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Macroeconomic production function of Russia and estimation of the marginal rate of technical substitution in the unprecedented socio-economic realities of 2020–2022

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Abstract

In the period 2020–2022 the Russian economy has been facing the new, unprecedented challenges of coronavirus and sanctions. In order to analyze the current state of affairs, we are offering an econometric study of Russia's macroeconomic production function for 1990–2022 and an estimation of the marginal rate of technical substitution under internal and external restrictions associated with the spread of the Wuhan coronavirus (SARS-CoV-2) and the conduct of Russia's special military operation in Ukraine, accompanied by increased sanctions pressure on the Russian economy. We have obtained several significant results. In the years 1991–1996 the marginal rate of technical substitution was increasing, and in 1997–2020 it was decreasing except for 2008–2009 and 2015. In the context of the Wuhan coronavirus pandemic, the main reasons for the Russian economy's decline in 2020 and growth in 2021 were, first of all, fluctuations in the world crude oil price, and not the Wuhan coronavirus pandemic as such. We did not find any evidence that the decline in the world crude oil price in 2020 was caused by a decrease in demand from China, since Russian oil exports to China increased. Contrary to many negative forecasts, the results of our forecasting of Russia's GDP for 2022 show

that under sharply increased sanctions pressure, with the world price of Urals oil at $60 per barrel, the average growth rate will be 0%, while at $70 it will be 4%, and at $80 it will be 7%. Under the reduced demand for Russian gas and the shutdown of the Nord Stream 1 gas pipeline, the forecast volumes of gross natural gas production by Gazprom (excluding Gazprom Neft) in the Tyumen Region for 2022, based on the exponential production function studied by econometric methods, range from 364 to 392 billion cubic meters. Using the example of Great Britain, where in 2021 the average actual export prices for Russian oil and gas were the lowest compared to other Western European countries, we discuss the economic inexpediency of setting marginal prices for Russian energy products by Western consumers.

Keywords: Russian economy, macroeconomic production function, world oil price, econometric forecasting, coronavirus restrictions, production capacities, natural gas production, oil and gas export, sanctions, price cap, UK economic and trade policy

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Introduction

An econometric study of the macroeconomic production function is one of the most important components of economic analysis and forecasting the dynamics of the development of any country's national economy, including Russia, especially in the unprecedented socio-economic realities of 2020–2022, i.e. under internal and external restrictions associated with the Wuhan coronavirus (SARS-CoV-2) pandemic and the conduct of Russia's special military operations in Ukraine, accompanied by increased sanctions pressure on the Russian economy from many of Russia's Western and overseas neighbors. A number of studies by Russian and foreign scientists are devoted to the study and the analysis of economic and mathematical models of production functions (for example, [1–6]). In our publications [7–9], we have studied the production function of the Russian economy in regard to the world price of Brent crude oil for 1990–2019. It is commonly known that 2019 was marked by the appearance, and 2020 was marked by the active spread of the Wuhan coronavirus, later named SARS-CoV-2 by virologists [9]. The socio-economic crisis which appeared during the pandemic did not bypass Russia. After some restoration of the world economy in 2021, the socio-economic crisis began to flare up again from the end of February 2022. That was mainly due to the sharply increased external economic and foreign policy pressure on the Russian national economy from the majority of Western countries, which disagreed with the launch of Russia's special military operation in Ukraine on February 24, 2022. Thus, it seems relevant to offer an econometric study of the macroeconomic production function of Russia for the period 1990–2021, covering the first two years of the pandemic, and to predict Russia's GDP for the first year of reinforced sanctions (2022).

1. Production function and statistics

For 1990–2021, we are offering an econometric study of the macroeconomic production function in regard to the world price of Brent crude oil [7–9]

$$Y_t = A(n_t Z_t)^{\gamma} V_t^{1-\gamma} e^{\delta O_t} \quad (1)$$

by the least squares method based on the statistical data of *Table 1*,

where Y_t is Russian GDP in constant 1990 prices for year *t*;

Z_t is average annual value of Russian economy fixed assets in constant 1990 prices for year *t*;

n_t is the average annual rate of use of production capacities in Russian industry for year *t*;

V_t is the average annual number of people employed in the national economy for year *t*;

O_t is the world price of Brent crude oil in 2010 US real dollars for year *t*.

Statistical data is presented in *Table 1*. Methodological features of the processing of time series of initial data for the purpose of their comparability are given below.

Average annual value of fixed assets. The calculation of the average annual value of fixed assets for 2020–2021 in constant prices was carried out according to the same methodology as in our previous works [7–9] (*Table 2*). Note that the value of the average annual price index in capital construction (now for investment products), which we calculated for 2020 using the Rosstat methodology (1.055), differs slightly from the value presented by Rosstat itself (1.057) due to the possible clarification of statistical data.

Average annual number of people employed in the national economy. Due to the 2016 change of the methodology for calculating the average annual number of people employed in the national economy by Rosstat, in order to proceed to an accurate comparison with the data for previous years, we calculate the values for 2017–2021 based on Rosstat's average annual growth rates for these years.

Average annual rate of use of production capacities in Russian industry. We also note that in 2020–2021 there was a significant multidirectional dynamic of the average annual rate of use of production capacities according to the Russian Economic Barometer (REB), the data of which we have been using since 1992 [10, p. 11], and according to Rosstat. Thus, according to the Russian Economic Barometer, the average annual rate of use of production capacities increased from 79% in 2020 to 84% in 2021, which is the highest since 1992 [13]. At the same time, the average rate of use of production capacities of industrial enterprises (OKVED C + D + E) n_{Rt} decreased from 62% in 2020 to 59% in 2021. To calculate it based on Rosstat data, we used the formula

$$n_{Rt} = \frac{n_{Ct} Z_{Ct} + n_{Dt} Z_{Dt} + n_{Et} Z_{Et}}{Z_{Ct} + Z_{Dt} + Z_{Et}},$$

where n_{Ct}, n_{Dt}, n_{Et} are arithmetic averages of the average monthly rate of use of production capacities for 12 months in year *t* according to OKVED C, D and E, respectively;

Z_{Ct}, Z_{Dt}, Z_{Et} are the average annual availability of fixed assets at constant prices in year *t* according to OKVED C, D and E, respectively.

This difference in the dynamics of the indicator may be explained by the fact that manufacturing enterprises predominate in the sample of the Russian Economic Barometer [14], and in the Rosstat sample fixed assets of extractive industries have the largest weight (38%), and extractive industries account for the largest decrease in the level of use of the average annual production capacity: from 64% in 2020 to 59% in 2021 (*Table 3*). At the same time, we do not know whether the Rosstat sample includes oil and gas companies, since Rosstat does not publish data on their production capacities. Thus, in our econometric study of function (1) for 1990–2021 we consider two values of the average annual rates of use of production capacities in 2021: the first is 84% according to the Russian Economic Barometer, and the second is the value equal to 75% which is obtained by multiplying the value of

Table 1.

Statistical data for 1990–2022

Year (t)	O_t, $/bb	n_t,%	Z_t, million rubles	V_t, thousands of people	Y_t, billion rubles
1990	28.65	100	1871649	75325	644
1991	24.50	100	1957288	73848	612
1992	23.14	73	2009054	72071	523
1993	19.72	74	2030396	70852	478
1994	18.91	61	2014984	68484	417
1995	18.57	60	1995229	66441	400
1996	22.90	54	1983823	65950	386
1997	22.22	54	1967098	64639	391
1998	15.48	55	1953216	63642	371
1999	22.10	62	1953747	63963	394
2000	35.54	66	1962932	64517	434
2001	31.89	69	1976006	64980	456
2002	32.99	70	1993845	65574	477
2003	36.24	73	2015564	65979	512
2004	45.05	74	2040209	66407	549
2005	62.07	76	2074736	66792	584
2006	72.72	78	2119496	67174	632
2007	76.18	80	2169707	68019	686
2008	94.95	77	2229842	68474	722
2009	64.13	65	2292706	67463	665
2010	79.64	72	2350079	67577	695
2011	99.97	78	2416816	67727	725
2012	101.61	79	2499424	67968	750
2013	99.21	78	2581327	67901	760
2014	91.59	77	2644159	67813	765
2015	53.65	75	2673133	68389	744
2016	46.98	77	2696319	68430	742
2017	55.91	79	2730170	68127	753
2018	70.01	78	2762511	68016	771
2019	64.37	79	2853595	67388	781
2020	42.73	79	2976450	65953	757
2021	70.04	84/75	3081807	67155	793
2022 (forecast)	60/70/80 *	85/76	3205079	66845	See *Table 6*

Sources: for 1990–2019 see [9], for 2020–2021 see Tables 2, 3 [10, p. 11], [11, pp. 49, 260], [12],Rosstat website (https://rosstat.gov.ru/labour_force).

* For 2022 the price forecast of Urals crude oil is presented in nominal US dollars (i.e. excluding the depreciation of t he US dollar) instead of Brent oil price.

Table 2.

Average annual value of fixed assets of the Russian economy in constant 1990 prices for 2020–2021 (for a full range of enterprises and organizations)

Year		2020	2021
At full book value in actual prices, million rubles [1)]	Availability at the beginning of the reporting year	344 257 518	372 337 039
	Commissioning of new fixed assets	18 505 278	22 863 184
	Liquidated fixed assets	1 275 458	1 515 663
	Availability at the end of the reporting year	361 804 806	397 315 582
Producer price index for capital construction, year as a multiple of the preceding year [2)]		1.055	1.051
Index of actual revaluation of fixed assets,year as a multiple of the preceding year [3)]		0.984	1.029
At full book value in comparable prices of 1990, million non-denominated rubles [3)]	Availability at the beginning of the reporting year	2 928 336	3 024 564
	Commissioning of new fixed assets	165 949	194 993
	Liquidated fixed assets	69 720	80 507
	Availability at the end of the reporting year	3 024 564	3 139 049
	Average annual value	2 976 450	3 081 807

Source: [1)] EMISS database (https://fedstat.ru/), [2)] Authors' calculations according to Rosstat methodology, [3)] The authors' calculations according to the methodology [7–9].

the indicator for 2020 according to the Russian Economic Barometer (79%) by the growth rate of the indicator for 2021 according to Rosstat (59%/62% = 0.952) (see *Table 3*).

2. Results of the econometric study: econometric and economic analysis

The results of the econometric study of function (1) are presented in *Table 4* and in *Figs. 1, 2.*

1. For the time period 1990–2020, which includes the first year of the coronavirus pandemic, the OLS estimates of the coefficients of the production function (1) remain almost unchanged compared to 1990–2019: the coefficient of neutral technical progress A slightly increases from 0.00058 to 0.00059, the elasticity of GDP with respect to fixed assets γ remains at the level of 0.80, and the coefficient at the world price of Brent oil δ remains equal to 0.003. In 1990–2020, all arguments of the production function remain statistically significant according to Student's t-test (*Figs. 1, 2*). Compared to 1990–2019, the values of t-statistics of the coefficient of neutral technical progress and elasticity of GDP

Table 3.

Average annual rate of use of production capacities in Russian industry

Years	n_{Ct}	n_{Dt}	n_{Et}	Z_{Ct}	Z_{Dt}	Z_{Et}	n_{Rt}	$\frac{n_{Rt}}{n_{Rt-1}}$	Recalculation REB's n_t
2020	64	61	60	43 390 182	40 706 473	30 820 307	62.14	–	79
2021	59	60	59	47 718 229	45 125 113	33 547 120	59.19	0.95247798	75
2022 (9 month)	58	61	62	n/a	n/a	n/a	60.00	1.013725079	76

Sources: EMISS database (https://fedstat.ru/), Rosstat website (https://rosstat.gov.ru/leading_indicators), [10, p. 11].

Note: We calculate the rate of use of production capacities for 9 months of 2022 based on fixed assets for 2021.

Table 4.

Results of an econometric study of production function (1) for 1990–2021

Time period, years	Coefficients and (in brackets) *t*-statistics			R^2	DW
	A	δ	γ		
1990–2019	0.00058 (–41)	0.80 (13)	0.003 (7)	0.96	1.24
1990–2020	0.00059 (–47)	0.80 (15)	0.003 (7)	0.96	1.24
At the average annual rate of use of production capacities $z_{2021} = 84\%$					
1990–2021	0.00067 (–47)	0.75 (14)	0.003 (7)	0.96	1.18
At the average annual rate of use of production capacities $z_{2021} = 75\%$					
1990–2021	0.00060 (–49)	0.79 (15)	0.003 (7)	0.96	1.22

Sources: for 1990–2019 see [9], for the remaining years we have made calculations based on the data *in Table 1*.

Note. Econometric study results for the time intervals from 1990 up to 2000–2018 see [9], *Figs. 1, 2*.

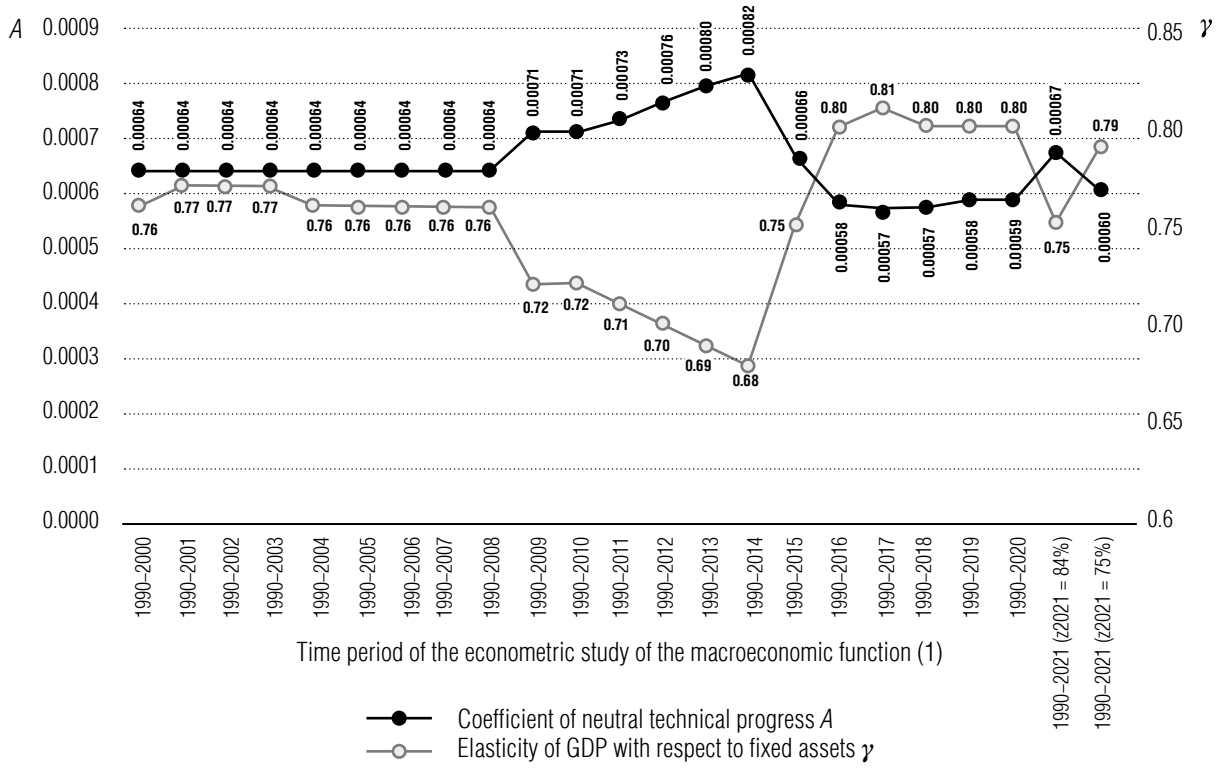

Fig. 1. Coefficients A and γ of function (1) for 1990–2021.
Source: [9] and *Table 4*.

with respect to fixed assets increases, and the value of *t*-statistics of the coefficient of the world price of Brent oil remains unchanged. The values of the coefficient of determination ($R^2 = 0.96$) and Durbin-Watson test ($DW = 1.24$) remain at the same level.

2. For the time period 1990–2021, which includes the first and the second coronavirus pandemic years, we offer two options for an econometric study of the parameters of the production function (1). That is due to significant differences in the directions of dynamics of the average annual rate of use of production capacities in the Russian industry for 2020–2021 published by the Russian Economic Barometer and Rosstat.

2.1. At the average annual rate of use of production capacities of 84% in 2021, published by the Russian Economic Barometer, for 1990–2021 the coefficient of neutral technical progress goes up to 0.00067, the elasticity of GDP with respect to fixed assets decreases to 0.75 and the coefficient at the world price of Brent crude oil remains unchanged at the level of 0.003 (*Figs. 1, 2*). The coefficient of determination remains at the level of the previous year ($R^2 = 0.96$), while the value of the Durbin-Watson statistics declines ($DW = 1.18$).

2.2. At the average annual rate of use of production capacities of 75% in 2021, which we calculated by multiplying the 2020 REB's rate by the Rosstat's rate of decline in the level of average annual rate of use of production capacities, there is a slight change in two parameters of the production function compared to 2020. Thus, the coefficient of neutral technical progress rises from 0.00059 to 0.00060, the elasticity of GDP with respect to fixed assets falls from 0.80 to 0.79, and the coefficient at

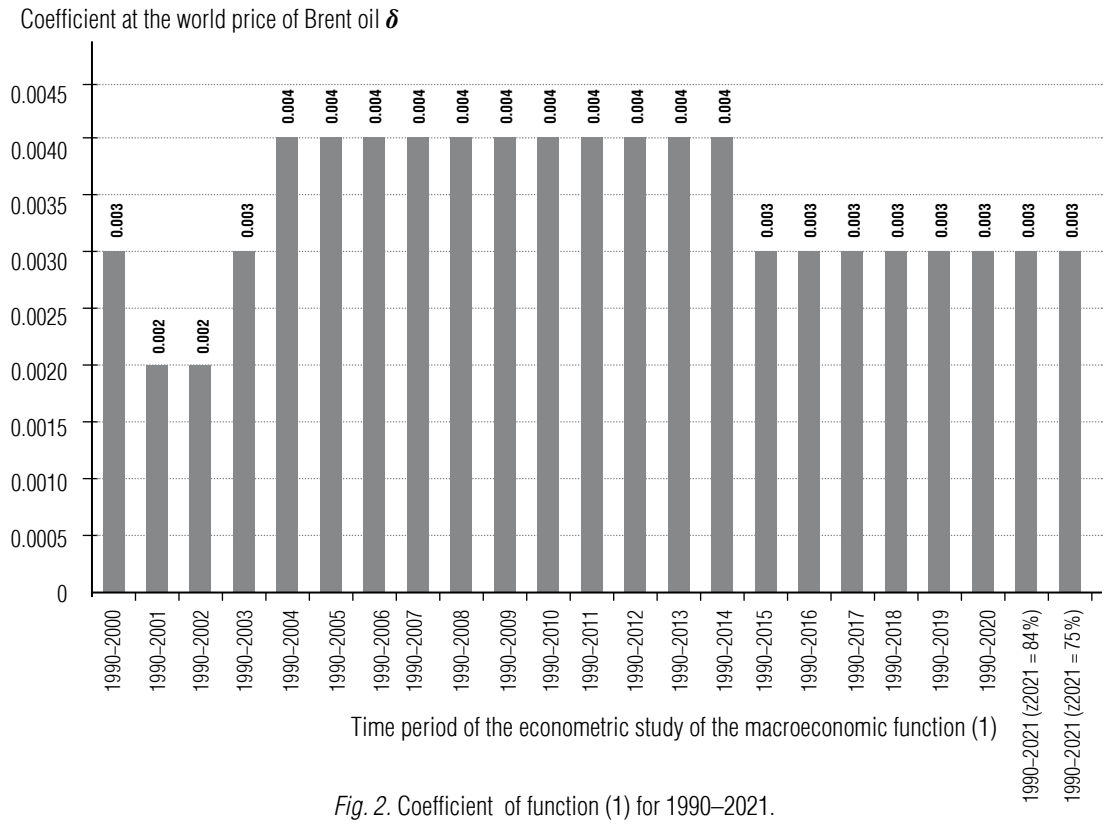

Fig. 2. Coefficient of function (1) for 1990–2021.

Source: [9] and *Table 4*.

the world price of Brent oil does not change and remained at the level of 0.003 (*Figs. 1, 2*). The coefficient of determination also remains unchanged ($R^2 = 0.96$), while the value of the Durbin-Watson statistics slightly decreases ($DW = 1.22$).

Thus, during 1990–2021, at the two considered values of the rate of use of production capacities of Russian industrial enterprises, the degree of dependence of Russia's GDP on the world crude oil price remains unchanged. The rate of 75% has almost no effect on the contribution of labor and capital to the expanded reproduction of GDP and the innovation-driven activity of the economy. However, at the rate of 84%, the innovation-driven activity of the national economy accelerates, the contribution of capital to the expanded reproduction of the Russian economy falls, and the contribution of labor, on the contrary, increases, i.e. there is a certain substitution of capital for labor. In this regard, it seems to us relevant to assess the marginal rate of technical substitution of factors in the Russian economy.

3. Marginal rate of technical substitution for 1990–2020

Let us calculate the marginal rate of technical substitution of labor for capital according to the formula [15]

$$MTRS_t = \frac{\gamma}{1-\gamma} \cdot \frac{V_t}{n_t z_t}, \qquad (2)$$

for 1990–2020 on the basis of the statistical data from *Table 1* and the OLS estimate of elasticity of GDP with respect to fixed assets of function (1) for 1990–2020. The calculation results are presented in *Table 5* and *Fig. 3*.

Table 5.

Marginal rate of technical substitution of factors in 1990–2020

Years	$\frac{\gamma}{1-\gamma}$	$\frac{n_t Z_t}{V_t}$	$MTRS_t$
1990	4	24.8	0.161
1991	4	26.5	0.151
1992	4	20.3	0.197
1993	4	21.2	0.189
1994	4	17.9	0.223
1995	4	18.0	0.222
1996	4	16.2	0.246
1997	4	16.4	0.243
1998	4	16.9	0.237
1999	4	18.9	0.211
2000	4	20.1	0.199
2001	4	21.0	0.191
2002	4	21.3	0.188
2003	4	22.3	0.179
2004	4	22.7	0.176
2005	4	23.6	0.169
2006	4	24.6	0.163
2007	4	25.5	0.157
2008	4	25.1	0.160
2009	4	22.1	0.181
2010	4	25.0	0.160
2011	4	27.8	0.144
2012	4	29.1	0.138
2013	4	29.7	0.135
2014	4	30.0	0.133
2015	4	29.3	0.136
2016	4	30.3	0.132
2017	4	31.7	0.126
2018	4	31.7	0.126
2019	4	33.5	0.120
2020	4	35.7	0.112

Source: the authors' calculations based on formula (2) and data from *Tables 1, 4*.

As is known, in a market economy under a constant volume of output and *caeteris paribus*, the marginal rate of technical substitution of production factors tends to decrease. And although we are considering the marginal rate under a changing volume of GDP, we can draw the following conclusions. In 1991–1996, there is an increasing trend in this indicator, which, in our opinion, is associated with the structural transformation of the Russian economy under the transition from a centrally-planned to a market economy, accompanied by a large-scale denationalization of property. For 1997–2020 in general, there is a downward trend, with the exception of 2008–2009 and 2015. In 2008–2009, the Russian national economy, like the entire world economy, experienced the financial and economic crisis, and the growth of the marginal rate of technical substitution was the result of the adaptation of the Russian economy to its consequences. Since 2014, after the reunification of Crimea with Russia, the Russian economy has been subjected to significant external economic pressure from most of Western countries, and therefore some increase in the marginal rate of technical substitution in 2015 illustrates the adaptation of the Russian economy to the new sanctions, and this adaptation turned out to be quite successful. It should be noted that in 2020, during the Wuhan coronavirus pandemic, the marginal rate continued to decrease, which indirectly indicates that the Russian economy was more easily able to adapt to the coronavirus than to the 2014 sanctions, although both were accompanied by economic recession.

4. *Ex-post* forecasts of Russian GDP for 2020–2021: causes for the decline in 2020 and growth in 2021

As we noted earlier, a distinctive feature of the macroeconomic production function (1) in 2001–2019 is not only the closeness of the *ex-post* forecast GDP values to the actual ones,

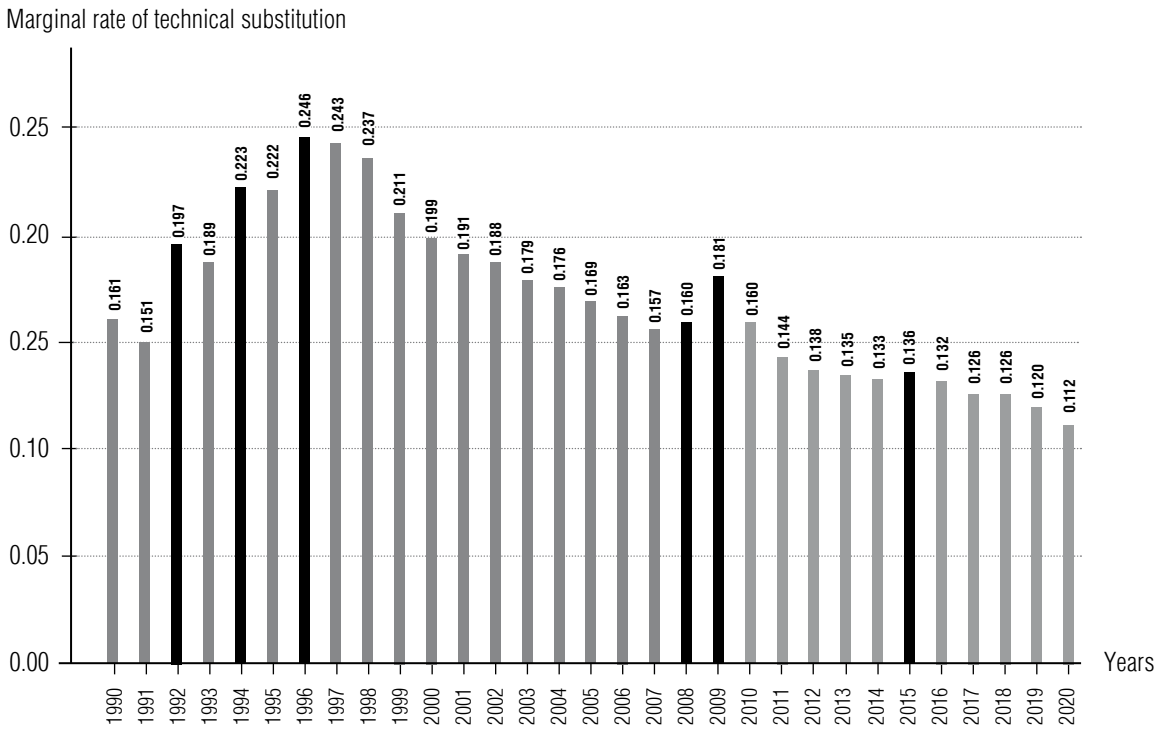

Fig. 3. Estimation of the marginal rate of technical substitution in Russia based on function (1) in 1990–2020.
Source: *Table 5*.

but also the coincidence of the dynamics of the *ex-post* forecast output with the dynamics of the actual one [7–9]. Such proximity and the same direction of dynamics are also observed in 2020–2021 (*Table 6*, *Fig. 4*).

Indeed, *ex-post* forecasts for all training samples show a decrease in Russia's GDP in 2020 and its growth in 2021, and at a rate of use of production capacities of 84% the *ex-post* forecast GDP grows faster than at a 75% (*Table 6*). Thus, it becomes clear why the average errors of the *ex-post* forecast for the test samples until 2021 at the 84% rate exceed the average errors at the 75% rate. The average errors for the test samples up to 2020 are in the range from 0.5% to 6.6%. Against the backdrop of constancy of OLS estimates of the macroeconomic production function (1) in 1990–2020, the main reason for the decline in GDP for 2020 was the fall in world oil prices from $64.37/bbl. in 2019 to $42.73/bbl in 2020. Thus, we cannot say that the Wuhan coronavirus spread was the main reason for the economic downturn in Russia. At the same time, the quarantine and isolation restrictions imposed by the central and regional authorities from late March to early June 2020 had a noticeable negative impact on the activities of public catering establishments, trade in non-food products, services and some types of transport [16, p. 252, 260; 17]. The greatest damage was inflicted on small and medium-sized enterprises in the above mentioned as well as in other sectors of the national economy.

There is a widely held view that COVID-19, which emerged in late 2019 in Wuhan, China, and the strict quarantine and isolation restrictions imposed by the PRC authorities, led to a decrease in demand for oil and petroleum products from China, which greatly contributed to a decrease in the world price of oil and a global recession [18]. However, the following fact testifies against this point of view. Accord-

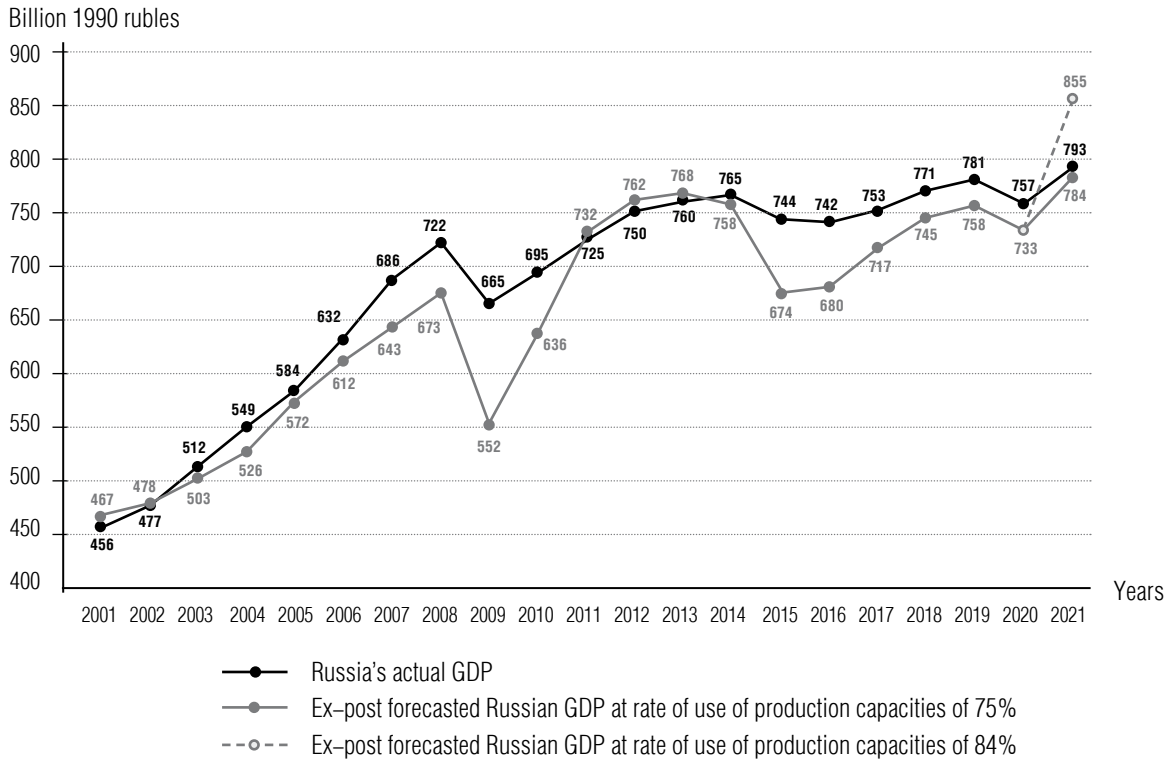

Fig. 4. Dynamics of the *ex-post* forecasted and actual Russian GDP for 2001–2021 at 75% and 84% rate of use of production capacities in 2021.

ing to the Russian Federal Customs Service[1], exports of Russian crude oil to China increased from 70.6 million tons in 2019 to 75.3 million tons in 2020 (in 2021, exports amounted to 71.0 million tons), and Russian natural gas exports increased from 0.3 billion m^3 in 2019 to 3.5 billion m^3 in 2020 and to 8 billion m^3 in 2021. Thus, in 2020 there was an increase in Chinese demand for oil and gas from Russia, despite strict quarantine in China. That does not support the idea that the Wuhan coronavirus is one of the main reasons for the fall in the world oil price through a decrease in Chinese demand for it. Our point of view is also confirmed by the results of an econometric study [19], which did not reveal a direct impact of the Wuhan coronavirus spread on the world market and the price of oil; it revealed only an inverse relationship between the frequency of the pandemic's mention in Internet search engines and the world oil price.

Returning to the forecast strength of Russia's macroeconomic production function (1), it should be noted that the increase in *ex-post* forecast GDP in 2021 was mainly due to an increase in the world oil price from $42.73/bbl. in 2020 to $70.04/bbl in 2021. In addition, growth was facilitated by an increase in the average annual number of employees from 66 million people in 2020 to 66.9 million people in 2021. *Ex-post* forecast GDP growth in the first version of the forecast was strengthened by

[1] See the website of the Federal Customs Service of the Russian Federation (http://stat.customs.gov.ru/analysis).

Table 6.

Russian GDP forecasts for 2022 and *ex-post* forecasts for 2019–2021

Forecast for year	Urals crude oil world price, USD dollars per barrel	Rate of use of production capacities, %	Learning samples from 1990 to year:																					
			2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Ex-post forecasted GDP, billion 1990 rouble																								
2019			758	740	744	759	784	778	778	784	784	787	789	776	766	759	755	777	791	792	791			
2020			733	725	726	733	743	741	741	742	742	735	735	730	723	716	713	742	762	764	763	761		
2021		75	784	764	768	786	815	809	808	815	816	821	823	808	795	787	784	806	820	822	821	819	818	
2021		84	855	833	838	857	888	881	881	888	889	890	892	876	861	851	846	877	898	901	899	897	896	
Forecasted GDP, billion 1990 roubles																								
2022	60	75	793	777	780	794	816	811	811	816	816	815	816	805	794	785	781	810	829	831	830	827	826	823
2022	60	84	863	846	850	865	888	883	883	888	888	883	885	871	858	848	843	881	907	910	908	905	903	880
2022	70	75	815	794	798	817	847	840	840	847	848	851	853	837	824	815	811	837	855	857	855	853	852	849
2022	70	84	888	866	870	890	922	915	915	922	923	922	924	907	891	880	875	910	935	938	936	933	932	909
2022	80	75	839	812	818	841	879	871	870	879	880	889	891	871	855	845	841	865	881	883	882	880	879	876
2022	80	84	913	885	891	916	957	948	947	957	958	963	966	943	925	913	907	941	964	967	965	962	961	939
Forecasted GDP growth rate, year as a multiple of the preceding year																								**Average rate**
2022	60	75	1.01	1.02	1.02	1.01	1.00	1.00	1.00	1.00	1.00	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.01	1.01	1.01	1.01	1.01	**1.00**
2022	60	84	1.01	1.02	1.01	1.01	1.00	1.00	1.00	1.00	1.00	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.01	1.01	1.01	1.01	1.01	**1.00**
2022	70	75	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.03	1.04	1.04	1.04	1.04	1.04	1.04	**1.04**
2022	70	84	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.03	1.03	1.03	1.04	1.04	1.04	1.04	1.04	1.04	**1.04**
2022	80	75	1.07	1.06	1.06	1.07	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	**1.07**
2022	80	84	1.07	1.06	1.06	1.07	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	**1.07**
Ex-post forecast errors																								
2020			3.2%	4.2%	4.0%	3.1%	1.9%	2.1%	2.1%	1.9%	2.0%	2.9%	2.9%	3.6%	4.5%	5.4%	5.8%	2.0%	0.7%	1.0%	0.8%	0.5%		
2021		75	1.1%	3.7%	3.2%	0.9%	2.8%	2.0%	1.9%	2.8%	2.9%	3.5%	3.7%	1.8%	0.3%	0.8%	1.2%	1.6%	3.4%	3.7%	3.5%	3.3%	3.2%	
2021		84	7.8%	5.1%	5.6%	8.1%	12.0%	11.1%	11.1%	12.0%	12.1%	12.3%	12.5%	10.4%	8.6%	7.3%	6.7%	10.6%	13.3%	13.6%	13.4%	13.1%	12.9%	
Average ex-post forecast errors																								
2020			4.4%	6.6%	6.5%	4.9%	4.4%	4.6%	4.9%	5.2%	5.6%	6.0%	6.6%	5.1%	4.8%	5.1%	6.0%	2.5%	0.9%	0.8%	1.0%	0.5%		
2021		75	4.3%	6.5%	6.3%	4.7%	4.3%	4.4%	4.7%	5.0%	5.4%	5.8%	6.3%	4.8%	4.3%	4.6%	5.3%	2.4%	1.4%	1.8%	1.9%	1.9%	3.2%	
2021		84	4.6%	6.5%	6.4%	5.1%	4.9%	5.0%	5.3%	5.7%	6.1%	6.5%	7.1%	5.6%	5.2%	5.4%	6.1%	3.9%	3.4%	4.0%	5.2%	6.8%	12.9%	

Note. *Ex-post* forecast errors and their average values are calculated using the formulas [9. p. 27–28]. The forecast GDP growth rate for 2022 is calculated as the ratio of the forecasted GDP for 2022 to the *ex-post* forecasted GDP for 2021.

an increase in the average annual rate of use of production capacities from 79% in 2020 to 84% in 2021, and in the second version of the forecast, GDP growth was somewhat weakened by a decrease in this rate to 75% in 2021 (*Fig. 4*). The average *ex-post* forecast errors of function (1) for 2021 vary from 1.4% to 6.5% (at a rate of use of production capacities of 75%) and from 3.4% to 12.9% (at a rate of use of production capacities of 84%).

Thus, according to the results of the econometric study of function (1) and *ex-post* forecasting based on it, the main reasons for the decline of Russian GDP in 2020 and growth in 2021 were fluctuations in the world oil price.

At the same time, since the end of February 2022, the Russian economy has been subjected to multiply increased sanctions pressure due to the disagreement of the governments of a number of European and American countries with the Russia's special military operation in Ukraine which started on February 24, 2022. This sanctions pressure was further exacerbated by explosions organized by international terrorists at vital Russian and international transport infrastructure facilities, which partially disabled the Crimean Bridge and completely deactivated Gazprom's main pipeline gas transportation facilities, Nord Stream 1, and one of the two lines of Ready-to-operate Nord Stream 2 (in accordance with the terminology adopted by the company, hereinafter *PJSC Gazprom* means the parent company and *Gazprom* means the group that includes the parent company and its subsidiaries).

The current difficult conditions require from the Russian economy as well as from the Russian government and Russian businesspersons new solutions to successfully and effectively overcome the negative consequences of foreign economic, political and financial restrictions imposed and newly introduced from abroad. Among them we can point out the increase in the well-being of the population and the maintenance of positive rates of economic growth. Meanwhile, according to Rosstat estimates, Russia's GDP in the first half of 2022 decreased by 0.4% compared to the same period in 2021 [20, p. 6]. It seems to us extremely important and relevant to give a forecast of Russia's GDP for 2022 based on the macroeconomic production function (1) that we have studied.

5. Econometric forecasting of Russian GDP for 2022

For the purposes of forecasting Russia's GDP for 2022, we chose the values of the factors of the macroeconomic production function (1) as follows (*Table 1*).

1. *Average annual value of fixed assets.* We assume that the average annual value of fixed assets in 1990 constant prices is growing at the same average annual rate as in 2020 and 2021. For these years, the average annual rate was 4%. Then the forecasting average annual value of fixed assets of the Russian economy (in constant 1990 prices) for 2022 will be equal to 3 205 079 million rubles (*Table 1*).

2. *Average annual rate of use of production capacities in the Russian industry.* For 2022 the rate of use of production capacities of Russian industrial enterprises was calculated, as for 2021, in two versions. In the first option, we use REB's data – the average value for 7 months of 2022, equal to 85% [10, p. 11]. In the second option, we calculate the average rate value according to the level growth rate according to Rosstat, which is the ratio of the average rate value for 9 months of 2022 to the average rate value for 12 months of 2021 (*Tables 1* and *2*).

3. *Average annual number of people employed.* The forecast rate of change in the average annual number of people employed in the Russian economy in 2022 was calculated as the ratio of the average number of labor force aged 15 years and older in the 1st half of 2022 (74 795.356 thousand people) to the same

indicator for 2021 (75 142.615 thousand people). This rate is equal to 0.995. Thus, the forecast average annual number of employees for 2022 will be equal to 66.845 thousand people (*Table 1*). In turn, the average labor force for the 1st half of the year is calculated on the basis of Rosstat data[2] as the arithmetic mean of the labor force for the 1st and 2nd quarters of the corresponding year (Q1 2021 – 75 034.1 thousand people, Q2 2021 – 75 251.2 thousand people, Q1 2022 – 74 698.4 thousand people, Q2 2022 – 74 892.4 thousand people). The expected decline in the number of people employed in the economy for 2022 is to some extent due to the outflow of some insignificant part of the labor force from Russia to abroad in March and October 2022.

4. *World crude oil price.* Instead of the world price of Brent oil in 2010 US dollars, we consider the world price of Urals oil (excluding the depreciation of the US dollar). That is due to the significant discrepancy (discount) formed in 2022 between the quotations of these two oil types. We will consider three scenarios for the world price of Urals oil: $60, $70, and $80 per barrel (*Table 1*). The first scenario is consistent with the irresistible desire of US Treasury Secretary Dr. Janet Yellen to purchase Russian oil by all over the world at any price less than $60 per barrel [21]. The third scenario corresponds to the forecasts for 2022 of the Ministry of Finance of Russia [22, p. 36]. And the second scenario is the average of the other two.

So, function (1) gives the following forecasts of Russia's GDP for 2022 with errors range from 1.5% to 7% (*Table 6*, *Fig. 5*). At a world price of Urals crude oil of $60 per barrel and at a rate of use of production capacities of 76% and 85%, GDP growth rates will range from –1% to 2%. At a world crude oil price of $70 per barrel and the rate of use of production capacities of 76% and 85%, the growth rate of GDP will range from 3% to 4%, and at a price of $80 per barrel and the rate of use of production capacities of 76% and 85%, the growth rate will range from 6% to 8%.

In other words, at both rates of use of production capacities and at a price of $60 per barrel, the average growth rate of Russian GDP will be equal to 0%, at $70 per barrel there will be a natural growth of the economy with an average rate of 4%, and at $80 per barrel, the average economic growth rate will be equal to 7% (*Table 6*).

Thus, at world prices for Urals oil ranging from $60 to $80 per barrel, the macroeconomic function of Russia (1) does not predict any significant economic downturn, contrary to the negative forecasts of some of our foreign colleagues, in particular, English ones, expecting a fall in Russia's GDP of at least 6% [23]. Our forecasts are consistent with the point of view of Academician S. Yu. Glazyev, who, speaking at the Moscow Academic Economic Forum on May 16, 2022, expressed the following idea: "Now Western forecasting centers are imposing a suicidal trajectory on us. Some say – minus 10% of GDP, others already say – minus 20% of GDP. This bacchanalia of negative forecasts should not program us for failure" [24, 25].

6. Discussion and forecasting of natural gas production by PJSC Gazprom in the Tyumen region for 2022

It should be noted that we consider the rate of use of production capacity only in industry, since data is not collected for other sectors of the Russian economy, including air transport, trade of imported goods and the banking system, which were affected to some extent by sanctions. In addition, the rate of use of pro-

[2] See Rosstat website (https://rosstat.gov.ru/labour_force).

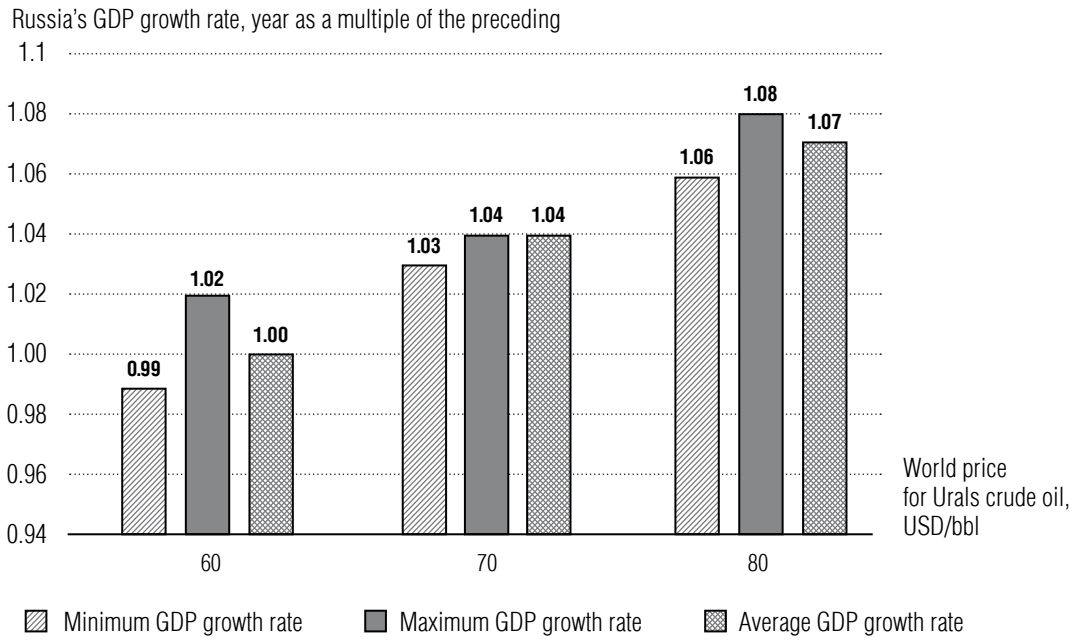

Fig. 5. Forecast of Russia's GDP growth rates in constant 1990 prices for 2022 at different values of the world price of Urals oil.
Source: *Table 6*.

duction capacity, which we are considering for 2022, may not take into account the capacities of oil and gas producing enterprises, including PJSC Gazprom subsidiaries reporting to Rosstat on the annual forms 1-TEK (oil) and 2-TEK (gas). When in the first half of 2022 the volume of production of Russian oil increased by 3.3% (according to Rosstat [26, p. 21]) and the volume of its export rose by 10–12% (according to various estimates [27, slide 3]) compared to the same period previous year, the volume of natural gas production decreased by 6.6% (according to Rosstat [26, p. 21]) and the volume of its export to non-CIS countries fell by 31% (according to Gazprom [28]) compared to the same period previous year. In this regard, the real rate of use of production capacities in 2022 may be lower than the value considered by us, and, therefore, the growth rates forecast of Russia's GDP may be somewhat lower. Indeed, as a result of the refusal of many European consumers to purchase Russian gas in 2022, caused by the disagreement of the governments of their countries with the conduct of Russia's special military operation in Ukraine, their unwillingness to buy gas from PJSC Gazprom for Russian rubles, as well as the disabling of two strings Nord Stream 1 and one line of Nord Stream 2, the volumes of gas produced by PJSC Gazprom have significantly decreased. Obviously, the main reduction in gas production will occur in the Tyumen region, where, as of January 1, 2022, PJSC Gazprom produced more than 90% of its gas. According to the forecasts [29] made on the basis of the production function of the form [30]:

$$\Gamma_t = e^{\alpha} \Phi_{t-1}^{\beta+\gamma G_{1963,\,t-2}} \qquad (3)$$

where Γ_t is gross natural gas production for year t;

Φ_t is the average annual value of fixed assets in constant 1990 prices for year t;

$G_{1963,\,t-1}$ is cumulative natural gas production since 1963 up to year $t-1$;

and according to the statistical reports of Gazprom [3], in 2022 natural gas production by Gazprom (excluding Gazprom Neft) in the Tyumen region will be range from 364 to 392 billion m^3 (*Fig. 6*, *7*).

We give these forecasts for 2022 on the basis of training samples for 1985–1991 and 1985–1993, since in the test time intervals of 1992–2021 and 1994–2021 function (3) has the smallest average *ex-post* forecast errors among all training samples (*Figs. 8*, *9*).

It should be noted that in [32], on the basis of an econometric study of function (3), the sustainability of the goals of the strategic development of the Gazprom gas production complex in the Tyumen region since 1985 was substantiated. This stability is due to stability of the parameters of function (3) over time, as well as the proximity and similarity of the directions of the dynamics of the actual and *ex-post* forecast gas production (*Fig. 6*). The negative dynamics of *ex-post* forecast production observed since 2015 and fluctuations in actual production relative to its curve (*Fig. 6*) indicate a forced strategic reduction in gas production by Gazprom due to several causes: (1) the uncertainty of export supplies to Europe, which increased sharply after the reunification of Crimea with Russia, (2) lack of delays in the commissioning of export pipeline capacities, (3) a refusal to buy Russian gas by some European consumers against the backdrop of Russia's special military operation in Ukraine, and, finally, (4) the disabling of Nord Stream 1 as a result of explosions organized by international terrorist groups that benefit from the destruction of long-term cooperation in the gas sector between Russia and Europe. It should be noted that all these negative actions of unfair competition are aimed at weakening one of the most efficient global oil and gas companies – Russian Gazprom, which, as empirically proven in [33, 34], since 1993 in the field of gas production has been a highly efficient energy company characterized by growing coefficient of neutral technical progress, declining unit cost of gas production at new fields and minimal production costs, the marginal and average values of which coincide and do not depend on the volumes of gas produced. We emphasize that, unlike the Russian Gazprom, we are not aware of similar econometric studies on other domestic and foreign oil and gas companies that would justify the increasing trend of their innovation-driven development and their being at the point of minimum cost for a quarter of a century.

At the same time, despite all these temporary difficulties, Russian Gazprom has been, is and will be a reliable supplier of natural gas, able to meet the demand for it from both Russian and foreign consumers in a timely manner.

In this regard, it is impossible to ignore the fact that in 2021–2022 a significant part of Western and overseas consumers of Russian oil and gas are striving to agree on a "price cap" (maximum price) for these energy resources or to completely abandon them. For many centuries, these Russia's foreign partners have been trying to buy Russian raw materials as cheaply as possible, and in return to sell small volumes of manufactured products at the highest possible prices. Here, the most illustrative example is the United Kingdom, whose principles of economic policy towards Russia were quite accurately disclosed by Dr. Adam Smith back in the 18th century. Smith wrote: "To Russia, for example, we send fine linen and other

[3] Statistics for 1985–2008 and the methodology for recalculating fixed assets into comparable prices are given in [30, 31]. For 2021, fixed assets were taken into account in accordance with RAS of Gazprom Dobycha Nadym LLC and Gazprom Dobycha Yamburg LLC (receipt of own fixed assets and the difference between leased fixed assets at the end and at the beginning of the year, taking into account their actual revaluation by PJSC Gazprom and its subsidiaries), as well as the commissioning of new fixed assets of PJSC Severneftegazprom. Fixed assets of LLC Gazprom Dobycha Urengoy and LLC Gazprom Dobycha Noyabrsk were not taken into account due to the lack of statistical information.

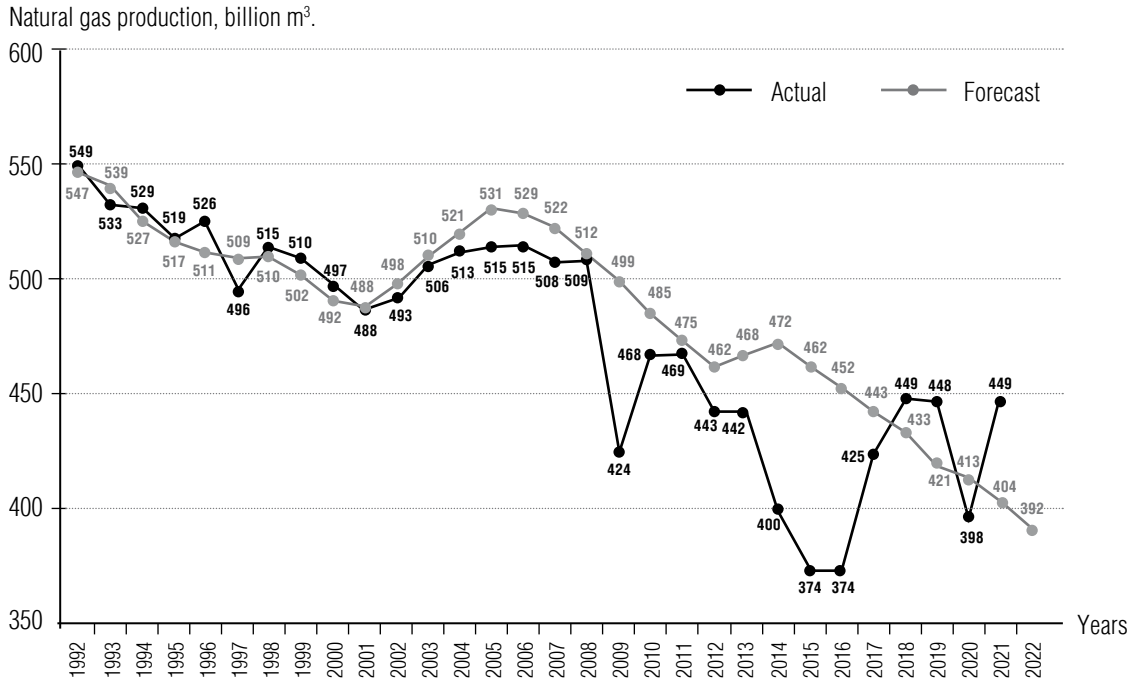

Fig. 6. Forecast for 2022, *ex-post* forecast for 1992–2021 and actual gross natural gas production by Gazprom (without Gazprom Neft) in the Tyumen region according to function (3) studied in 1985–1991, billion cubic meters.

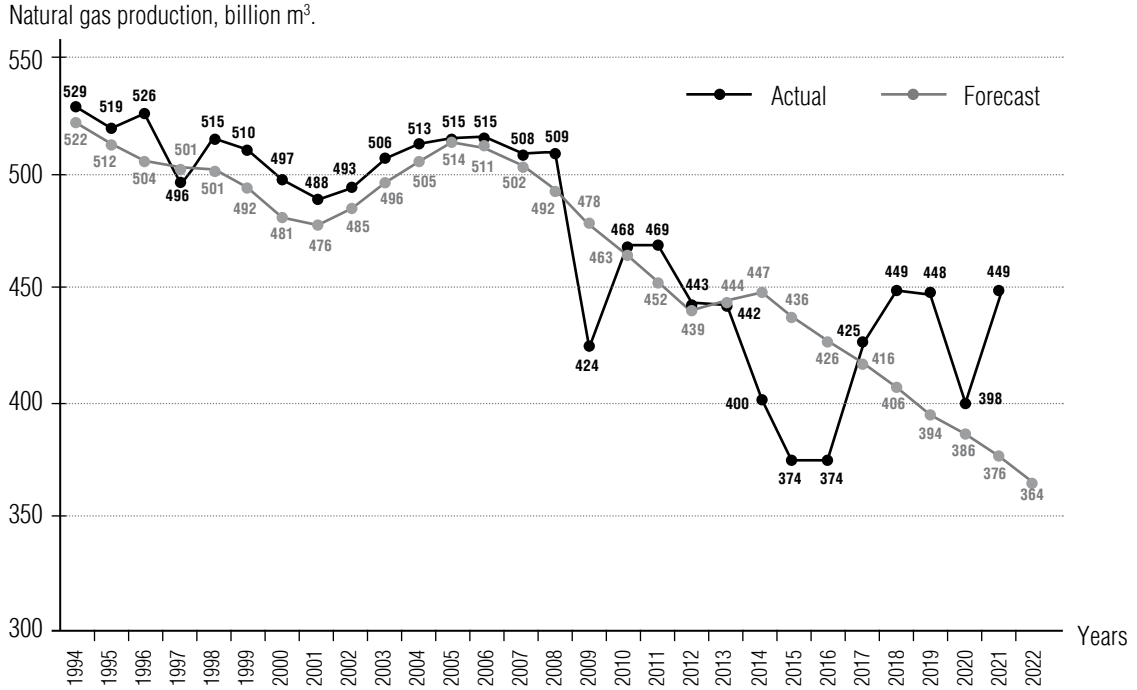

Fig 7. Forecast for 2022, *ex-post* forecast for 1994–2021 and actual gross natural gas production by Gazprom (without Gazprom Neft) in the Tyumen region according to function (3) studied in 1985–1993, billion cubic meters.

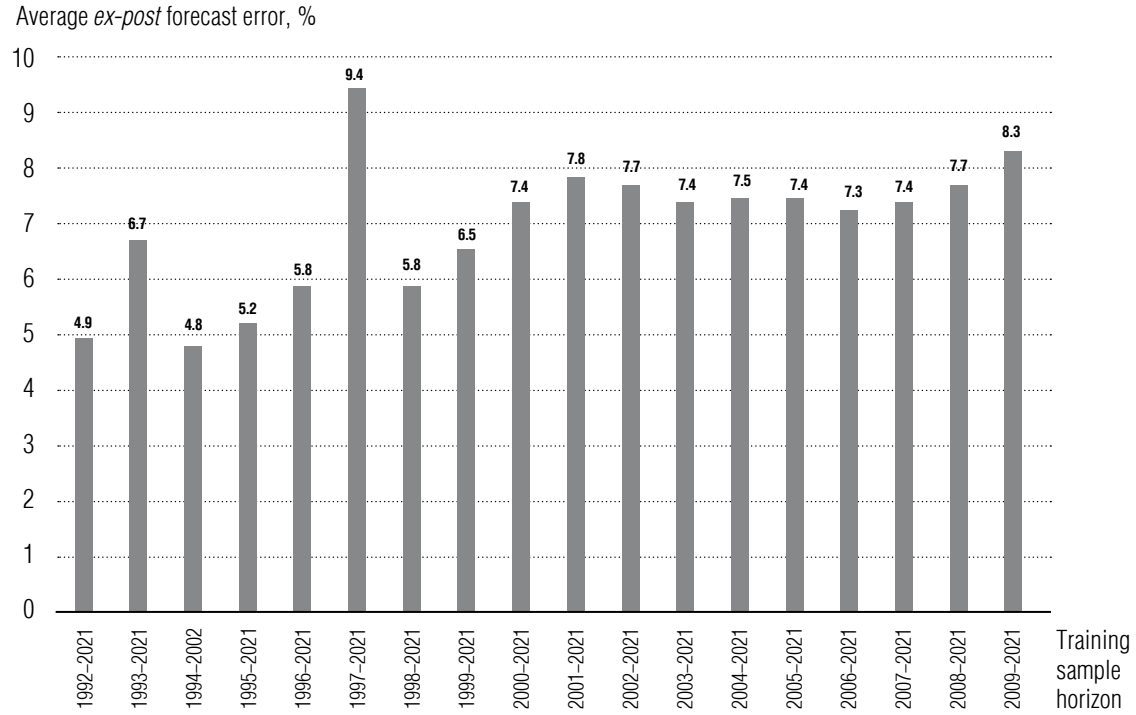

Fig. 8. Arithmetic mean of *ex-post* forecast errors of gross natural gas production by Gazprom (excluding Gazprom Neft) in the Tyumen region for 1992–2021 based on the training samples of function (3), studied from 1985 to 1991–2008.
Note. The average *ex-post* forecast errors are calculated using the formulas [9, p. 27–28].

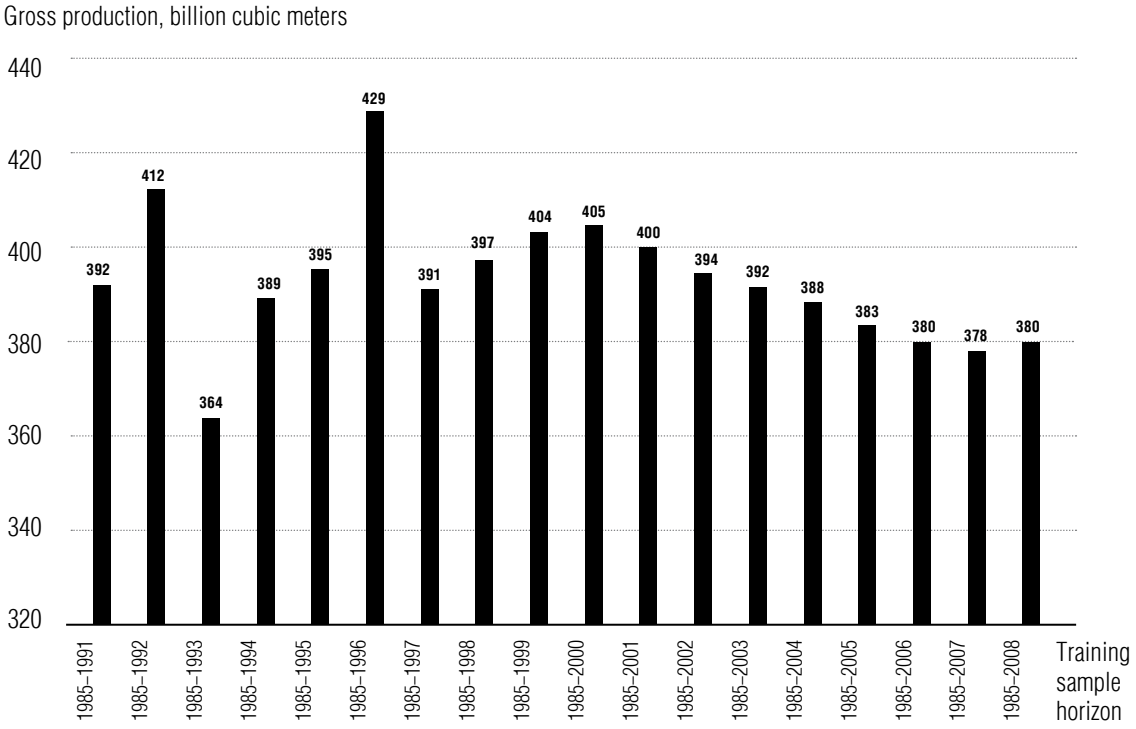

Fig. 9. Forecasts of gross natural gas production by Gazprom (excluding Gazprom Neft) in the Tyumen region for 2022 based on training samples of function (3) from 1985 to 1991–2008.

manufactured goods, and for a small quantity of these receive, in return, great quantities of unmanufactured goods. This kind of trade is very advantageous, because goods in an unmanufactured and rude state afford employment and maintenance to a great number of persons" [35, p. 247].

The economic and trade policy of England remains the same today. Thus, according to the Federal Customs Service of Russia[4], in 2021 Russia exported 12.3 million tons of goods to the United Kingdom in the amount of $22.3 billion at an average actual export price of 1.810 dollars per ton, and imported from it 0.5 million tons of goods worth $4.7 billion at an average actual import price of $9.393 per ton. The bulk of Russian exports were pearls and precious metals ($17.3 billion), fuel and energy minerals and ores ($3.7 billion), and most (at least three-quarters) of imports from the UK amounted to finished goods (at least $3.5 billion).

We should note that Russia sells oil and gas to the United Kingdom at a significant discount, i.e. much cheaper than to other Western European countries. Thus, calculations based on the data of the Russian Federal Customs Service show that in 2021 the average export price of Russian natural gas in gaseous state supplied to the United Kingdom ($131.56 per thousand cubic meters) was approximately at the same level of the average price of gas supplied by Russia to the allied Belarus ($131.78 per cubic meters) (*Fig. 10*). In 2020, the average price of Russian gas for the British, which amounted to $105.96 per thousand cubic meters, was even lower than for the Belarusians ($130.73 per thousand cubic meters). In 2021, Belgium was in second place in terms of the cheapness of Russian natural gas: the average export price for it was $143 per thousand cubic meters. Moreover, according to the Russian Federal Customs Service, in 2021, the average export prices for Russian liquefied natural gas and crude oil to the United Kingdom amounted to $185 and $457 per ton, respectively, which are lower than the average export prices of these energy resources sold by Russia to Belgium ($197 and $547 per ton), to France ($198 and $477 per ton), to the Netherlands ($236 and $463 per ton) and to Germany (oil – $483 per ton), which are geographically closer to Russia (*Fig. 10*).

Against this background, the desire of the British government to refuse to import cheap Russian energy resources or to buy them even more cheaper does not look economically justified. The recent seizure of Russian assets in the UK is even more unjustified. In early November 2022, the British government seized Russian assets worth £18 billion [23], comparable in size to the volume of all Russian exports to the UK in 2021 ($22.3 billion). Thus, Russia, having a positive trade balance with the UK and a number of other states and leaving the income from its net exports in these countries instead of investing in the growth of its own national economy, incurs significant losses over the years [36], which, as we may see, increased manifold in 2022 after the arrest of Russian foreign exchange reserves and other assets in many European countries and the United States.

Under these new conditions, Russia has the opportunity to revise its economic policy, to lower its centuries-old export dependence on raw materials and to transit to a new technical order [25] taking into account the active use of its significant production and rich scientific potential.

Conclusion

In this paper, we offered an econometric study of Russia's macroeconomic production function (1) in the unprecedented socio-eco-

[4] See the website of the Federal Customs Service of the Russian Federation (http://stat.customs.gov.ru/analysis).

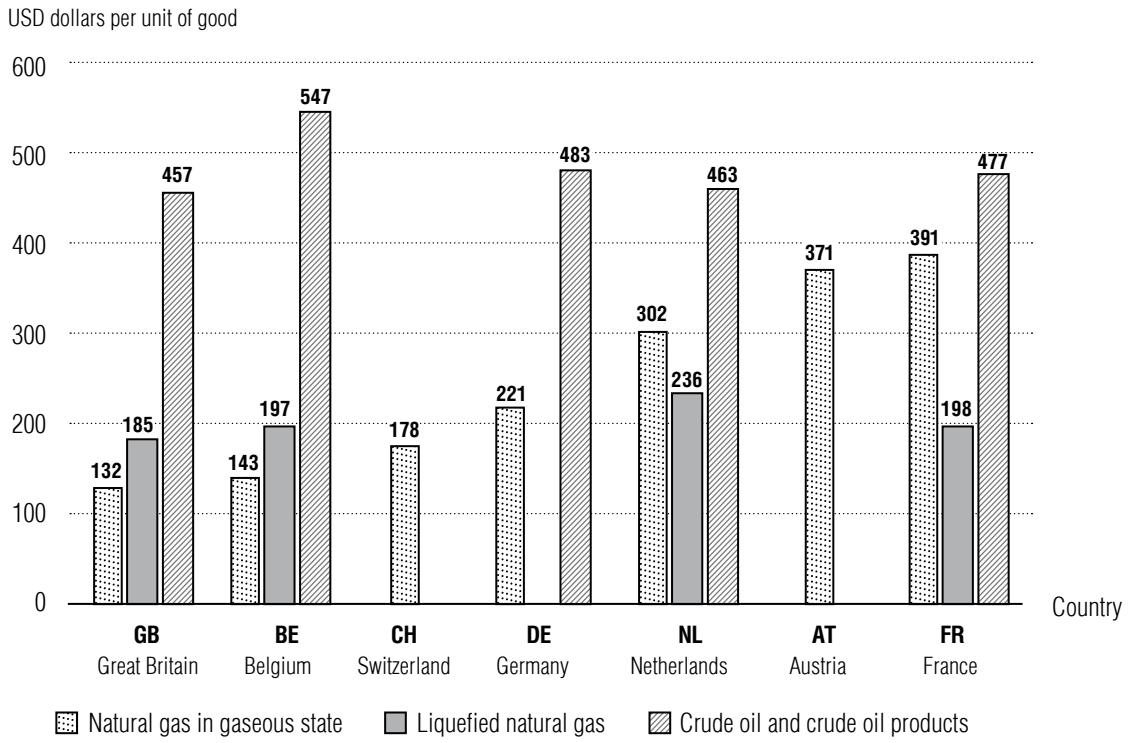

Fig. 10. Average export prices for Russian energy resources for Western European countries in 2021, USD per ton (natural gas in gaseous state – USD per thousand cubic meters)

Source: calculations based on data from the Federal Customs Service of Russia (http://stat.customs.gov.ru/analysis).

nomic realities 2020–2022, i.e. under internal and external restrictions associated with the Wuhan coronavirus (SARS-CoV-2) pandemic and the conduct of Russia's special military operation in Ukraine, accompanied by increased sanctions on the Russian economy from many Western countries. We also estimated the marginal rate of technical substitution for 1990–2020. The results of our econometric study, *ex-post* forecasting for 2020–2021 and forecasting for 2022 show the following:

1. In 1991–1996 there was an increase in the marginal rate of technical substitution, and in 1997–2020 we observed its decrease except for 2008–2009 and 2015. Its growth in the early 1990s we explain by the structural transformation of the Russian economy in the context of the transition from centrally-planned to market economy, accompanied by a large-scale denationalization of property. Increase in the marginal rate of technical substitution in 2008–2009 was a consequence of the reaction of the Russian economy to the global financial and economic crisis, and in 2015 it was a consequence of the adaptation of the national economy to external sanctions pressure that began after the reunification of Crimea with Russia.

2. During the Wuhan coronavirus pandemic, the main reasons for the Russian economy's decline in 2020 and growth in 2021 were fluctuations in the world oil price: its decline in 2020 and increase in 2021. Our analysis refutes the widespread view that one of the main reasons for the decline in the world oil price in 2020

was the reduction in Chinese demand for it, as the export of crude oil from Russia to China increased in 2020 compared to 2019.

3. Contrary to many negative forecasts, the results of our forecast of Russia's GDP for 2022 based on the macroeconomic production function (1) show that under a sharply increased sanctions pressure, at the world price of Urals crude oil at $60 per barrel, the average growth rate will be 0%, at $70 per barrel, natural economic growth will be observed at an average rate of 4%, and at $80 per barrel, the average economic growth rate will be equal to 7%. The average forecast errors range from 1.5% to 7%.

4. Under reduced demand for Russian gas and the shutdown of the Nord Stream 1 gas pipeline, the forecast volumes of gross natural gas production by Gazprom (excluding Gazprom Neft) in the Tyumen Region for 2022 based on the exponential production function studied by econometric methods (3) range from 364 to 392 billion cubic meters. Average forecast errors do not exceed 5%.

5. Using the example of Great Britain, where in 2021 the average actual export prices for Russian oil and gas were the lowest compared to other Western European countries, we discuss the economic inexpediency of setting marginal prices for Russian energy products by Western consumers.

6. Under the current new conditions, Russia has the opportunity to revise its economic policy, reduce its centuries-old export dependence on raw materials and transit to a new technological order using Russia's significant production and rich scientific potential.

The results of our study may be used by relevant ministries and departments, large companies and other interested organizations for economic analysis and forecasting of the national economic and sectoral dynamics, as well as for developing the foundations of Russia's new economic policy under the new unprecedented coronavirus and sanctions conditions. ■

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