



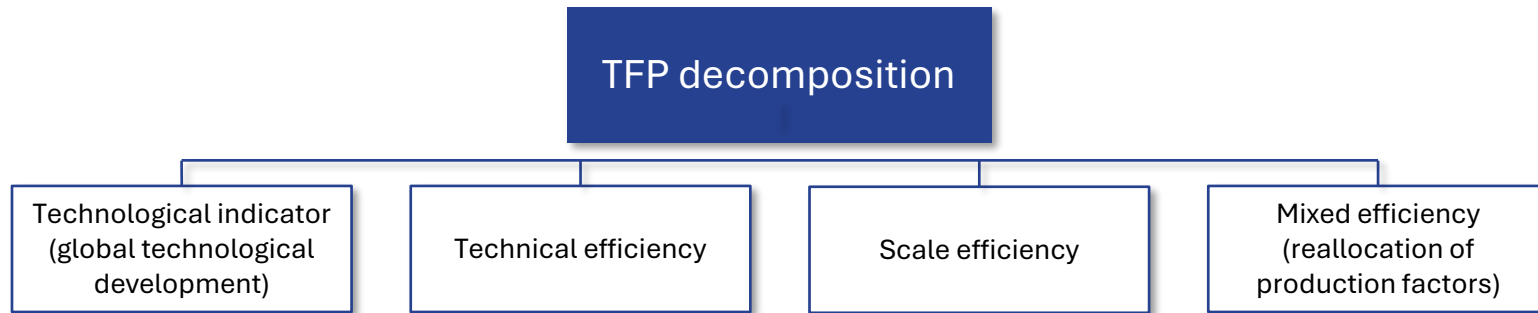
Modeling Total Factor Productivity and Its Components for Russia from Efficiency and Technology Development Factors

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Introduction: Main Definitions and Goal

- Total factor productivity (TFP) is an indicator of the overall efficiency of an economy: the efficiency of using production factors, the efficiency of production factors allocation across industries, the efficiency of scale of production, etc.



The main goal is modeling TFP and its components for Russia from efficiency and technology development factors in three steps:

1. Estimating technical efficiency using SFA approach
2. Estimating TFP and its other components using TFP decomposition method
3. Modeling TFP and its components from exogenous factors

Literature Review

TFP

- Malmquist (1953)
- Solow (1957)
- Caves, Christensen, Diewert (1982)
- Balk (1995)
- Färe, Primont (1995)
- Barro (1999)
- O'Donnell (2012)
- O'Donnell (2014)
- Fernald (2014)
- Maslennikov (2015)

Decomposition

- Shephard (1953)
- Farrell (1957)
- Balk (1998)
- Kumar, Russell (2002)
- Morrison Paul, Nehring (2005)
- O'Donnell (2008)

SFA

- Aigner, Lovell, Schmidt (1977)
- Meeusen, Van den Broeck (1977)
- Azzalini (1985)
- Battese, Coelli (1988)
- Heshmati Kumbhakar, Hjalmarsson (1995)
- Kumbhakar, Lovell (2000)
- Greene (2005)
- Kumbhakar, Sun (2013)

Examples

- Bessonov, Voskoboynikov (2004)
- Ipatova (2015)
- Mamonov, Pestova (2015)
- Timmer, Voskoboynikov (2016)
- Apokin, Ipatova (2017)
- Haider, Kunst, Wirl (2021)
- Eita, Pedro (2021)
- Radygin, Abramov, Chernov (2024)

SFA Approach

- Stochastic frontier analysis (SFA) is a parametric method for technical efficiency (TE) estimation
- Logarithmic Cobb-Douglas production function with inefficiency error:

$$\ln Y_{it} = \alpha \ln L_{it} + \beta \ln K_{it} + \gamma \ln H_{it} + \varepsilon_{it} \quad \varepsilon_{it} = v_{it} - u_{it}$$

where

Y_{it} – output of country i at moment t

L_{it} – labor used by country i at moment t

K_{it} – capital stock used by country i at moment t

H_{it} – human capital used by country i at moment t

$v \sim N(0, \sigma_v^2)$ – random error

$u \sim N^+(0, \sigma_u^2)$ – inefficiency error

$$TE_{it} = E\left(e^{-u_{it}} \mid \varepsilon_{it}\right)_{\varepsilon_{it}=\hat{\varepsilon}_{it}}$$

Inefficiencies in the production process:

- poor-quality raw materials
- poor management
- organizational process failures
- production losses
- other internal factors

TFP Decomposition

- TFP is calculated as the ratio of aggregate output to aggregate input

$$TFP_{it} = \frac{Y_{it}}{X_{it}} \equiv \frac{Y(y_{it})}{X(x_{it})}$$

where

y_{it} and x_{it} – vectors of outputs and inputs of country i at moment t

$Y(\cdot)$ and $X(\cdot)$ – non-negative, non-decreasing and linearly homogeneous aggregation functions for outputs and inputs

$$TFP_{it} = TFP_t^* \cdot TE_{it} \cdot SME_{it} \quad TFP_t^* = TFP_{\max t}$$

where

TFP_t^* – technological indicator of the level of technological development in the world at moment t

TE_{it} – technical efficiency of country i at moment t

SME_{it} – scale and mixed efficiency of country i at moment t

1. Penn World Tables (PWT) database, version 10.01

- Comparability across countries and years
- 144 countries
- 1991-2019

2. WB World Development Indicators (WDI)

Variable	PWT indicators (production function)
Y	Real GDP at constant 2017 national prices (in millions 2017US\$)
K	Capital stock at constant 2017 national prices (in millions 2017US\$)
L	Number of persons engaged (in millions)
H	Human capital index, based on years of schooling and returns to education
Variable	WDI indicators (modeling TFP and its components)
RD_EXPEND	Research and development expenditure (% of GDP)
COMP_IMP	Computer, communications and other services imports (% of commercial service imports)
COMP_EXP	Computer, communications and other services exports (% of commercial service exports)
ICT_EXP_SERV	ICT service exports (% of service exports, BoP)
ICT_EXP_GOODS	ICT goods exports (% of total goods exports)
NET_USERS	Individuals using the Internet (% of population)
JOUR_ARTICLES	Scientific and technical journal articles
PATENT_NONRES	Patent applications, nonresidents
PATENT_RES	Patent applications, residents

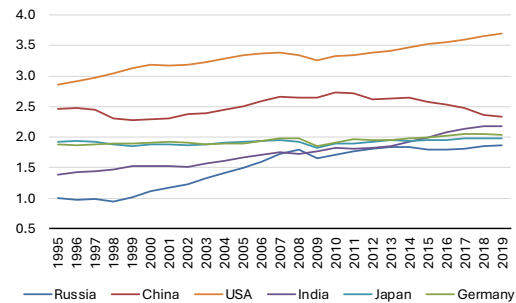
Production Function Estimation

Endogenous variable – lnY (144 countries, 1991-2019)

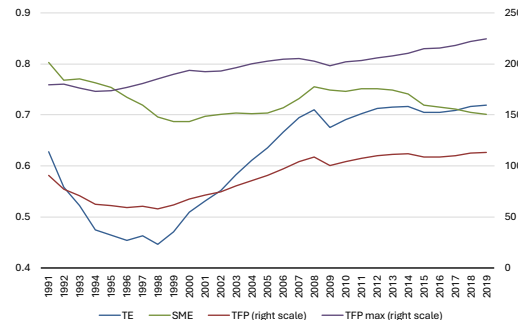
Exogenous variables	Parameter estimates
lnK	0.712*** (0.00641)
lnL	0.264*** (0.00661)
lnH	0.301*** (0.0304)
Const	2.200*** (0.0583)
sigma_v	0.258*** (0.00630)
sigma_u	0.534*** (0.0117)

Note: *** p<0.01, ** p<0.05, * p<0.1

TFP indices of the largest economies in 1995–2019
(1995 for Russia = base year)



Estimates of TFP and its components for Russia in 1991–2019



Modeling TFP Growth Rates for Russia

Exogenous variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
L.TFP	-0.741*** (0.199)	-1.148*** (0.121)	-0.998*** (0.198)	-1.242*** (0.218)	-1.044*** (0.140)	-1.234*** (0.156)	-1.050*** (0.135)	-1.083*** (0.142)
L11.RD_EXPEND	17.90* (8.965)	17.08*** (4.388)	13.80* (7.639)	25.68*** (7.034)	26.94*** (5.813)	25.86*** (5.405)	38.67*** (6.958)	13.79** (5.430)
L11.COMP_IMP		0.484*** (0.0846)						
L8.COMP_EXP			0.362** (0.154)					
ICT_EXP_SERV				1.930** (0.622)				
L4.ICT_EXP_GOODS					10.33*** (2.410)			
L8.NET_USERS						0.143*** (0.0307)		
L6.JOUR_ARTICLES							0.00107*** (0.000237)	
L5.PATENT_NONRES								0.000871*** (0.000199)
Const	61.26*** (17.57)	88.40*** (9.817)	77.78*** (16.182)	93.92*** (16.64)	80.50*** (11.53)	102.5*** (13.41)	35.90** (11.68)	91.71*** (12.59)
R²	0.581	0.910	0.741	0.797	0.862	0.877	0.872	0.866

Note: *** p<0.01, ** p<0.05, * p<0.1

Modeling TE Growth Rates for Russia

Exogenous variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
L.TE	-136.8*** (30.47)	-181.6*** (20.50)	-163.2*** (29.76)	-188.3*** (32.25)	-177.1*** (22.84)	-189.8*** (24.91)	-172.2*** (20.84)	-172.3*** (23.35)
L11.RD_EXPEND	11.50** (4.761)	10.27*** (2.808)	9.072* (4.343)	13.97*** (3.989)	16.89*** (3.461)	14.47*** (3.275)	20.89*** (3.746)	8.804** (3.371)
L11.COMP_IMP		0.223*** (0.0499)						
L8.COMP_EXP			0.161* (0.0804)					
ICT_EXP_SERV				0.797** (0.320)				
L5.ICT_EXP_GOODS					6.829*** (1.831)			
L10.NET_USERS						0.0889*** (0.0242)		
L6.JOUR_ARTICLES							0.000523*** (0.000128)	
L5.PATENT_NONRES								0.000395*** (0.000114)
Const	84.03*** (18.82)	108.7*** (12.35)	98.29*** (17.95)	112.3*** (19.02)	104.4*** (13.57)	116.8*** (15.39)	81.12*** (11.74)	107.0*** (14.55)
R ²	0.669	0.897	0.771	0.804	0.870	0.868	0.885	0.859

Note: *** p<0.01, ** p<0.05, * p<0.1

Modeling Global TFP Growth Rates

Exogenous variables	Model 1	Model 2	Model 3	Model 4	Model 5
L.TFP max	-0.0673* (0.0370)	-0.181** (0.0668)	-0.115*** (0.0391)	-0.0178 (0.0426)	-0.0450 (0.0306)
L4.RD_EXPEND	7.933** (2.932)	5.750* (2.926)	5.554* (2.814)	10.23*** (2.956)	7.478*** (2.366)
L5.COMP_IMP		0.288* (0.146)			
L.ICT_EXP_SERV			1.529** (0.663)		
ICT_EXP_GOODS				0.227* (0.116)	
L5.PATENT_RES					0.0888*** (0.0278)
Const	-6.272 (5.729)	13.70 (11.40)	2.585 (6.398)	-25.11** (10.98)	-10.09* (4.766)
R ²	0.302	0.439	0.476	0.437	0.574

Note: *** p<0.01, ** p<0.05, * p<0.1

Modeling SME Growth Rates for Russia

Exogenous variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
L.SME	-24.44** (11.46)	-5.852 (11.77)	-3.968 (12.32)	-26.56** (9.275)	-15.56 (9.022)	-18.87* (10.03)	-28.73** (11.11)	-20.75* (10.23)
L4.RD_EXPEND	7.528** (2.872)	4.728 (2.686)	8.859*** (2.494)	6.576** (2.338)	5.040** (2.281)	6.470** (2.490)	6.179** (2.772)	6.842** (2.552)
L8.COMP_IMP		-0.126*** (0.0420)						
L6.COMP_EXP			-0.0736** (0.0270)					
L5.ICT_EXP_SERV				-0.699*** (0.220)				
ICT_EXP_GOODS					-3.958*** (1.075)			
L6.NET_USERS						-0.0259** (0.00966)		
L.JOUR_ARTICLES							-3.95e-05** (1.70e-05)	
L8.PATENT_NONRES								-0.000188** (7.82e-05)
Const	9.539 (8.129)	3.707 (8.097)	-3.860 (8.490)	15.36** (6.813)	7.345 (6.194)	7.199 (7.012)	15.74* (8.484)	9.420 (7.177)
R²	0.354	0.601	0.559	0.604	0.650	0.555	0.524	0.526

Note: *** p<0.01, ** p<0.05, * p<0.1

Modeling TFP and Its Components for Russia

Indicators	TFP	TE	TFP max	SME
RD_EXPEND	Lag 11 +	Lag 11 +	Lag 4 +	Lag 4 +
COMP_IMP	Lag 11 +	Lag 11 +	Lag 5 +	Lag 8 -
COMP_EXP	Lag 8 +	Lag 8 +	not identified	Lag 6 -
ICT_EXP_SERV	no lag +	no lag +	Lag 1 +	Lag 5 -
ICT_EXP_GOODS	Lag 4 +	Lag 5 +	no lag +	no lag -
NET_USERS	Lag 8 +	Lag 10 +	not identified	Lag 6 -
JOUR_ARTICLES	Lag 6 +	Lag 6 +	not identified	Lag 1 -
PATENT_NONRES	Lag 5 +	Lag 5 +	not identified	Lag 8 -
PATENT_RES	not identified	not identified	Lag 5 +	not identified

Main Conclusions

- A three-factor Cobb-Douglas production function was estimated using the SFA method on a sample of 144 countries in 1991-2019
- Based on the estimates of the production function parameters, estimates of the TFP and TE were obtained. After this, the estimates of the technological indicator (TFP max) and SME were calculated
- TFP and its components growth rates for Russia were modeled from efficiency and technology development factors
- R&D expenditure leads to growth in TFP and its components. Moreover, for the United States, as the most progressive country, the return on R&D investment takes much less time: four years versus 11 years in Russia
- Computer, communications and other services imports, as a technology transfer, stimulate TFP and TE growth with a 11-year lag (faster in the US), but slowdown SME growth, which may be due to drawing resources from other industries
- High-tech exports of goods and services (three variables) contribute to TFP and TE growth with different lags, but hinder SME growth, which may be due to the diversion of resources from more traditional areas
- Individuals using the Internet as % of the total population have a positive impact on TFP and TE, as a more progressive population is growing up, with a broader outlook and higher professional skills
- The number of scientific and technical journal articles also correlates positively with technological progress and overall efficiency
- An interesting result was obtained for the last two variables. Only patent applications from nonresidents have a positive impact on Russia's TFP and TE. In the US case, only patent applications from residents have a positive impact, as if patent applications would also have their own effectiveness



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Thank you for attention!

Moscow, 24 April 2026