HIGHER SCHOOL OF ECONOMICS
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The dynamics of total factor productivity and its components: Russian plastic production

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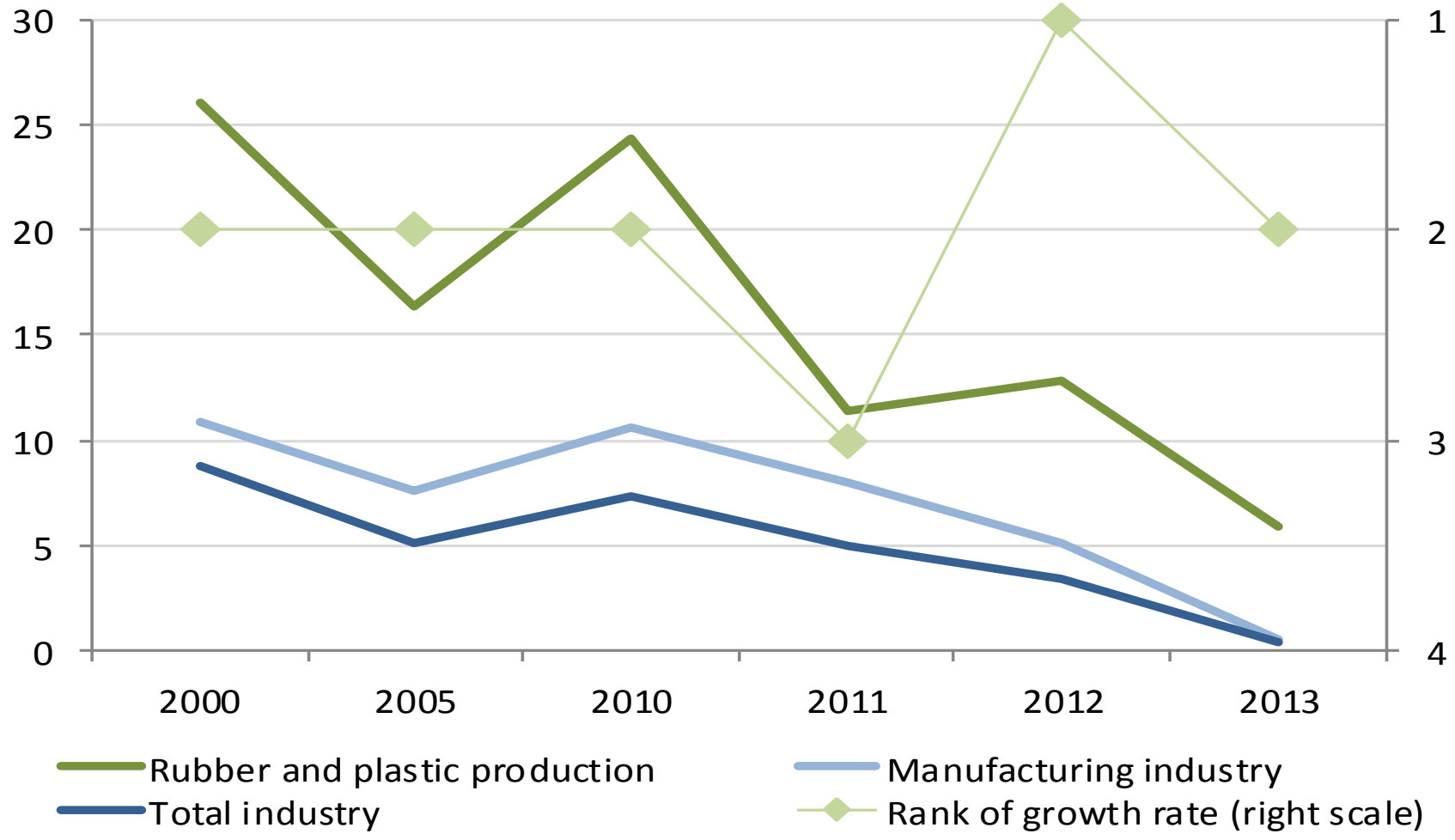
Introduction
Russian plastic production sector

- Plastic production is a part of a medium-tech sector (NACE: 22.2)
- Its main consumers are construction, field of consumer goods and services
- This sector has sufficient competitiveness in domestic market: share of Russian firms amounts to more than 70%
- Growth rates plastic production are significantly higher than growth rates of manufacturing and total industry
- Plastic production is one of the leaders among manufacturing sectors according to its growth rates rank

Introduction
Comparison of growth rates



Source: Russian statistical year book, 2014

Introduction
Russian plastic production sector

- There was observed a sharp slowdown of growth rates in 2013
- The lack of modern and efficient capital assets (mean value of capacity utilization coefficient was 58% at the end of 2013) decreases competitiveness abroad
- (Gnidchenko, 2015):
  - This sector revealed growth of competitiveness before the global economic crisis and declining – after
  - It's presented in cheap market segment
  - However modificated Hausmann-Klinger approach demonstrates high both export potential and potential of import substitution in plastic production sector

Introduction
Russian plastic production sector

- In the report (National Council of Russian Federation, 2014) Russian plastic production was included in a set of priority sectors for import substitution
- Assumed measures of government support:
  - subsidy
  - concessional lending
  - public purchases et al.
- I study efficiency and productivity of Russian plastic production firms using TFP approach and SFA and DEA methods
  - TFP is equal to ratio of aggregate output to aggregate input

Hypotheses

- Technical efficiency (TE) is one of the main drivers of total factor productivity (TFP) dynamics
- TFP and technical efficiency significantly declined in 2009 because of the global economic crisis (Gnidchenko, 2015)
- TFP and technical efficiency also decreased in 2013 over total slowdown of Russian economy growth
- Results are robust across different models and methods

Literature review
Main theoretical aspects

- Shepard (1953) – distance function
- Farrell (1957) – formula of technical efficiency
- Meeusen, Van den Broeck (1997) and Aigner et al. (1977) – Stochastic Frontier Analysis (SFA)
- Charnes et al. (1978) – Data Envelopment Analysis (DEA)
- Balk (1998) – formula of scale efficiency
- O'Donnell (2008) – formula of TFP index decomposition used in this research

SFA vs. DEA

- SFA
  - Parametric method
  - Estimation of stochastic production frontier
  - Fixed functional form of production function for all firms
  - Necessity of a priori assumption about error components' distribution
- DEA
  - Non-parametric method
  - Optimization problem of mathematical programming
  - Estimation of deterministic production frontier
  - High sensitivity to outliers

Total factor productivity change

- $q_{it} \in \mathbb{R}_+^N, \; x_{it} \in \mathbb{R}_+^M$ – output and input vectors of firm *i* in period *t*
- $Q_{it} \equiv Q(q_{it}), \; X_{it} \equiv X(x_{it})$ – aggregate output and input (nonnegative, nondecreasing and linearly homogeneous) functions

$$TFPI_{hs,it} = \frac{Q_{it}/Q_{hs}}{X_{it}/X_{hs}} = \frac{QI_{hs,it}}{XI_{hs,it}}$$

- where
  - $TFPI_{hs,it}$ – TFP index
  - $QI_{hs,it}$, $XI_{hs,it}$ – aggregate output and input quantity indices

TFP change and its components (O'Donnell, 2008)

- Technical change is a measure of production frontier movement as a result of change in technology
- Technical efficiency change is movement towards or away from the production frontier as a result of more or less efficient factors use
- Scale efficiency change is movement along the production frontier in an effort to capture economy of scale
- Mix efficiency change is movement along the production frontier in an effort to capture economy of scope (recombination of inputs and outputs)

TFP change decomposition

$$TFP_{it} = TFP_t^* \times TFPE_{it} = TFP_t^* \times OTE_{it} \times OSME_{it}$$

- where
  - TFP_{it} – TFP of firm *i* in period *t*
  - TFP_t^* – maximum TFP using technology of period *t*
  - $TFPE_{it}$ – TFP efficiency
  - OTE_{it} – output technical efficiency
  - $OSME_{it}$ – output scale and mix efficiency

$$TFPI_{hs,it} = \left(\frac{TFP_t^*}{TFP_s^*}\right)\left(\frac{TFPE_{it}}{TFPE_{hs}}\right) = \left(\frac{TFP_t^*}{TFP_s^*}\right)\left(\frac{OTE_{it}}{OTE_{hs}}\right)\left(\frac{OSME_{it}}{OSME_{hs}}\right)$$

Aggregate function

- DEA – Färe-Primont TFP function:

$$TFP_{it} = \frac{Q_{it}}{X_{it}} = \frac{D_O(x_0, q_{it}, t_0)}{D_I(x_{it}, q_0, t_0)}$$

- where
  - $D_O(\cdot)$, $D_I(\cdot)$ – output and input distance functions
  - x_0, q_0 – vectors of representative quantities
  - t_0 – a representative time period
- SFA – TFP function from model estimation:

$$TFP_{it} = \frac{Q_{it}}{X_{it}} = q_{it} \Big/ \prod_k x_{k,it}^{\eta^{-1}\hat{\beta}_k}, \quad \eta = \sum_k \hat{\beta}_k$$

- where
  - $\hat{\beta}$ – vector of estimated parameters

Data

- Database RUSLANA (Bureau van Dijk):
  - country – Russian Federation
  - main OKVED code – code 25.2 (plastic production)
  - years – 2006-2013
  - minimum value of total revenue, total assets, and fixed assets, is 1 thousand rubbles, of the number of employees is 16 persons
- Observation was recognized an outlier in case when its deviation from mean value of some variable in some year exceeded 3 st. dev.
- Balanced panel consists of 530 firms
- All variables are expressed in constant prices 2006 (except number of employees)

Descriptive statistics of variables in 2006-2013

Variable	Mean	Std. Dev.
Total revenue	117218	163927
Capital	28123	53996
Labour	97	104
Remaining assets	42348	63604

- Capital = Fixed assets
- Remaining assets = Total assets – Fixed assets
- Labour = number of employees

Correlation matrix of variables in 2006-2013

	Total revenue	Capital	Labour	Remaining assets
Total revenue	1			
Capital	0.639	1		
Labour	0.650	0.531	1	
Remaining assets	0.785	0.631	0.603	1

- Capital = Fixed assets
- Remaining assets = Total assets – Fixed assets
- Labour = number of employees

SFA pooled model

- $\ln TR_{it} = \beta_0 + \beta_1 \ln K_{it} + \beta_2 \ln L_{it} + \beta_3 \ln Rem_{it} + v_{it} - u_{it}$

  $v_{it} \sim N(0, \sigma_v^2),\ u_{it} \sim N^+(0, \sigma_u^2),\ i = 1, \ldots, 530,\ t = 2006, \ldots, 2013$
- where
  - $\ln TR_{it}$ – logarithm of total revenue
  - $\ln K_{it}$ – logarithm of capital (fixed assets)
  - $\ln L_{it}$ – logarithm of labour (number of employees)
  - $\ln Rem_{it}$ – logarithm of remaining assets (total assets – fixed assets)

- Battese, Coelli (1988):
- $TE_i = \mathrm{E}\left(e^{-u_i} \mid \varepsilon_i\right)_{\varepsilon_i = \hat{\varepsilon}_i}$

SFA panel model RE-2S

- Random effects model, 2-step procedure (Heshmati et al., 1995)

$$\ln TR_{it} = \beta_0 + \beta_1 \ln K_{it} + \beta_2 \ln L_{it} + \beta_3 \ln Rem_{it} + w_i + \varepsilon_{it}$$

$$\varepsilon_{it} = \delta + v_{it} - u_{it}, \;\; w_i \sim N(0, \sigma_w^2)$$

$$v_{it} \sim N(0, \sigma_v^2), \;\; u_{it} \sim N^+(0, \sigma_u^2), \;\; i = 1, ..., 530, \;\; t = 2006, ..., 2013$$

- where
  - $\ln TR_{it}$ – logarithm of total revenue
  - $\ln K_{it}$ – logarithm of capital (fixed assets)
  - $\ln L_{it}$ – logarithm of labour (number of employees)
  - $\ln Rem_{it}$ – logarithm of remaining assets (total assets – fixed assets)
  - w_i – random individual effect of firm *i*

SFA panel model TRE

- "True" random effects model (Greene, 2005)

$$\ln TR_{it} = \beta_0 + \beta_1 \ln K_{it} + \beta_2 \ln L_{it} + \beta_3 \ln Rem_{it} + w_i + v_{it} - u_{it}$$

$$w_i \sim N(0, \sigma_w^2)$$

$$v_{it} \sim N(0, \sigma_v^2),\ u_{it} \sim N^+(0, \sigma_u^2),\ i = 1, \ldots, 530,\ t = 2006, \ldots, 2013$$

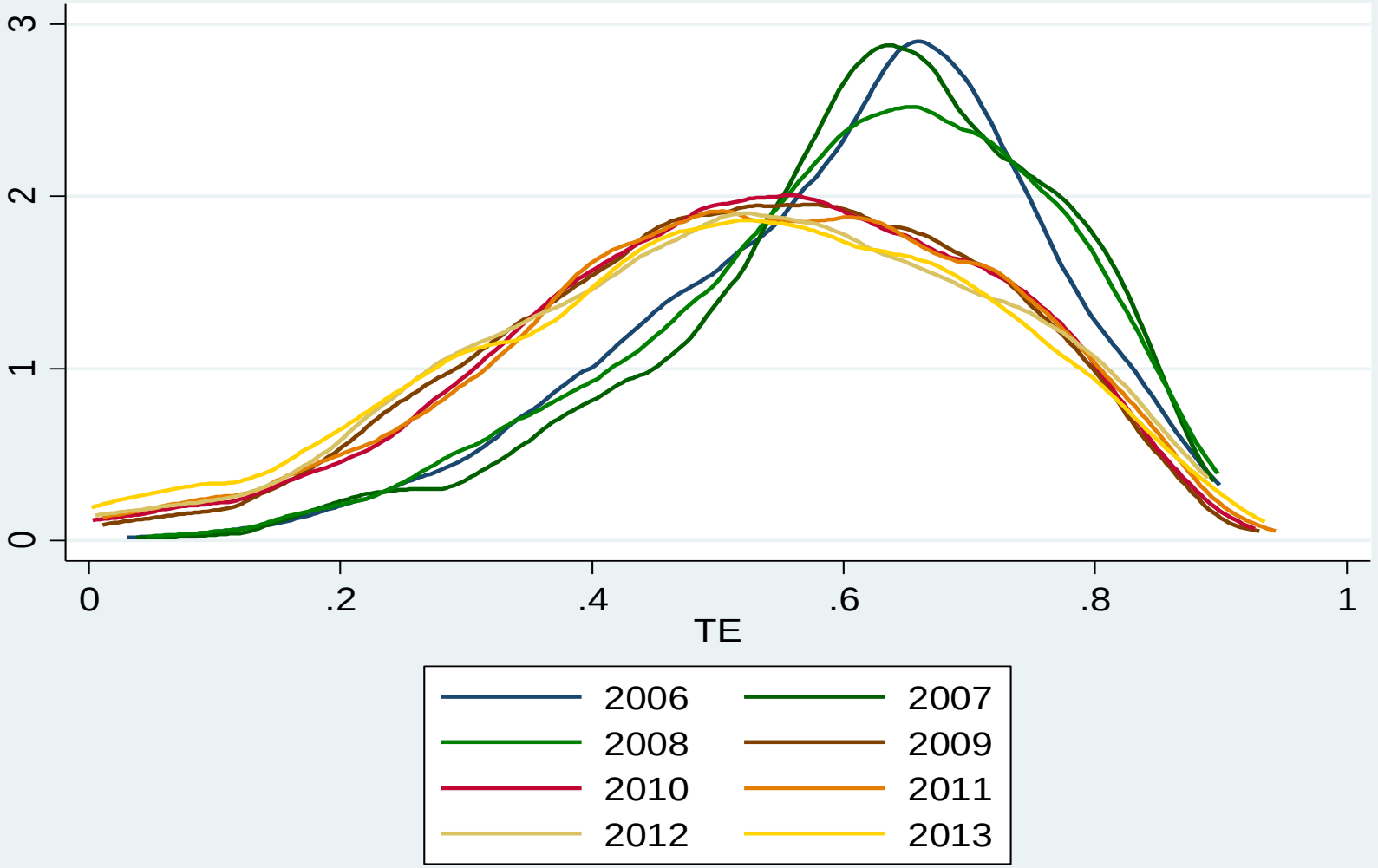
- where
  - $\ln TR_{it}$ – logarithm of total revenue
  - $\ln K_{it}$ – logarithm of capital (fixed assets)
  - $\ln L_{it}$ – logarithm of labour (number of employees)
  - $\ln Rem_{it}$ – logarithm of remaining assets (total assets – fixed assets)
  - w_i – random individual effect of firm *i*

SFA models estimates
Dependent variable is ln(Total revenue)

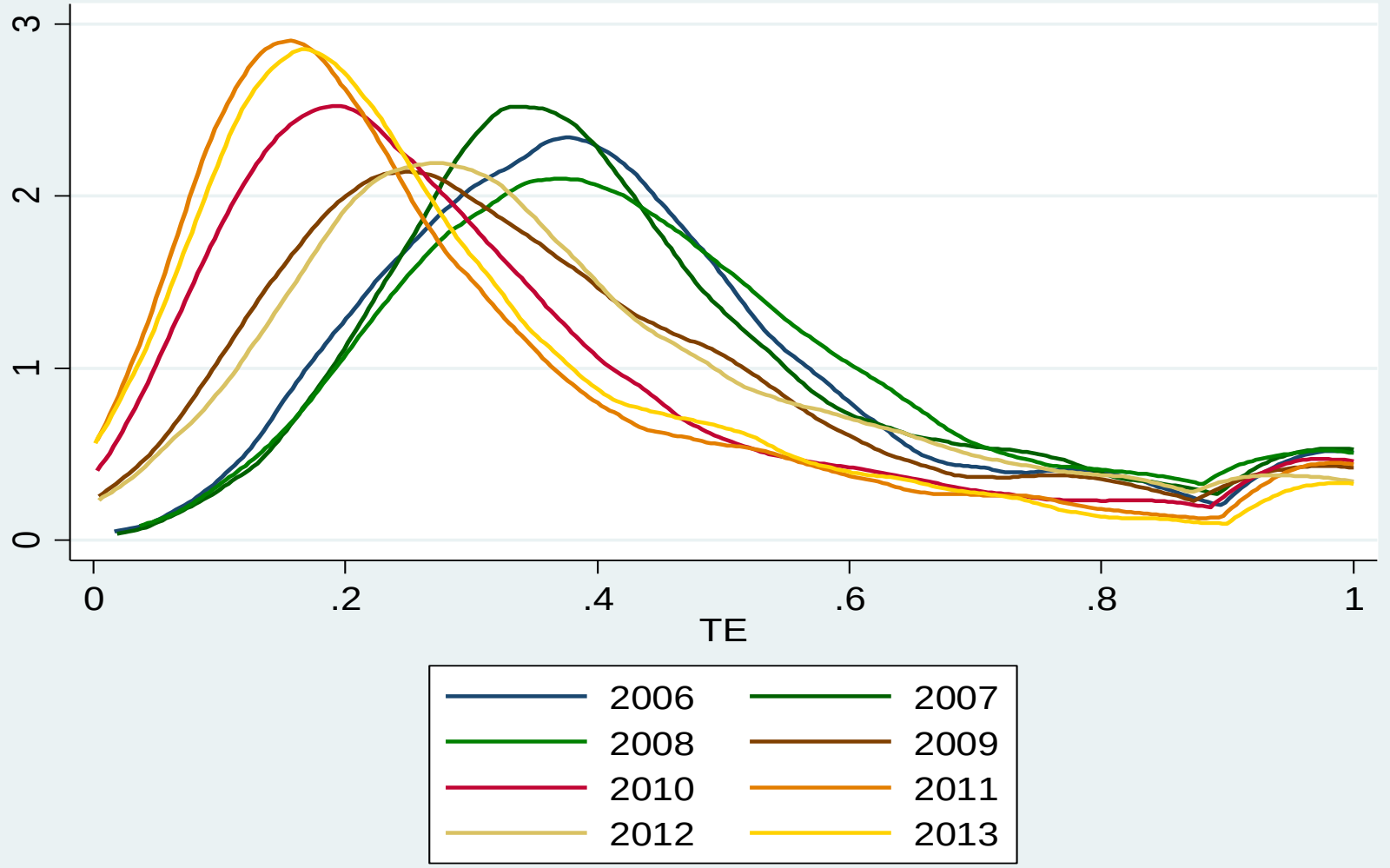
Variable	Pooled	Panel RE-2S	Panel TRE
ln(Capital)	0.0689***	0.109***	0.0951***
	(0.00596)	(0.00862)	(0.00644)
ln(Labour)	0.514***	0.687***	0.585***
	(0.0181)	(0.0280)	(0.0222)
ln(Remaining assets)	0.464***	0.334***	0.290***
	(0.00982)	(0.0141)	(0.0108)
Constant	4.344***	3.809***	5.238***
	(0.0668)	(0.116)	(0.105)
lnsig2v	-2.037***	-2.107***	-3.689***
	(0.0541)	(0.0361)	(0.0973)
lnsig2u	-0.114***	-1.672***	-1.745***
	(0.0367)	(0.0643)	(0.0481)
Observations	4,240	4,240	4,240
logL	-4182	-2466	-2692
Number of firms	-	530	530

Note. *, **, *** — 10, 5, 1% significance levels.

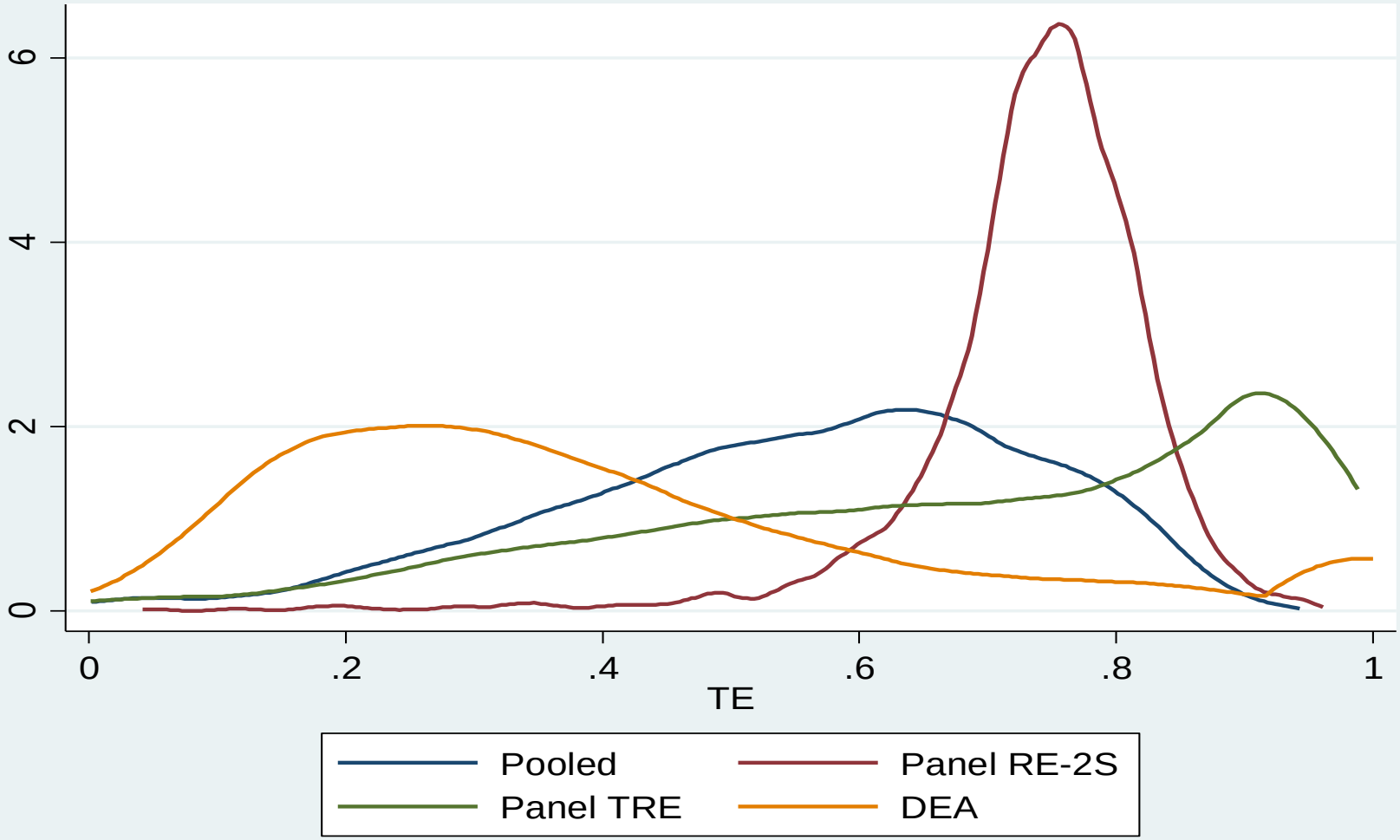
Kernel density of technical efficiency estimates, SFA, pooled



Kernel density of technical efficiency estimates, DEA



Kernel density of technical efficiency estimates in 2006-2013



Spearman coefficient of TFP and technical efficiency estimates

- Technical efficiency estimates

TE	Pooled	Panel RE-2S	Panel TRE	DEA
Pooled	1			
Panel RE-2S	0.650	1		
Panel TRE	0.947	0.618	1	
DEA	0.746	0.544	0.753	1

- TFP estimates

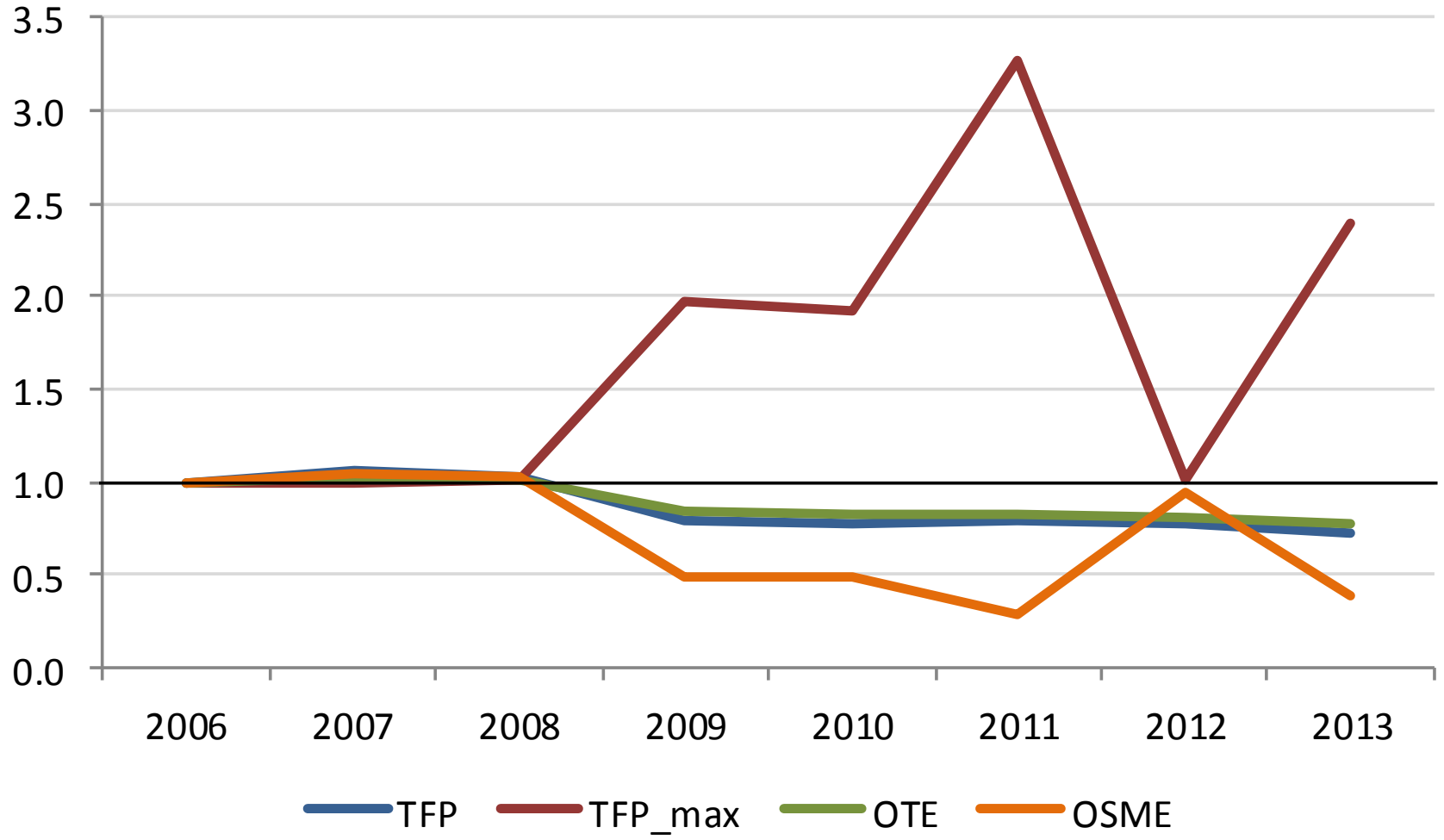
	Pooled	Panel RE-2S	Panel TRE	DEA
Pooled	1			
Panel RE-2S	0.972	1		
Panel TRE	0.974	1.000	1	
DEA	0.819	0.900	0.896	1

Average values of TFP efficiency components in 2006, SFA and DEA

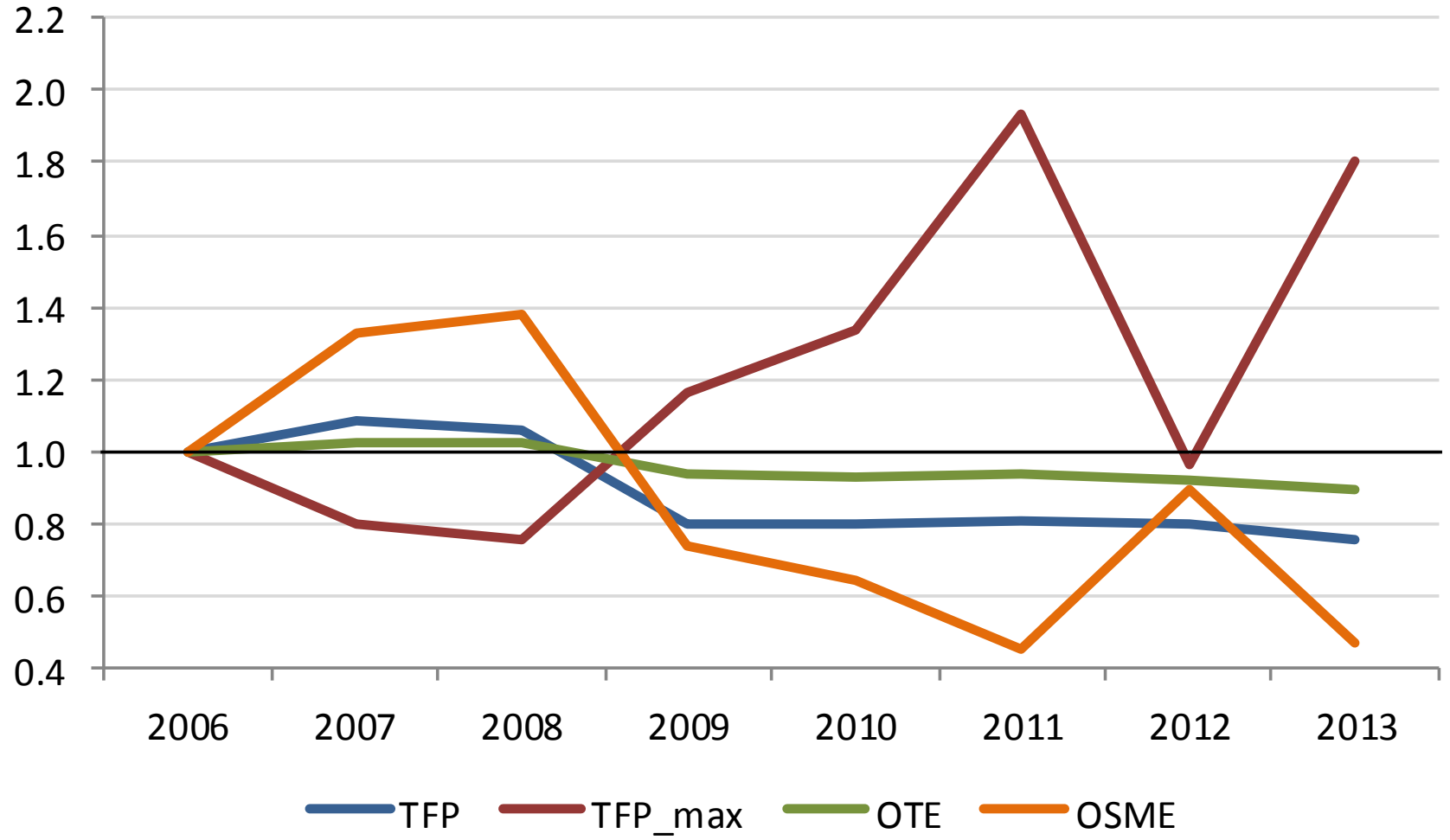
	Pooled	Panel RE-2S	Panel TRE	DEA
TFP Efficiency	0.136	0.135	0.135	0.135
Technical efficiency	0.506	0.728	0.603	0.312
Scale and mix efficiency	0.270	0.186	0.224	0.431

- TFP efficiency estimates are the same across different models and methods. However other components estimates differ as a result of inefficiency redistribution

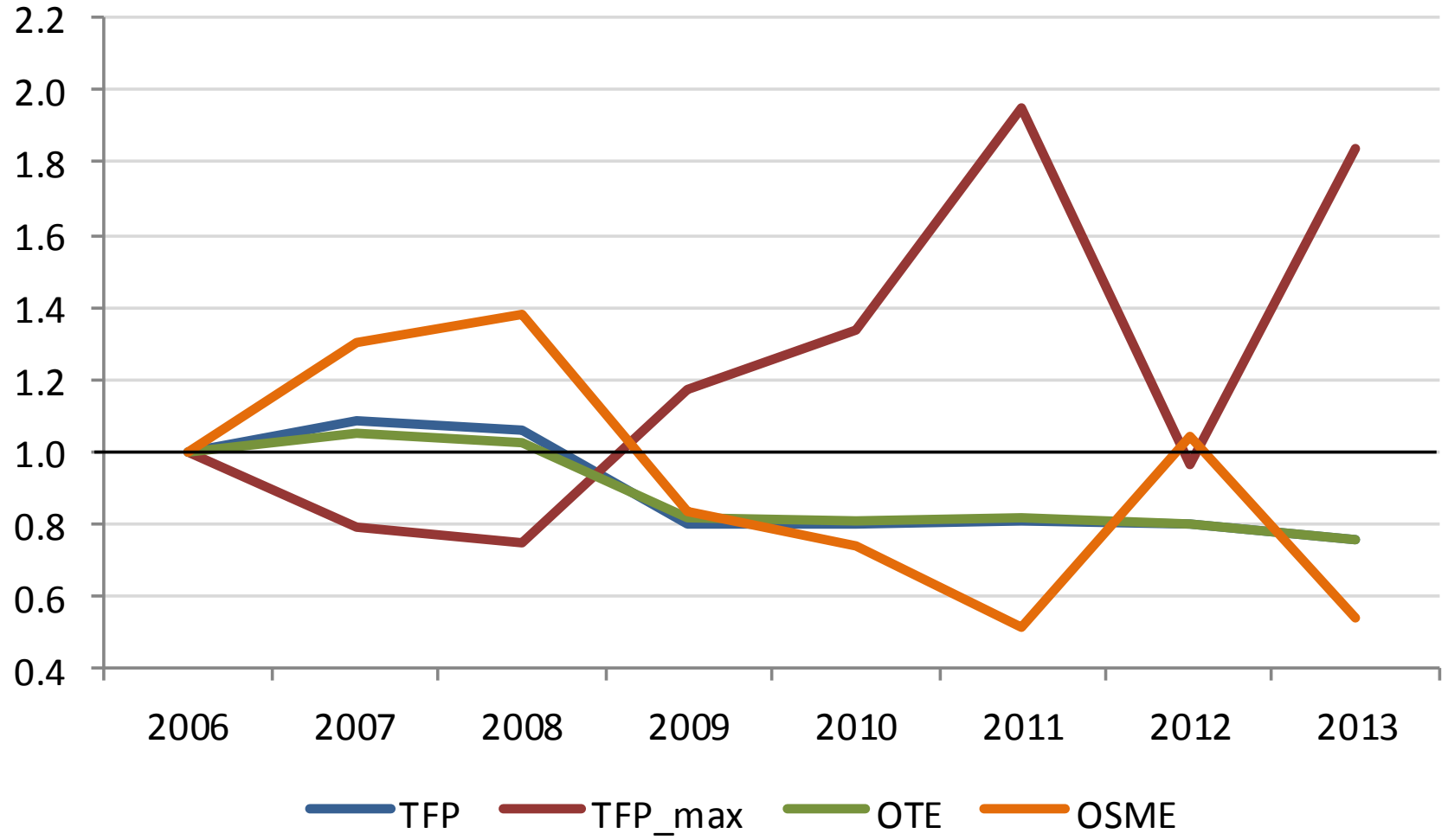
Average values of TFP index and its components, SFA, pooled



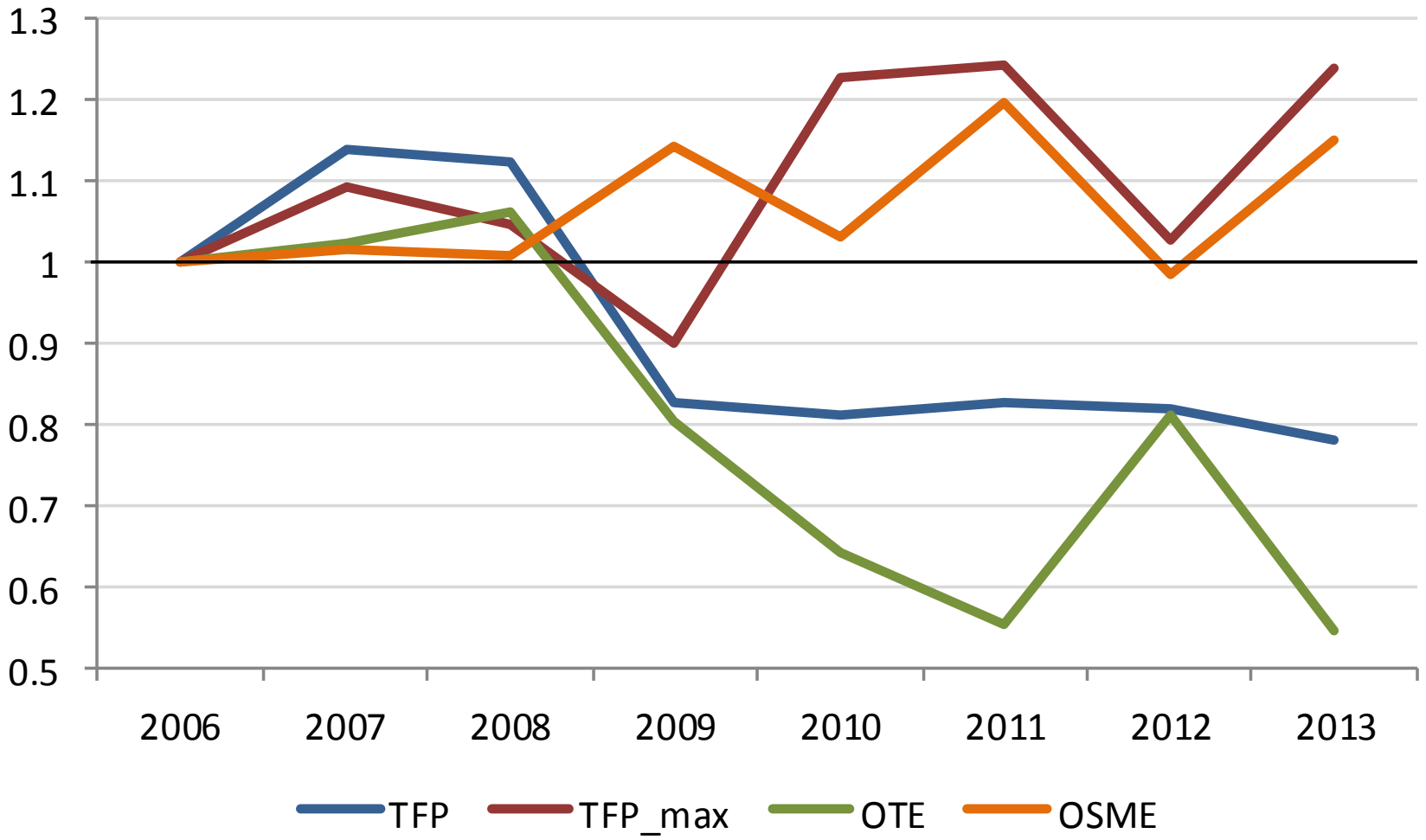
Average values of TFP index and its components, SFA, panel RE-2S



Average values of TFP index and its components, SFA, panel, TRE



Average values of TFP index and its components, DEA



Conclusion

- Technical efficiency has almost the same dynamics as TFP in SFA models and it's the main driver of TFP dynamics according to DEA results
- TFP and technical efficiency dramatically dropped after the global economic crisis
- The recovering process was not completed to the end of 2013. Results of analysis allow to verify that it has not started at all
- Firms rankings by TFP and technical efficiency estimates are rather robust across different models and methods. However the dynamics of TFP components differs across methods

Thank you for your attention!