,}085t}, \quad (4)$$

- Function with cumulative production through year $t - 1$

$$\frac{\Gamma_t}{L_t} = e^{-1{,}20}\left(\frac{\bar{\Phi}_{t-1}}{L_t}\right)^{0{,}89} \times e^{-1{,}68 \cdot 10^{-7} G_{1963,t-1}}, \quad (5)$$

- Function with cumulative production through year $t - 2$

$$\frac{\Gamma_t}{L_t} = e^{-1{,}25}\left(\frac{\bar{\Phi}_{t-1}}{L_t}\right)^{0{,}89} \times e^{-1{,}67 \cdot 10^{-7} G_{1963,t-2}}. \quad (6)$$

The following is believed to apply here: First, these func-

Table 2

Statistics for econometric study of production functions: Gazprom subsidiaries (including Severneftegazprom) in Tyumen region, 1992 – 2007

Year t	Gross gas production, million m³ Γ_t	Average annual value of FIA (in constant 1990 prices), thousand non-denominated roubles $\overline{\Phi}_t$	Average annuals for employed in gas production L_t	Cumulative gas production since 1963 by year, , million m³ $G_{1963,t-1}$
1992	–	9,682,311	–	4,747,048
1993	533,438	10,083,994	8,894	5,296,510
1994	528,721	10,598,310	9,643	5,829,948
1995	518,731	11,244,786	10,706	6,358,669
1996	526,438	12,139,590	11,818	6,877,400
1997	495,795	13,238,623	12,550	7,403,838
1998	514,626	13,954,843	13,068	7,899,633
1999	509,913	14,558,696	17,506	8,414,259
2000	496,891	15,628,308	20,261	8,924,172
2001	487,781	17,646,261	25,781	9,421,063
2002	492,786	20,095,333	26,806	9,908,845
2003	506,360	22,766,464	28,167	10,401,630
2004	512,767	25,772,162	29,308	10,907,991
2005	514,634	28,034,862	24,208	11,420,757
2006	514,655	29,823,655	18,242	11,935,391
2007	507,698	N/A	18,141	12,450,046

Table 3

Summary for econometric study of one year-lagged production function of FIA over 1993–2007 (based on Table 2 data and observations count, 15)

Production function	Coefficients (t-statistics) α_0	α_1	α_2	R^2	DW	Breusch–Godfrey Lagrange multiplier test for first-order autocorrelation of residuals*	Shapiro-Wilk test, W, for normal distribution of residuals*
With time trend $\frac{\Gamma_t}{L_t} = e^{\alpha_0}\left(\frac{\overline{\Phi}_{t-1}}{L_t}\right)^{\alpha_1} e^{\alpha_2 t}$	168 [51]	0.89 [34]	–0.085 [–51]	0.996	1.05	Fcm. = 2.26 [p = 0.16] TR^2 = 2.55 [p = 0.11]	W = 0.95 [p = 0.47]
With cumulative production through year $t-1$ $\frac{\Gamma_t}{L_t} = e^{\alpha_0}\left(\frac{\overline{\Phi}_{t-1}}{L_t}\right)^{\alpha_1} e^{\alpha_2 G_{1963,t-1}}$	–1.20 [–6]	0.89 [31]	$-1.68\cdot10^{-7}$ [–46]	0.996	0.90	Fcm. = 3.50 [p = 0.09] TR^2 = 3.62 [p = 0.06]	W = 0,95 [p = 0.46]
With cumulative production through year $t-2$ $\frac{\Gamma_t}{L_t} = e^{\alpha_0}\left(\frac{\overline{\Phi}_{t-1}}{L_t}\right)^{\alpha_1} e^{\alpha_2 G_{1963,t-2}}$	–1.25 [–6]	0.89 [30]	$-1.67\cdot10^{-7}$ [–45]	0.995	0.93	Fcm. = 3.14 [p = 0.10] TR^2 = 3.33 [p = 0.07]	W = 0.95 [p = 0.45]

* Square brackets show p-values.[10 (p. 68)]

tions have a very high (about 1) coefficient of determination, R^2, revealing the statistic proximity between the dependent variable (labour productivity in gas production) and explanatory variables (fixed industrial assets per employee and time or cumulative production). Consequently, in 1993–2007 the variation of labour productivity more than by 99% was caused by changing fixed industrial assets per employee and time or cumulative production.

Second, the Shapiro-Wilk tests, W, do not deny normal distribution of investigated functions' regressive residuals (Eqs. 4 through 6) at 5% significance level,[11 (p. 605)] which enables us to test the main statistical hypotheses.

Third, since the Durbin-Watson test statistics appears inconclusive,[13 (pp. 174-175)] both the F-statistics and the Breusch–Godfrey Lagrange multiplier[13 (pp. 426-427)] test, TR^2, show no autocorrelation exists for residuals under 5% significance level.

Fourth, since t-statistics absolute values of production function coefficient estimates are over 2, all factors taken into account would be statistically significant. The signs of their coefficients well comply with economic vision. Indeed, the negative coefficient for time and cumulative production, α_2, evidences falling gas production since, under unchanged FIA, first, gas production is progressively falling over time and, second, rising cumulative production is accompanied by falling formation pressure and gas well productivity. At preset gas reserve depletion and employee numbers, the positive coefficient for fixed industrial assets per employee, α_1, indicates that gas production goes up with FIA increases.

Fifth, at fixed industrial assets per employee, the values of the coefficients α_1 with time trend (Eq. 4) and cumulative Gazprom subsidiaries production (Eqs. 5 through 6) appear to be equal, which proves consistency of the produced econometric estimates.

Sixth, the absolute values of correlation coefficients, r, between the explanatory variables are under 0.75,

$$r\left(\ln\left(\frac{\bar{\Phi}_{t-1}}{L_t}\right), t\right) = 0.15$$

$$r\left(\ln\left(\frac{\bar{\Phi}_{t-1}}{L_t}\right), G_{1963,t-1}\right) = 0.15$$

$$r\left(\ln\left(\frac{\bar{\Phi}_{t-1}}{L_t}\right), G_{1963,t-2}\right) = 0.14$$

Where: t = 1993,..., 2007 indicates the absence of multicollinearity effect.[14 (p. 75)]

Thus, both high quality of econometric model approximations (Eqs. 3 – 6) and the results for statistical hypothesis testing appear to agree with the fact that the parameters of production function estimators (Eqs. 3 – 6) derived using the least squares during 1993–2007 would likely be the best linear unbiased estimators among all others.

INNOVATIONS-DRIVEN DEVELOPMENT

Eq. 3, Eqs. (5 – 6), and Tables 1 and 3 evidence the first important result of this study. They prove that neutral technical progress coefficients, e^{α_0} (also called technological efficiency parameters[9 (p. 47-49)]) in production functions (Eqs. 5 – 6) describing gas production in market economy between 1993 and 2007 are much greater (1.75 and 1.85 times) than that for Eq. 3 function which models gas production in centrally planned environment over the 1965 – 1990 period.

Economic outcome I*. In the market economy of 1993–2007, significant gas production technology improvements were reported for Tyumen region which, all other things being equal, allowed gas to be produced under much smaller loads on available resources.*

Actually, improvements with technology helped diminish the falling Tyumen gas production in 1993 – 2001 and also enabled significant production growth after bringing new fields on stream in years to follow.

PARETO-EFFICIENCY AND COST MINIMISATION

Another important implication of our study is evident from Eqs. 4 – 6 and Tables 3 and 4. Labour elasticity of gross gas production, $1-\alpha_1$, for Gazprom subsidiaries (Eqs. 4 – 6) agrees in full with average wages (over 1993–2007 period) and social payments share (amounting to 0.11) in gas production cost for large Gazprom gas producers operating in Tyumen area.

Therefore, if the 1993–2007 average for wages plus social payment share in gas production cost are equal labour elasticity of gas production:

$$\frac{w_t L_t}{w_t L_t + r_t \bar{\Phi}_{t-1}} = 1-\alpha_1, \qquad (7)$$

then, as the material expenses share is very low (3.2%), the balance of the cost price in this average over 1993–2007 equals the capital elasticity of gas production:

$$\frac{r_t \bar{\Phi}_{t-1}}{w_t L_t + r_t \bar{\Phi}_{t-1}} = \alpha_1, \qquad (8)$$

Where: w_t = average annual wages and social payments per employee over year t; r_t = FIA price in year t including FIA amortisation and rental payments, tax payments (within prime costs, including Mineral Extraction Tax), capitalised repairs, and other expenses.

Economic outcome II*. For the 1993–2007 average, the marginal rate of substitution between labour and capital for Gazprom subsidiaries gas production in Tyumen region equals the factor price ratio:*

$$\frac{\partial \Gamma_t}{\partial L_t} \Big/ \frac{\partial \Gamma_t}{\partial \bar{\Phi}_{t-1}} = \frac{w_t}{r_t}. \qquad (9)$$

Table 4

tructure of gas production costs for large Gazprom producers in Tyumen region, 1993 – 2007

Year	Gas production cost structure, %						Enterprise share, %	
	Total expenses	Including: Wages and social payments (including the unified social tax);	Materials	FIA amortisation and rental payments	Tax payments (without unified social tax)	Other expenses	In Tyumen production totals	In Gazprom gas output in Tyumen
Average for 2005–2007	100	9.3	2.4	24.0	44.8	19.6	86.51	93.91
2004	100	14.5	2.7	19.5	50.1	13.3	91.22	96.59
2003	100	15.9	3.8	29.0	24.0	27.4	92.37	96.99
2002	100	15.1	4.6	26.3	34.6	19.4	93.44	96.93
2001	100	13.0	4.1	28.0	35.8	19.0	94.81	96.86
2000	100	13.8	4.8	14.6	40.0	26.8	95.90	97.17
1999	100	11.6	3.4	17.6	42.2	25.3	98.27	99.24
1998	100	9.6	3.9	21.9	41.0	23.6	99.70	99.99
1997	100	7.8	3.7	23.3	41.5	23.6	99.91	99.99
1996	100	7.6	2.8	35.4	31.8	22.4	99.50	99.50
1995	100	10.5	2.8	24.9	32.2	29.6	99.99	99.99
1994	100	10.7	2.6	15.8	36.5	34.3	99.99	99.99
1993	100	6.7	1.8	2.4	32.6	56.6	99.99	99.99
Average for 1993–2007	100	11.0	3.2	22.0	38.4	25.3	95.0	97.7

Indeed, Eq. 1 produces:

$$\frac{\partial \Gamma_t}{\partial L_t}=(1-\alpha_1)\bar{\Phi}_{t-1}^{\alpha_1}L_t^{-\alpha_1}e^{\alpha_2 t};$$

$$\frac{\partial \Gamma_t}{\partial \bar{\Phi}_{t-1}}=\alpha_1\bar{\Phi}_{t-1}^{\alpha_1-1}L_t^{1-\alpha_1}e^{\alpha_2 t},$$

and Eqs. 7 and 8:

$$\frac{1-\alpha_1}{\alpha_1}=\frac{w_t}{r_t}\frac{L_t}{\bar{\Phi}_{t-1}}.$$

Then, here comes Eq. 9

$$\frac{\partial \Gamma_t}{\partial L_t}\Big/\frac{\partial \Gamma_t}{\partial \bar{\Phi}_{t-1}}=\frac{1-\alpha_1}{\alpha_1}\frac{\bar{\Phi}_{t-1}}{L_t}=$$

$$=\frac{w_t}{r_t}\frac{L_t}{\bar{\Phi}_{t-1}}\frac{\bar{\Phi}_{t-1}}{L_t}=\frac{w_t}{r_t}.$$

This economic result has two consequences.

Consequence 1. Given the existing technologies and factor price averages over 1993–2007 period, Gazprom gas production in Tyumen region yielded target volumes, under the lowest labour and capital costs, i.e. the following applies:

$$\min_{L_t,\bar{\Phi}_{t-1}} w_t L_t + r_t\bar{\Phi}_{t-1}; \qquad (10)$$

$$e^{\alpha_0}\bar{\Phi}_{t-1}^{\alpha_1}L_t^{1-\alpha_1}e^{\alpha_2 t}\geq \hat{\Gamma}_t, \qquad (11)$$

Where: $\hat{\Gamma}_t$ = target gas production over year t.

It can be seen that Eq. 9 constitutes the first-order condition for Eqs. 10 and 11.

It should be also noted that the net cost of gas production in Tyumen and Yamal-Nenets regions is rising from year to year. According to our estimates for 2007, it amounted to nearly 360 roubles for 1000 m^3 which is about 8% higher than in 2006. One of key reasons behind the rising net costs is associated with increasing capital expenses for new gas production, which is mainly attributable to far more worse geological conditions, deeper drilling, and progressively challenging environment for future exploration and production activities. In fact, in 2007, average effective cost of bringing a gas well on stream in Tyumen region rose 1.31 times against 2006, while that for Yamal-Nenets region was reported to be 1.34 times higher.[15 (pp. 27–28)] At the same time, the 2007 effective value per 1 m development drilling in Tyumen region grew to about 31,000 roubles, or a 27% growth from 2006.

In addition, all other things being equal, the net cost of gas production, C_t^{min}, is progressively growing (over time t), or in line with ramping up cumulative gas production which can be seen from solutions of Eqs. 10 and 11:

$$C_t^{min}=\alpha_1^{-\alpha_1}(1-\alpha_1)^{\alpha_1-1}\times$$

$$\times\frac{r_t^{\alpha_1}w_t^{1-\alpha_1}}{e^{\alpha_0+\alpha_2 t}}\hat{\Gamma}_t, \qquad (12)$$

where Eq. 11 is replaced by any α_2 of the functions (Eqs. 4 – 6) and coefficient is negative (see Table 3).

Consequence 2. *With particular technology and factor price averages for 1993–2007, the use of labour and capital by Gazprom's producers in Tyumen region was apparently Pareto-efficient, i.e. the target production volumes could be made achievable only through simultaneous increases for one of such factors while decreasing another one.*

In other words, the efficiency (or optimality, according to Pareto,[16 (p. 84)]) indicates that Gazprom's producers employ in full their labour and funding available to them. In fact, Eq. 9 shows that the solution for Eqs. 10 and 11 is on the Pareto-efficient frontier identified by one of equations, Eqs. 4 through 6.

Table 5

Average wages and social payment share in gas production cost of major Gazprom subsidiaries in Tyumen region. Labour elasticity of gross gas production during 1993–2007, 1993–2006, 1994–2007, and 1994–2006

Year	Wages and social payment share of cost	Labour elasticity of gross gas production $1-\alpha_1$		
		Function with time trend	Function with cumulative production through year $t-1$	Function with cumulative production through year $t-2$
1993-2007	0.11	0.11	0.11	0.11
1993-2006	0.12	0.12	0.13	0.13
1994-2007	0.11	0.09	0.09	0.10
1994-2006	0.12	0.11	0.11	0.12

It is also easy to prove that Eq. 9 is the first-order condition for Eqs. 13 – 14 which is actually a dual one for Eqs. 10 and 11:

$$\max_{\bar{\Phi}_{t-1},L_t} e^{\alpha_0}\bar{\Phi}_{t-1}^{\alpha_1}L_t^{1-\alpha_1}e^{\alpha_2 t}; \quad (13)$$

$$w_t L_t + r_t \bar{\Phi}_{t-1} \le \hat{C} \quad (14)$$

Where: $\hat{C}$ = gas production cost over year t.

Therefore, we can prove that under given resource constraints, the Gazprom subsidiaries achieved their peak (or Pareto-efficient) gas production levels. According to literature,[17 (p. 100)] the output of product $\tilde{\Gamma}$ is considered Pareto-efficient if $\tilde{\Gamma} = \max F(\Phi, L)$ for all, $(\Phi, L) \in X$ where X is a feasible factor set, i.e. for any $(\Phi, L) \in X$, no $\Gamma = F(\Phi, L) > \tilde{\Gamma}^{1}$ exists.*

Consequently, any other combination of labour and capital, except the Pareto-efficient one from Eq. 9, leads to falling gas production in Eqs. 13 – 14 or to rising costs in Eqs. 10 – 11.

UNBUNDLING THE GAZPROM'S UPSTREAM? A QUESTIONABLE VIABILITY

Building on the Consequences 1 and 2 above, the first important conclusion can be made.

1. *Under given technologies and production costs, restructuring the Tyumen gas production sector in 1993–2007 – for example, Gazprom unbundling and shifting its subsidiaries to independents – would most likely have resulted in neither the lower costs nor in production growth, with no added benefits viable to labour and capital efficiency in gas production.*

This conclusion brings us to the following: As no other <better> condition exists other than Pareto-efficient case, and the Gazprom's gas production sector in Tyumen over 1993–2007 actually comprised the Pareto-efficient state – in terms of both costs and output – its splitting into independents would by no means ever improve the overall performance of regional gas production.

It can be seen in Table 5 that both the Pareto-efficiency and cost minimisation were obvious in previous years. In fact, the labour elasticity levels for gross gas production estimated by 14 observations over 1993-2006 and 1994–2007 as well as by 13 observations during 1994–2006 appeared to differ, at maximum, only by 0.01-0.02 from average wages and social payment shares across Gazprom's production operators in Tyumen region for those years. There is no much sense evaluating elasticity from smaller count of observations without the risk to erode precision of econometric estimates. First, the number of observations should be at least 5 times higher that for regression coefficients. Second, over t = 1993, ..., T period, where $T \le 2004$, strong correlation exists (about 90%) between the explanatory variables.

Production function estimates and experience gained during 1993–2007 bring the second important conclusion.

2. *As the Gazprom subsidiaries' production functions (Eqs.4 – 6) for 1993-2007 have the constant return to scale and, consequently, no optimum existed over that period with regard to size of Gazprom's gas production in Tyumen region, past experience prompts the following: nothing would ever prevent Gazprom from increasing its gas output in next years, including new field development, while remaining within the Pareto-efficiency range. In other words, the 1993–2007 experience shows that, all other things being equal, future development of major gas fields in Yamal-Nenets region (such as Bovanenkovskoye) would likely be more viable for gas independents, i.e. other than Gazprom.*

In fact, the solution to Eqs. 10 – 11 where instead of Eq. 11 any of Eqs. 4 – 6 functions is substituted, shows that the lowest cost for Gazprom subsidiaries comprises a linear function of gross gas production (see Eq. 12). Thus, marginal cost appears equal the average cost, irregardless of actual production levels.

Therefore, the results of production function econometric research, based on statistics from Rosstat (the Russian Federal State Statistics Service) and Gazprom, offer the following conclusions: During 1993–2007, the Tyumen production by Gaz-

* This definition of Pareto-optimal solution for a single-criterion (scalar) optimisation problem is a particular case for a more general definition of the Pareto-optimal solution regarding multi-criteria (vector) optimisation problems.[17 (p. 100)]

prom's operators largely remained driven by the market and innovations, progressively bringing the most recent field technologies, under minimum gas production costs, and using Pareto-efficiently benefits. In our opinion, these three key components have successfully tested performance of the Gazprom's upstream gas policy.

The following conclusions can be drawn from the analysis above.

- These gas production function-derived models explored in this study are believed useful for efficiency outlooks regarding Gazprom's gas production in Tyumen region for the next years and could help compare production performance in Russia and other countries.
- The results of this research lead us to conclusion that Gazprom gas production in Tyumen over 1993–2007 was successful for field development innovations, as shown by higher neutral technical progress coefficients and upstream cost minimisation. This should be addressed as an obvious advantage of Gazprom over many other Russian and foreign oil and gas producers – mainly benefiting from favourable world market prices rather than cost savings and production technology improvements.
- All other things being equal, gas production under minimum costs is believed profitable both for the Russian economy and for society in general as well as for Gazprom's production in Tyumen region, its shareholders and investors (as cost minimisation indicates the company is keen on gaining maximum revenue).
- During 1993–2007, Gazprom's gas output in Tyumen was reported to achieve the best performance of its existing technologies and Pareto-efficient gas production, as it was driven by company's strategic targets – maximising gas supply for both Russian and international customers.
- Technology improvements (which cut lifting-cost), Pareto-efficient gas production and development cost minimisation applied to Gazprom's operations in Tyumen region, both make any unbundling of its upstream business into independents an economically unviable option and would rather point to potential economic benefits from progressive expansion and consolidation of these operations as the choice of optimum size for this sector is highly unlikely to be a short-term issue.
- Technology improvements and Pareto-efficient gas production, which are focal for Gazprom subsidiaries, are believed profitable not only for the Russian economy, but potentially for other countries where Gazprom is already producing hydrocarbons or is expected come in future. Company's experience in Tyumen undoubtedly favours technology innovations, cutting costs, and optimised Pareto mineral resources performance in upstream sectors of these countries, and Gazprom is expected to do so in the future.
- The innovations-driven development and Pareto-efficiency of Gazprom's upstream operations in Tyumen region are attributable not only to its focuses on maximum revenues in market conditions, but also to high professional skills of personnel and managers of gas producers and associations, along with huge experience with gas development in the Far North gained over the past 45 years, as well as to preserving and supporting gas industry R&D centres by Gazprom in hard times of economic recession of the 1990s.

Therefore, if the innovative policy, Pareto-efficiency, and cost minimisation are set to remain – and in other core and non-core activity areas of Gazprom in addition to key upstream gas operations – this would obviously benefit its growth into a global energy producer and progressive consolidation of its competitive position in international markets, on the one hand, and progressive shifting all other segments and industries of entire Russia to innovations-driven development, on the other.*

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* In 2008, Gazprom's gas production in Tyumen region rose to 509,026 million m^3 while its average annual employees (according to OKVED 11.10.2, "Natural gas and gas condensate production") reached 18,981. In 2007, the value of new commissioned FIAs (in 1990 roubles), as stated in one source[18, (p. 38)] amounted to 1,275,726 thousand non-denominated roubles. During 1993-2008, the annual wages and social payment share in gas production cost for major Gazprom subsidiaries in Tyumen region averaged 0,10. The labour coefficients, $1 - \alpha_1$, in Eqs. 4 - 6 estimated for 1993-2008 amounted, respectively, to 0.09; 0.09 and 0.10.[19, (pp. 9-10)] Consequently, it can be stated that in spite of the world financial and economic crisis, Gazprom's output in Tyumen still remains Pareto-efficient and its subsidiaries produce natural gas at minimum costs.