SSE Riga Student Research Papers
2016 : 6 (182)

LATVIA: CATCHING-UP TOWARDS THE WORLD PRODUCTION FRONTIER, AN INDUSTRY-LEVEL ANALYSIS

Authors: Edgars Kokins
Valentīns Lavrinovičs

ISSN 1691-4643
ISBN 978-9984-842-99-8

November 2016
Riga

Latvia: Catching-Up Towards the World Production Frontier, An Industry-Level Analysis

Edgars Kokins

and

Valentīns Lavrinovičs

Supervisor: Oļegs Krasnopjorovs

November 2016
Riga

Table of contents

Abstract

We applied the Stochastic Frontier Analysis True Fixed Effects model with time-varying technical progress to the World Input-Output Database to study in which industries Latvia has been catching-up towards the world production frontier during the past two decades and which factors could foster this convergence in the future. Our results show that (given the amount of capital stock and labour) output of the agriculture, hospitality, trade and transportation industries in Latvia still substantially lags behind its peers. Over the last 20 years, construction and private sector services such as trade, transportation and hospitality experienced substantial efficiency gains, spurring Total Factor Productivity (TFP) growth well above average in our sample. In turn, manufacturing and agriculture failed to increase efficiency and thus has experienced rather low TFP growth. We find that R&D spending and trade openness are significant efficiency determinants for all industries while foreign direct investments are not. Furthermore, we document the positive association between efficiency and several variables of The Economic Freedom Index and Global Competitiveness Report. Thus, business-friendly institutional reforms such as fighting corruption and judicial system improvements can raise labour productivity not only by promoting capital accumulation, but also through TFP gains.

1 Introduction

Total factor productivity has been researched extensively and is of great importance to both policy makers and as a tool of assessing a country's performance. Although several researchers, such as Fadejeva and Melihovs (2010), analysed TFP by industries, to our knowledge none of the researchers have touched upon a sectoral breakdown of TFP in Latvia in the post-crisis period. In this paper, we fill this gap by identifying the efficiency determinants of main private sector industries in Latvia: agriculture, construction, accommodations and hospitality, manufacturing, trade and transportation. We analyse the period from 1995 to 2014, and compare the growth of TFP in Latvia along with 39 other countries. This forms our sample and allows us to capture Latvia's position relative to the world's production frontier.

Thus, the goal of the study is: first, to study TFP growth across sectors in Latvia, decomposing it into world technical progress (movements of world production frontier over time) and efficiency growth (catch-up to world production frontier); second, to identify factors that have a significant effect on efficiency within each industry. Our analysis covers the following factors: spending on Research and Development (R&D), the trade openness of a country, the amount of Foreign Direct Investments (FDI) as well as various indicators from the Economic Freedom Index (EFI) and Global Competitiveness Index (GCI).

We employ Stochastic Frontier Analysis (SFA) True Fixed Effects (TFE) with time-varying technical progress as our main model and Data Envelopment Analysis (DEA) 2-stage method as a check for robustness. Both models are widely used for TFP growth decomposition; the majority of prominent scholars in their papers on this topic employ at least one of these models. Performing our analysis, we answer three research questions:

1. *In which industries is Latvia more efficient (close to the world production frontier)?*
2. *Which one, technical or efficiency change, is the main driver of TFP growth within the analysed industries in Latvia?*
3. *How can Latvia foster a catch-up to the world's production frontier?*

Our paper is structured in the following manner: section 2 consists of a literature review; section 3 describes methodology and data; section 4 presents our empirical findings, section 5 discusses the results, while the conclusion is in the last section.

2 *Literature review*

In this paper, we employ the neoclassical theory of production; according to this theory, output depends on three key factors: the amount of physical capital, labour and technology. Felipe and Adams (2005) note that this function is the most widely used in the analysis of labour productivity and growth. Many prominent scholars have studied which factors are the main determinants of labour productivity growth. Blinder and Yellen (2002) state that labour productivity is directly related to economic performance, and that a decrease in the growth of labour productivity in the 1970s was responsible for "the woeful macroeconomic performance of that decade". Mankiw, Romer and Weil (1992) study a sample of 98 countries and report that about 80% of cross-country difference in per capita income can be explained by physical and human capital. For example, Jorgenson and Stiroh (2000) report that during the period from 1958 to 1998, capital accumulation was the main factor for labour productivity growth in the US, while Stiroh (2001) states that in the 2000's, productivity growth in the US was mainly driven by technology improvements. Baier, Dwyer and Tamura (2006) report that TFP accounts for about 34% of the economic growth in Western Countries. These thoroughly different results highlight the importance of both TFP and capital on productivity.

2.1 Scope of the research

Existing literature on the topic differs by scope. We divide existing evidence in three groups – country level, industry level and firm level. A country level analysis of labour productivity seems to be the most prevalent, as evident by the bulk of researches focusing on this field. Country level analysis allows conducting a cross-country comparison of developments in labour productivity, and gives macro level understanding of a countries' performance. A country level analysis of labour productivity with a subsequent analysis of several industries and efficiency determinants, with particular focus on Latvia (among other countries), was conducted by Krasnopjorovs (2012), Filippetti and Peyrache (2013), Puharts and Kloks (2015).

Other authors have studied labour productivity using firm-level data. For example, Battese, Heshmati and Hjalmarsson (2000) studied labour productivity in the Swedish banking industry; Børing (2012) analysed labour productivity across Norwegian manufacturing firms, and Selim (2012) covered labour productivity in the agricultural sector of Bangladesh. To our knowledge there have been only a few papers which studied firm-level productivity in Latvia, for example Aleksandrovics and Smilts (2015).

The remaining group of works focuses on industry level analysis of labour productivity. Dozens of labour productivity related papers, which cover Europe and Asia, indicate that this sphere of the economy is of great interest to both academics and policymakers, e.g. Dragomir and Tanasie (2010), and thus we believe that it is worth expanding it to include Latvia. Fadejeva and Melihovs (2010) published the only paper, which presents an industry-level TFP study in Latvia. The authors of that paper construct estimates of TFP growth across six sectors of the Latvian economy, though the analysis does not present the decomposition into technical progress and efficiency catch-up. Moreover, their paper covers the period from 2000 to 2008, hence the post-crisis period is left unanalysed. Znotina and Jermolajeva (2011) compare the labour productivity of regions in Latvia with labour productivity of the European Union. They briefly observe productivity changes by industry, but don't analyse the driving factors of changes in labour productivity.

A countrywide analysis could show that productivity has increased on a country level, but without a sectoral breakdown as it is impossible to conclude whether productivity has indeed increased in every industry or there has been an expansion of more productive industries and a contraction of less productive ones. This phenomenon is discussed by Javorcik, Fitriani and Iacovone (2012) and MTI (2014) in the context of Indonesia and Singapore, respectively. On the other hand, a country level analysis that reports no changes in productivity fails to explain the reasons of such results: it is impossible to say whether the productivity was constant in all of the industries or it fell in some sectors of the economy and increased in others. Both cases present the weakness of a country level analysis. The latter idea is supported by the empirical research, which covers 20 countries across the globe, and shows that it is crucial to study productivity with an industry breakdown to better explain overall productivity in the economy (Manyika et al., 2010). Thus, to present country-level evidence and avoid misleading conclusions about a country's productivity and competitiveness, we analyse productivity by industries.

Many researches have shown that TFP growth has been positive during a prolonged period of time. For example, Fadejeva and Melihovs (2010) show that TFP growth was positive after Latvia was admitted to the EU, as well as it differed across industries. Puharts and Kloks (2015) show that countrywide TFP growth was positive in the Baltic States and particularly for Latvia in the period of 1995 - 2013. Based on these results, we propose our first hypothesis: *although countrywide TFP growth was positive in Latvia during 1995-2014, it differed across industries.*

2.2 Direction of the research

TFP growth can be decomposed into the catching-up effect and technical changes. Escribano and Stucchi (2008) study TFP emphasizing the catching-up effect: a movement towards a production possibility frontier. Other scholars focus on studying the technical change or a shift in the production possibility frontier over time (Mitra et.al. (2011) and Sabasi and Shumway (2014)). We study both factors in conjunction.

Performing an industry level analysis of TFP growth, we seek to analyse the impact of technical change and efficiency change across different industries. Worthington (2000) reports that in Australia, change in TFP was mainly driven by technical change, Färe et al. (1994) documents that technical change alone explained more than 50% of Japanese TFP change. According to Nishimizu and Page (1982), TFP growth in Yugoslavia was driven mainly by an efficiency catch-up. We are not able to predict which component of TFP is the dominant driver of productivity growth in each industry in Latvia and the other countries sampled. However, we believe that in 1995, Latvia had low efficiency in all industries, which is partially supported by Badunenko, Henderson and Zelenyuk (2008) who report that all post-Soviet countries had low efficiency scores in the 1990s; thus, our second hypothesis is as follows: *in the period of 1995 – 2014, all industries in Latvia the catching-up effect accounts for a larger part of TFP growth as compared to technical change.*

Two frontier models are often used in literature to decompose TFP growth. The first, Data Envelopment Analysis (DEA) is a nonparametric model based on the linear programming (Färe et al. (1994), Perelman (1995), and Hu and Cai (2004)). The second, Stochastic Frontier Analysis (SFA), first proposed by Aigner, Lovell, and Schmidt (1977). The main difference between the models is that SFA operates within the econometric framework, while DEA does not. SFA is based on maximum likelihood estimations, as well it accounts for noise in the data. DEA is based on linear programming and assumes no noise.

Still, both models provide similar tools for TFP decomposition. SFA and DEA allow determining inefficiency, which measures the output distance between a country and the production frontier. Pilat (1996) documents that the importance of decreasing inefficiency is well-pronounced as companies that fail to use existing technologies efficiently are outperformed and are forced “to restructure, freeing resources for other productive users”, thus creating structural changes in the economy. Ikhsan-Modjo (2006) employs SFA to decompose TFP into technical progress, changes in technical efficiency and scale economies effect. Kong et.al. (1999) performs analysis on Chinese state-owned companies, while Bragagnolo et.al. (2010) performs a SFA analysis in the agricultural industry. Moreover, both approaches are used to find factors that affect efficiency.

In this paper we not only decompose TFP growth into technical and efficiency change, but also try to find variables that influence changes in efficiency. Several authors have tried to identify factors that affect labour productivity in several industries. For example, Attar et.al. (2009) study factors affecting the construction industry, Khan (2006) assesses the impact of several well-known factors to TFP, without introducing any experimental ones in the manufacturing industry. There are only a handful of papers looking at several factors that affect TFP in a countrywide dimension, e.g. Razak et.al. (2014), and there are none, to the authors attention, which assess variables in an industry-wide dimension.

Many scholars have studied the effect of R&D expenditure on efficiency. For example, Pilat (1996) claims that R&D expenditure significantly boosts efficiency (and thus, labour productivity). Perelman (1995) finds that R&D activities significantly and positively correlate with technical changes in the sample of OECD countries. Similarly, CBO (2005) reports that R&D expenditure has a significant impact on labour productivity in the US. We aim to identify sectors of economy in which efficiency is significantly linked to the amount of R&D expenditure.

Several researches have shown that FDI has a significant impact on labour productivity growth. Baltabaev (2013) analyses 49 countries and reports that FDI is a statistically significant determinant of productivity growth. Studying 34 OECD economies over the period of 1990 – 2010, Amann and Virmani (2015) report that FDI has a positive long term impact on labour productivity growth. Ilbuodo (2014) and Tanna (2009) report that FDI has a statistically significant impact on productivity growth for the mining and banking industries, respectively. Based on these works, we expect to obtain similar results for Latvia.

Moreover, efficiency is likely to be linked with institutions. For instance, Puharts and Kloks (2015) identify that efficiency could be promoted by the development of property rights, and, consequently, the court system. Thomson and Rushing (1999) report that patent protection positively correlates with TFP, while Chanda and Dalgaard (2008) emphasise the importance of strong protection of property rights for the level of TFP. Thus, we analyse whether changes in the Economic Freedom Index (EFI) and Global Competitiveness Index (GCI) drive efficiency changes, and, if true, which sub-indices of EFI and GCI are the most important for each industry.

Openness to trade positively correlates with TFP growth, as reported by Khan (2006). Ferreira and Trejos (2011) argue that trade is associated with a more efficient allocation of resources which further increases TFP. In general, trade allows for a spillover of both knowledge and technology which leads to larger TFP growth in countries further from the production possibility frontier. This view is supported by Bloch and Tang (2007) as well as Hwang and Wang (2004).

Thus, we propose our third hypothesis: *higher R&D spending, FDI, better institutions and trade openness is positively linked to efficiency.*

3 Methodology and data

We use the Stochastic Frontier Analysis (SFA) True Fixed Effect (TFE) model with a time-varying technical progress as our base specification and nonparametric Data Envelopment Analysis (DEA) 2-stage method as a robustness check.

First, we employ SFA to measure output elasticity with respect to labour and capital and decompose TFP growth in Latvia to technical and efficiency changes in each industry. Then we proceed with analysing possible efficiency determinants. Additionally, as a robustness check, we test whether efficiency determinants obtained from SFA are robust within the DEA framework.

3.1 Stochastic Frontier Analysis True Fixed Effect model

In general, the SFA frontier stems from the Cobb-Douglas production function. A generalized formula for the model is as follows (to simplify the equation, industry specific indexes aren't included):

$$y_{it} = \beta + \beta_1 * k_{it} + \beta_2 * l_{it} + e_{it}, \qquad e_{it} = v_{it} - u_{it} \tag{2}$$

We use labour and capital (both in logs) as inputs (denoted as k_{it} and $l_{it.}$ respectively), while beta is a vector of technology parameters. Unlike DEA, y_{it}, k_{it} and l_{it} are in logarithmic form for the SFA model. The error component (e_{it}) consists of statistical noise v_{it} and inefficiency u_{it}. Employing the model, one can estimate whether a particular industry operates on ($u_{it} = 0$) or beneath ($u_{it} > 0$) the production frontier. While v_{it} is normally distributed by default, we adhere to a half-normal distribution of u_{it}; estimation function is following the method documented by Jondrow et al. (1982).

Given the period of 1995 – 2014 (T=20 years) maximum likelihood estimate is appropriate, as highlighted by Belotti and Ilardi (2012). Otherwise, the estimates might be inconsistent – an incidental parameter problem (biased country specific intercepts) could arise as first described by Neyman and Scott (1948) who argue that for smaller samples, it is impossible to obtain consistent results. Heckman (1981) also discussed this problem; he reports that the problem becomes unimportant when the number of analysed periods becomes large. He shows that the problem ceases when a sample of 100 individuals is analysed over 8 periods (total number of observations, 800, is the same as in our study). Moreover, Wright and Douglas (1976) use 20 years for each individual in their sample and report no bias. In this study we use exactly the same number of periods, so we believe that a problem with incidental parameters will not arise.

In addition to country specific intercepts, we add a time dummy variable, as proposed by Kumbhakar and Lovell (2003). A time dummy allows a frontier to move over time thus reflecting technical changes and global economic cycles. SFA TFE model with time-varying production frontier takes the following form:

$$y_{it} = \beta_i + \beta_1 * k_{it} + \beta_2 * l_{it} + \sum_{t=1996}^{2014} \beta_t \, dyear_t + v_{it} - u_{it} \tag{3}$$

Further, we extend our model. In order to test which factors are significant determinants of inefficiency, we expand u_{it} term. The extended model consists of 2 equations which are estimated simultaneously. The first is the same as in equation (3), while the second equation expresses inefficiency term as a function of possible inefficiency determinants:

$$u_{it} = \delta + \delta_1 * R\&D_{it} + \delta_2 * TO_{it} + \delta_3 * I_{it} + \delta_4 * EFI_{it} + \delta_5 * GCI_{it} + e_{it} \qquad (4)$$

In this paper we test whether R&D expenditure as a percentage of GDP, exports as a percentage of GDP (denoted as TO – trade openness), Foreign Direct Investments as a percentage of GDP, institutional proxies (EFI and GCI and its sub-variables) are significant efficiency determinants. First, we test each factor alone, for significant ones we complete a robustness check by looking at whether they remain significant in the presence of other factors.

3.2 Robustness check via two-stage DEA approach

To check the robustness of our results, we use a two-stage DEA approach. Although we believe that TFE is a superior model due to its econometric nature, we check whether the results obtained from TFE are similar to ones that we get from DEA.

In the first stage, we use output-oriented DEA and calculate inefficiency for each observation in our sample. We don't compare inefficiency estimates obtained from DEA with ones we obtain from TFE. Due to different assumptions of the models, efficiency estimates could differ a great deal.

In the second stage, we study which factors are significant determinants of efficiency. As efficiency is censored between 0 and 1, we use Tobit regression, with upper limit 1 for dependent variable. Tobit regressions are widely used in a two-stage DEA framework; it uses maximum likelihood estimation and assumes a truncated normal distribution (Tu and Wan-Chu, 2013). Coefficients from Tobit regressions are easily interpretable and comparable to ones we obtain from TFE model.

The advantage of DEA is its simplicity, but it suffers from ignoring "noise" in the data and its non-parametricity, which causes problems with hypothesis testing (Trick, 1998). Unlike DEA, SFA TFE accounts for noises, eliminates heterogeneity problems associated with using country specific intercepts and is widely used by prominent scholars, e.g., Greene (2005) and Carroll et.al. (2007).

3.3 Data

We use the data of 40 countries from 1995 to 2014 (see appendix A, table A.1). Our main data source is WIOD (World Input Output Database). The data in WIOD is available up to 2009 or 2011. For the subsequent period, we extrapolate data by using both the IMF and World Bank databases. These databases are compatible since WIOD itself was formed using data from World Bank, IMF, and Eurostat.

As a target variable (dependent variable), we use value-added produced within a particular industry, data is adjusted to purchasing power parity (PPP) in USD. We have two inputs: labour, measured as a total number of hours worked, and stock of capital, measured in USD at PPP. We obtain data for the total number of hours worked from WIOD, and, as the data from WIOD does not cover 2012-2014, it was prolonged with data from Eurostat and the World Bank. We use the WIOD database to obtain data on capital stock in 1995 within each industry of our interest and calculate changes in capital stock by applying the perpetual inventory method. We assume geometric depreciation at a constant rate, which allows the expression of capital stock at time *t* as follows:

$$K_t = (1 - depreciation\ rate) * K_{t-1} + GFCF_{t-1}, \quad (5)$$

where GFCF stands for Gross Fixed Capital Formation for a particular industry. Data about GFCF is collected from WIOD, Eurostat and IMF. We use WIOD to obtain data on GFCF until 2009, and prolong it to 2014 using Eurostat and IMF. We calculate annual changes in GFCF from 2009 to 2014 using data from Eurostat/IMF, and then these results are used to extend data obtained from WIOD. Capital depreciation rates vary by industry and are obtained from WIOD. Initial capital stock in 1995 was summarized by WIOD from long time-series of data, or using estimates (when data is unavailable). Capital estimates are pulled via ICVAR and Harberger methods (Erumban et al., 2012). The full list of variables which regressions are used along with the sources are listed in appendix A, table A.2.

4 Empirical results

We find technical change to be positive in Latvia during 1995-2014 in all 6 industries within our sample. Furthermore, 4 out of 6 industries – construction, hospitality, trade and transportation - benefited from catching-up towards the world production frontier.

Thus, TFP growth in these industries in Latvia was higher than average in the sample. However, manufacturing and agriculture industries in Latvia failed to catch-up.

Results show that R&D is a significant determinant of efficiency in all industries observed, while EFI was significant in all tested industries except for agriculture. FDI is not a significant determinant of efficiency in any of the industries. We find that higher exports are associated with higher efficiency in the manufacturing, trade and transportation industries. Also, efficiency in various industries is dependent on freedom from corruption, monetary freedom, trade freedom, and financial freedom. We document that better infrastructure, a stable macroeconomic environment and well-developed higher education and training improve efficiency in some of the analysed industries.

4.1 Analysis of TFP growth and efficiency

In this section, we present the results obtained from TFE regressions for each industry following the SFA approach. At this time, efficiency determinants are not included. For each industry, we find labour and capital to be significant output determinants at the 1% level. Coefficients for labour and capital can be viewed as output elasticity to respective production factor. Constant returns to scale in respect to capital and labour together are evident in the construction, manufacturing and trade industries (see table 1). According to our results, the law of diminishing returns applies to agriculture and hospitality, possibly reflecting the importance of geography and climate. A similar result is observed in transportation.

Table 1. Output elasticities to labour and capital

	Agriculture	Construction	Hospitality	Manufacturing	Trade	Transportation
Labour	0.197***	0.490***	0.240***	0.446***	0.459***	0.273***
Capital	0.193***	0.415***	0.043***	0.543***	0.533***	0.091***
Wald test	0.000	0.356	0.000	0.128	0.657	0.000
Observations	800	800	800	800	800	800

Significance: ***:1% level; **: 5% level; *:10% level.
Wald test: testing for scale effect; p-value>0.1 – constant return to scale, otherwise – decreasing returns to scale.

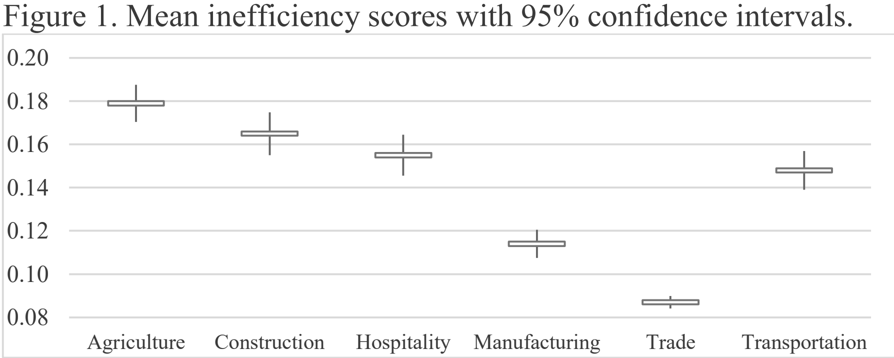
Time dummies in our model allowed us to track annual technical changes. The majority of time dummies in our regressions are statistically different from 0 at 1% confidence level (see appendix B). Results suggest that for all industries, the production frontier moved up as compared to the base period (1995), reflecting world technical progress. The weighted average technical change for the whole sample over the 20-year period is 29.2%, the largest positive technical change was recorded in the hospitality industry (73.8%) and the lowest in agriculture (17.9%).

The years of the Great Recession are capturing effects of the global economic crisis on the production frontier. Our results show that all industries faced downward movements in the production frontier around 2008 and 2009: evidence that is supported by Fernald (2014) and Hicks (2013). Annual technical changes in the agriculture industry are volatile, which is partially supported by work of Sunding and Zilberman (2001), who state that in the agriculture industry, each technical change is only accepted gradually, with long adaptation periods that creates spikes of technical changes followed smaller amounts of new technical inputs. This is also explained by a high dependency on weather conditions in agriculture, as reported by Gornall et.al. (2010), and weak output elasticity to labour and capital inputs (consistent with our results). In appendix C year by year technology changes for each industry are presented.

For all industries, we find the inefficiency term, σ_u, to be significant at the 1% level (see appendix B). We also calculate signal-to-noise ratio, γ, that indicates whether deviations from frontier come from inefficiency or is pure statistical noise. We find that γ varies from 0.634 to 1, which again strongly supports the presence of inefficiency.

We observe that the mean of inefficiency term in our country sample ranges from 8.7% to 17.9%, with trade and manufacturing being closer to the world production frontier than other industries. Figure 1 presents mean inefficiency scores for all industries with 95% confidence intervals.

Figure 1. Mean inefficiency scores with 95% confidence intervals.



Note. Bars depict average inefficiency and lines show 95% confidence interval. Created by the authors.

In appendix D, we compare industry inefficiency in Latvia with a sample average of industry inefficiency, and the inefficiency of Latvia's entire economy. Although agriculture had a rapid catch-up period at the end of the 1990s, estimates suggest that the efficiency of the agriculture industry is below Latvia's economy efficiency and is close to average efficiency within our sample. The agriculture industry in Latvia in 2014 had the highest inefficiency estimate, 22.8%, among major industries included in our research. The transportation and hospitality industries were less efficient in 2014 than the entire economy of Latvia, but more efficient than the respective industries in other countries.

In turn, the construction industry in Latvia is more efficient than the entire economy of Latvia. Similar results are obtained for manufacturing and trade industries in Latvia: these industries are more efficient than both the Latvian economy and the average of our sample.

Table 2 shows our results of TFP decomposition into technical and efficiency change during 1995-2014. These results support our first hypothesis, overall countrywide TFP growth was positive, but doesn't support our second hypothesis – technical change is larger than efficiency change in all industries.

Table 2. TFP growth decomposition on technical and efficiency change by industry (1995-2014)

	Agriculture	Construction	Hospitality	Manufacturing	Trade	Transportation
Efficiency change						
Latvia	-3.2%	26.7%	52.6%	-1.1%	17.8%	34.5%
Sample (average)	-1.8%	-2.0%	-0.1%	4.1%	1.1%	3.3%
Technical change	17.9%	30.6%	73.8%	19.1%	28.3%	51.5%
TFP growth						
Latvia	14.7%	57.3%	126.4%	17.9%	46.1%	86.0%
Sample (average)	16.1%	28.5%	73.7%	23.2%	29.4%	54.8%

Source: authors' calculations.

We find that efficiency has increased in 4 out of 6 industries in Latvia. The largest increase in efficiency in Latvia is in the hospitality industry (52.6%), while the sample average is -0.1%, so a big efficiency change in the hospitality industry could be explained by its large inefficiency at the beginning of 1995 (when estimated inefficiency was 67%).

Latvia recorded higher than the sample average of TFP growth in 4 out of 6 industries –hospitality, construction, trade and transportation. The largest TFP growth is recorded in hospitality and transportation industries (126.4% and 86.0 % respectively).

4.2 Analysis of efficiency determinants

Further, we proceed with an analysis of possible efficiency determinants. At this stage, we analyse four factors: R&D, EFI, FDI and exports. Later, the analysis is moved to another institutional variable: GCI and its sub-variables (because data is only available from 2006). First we test each factor separately and then combine them to test robustness. While below we present only inefficiency equations separately for each industry, in appendix E we report detailed output from TFE regressions with 4 exogenous factors added to the inefficiency equation.

We exclude the hospitality industry from further analysis since the efficiency in this industry is largely dependent on tourism / geographic factors, therefore the results obtained from factor analysis would not be reliable if efficiency is explained solely by, e.g. institutional variables. As any papers that discuss the factors affecting efficiency in hospitality industry were not found, we assume that the other authors came to the same conclusion.

Our analysis shows that the agriculture industry, the only significant and robust determinant of efficiency is R&D. None of the remaining factors pass the robustness test as seen in table 3. Although EFI is significant in regression with all factors, when combined with only R&D, it becomes insignificant.

Table 3. Inefficiency equations for agriculture

EFI			0.013	(0.009)			-0.064***	(0.024)
R&D	-0.536***	(0.057)	-0.617***	(0.085)	-3.002**	(1.435)	-1.913***	(0.430)
FDI					-0.096	(0.077)	-0.036	(0.056)
Exports					-0.204***	(0.075)	-0.018	(0.013)
Constant	-1.738***	(0.096)	-2.455***	(0.502)	7.38	(5.287)	2.507*	(1.399)

Note. Significance: ***:1% level; **: 5% level; *:10% level. Standard errors in parenthesis.

We find that two factors, EFI and R&D, are significant efficiency determinants for the construction industry (table 4).

Table 4. Inefficiency equations for construction

EFI	-0.082***	(0.007)	-0.131***	(0.018)	-0.129***	(0.018)	-0.133***	(0.020)
R&D			-2.350***	(0.281)	-2.389***	(0.284)	-2.366***	(0.288)
FDI					-0.033	(0.022)	-0.031	(0.021)
Exports							0.004	(0.008)
Constant	2.756***	(0.447)	6.756***	(1.101)	6.688***	(1.100)	6.801***	(1.130)

Note. Significance: ***:1% level; **: 5% level; *:10% level. Standard errors in parenthesis.

We find three factors, R&D, EFI and exports, to be significant determinants of efficiency in manufacturing, trade and transportation industries (see table 5, 6, and 7, respectively). All factors are significant at a 1% or 5% confidence level, both separately and combined together. Similar results from Tobit regressions for DEA model are shown in appendix F, table F.1.

Table 5. Inefficiency equations for manufacturing

EFI	-0.121**	(0.056)	-0.117***	(0.027)	-0.029***	(0.009)	-0.093***	(0.028)
R&D			-0.831***	(0.293)	-0.287***	(0.086)	-0.667**	(0.086)
FDI					0.000	(0.002)	-0.058	(0.042)
Exports							-0.042***	(0.009)
Constant	2.658	(2.847)	3.134**	(1.536)	2.472***	(0.568)	3.103**	(1.573)

Note. Significance: ***:1% level; **: 5% level; *:10% level. Standard errors in parenthesis.

Further, we divide manufacturing into two groups based on their reliance on technology and innovation according to CSB (2015) classification. The first group consists of medium-high technology manufacturing such as pharmaceutical and chemical products, electronics, optical products, machinery, weapons, etc. In turn, the second group, low technology manufacturing, combines the manufacture of basic metals, plastic products, food products and beverages, apparel and paper products, etc.

The results suggest that country's R&D expenditure is a significant and robust determinant of inefficiency the in medium-high technology manufacturing sub-industry. Contrary, and as expected, inefficiency in the low technology manufacturing sub-industry doesn't significantly dependant on R&D expenditure in the country (the coefficient is insignificant) (see appendix G).

We present inefficiency equations for trade from TFE model in table 6 and similar results from Tobit regressions for DEA model in appendix F, table F.2.

Table 6. Inefficiency equations for trade

EFI	-0.142***	(0.031)	-0.119***	(0.028)	-0.119***	(0.030)	-0.110***	(0.023)
R&D			-0.651***	(0.214)	-0.659***	(0.213)	-0.743***	(0.227)
FDI					-0.019	(0.013)	-0.030	(0.029)
Exports							-0.026***	(0.009)
Constant	4.880***	(1.632)	4.207***	(1.579)	4.258**	(1.684)	4.502***	(1.358)

Note. Significance: ***:1% level; **: 5% level; *:10% level. Standard errors in parenthesis.

Inefficiency equations from the TFE model for transportation are presented in table 7. We find that EFI, R&D, and exports are significant determinants of the inefficiency in transportation.

Table 7. Inefficiency equations for transportation

EFI	-0.111***	(0.006)	-0.155***	(0.016)	-0.151***	(0.016)	-0.153***	(0.017)
R&D			-2.543***	(0.282)	-2.513***	(0.276)	-2.645***	(0.291)
FDI					0.009	(0.007)	-0.018	(0.024)
Exports							-0.021***	(0.007)
Constant	4.165***	(0.430)	8.282***	(1.018)	8.055***	(0.985)	8.888***	(0.990)

Note. Significance: ***:1% level; **: 5% level; *:10% level. Standard errors in parenthesis.

In table 8 we summarize the TFE model's results about factors that are statistically significant determinants of efficiency. We find that FDI is not a significant efficiency determinant in any of the industries in our study. We report that R&D is a significant determinant of efficiency in all 5 industries, while institutional variables (EFI and its components) have significant and robust impact on efficiency in all but agriculture industry. Trade openness is associated with higher efficiency in manufacturing, which could reflect its export-intensiveness, as well as in trade and transportation.

Table 8. Efficiency determinants by industry: summary

	Agriculture	Construction	Manufacturing	Trade	Transportation
EFI		x	x	x	x
R&D	x	x	x	x	x
FDI					
Trade openness			x	x	x

Note. Factors that have significant impact on labour efficiency in a particular industry are marked with “x”. For example, efficiency in trade industry is determined by EFI, R&D and exports.

Further, to test for institutional variables, we break EFI into its components: property rights, freedom from corruption, fiscal freedom, government spending, business freedom, labour freedom, monetary freedom, trade freedom, investment freedom and financial freedom. In this work the labour freedom sub-variable was excluded from our analysis. The reason for this is data shortage – data on labour freedom is available only from 2005, while data on other EFI sub-variables is available from 1995.

We begin with the construction industry, and find that five EFI sub-variables are significant efficiency determinants if taken alone. Robustness check excludes three of them: property rights, monetary freedom and trade freedom. In table 9, we show that freedom from corruption and financial freedom are robust determinants of efficiency in the construction industry.

Table 9. Inefficiency equations with EFI sub-variables, construction

Freedom from corruption	-0.035***	(0.003)			-0.347***	(0.005)
Property rights			-0.041***	(0.003)	-0.002	(0.006)
Monetary freedom			-0.005	(0.005)		
Trade freedom					0.005	(0.005)
Financial freedom	-0.017***	(0.004)			-0.017***	(0.004)
Constant	0.207	(0.195)	0.417	(0.348)	-0.016	(0.314)

Note. Significance: ***:1% level; **: 5% level; *:10% level. Standard errors in parenthesis.

Our results for manufacturing suggest that monetary freedom, freedom from corruption and business freedom are significant efficiency determinants if taken alone. Taken together, only monetary freedom remains statistically significant (see table 10).

Table 10. Inefficiency equations with EFI sub-variables, manufacturing

Monetary freedom	-0.030***	(0.005)	-0.028***	(0.005)	-0.029***	(0.005)
Business freedom			-0.006	(0.005)	0.002	(0.004)
Freedom from corruption					-0.007	(0.006)
Constant	-1.360***	(0.354)	-1.066**	(0.441)	-0.995	(0.463)

Note. Significance: ***:1% level; **: 5% level; *:10% level. Standard errors in parenthesis.

We find that all variables are significant determinants of inefficiency in trade industry if taken alone. However, only three of them (trade freedom, financial freedom and monetary freedom) remain statistically significant after a robustness check (see table 11).

Table 11. Inefficiency equations with EFI sub-variables, trade

Trade freedom	-0.077***	(0.014)	-0.039***	(0.007)	-0.030***	(0.007)
Financial freedom			-0.037***	(0.007)	-0.028***	(0.007)
Monetary freedom			-0.013***	(0.005)	-0.010**	(0.005)
Freedom from corruption					-0.008	(0.008)
Property rights					-0.012	(0.008)
Constant	0.905	(0.655)			1.878***	(0.577)

Note. Significance: ***:1% level; **: 5% level; *:10% level. Standard errors in parenthesis.

Freedom from corruption, monetary freedom and trade freedom are all significant determinants of efficiency in transportation at a 1% confidence level (see table 12).

Table 12. Inefficiency equations with EFI sub-variables, transportation

Freedom from corruption	-0.044***	(0.002)	-0.029***	(0.003)	-0.024***	(0.004)
Monetary freedom			-0.037***	(0.005)	-0.041***	(0.006)
Trade freedom					-0.029***	(0.005)
Constant	-0.578***	(0.145)	1.317***	(0.339)	3.205***	(0.489)

Note. Significance: ***:1% level; **: 5% level; *:10% level. Standard errors in parenthesis.

We find that property rights, government spending, business freedom, and investment freedom are not significant determinants of efficiency in any of the industries presented in this study. Consistent results for freedom from corruption were achieved in all but the manufacturing industry. Monetary freedom is significant in the manufacturing and transportation industries. Trade freedom is a significant determinant of efficiency in trade and transportation industries, while financial freedom is robust in the construction and trade industries. The summary of our results is shown in Table 13, while a discussion is presented in Section 5.

Table 13. Institutional variables that have significant impact on inefficiency

	Construction	Manufacturing	Trade	Transportation
Property rights				
Freedom from corruption	x		x	x
Fiscal freedom				
Government spending				
Business freedom				
Monetary freedom		x		x
Trade freedom			x	x
Investment freedom				
Financial freedom	x		x	

Note. Factors that have significant impact on labour (in) efficiency in a particular industry are marked with "x".

Further, we test GCI and its pillars. As data for GCI is available beginning from 2006, GCI against EFI was first tested to see which is a better determinant in the later years. These two variables are compared since both of them include significant amount of institutional variables and are very close in composition. We find that higher GCI scores are associated with higher efficiency in the construction, trade and transportation industries. Moreover, in the construction and trade industries, we find that EFI has become insignificant once GCI is added to the regressions, thus indicating that GCI is closer linked to efficiency. The summary of these results is shown in Table 14 (other industries are excluded from this table to conserve space). Then, for the industries where GCI is a significant determinant, we test for its sub-variables.

Table 14. Inefficiency equations with GCI and EFI as inefficiency determinants, all industries

	Construction		Trade		Transportation	
GCI	-1.274***	(0.212)	-1.776***	(0.197)	-2.516***	(0.757)
EFI	0.011	(0.012)	0.005	(0.012)	-0.246***	(0.040)
Constant	1.809**	(0.824)	3.366***	(0.727)	21.008***	(4.629)

Note. Significance: ***:1% level; **: 5% level; *:10% level. Standard errors in parenthesis.

In total, the GCI index is formed by 12 pillars. In this analysis, we choose 5 of them: institutions, infrastructure, macroeconomic environment, health and primary education, and higher education and training. We choose these pillars because government has an opportunity to influence them directly and thus there is a possibility of changes to them.

In table 15, we present results for determinants of inefficiency in construction using GCI sub-variables. We find that infrastructure, macroeconomic environment and higher education are significant and consistent determinants of inefficiency.

Table 15. Inefficiency equations for construction with GCI sub-variables

Infrastructure	-0.498***	(0.129)	-0.256*	(0.152)	-0.274**	(0.138)
Macroeconomic environment			-0.661***	(0.101)	-0.637***	(0.100)
Health and primary education					0.507	(0.361)
Higher education and training			-0.256*	(0.152)	-0.745***	(0.258)
Constant	-0.934**	(0.464)	-0.661***	(0.101)	1.531	(1.763)

Note. Significance: ***:1% level; **: 5% level; *:10% level. Standard errors in parenthesis.

For the trade industry, we find that infrastructure, macroeconomic environment and higher education and training are significant determinants of inefficiency. In turn, pillars 1 and 4 are insignificant when combined with other variables (see table 16).

Table 16. Inefficiency equations for trade with GCI sub-variables

Institutions	0.113	(0.164)			0.124	(0.167)
Infrastructure	-0.426***	(0.158)	-0.364***	(0.128)	-0.411**	(0.164)
Macroeconomic environment	-0.189*	(0.098)	-0.154*	(0.086)	-0.192*	(0.098)
Health and primary education					-0.159	(0.449)
Higher education and training	-1.084***	(0.203)	-1.049***	(0.201)	-1.042***	(0.241)
Constant	3.21***	(0.792)	3.069***	(0.779)	3.862*	(1.975)

Note. Significance: ***:1% level; **: 5% level; *:10% level. Standard errors in parenthesis.

We find infrastructure and macroeconomic environment having significant efficiency determinants in transportation (at 1% significance level; in all combinations; see table 17).

Table 17. Inefficiency equations for transportation with GCI sub-variables

Institutions	-0.206	(0.164)			-0.068	(0.187)
Infrastructure	-0.649***	(0.145)	-0.724***	(0.130)	-0.573***	(0.157)
Macroeconomic environment	-0.228**	(0.093)	-0.278***	(0.082)	-0.270***	(0.097)
Health and primary education			-0.249	(0.328)	0.079	(0.383)
Higher education and training					-0.328	(0.280)
Constant	0.442	(0.568)	1.647	(1.610)	0.801	(1.656)

Note. Significance: ***:1% level; **: 5% level; *:10% level. Standard errors in parenthesis.

To summarize, we find that institutions and health and primary education are not robust in any of the industries, while higher education is significant in the construction and trade industries. Moreover, macroeconomic environment and infrastructure is a significant determinant in all of the industries (see table 18).

Table 18. GCI sub-variables that have significant impact on inefficiency

	Construction	Trade	Transportation
Institutions			
Infrastructure	x	x	x
Macroeconomic environment	x	x	x
Health and primary education			
Higher education and training	x	x	

Note. Factors that have significant impact on labour efficiency in a particular industry are marked with "x".

In order to obtain additional insights, GCI pillar sub-variables were tested. Finding which of them are significant efficiency determinants, allows us to make more substantiated policy suggestions. Moreover, while the pillar itself is not a significant determinant of efficiency, some of its sub-variables may still be significant. Thus, we test not only pillars 2, 3 and 5, bus also pillar 1. We exclude health and primary education from our analysis as this aspect of economy is already well developed in most of the countries in the sample.

Pillar 1 is comprised from more than 25 sub-variables. We test only a handful of them (see table A.2 in appendix A) and find that many of them alone are significant determinants of efficiency, but judicial independence remains significant also in combinations with other institutional variables (see appendix H, table H.1). Although wastefulness of government spending and transparency of policy making are significant efficiency determinants if taken alone, these factors become insignificant if other variables are included in the model.

Further, we test three sub-variables of the second pillar (infrastructure): quality of roads, quality of port infrastructure and quality of air infrastructure. We find that higher quality of all these factors have a positive impact on efficiency in construction, trade and transportation industries with all variables being significant at the1% level (see appendix H, table H.2). Caution should be made when interpreting these results, however, as factors have a rather high mutual correlation which indicates that infrastructure has been developed evenly, without significant emphasis on any certain category.

An in-depth analysis of the third pillar (macroeconomic environment) shows that government debt and gross national savings (both as % GDP) are significant and consistent determinants of efficiency. Lower government debt results in higher efficiency (so positive coefficients in the inefficiency equation). In turn, higher gross national savings are positively linked to efficiency in three industries: construction, trade and transportation (see appendix H, table H.3).

Our previous results suggest that among 5 GCI pillars, higher education and training are among the efficiency determinants for construction and trade. The fifth pillar (higher education and training) is broken into sub-variables and tested to determine which of them is a significant determinant of efficiency. We find that tertiary education enrolment rate (in gross %), extent of staff training, and quality of educational system is associated with higher efficiency (see appendix H, table H.4).

5 Discussion of the results

Our analysis shows that for each industry time dummy, which is interpreted as technical changes, is positive and significant at a 1% level for year 2014. We find that all analysed industries faced improvements in technologies over the period of 1995 to 2014, but each rate of improvement was different. Positive efficiency changes are observed in 4 out 6 industries in Latvia. More interestingly, we see that there are certain factors that have influenced improvements in efficiency in different industries. Notably, we see that EFI and R&D are significant determinants of efficiency, while FDI is not.

We find that industry-level TFP growth in Latvia was faster than average TFP growth in our sample in 4 industries – construction, hospitality, trade, and transportation. Although for the agriculture and manufacturing industries Latvia had slower TFP growth, the difference of the sample average and Latvia's TFP growth is small (1.4 pp and 5.2 pp respectively).

Next, we propose a discussion of each variable separately to understand the impact of efficiency determinants and further implications about them.

R&D

We find that R&D is a significant determinant of efficiency in all industries in our sample. Moreover, in all but one industry the variable is significant at a 1% level.

Several researches have documented importance of R&D spending. For example, Alston et.al. (2000) surmises that return on investment (ROI) on agriculture R&D brings in on average a 100% return. Indeed, Beintema and Elliott (2009) report that R&D expenditure has increased by an average of 3% per year. This, undoubtedly, fuels the efficiency changes, since there is a high correlation between R&D spending and efficiency. As Alston (2010) writes: "[productivity growth in agriculture] has been enabled by technical change resulting from public and private investments in agricultural R&D". So, it is reasonable to say that R&D expenditure also drives technical changes. In other studies, Singh and Trieu (1996) and Voutsinas and Tsamadias (2014) look at a macro level and show that R&D positively influence efficiency. Thus, we document that efficiency is improved not only by direct R&D expenditure in specific industries, but also by the country's overall R&D expenditure.

We can therefore surmise that R&D is indeed an important efficiency determinant. Further implications are that if a country aims to catch-up towards the world production frontier, it should promote R&D.

It seems that in Latvia low R&D spending (0.6% of GDP in 2013, compared to the EU average of 2.0%) could be one of the factors hindering efficiency catch-up and therefore also TFP growth.

FDI

We find that FDI is not a significant determinant of efficiency in any of the industries. This is contrary to view of Amann and Virmani (2015) who claimed that FDI enhances productivity growth. This contradiction may reflect situations where FDI has a direct impact only on labour productivity via capital accumulation, without affecting the distance to the frontier. In addition, our sample consists of already well-developed countries, for which FDI are unlikely to bring technology transfer, as it might be the case for less-developed economies.

Exports

Our results show that trade openness (export) is a significant determinant of efficiency in the manufacturing, trade, and transportation industries.

There are at least two explanations about an export-led increase in efficiency. First, in the past there was a conception that exports increase efficiency via learning-effects. As reported by the Stiglitz (1996), countries who enjoyed freer trade (and thus more exports) learned from others and thus increased efficiency. This was achieved by both technical spillovers and knowledge migration. Alternatively, new studies show that there could be another effect: exports do not lead to increased efficiency per se, rather self-selection phenomenon takes place, whereby the more efficient companies become, the higher exports they have, as reported Graner and Isaksson (2009). Therefore, we cannot be certain which of the effects take place first, but this does not impede our analysis, the conclusion still stands that exports are associated with higher efficiency.

Furthermore, it is reasonable that exports are not a significant efficiency determinant in the construction industry, as our results show. Our conclusion is supported by Grosso, Jankowska and Gonzales (2008) who report, "the construction sector generally remains a local activity", with a share of total service exports of about 1.8% among OECD countries.

EFI

The Economic Freedom Index variable was observed to be a significant and robust determinant of efficiency in every industry, except agriculture. We find that 4 out of 9 variables comprising EFI are significant determinates of efficiency in at least one of the industries.

We find that property rights, fiscal freedom, government spending, business freedom, and investment freedom are not significant determinants.

This is an interesting insight, since it is contrary to results by Puharts and Kloks (2015) who found that the property rights variable is a significant determinant of efficiency. While Puharts and Kloks chose a sample of three (out of 9) EFI variables, we enlarged the sample to encompass all available variables. This allowed for the identification of variables, which are better determinants of efficiency (and thus rendered property rights insignificant).

Also fiscal freedom, measured as a tax burden, is found to be insignificant. Our results are supported by OECD paper on tax and policy reforms (OECD, 2010), which states "effects of [tax] on the long-run level of TFP is estimated to be relatively small".

Our results suggest that, overall, government spending is not a significant determinant of efficiency, and these results are supported by both, IISD (n.d.) and a paper by Espinoza (2012) who state that governments can rarely affect industry performance (and thus efficiency) directly with spending patterns.

It is possible that business freedom is not a significant determinant of efficiency, since this variable deals mostly with starting the business. As the most value added is generated by companies that are already established, this index may not represent any hurdles or assistance to those companies. We find that business freedom and investment freedom have a rather high correlation of 0.54, which explains the insignificance of this variable in explaining efficiency; since both are strongly correlated, both have a similar effect on efficiency.

We find that freedom from corruption is a significant determinant of efficiency in three out of four industries for which the EFI variable was significant. Higher corruption levels are usually associated with lower efficiency as documented by Kato and Sato (2014). We document that freedom from corruption is not a significant determinant of efficiency in the manufacturing industry, which can partially be explained by the results reported by OECD (2014). They report that: i) manufacturing is less exposed to bribery cases than, for instance, construction and transportation; ii) bribes in manufacturing are lower than in other industries, e.g. trade and transportation.

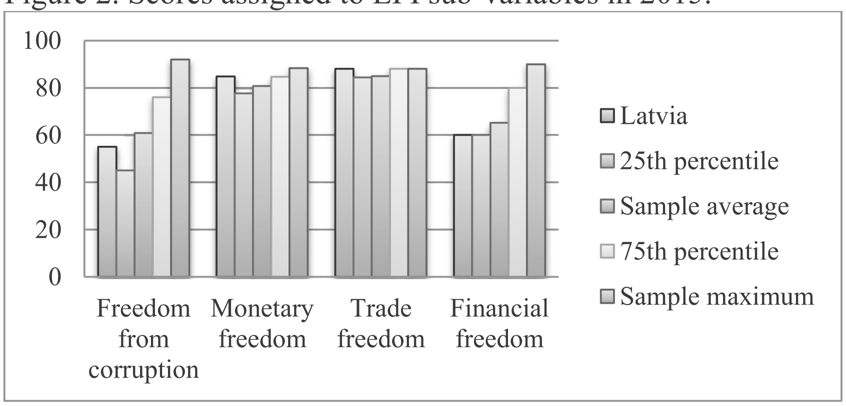
Further, monetary freedom is the only (from EFI sub-variables) significant efficiency determinant in manufacturing. Monetary freedom is comprised of data evaluating price controls and inflation levels. It stands to reason that more stable prices, and hence also stable and predictable exchange rates, are more beneficial for export intensive industries. This evidence is exhaustively covered by Cavalcanti et.al. (2012) who claim that price volatility has a negative impact on exports. Moreover, the manufacturing industry could be exposed to inflationary shocks much more than the construction, trade or transportation industries due to long term contracts in the latter industries (BCG, 2011).

In the Heritage Foundation's methodology, the trade freedom index is composed of two factors: trade-weighted average tariff rate and non-tariff barriers. Both variables include barriers that may hinder exports, and thus higher coefficient would mean less hindrance to trade. Therefore, it is reasonable that this variable is significant for the trade industry, which is import-dependent. In addition, the transportation industry benefits from trade freedom via freer trade, as noted by ATAG (2005), who claim that transportation is one of the building blocks of the modern world, and that a reduction in international trade barriers have promoted transportation development.

Financial freedom is composed of data about the banking sector and government regulations affecting opportunities to attract funds. Construction, being highly capital dependent, benefits a great deal from more opportunities to attract funds, as evident by the real estate building crisis following the Great Recession (when funds were harder to obtain). Toby and Peterside (2014) document that commercial loans (used as a proxy for financial freedom) in the manufacturing industry does not have a significant impact to value added in the total economy.

In figure 2 we compare EFI sub-variables' scores assigned to Latvia in 2014 to our sample average scores and maximum scores within our sample. We can see that freedom from corruption and financial freedom are significantly below sample average. It means that fighting corruption as well as promoting financial freedom is likely to foster catching-up towards the world production frontier, thus, accelerating TFP growth.

Figure 2. Scores assigned to EFI sub-variables in 2015.



Created by the authors, based on GCI database.

GCI

In all industries, pillar 1 (institutions) is a significant determinant of efficiency if taken alone. However, our results suggest that other pillars are even better determinants of efficiency than pillar 1, since it is rendered not as significant when tested together with other variables. So the conclusion is as follows: while better developed institutions promote efficiency in observed industries, the impact is likely to be indirect, for instance, via a better infrastructure and macroeconomic environment.

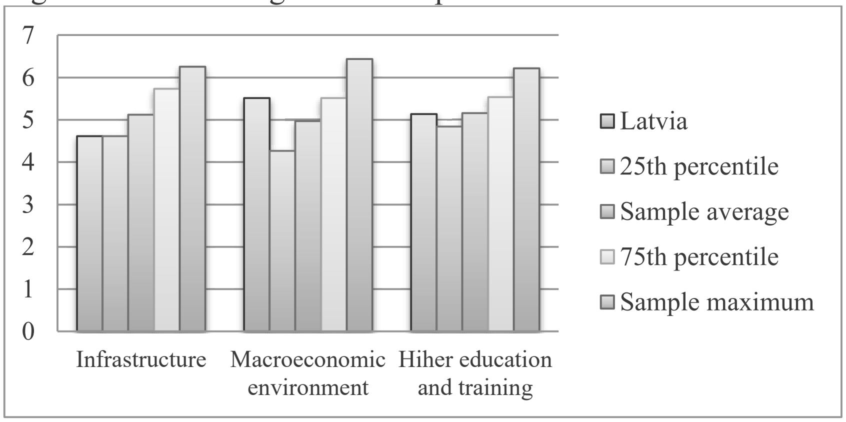
Our results for infrastructure variable are similar to what we expected. For construction, trade, and transportation, infrastructure is crucial for generating value added, mainly through roads, railroads, ports and air transport.

We find that macroeconomic stability is an important efficiency determinant for all industries. This is explained by the fact that stability in a macroeconomic environment usually leads to higher ease of doing business which further translates to productivity growth. This view is supported by Bhattacharjee et.al. (2009). Moreover, there is a strong association between macroeconomic instability and economic downturn, as reported by Haghighi et.al. (2012).

Our results show that efficiency in transportation is less dependent on higher education and training than in construction and trade. This is partly supported by Corrado, Hulten and Sichel (2005) who show that in the US similar trends were observed, namely, higher education had a much larger impact on trade, than on other industries. Moreover, in all industries pillar 4 (health and primary education) loses its significance when combined with pillar 5 (higher education and training). All industries require specific skills and knowledge, so there is a relatively higher importance of higher education as compared to primary education, as discussed by Bloom, Canning and Chan (2006). In addition, for majority of countries in our sample, a very high level of primary education attainment has already been achieved; therefore, the variable is rather similar across countries and does not explain the differences in inefficiency.

In figure 3 we compare the GCI pillar scores assigned to Latvia in 2014 to our sample average scores and the maximum scores within our sample. The figure suggests that infrastructure in Latvia is still insufficiently developed in comparison with other countries within our sample. Thus, there is space for infrastructure improvement, which has a potential to boost efficiency and therefore also labour productivity in Latvia, particularly in construction, trade, and transportation. Macroeconomic environment indicator in Latvia is above sample average, and higher education and training is almost at par with the sample average. Still, there may be an opportunity for improvement as Latvia scores substantially below the sample maximum. Further each pillar is discussed in detail.

Figure 3. Scores assigned to GCI pillars in 2015.

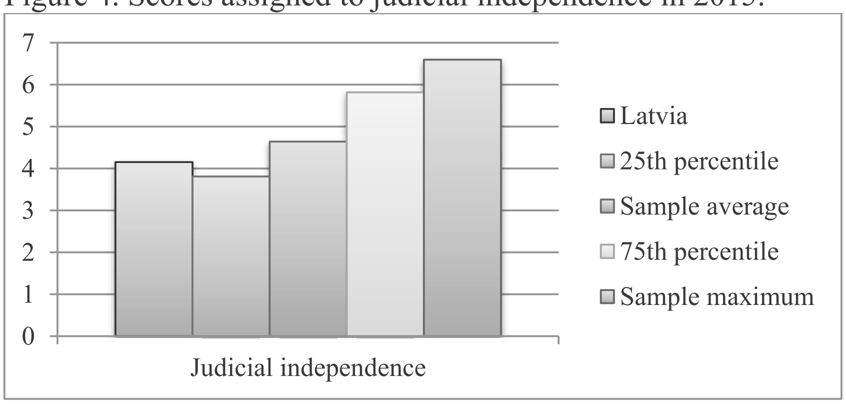


Created by the authors, based on GCI database.

GCI sub-variables

We find that improvements in the judicial system have the potential to increase efficiency in construction, trade and transportation. As Fox et.al. (n.d.) report, a well-functioning judicial system is a crucial component for any economy to perform well. This is important for Latvia, according to GCI, the Latvian judicial system is less independent than the majority of countries in our sample.

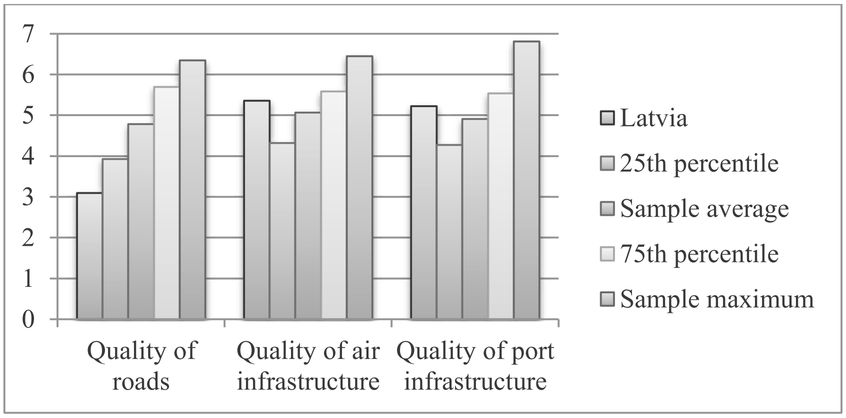
Figure 4. Scores assigned to judicial independence in 2015.



Created by the authors, based on GCI database.

The results suggest that investing in the development of roads, ports or air infrastructure may increase efficiency. We suggest policy makers should focus on the improvement of roads in Latvia, as the current quality of roads in Latvia is substantially lower than the quality of port and air infrastructure, as evident by GCI which ranks Latvia 108^{th} (out of 144) in road quality, while 35^{th} and 31^{st} respectively in air transport and port infrastructure (GCI, 2016.). While the quality of air and port infrastructure in Latvia is above the sample average and not far from the 75th percentile, the quality of roads in Latvia is below the 25th percentile (see figure 5). Thus, investing in roads might have a large potential to boost efficiency, especially in construction, trade and transportation.

Figure 5. Scores assigned to GCI pillar 2 sub-variables in 2015.



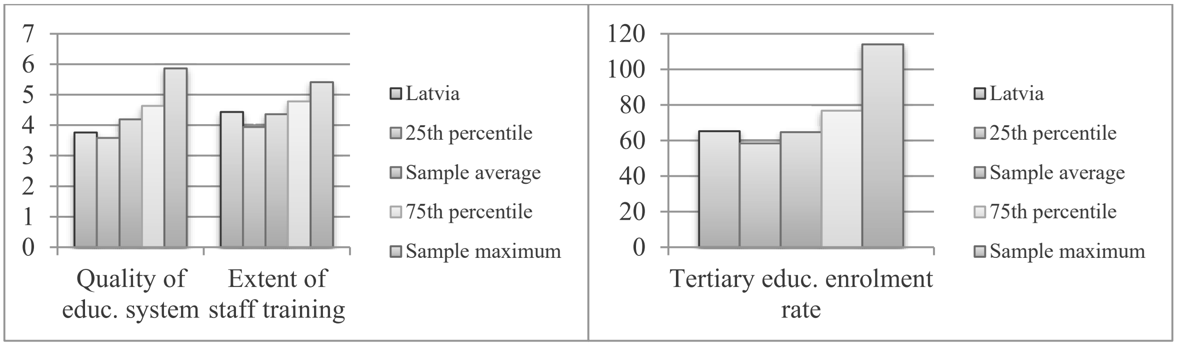
Created by the authors, based on GCI database.

Moreover, we find that higher national savings and lower government debt are associated with higher efficiency. This finding is supported by the World Bank (2011) which report that a higher national savings rate improves economic growth rates and productivity. Moreover, Ceccheti, Mohanty and Zampolli (2011) argue that higher government debt (above 85% of GDP threshold) is associated with lower growth and damages efficiency in the economy. This is the case for 11 countries in our sample, hence we believe as applicable in this analysis.

Although the savings rate in Latvia is broadly at par with the sample average and government debt is relatively low, our results imply that maintaining of prudent fiscal policy is one of the necessary conditions for a fast catch-up towards the world production frontier, and thus, TFP growth.

The quality of the education system in Latvia is below sample average (ranked 65th out of 108 in the latest GCI report). Thus, additional efforts should be concentrated on improving quality in the education system to achieve higher efficiency. Furthermore, our results (appendix H, table H.4) suggest that for the construction and transportation industries, the quality of the education system is important to a lesser extent than to staff training, and vice versa for trade industry. This result is supported by the papers of ILO (2001) who states that "[the construction industry] provides employment for those with little education or skill, many of them are from the poorer sections of society". Similar evidence is recorded by US DL (2007) for the transportation industry. Thus, promoted staff training has the potential to improve efficiency in construction and transportation.

Figure 6. Scores assigned to GCI pillar 5 sub-variables in 2015.



Note. Quality of the education system and the extent of staff training are ranged from 1 to 7. Tertiary education enrolment rate is expressed in gross % of people after secondary education. Result above 100% means that older people (exceeding ratio's target age group) are enrolling in tertiary education.
Created by the authors, based on GCI database.

6 *Conclusions*

In this paper we applied the Stochastic Frontier Analysis True Fixed Effects model with time-varying technical progress to the World Input-Output Database to study in which industries Latvia has caught-up towards the world production frontier over the past two decades and which factors could foster this convergence in the future. A 2-stage Data Envelopment Analysis was employed as a robustness check.

Our results show that (given the amount of capital stock and labour) output of the agriculture, hospitality, trade and transportation industries in Latvia still substantially lags behind its' peers. For the last 20 years, construction and private sector services like trade, transportation and hospitality experienced substantial efficiency gains, spurring Total Factor Productivity (TFP) growth well above average in our country sample. In turn, manufacturing and agriculture has failed to increase efficiency and thus experienced rather low TFP growth. The result for agriculture is sensible – efficiency in this industry cannot be easily influenced as it depends mainly on climate and soil quality. In turn, manufacturing in Latvia was rather efficient already in 1995, so over the past 20 years this industry has managed to remain efficient. These results answer the first research question: Latvia is more efficient (close to the world production frontier) in construction and manufacturing; and also supports our first hypothesis: while technical and efficiency changes differ across industries, TFP growth in all observed industries was positive.

We document that the efficiency change in Latvia's agriculture and manufacturing industries was negative, -3.2% and -1.1%, respectively. Contrary, in the construction, hospitality, trade and transportation industries it was significantly positive, 26.7%, 52.6%, 17.8% and 34.5%, respectively. For all industries in Latvia, technical change was positive and larger than efficiency change. Thus, our second hypothesis is rejected. This answers our second research question: technical rather efficiency change, is the main driver of TFP growth in analysed industries in Latvia.

Our third hypothesis is partly supported as we have identified significant and robust efficiency determinants. We find that R&D spending and trade openness are significant efficiency determinants for all industries while foreign direct investments are not. Furthermore, we document a positive association between efficiency and several variables of the Economic Freedom Index and Global Competitiveness Report.

To answer third research question: How Latvia may foster a catch-up to the world's production frontier; we perform an analysis on each of the factors.

R&D expenditure in Latvia should be promoted in order for efficiency gains to take place in all of the analysed industries. Moreover, higher R&D expenditure in Latvia should positively affect efficiency in high-medium technology manufacturing and, thus promote the growth of this industry. Trade openness is an important factor for certain industries: manufacturing, trade, and transportation, thus export-friendliness should improve efficiency in these industries. We find that the following EFI sub-variables are significant determinants of efficiency: freedom from corruption is a significant determinant for efficiency in the construction, trade, and transportation industries as there is international evidence that these industries are more associated with bribes than other industries. Monetary freedom: in manufacturing and transportation industries as price and exchange rate stability and predictability are important for export performance. Trade freedom: in trade and transportation as trade barriers determine the ease of doing business in these industries; while financial freedom is in the construction and trade industries. Prudent reforms in these mentioned areas should improve efficiency, especially in industries that are lagging from the world production frontier. We also conclude that efficiency in trade, transportation and construction might be increased by improvements in infrastructure. In the context of Latvia's infrastructure, poor road quality is the main factor that is likely to harm efficiency of these industries. According to the results, better quality of higher education is associated with higher efficiency, so adapting the best international educational standards and practices should help Latvian industries in moving towards the world production frontier. Business-friendly institutional reforms, like judicial system improvements and stabilized macroeconomic environment, should raise labour productivity not only by promoting capital accumulation, but also through TFP gains.

We acknowledge the need for further research on the topic for the analysis to be exhaustive. First, we propose to analyse the remaining industries, thus covering the whole economy of Latvia and other countries. Second, further research needs to be made in a more detailed breakdown of EFI and GCI variables, as well as subdivision on how the economy of Latvia has developed and what further improvements can be made. By performing aforementioned activities, more specific recommendations for policy makers can be provided.

7 References

Aigner, D., Lovell, C. K., & Schmidt, P. (1977). Formulation and estimation of stochastic frontier production function models. *Journal of Econometrics*, *6*(1), 21-37.

Aleksandrovics A., Smilts S. (2015). Measuring the EU structural fund impact on Latvia's Agricultural sector: Malmquist Index approach. *Retrieved from SSE Riga Bachelor Thesis database.*

Alston, J. M. (2010), The Benefits from Agricultural Research and Development, Innovation, and Productivity Growth. *OECD Food, Agriculture and Fisheries Papers, No. 31, OECD Publishing*.

Alston, J. M., Chan-Kang, C., Marra, M. C., Pardey, P. G., & Wyatt, T. J. (2000). *A meta-analysis of rates of return to agricultural R&D: Ex pede Herculem?* (Vol. 113). Intl Food Policy Res Inst.

Amann, E., & Virmani, S. (2015). Foreign direct investment and reverse technology spillovers. *OECD Journal: Economic Studies*, *2014*(1), 129-153.

ATAG (2005). The economic and social benefits of air transport. Retrieved from: http://www.icao.int/Meetings/wrdss2011/Documents/JointWorkshop2005/ATAG_SocialBenefitsAirTransport.pdf

Attar A.A., Gupta A.K., Desai D.B. (2009). A Study of Various Factors Affecting labour Productivity and Methods to Improve It. *Journal of Mechanical and Civil Engineering. ISSN: 2278-1684, PP: 11-14.*

Badunenko O., Henderson D., Zelenyuk V. (2008). Technical Change and Transition: Relative Contributions to Worldwide Growth during the 1990s. *Oxford Bulletin of Economics and Statistics, 70(4),* 461-492.

Baier, S. L., Dwyer, G. P., & Tamura, R. (2006). How important are capital and total factor productivity for economic growth? *Economic Inquiry, 44(1),* 23-49.

Baltabaev, B. (2013). *FDI and Total Factor Productivity Growth: New Macro Evidence* (No. 27-13). Monash University, Department of Economics.

Battese G., Heshmati A. and Hjalmarsson L. (2000). Efficiency of labour use in the Swedish banking industry: a stochastic frontier approach. *Empirical Economics (2000) 25:623-640*

BCG (2011). Making your company inflation ready. Retrieved from: http://www.bcg.com/documents/file72671.pdf

Beintema, N., & Elliott, H. (2009). Setting meaningful investment targets in agricultural research and development: challenges, opportunities and fiscal realities. In *How to feed the World in 2050. Proceedings of a technical meeting of experts, Rome, Italy,* *24-26 June 2009.* (pp. 1-29). Food and Agriculture Organization of the United Nations (FAO).

Belotti, F., & Ilardi, G. (2012). Consistent Estimation of the 'True' Fixed-Effects Stochastic Frontier Model. *CEIS Research Papers, 10(5).*

Bhattacharjee, A., Higson, C., Holly, S., & Kattuman, P. (2009). Macroeconomic instability and corporate failure: the role of the legal system. *Review of Law & Economics*, *5*(1), 1-32.

Blinder, A., Yellen, J., (2002). The Fabulous Decade: Macroeconomic Lessons from the 1990s. In: A.B. Krueger and R.M. Solow (eds.) The Roaring 1990s: Can Full Employment Be Sustained? *New York: Russel Sage Foundation, 2002.*

Bloch, H., & Tang, S. H. K. (2007). The effects of exports, technical change and markup on total factor productivity growth: Evidence from Singapore's electronics industry. *Economics Letters*, *96*(1), 58-63.

Bloom, D. E., Canning, D., & Chan, K. (2006). *Higher education and economic development in Africa* (Vol. 102). Washington, DC: World Bank.

Børing P. (2012). The impact of manufacturing firms' use of academic workers on their productivity level. *Bulletin of Economic Research 66:2, 2014.*

Bragagnolo, C., Spolador, H. F., & Barros, G. S. C. (2010). Regional Brazilian agriculture TFP analysis: a stochastic frontier analysis approach. *Revista Economia*, *11*, 217-242.

Carroll, J., Newman, C., & Thorne, F. (2007). *A comparison of stochastic frontier approaches to estimating inefficiency and total factor productivity: an application to Irish dairy farming* (No. tep0907). Trinity College Dublin, Department of Economics.

Cavalcanti T., Mohaddes K., Raissi M. (2012). Commodity Price Volatility and the Sources of Growth. *IMF Working Paper. WP/12/12.*

CBO, U. (2005). R&D and Productivity Growth: A Background Paper. *In Washington, DC: The Congress of the United States.*

Ceccheti S.G., Mohanty M.S., Zampolli F. (2011). The real effect of debt. Retrieved from: http://www.bis.org/publ/othp16.pdf

Chanda, A., & Dalgaard, C. J. (2008). Dual economies and international total factor productivity differences: Channelling the impact from institutions, trade, and geography. *Economica*, *75*(300), 629-661.

Corrado, C., Hulten, C., & Sichel, D. (2005). Measuring capital and technology: an expanded framework. In *Measuring capital in the new economy* (pp. 11-46). University of Chicago Press.

CSB. (2015). Structural business indicators in industry. Retrieved from: http://www.csb.gov.lv/en/statistikas-temas/metodologija/structural-business-indicators-industry-37406.html

Dragomir, L. A. U. R. E. N. T. I. U., & Tanasie, A. N. C. A. (2010). The Importance of Labor Productivity for the Romanian Industry for the Growth of its Competitiveness. In *Proceedings of the 5th WSEAS International Conference on Economy and Management Transformation* (Vol. 2, pp. 837-842).

Erumban, A., Gouma, R., de Vries, G., de Vries, K., & Timmer, M. (2012). WIOD Socio-Economic Accounts (SEA): Sources and Methods. *Groningen, April*.

Escribano, Á., & Stucchi, R. (2008). Catching up in total factor productivity through the business cycle: evidence from Spanish manufacturing surveys.

Espinoza, R. (2012). *Government Spending, Subsidies and Economic Efficiency in the GCC* (No. 095). Oxford Centre for the Analysis of Resource Rich Economies, University of Oxford.

Fadejeva, L., & Melihovs, A. (2010). Measuring Total Factor Productivity and Variable Factor Utilization: Sector Approach, the Case of Latvia. *Eastern European Economics*, *48*(5), 63-101.

Färe, R., Grosskopf, S., Norris, M., & Zhang, Z. (1994). Productivity growth, technical progress, and efficiency change in industrialized countries. *The American economic review*, 66-83.

Felipe, J., & Adams, F. G. (2005). “A theory of production" the estimation of the cobb-douglas function: A retrospective view. *Eastern Economic Journal*,*31*(3), 427-445.

Fernald, J. (2014). *Productivity and Potential Output before, during, and after the Great Recession* (No. w20248). National Bureau of Economic Research.

Ferreira, P. C., & Trejos, A. (2011). Gains from trade and measured total factor productivity. *Review of Economic Dynamics*, *14*(3), 496-510.

Filippetti, A., & Peyrache, A. (2013). Is the convergence party over? Labour productivity and the technology gap in Europe. *JCMS: Journal of Common Market Studies*, *51*(6), 1006-1022.

Fox L., Gardaphe F., Nagpal Z., Unger M., Zaklouta H. (n.d.) The Italian Economy: Obstacles and Recommendations for Growth. Retrieved from: http://www.stern.nyu.edu/sites/default/files/assets/documents/con_047349.pdf

GCI (2016). Competitiveness ranking. Retrieved from: http://reports.weforum.org/global-competitiveness-report-2014-2015/rankings/

Gornall, J., Betts, R., Burke, E., Clark, R., Camp, J., Willett, K., & Wiltshire, A. (2010). Implications of climate change for agricultural productivity in the early twenty-first century. *Philosophical Transactions of the Royal Society of London B: Biological Sciences*, *365*(1554), 2973-2989.

Granér, M., & Isaksson, A. (2009). Firm efficiency and the destination of exports: evidence from Kenyan plant-level data. *The Developing Economies*, *47*(3), 279-306.

Greene, W. (2005). Fixed and random effects in stochastic frontier models. *Journal of Productivity Analysis, 23(1), 7-32.*

Grosso, M. G., Jankowska, A., & Gonzales, F. (2008). Trade and regulation: the case of construction services. In *OCED Experts Meeting on Construction Services, Paris*.

Haghighi, H. K., Sameti, M., & Isfahani, R. D. (2012). The effect of macroeconomic instability on economic growth in Iran. *Research in Applied Economics*, *4*(3), 39-61.

Heckman J. J. (1981). The incidental parameters problem and the problem of initial conditions in estimating a discrete time-discrete data stochastic process. In *Structural Analysis of Discrete Data with Econometric Applications,* Manski, C. F. and McFadden D. MIT Press, 1981.

Hicks, M. J. (2013). Manufacturing Productivity Through the Great Recession: What Does It Mean for the Future?. *Center for Business and Economic Research, Ball State University*.

Hu B.A., Cai L.A. (2004). Hotel Labour Productivity Assessment. *Journal of Travel & Tourism Marketing, Volume 16, Issue 2-3, pages 27-38.*

Hwang, I., & Wang, E. C. (2004). Does openness to trade affect total factor productivity growth: evidence from 45 Japanese manufacturing industries.*Journal of Economic Research*, *9*(2), 147-173.

Jondrow J., Lovell C. K., Materov I. S., Schmidt P. (1982). On the estimation of technical inefficiency in the stochastic frontier production function model. *Journal of econometrics*, 19(2), 233-238.

Jorgenson, Dale W., Stiroh, Kevin J. (2000). Raising the speed limit: U.S. economic growth in the information age. *Brookings Papers on Economic Activity, 2000, iss. 1,* pp. 125-211.

Razak M. I. M., Idris O., Mohd Y.M.A., Nasni N.R.N., Nazri A.M. (2014). Factors affecting labour productivity in Malaysia: an overview. *International Journal of Economics, Commerce and Management. Vol. II, Issue 10, Oct 2014*

Ikhsan-Modjo, M. (2006). Total factor productivity in Indonesian manufacturing: a stochastic frontier approach. *Monash University (ABERU Discussion Paper 28)*.

Ilbuodo P.S. (2014). Foreign Direct Investment and Total Factor Productivity in the Mining Sector: the Case of Chile. Retrieved from: http://digitalcommons.conncoll.edu/cgi/viewcontent.cgi?article=1015&context=econhp

IISD (n.d.). The effect of subsidies. Retrieved from: https://www.iisd.org/GSI/effects-subsidies

ILO (2001). The construction industry in the twenty first century: Its image, employment prospects and skill requirements. *International Labour Office.* Retrieved from: http://www.ilo.org/public/english/standards/relm/gb/docs/gb283/pdf/tmcitr.pdf

Kato, A., & Sato, T. (2014). The effect of corruption on the manufacturing sector in India. *Economics of Governance*, *15*(2), 155-178.

Khan, T. S. (2006). *Productivity Growth, Technological Convergence, R&D, Trade, and Labor Markets: Evidence From the French Manufacturing Sector*(No. 6-230). International Monetary Fund.

Kong, X., Marks, R. E., & Wan, G. H. (1999). Technical Efficiency, Technological Change and Total Factor Productivity Growth in Chinese State-Owned Enterprises in the Early 1990s. *Asian Economic Journal*, *13*(3), 267-282.

Krasnopjorovs, O. (2012). Measuring the sources of economic growth in the EU with parametric and non-parametric methods. *Journal of Economics and Management Research (University of Latvia)*, *1*, 106-122.

Kumbhakar, S. C., & Lovell, C. K. (2003). *Stochastic frontier analysis*. Cambridge University Press.

Mankiw N. G., Romer D. & Weil D. N. (1992). A contribution to the empirics of economic growth. *Quarterly Journal of Economics, May 1992*

Manyika J., Mendonca L., Remes J., Klubmann S., Dobbs R., Karkun K., Tormanen A. (2010). How to compete and grow: A sector guide to policy. *McKinsey Global Institute.*

Mitra A., Sharma C., Varoudakis M.A. (2011). Total Factor Productivity and Technical Efficiency of Indian Manufacturing: The Role of Infrastructure and Information & Communication Technology. *CERDI, Etudes et Documents, E 2011.15*

MTI (2014). A sectoral examination of Singapore's productivity growth. Retrieved from: https://www.mti.gov.sg/ResearchRoom/SiteAssets/Pages/Economic-Survey-of-Singapore-Second-Quarter-2014/BA_2Q14.pdf

Neyman, J., and E. L. Scott. (1948). Consistent estimates based on partially consistent observations. *Econometrica 16,* 1-32

Nishimizu M., Page J. M. (1982). Total factor productivity growth, technical progress and technical efficiency change: dimensions of productivity change in Yugoslavia. *The Economic Journal, 92, December 1982,* 920-93

OECD (2010). *OECD Tax Policy Studies Tax Policy Reform and Economic Growth.* OECD publishing.

OECD (2014). *OECD Foreign Bribery Report: An Analysis of the Crime of Bribery of Foreign Public Officials*. OECD Publishing.

Perelman S. (1995). R&D, technical progress and efficiency change in industrial activities. *Review of Income and Wealth. Series 41. Number 3,* 349-366.

Pilat, D. (1996). Competition, productivity and efficiency. *OECD Economic Studies*, *27*(2), 107-46.

Puharts A., Kloks P. (2015). Sources of TFP Growth in the Baltic States: The Frontier Approach. *Retrieved from SSE Riga student Bsc Thesis database.*

Sabasi, D., & Shumway, C. R. (2014). Technical Change, Efficiency, and Total Factor Productivity in US Agriculture. In *2014 Annual Meeting, July 27-29, 2014, Minneapolis, Minnesota* (No. 170225). Agricultural and Applied Economics Association.

Selim S. (2012). Labour productivity and rice production in Bangladesh: a stochastic frontier approach. *Applied Economics, 2012, 44,* 641-652

Singh, N., & Trieu, H. (1996). *The Role of R & D in Explaining Total Factor Productivity Growth in Japan, South Korea, and Taiwan*. University of California.

Stiglitz, J. E. (1996). Some lessons from the East Asian miracle. *The world Bank research observer*, *11*(2), 151-177.

Stiroh, K. J. (2001). What drives productivity growth? *Economic Policy Review*, *7*(1).

Sunding, D., & Zilberman, D. (2001). The agricultural innovation process: research and technology adoption in a changing agricultural sector. *Handbook of agricultural economics*, *1*, 207-261.

Tanna S., (2009). The impact of foreign direct investment on total factor productivity growth: International evidence from the banking industry. Managerial Finance, Vol. 35 Iss: 3, pp.297 – 311

Thomson M.A., Rushing F.W. (1999). An Empirical Analysis of the Impact of Patent Protection on Economic Growth: An Extension. *Journal of economic development. Volume 24, Number 1, June 19.*

Toby, A. J., & Peterside, D. B. (2014). Analysis of the Role of Banks in Financing the Agriculture and Manufacturing Sectors in Nigeria. *International Journal of Research in Business Management (IMPACT: IJRBM) ISSN (E)*.

Trick M.A. (1998). Strengths and Limitations of DEA. Retrieved from: http://mat.gsia.cmu.edu/classes/QUANT/NOTES/chap12/node7.html

Tu, H. J., & Wan-Chu, Y. (2013). Measuring the operating efficiency of internet channels using the two-stage DEA approach. *Asia Pacific Management Review*, *18*(3).

US DL (2007). Identifying and Addressing Workforce Challenges in America’s Transportation Industry. *The U.S. Department of Labour*. Retrieved from: https://www.doleta.gov/brg/pdf/Transportation%20Report_final.pdf

Voutsinas, I., & Tsamadias, C. (2014). Does research and development capital affect total factor productivity? Evidence from Greece. *Economics of Innovation and New Technology*, *23*(7), 631-651.

Wright B. D. and Douglas G. (1976). Better procedures for sample-free item analysis. *Research memorandum 20. Statistical Labouratory, Department of Education, University of Chicago.*

World Bank. (2011). Turkey - Country Economic Memorandum (CEM): Sustaining High Growth - The Role of Domestic savings: Synthesis Report. *Washington, DC. World Bank.*

Javorcik B., Fitriani F., Iacovone L. (2012). Productivity performance in Indonesia's manufacturing sector. *Indonesia PREM policy note; no. 5. Washington, DC: World Bank*

Worthington A. C. (2000). Technical Efficiency and Technical Change in Australian Building Societies. *Abacus. Jun2000, Vol. 36. Issue 2, p180.*

Znotina D. & Jermolajeva E. (2011). Labour productivity in the regions of Latvia. *European integration studies. 2011. No 5.*

8 Appendices

Appendix A. Data.

Table A.1. List of countries.

Australia	Estonia	Japan	Romania
Austria	Finland	Korea, Rep.	Russia
Belgium	France	Latvia	Slovakia
Brazil	Germany	Lithuania	Slovenia
Bulgaria	Greece	Luxembourg	Spain
Canada	Hungary	Malta	Sweden
China	India	Mexico	Taiwan
Cyprus	Indonesia	Netherlands	Turkey
Czech Republic	Ireland	Poland	United Kingdom
Denmark	Italy	Portugal	United States

Table A.2. List of variables used in regressions.

Variable	**Description**	**Source**
Y	Value added (at PPP), million USD	WIOD, Eurostat, and IMF database
L	Labour input (hours worked), million hours	WIOD, Eurostat, and the World Bank database
K	Capital stock (at PPP), million USD	WIOD, extended by authors using data from WIOD, Eurostat and IMF databases via perpetual inventory method
R&D	Spending on R&D, percentage of GDP	UNESCO Statistics database
TO	Exports, percentage of GDP	The World Bank database
EFI	Economic freedom index (0-100): Following sub-variables were analyzed: • Freedom from corruption • Business freedom • Property rights • Monetary freedom • Trade freedom • Financial freedom	The Heritage Foundation data

	• Fiscal freedom • Government spending • Investment freedom	
FDI	Foreign Direct Investments, percentage of GDP	The World Bank database

GCI	Global Competitiveness Index (1-7)
	
	Following sub-variables were analyzed:
	• Institutions
	  • Diversion of public funds
	  • Efficiency of legal framework in setting disputes
	  • Judicial independence
	  • Organized crime
	  • Public trust in politicians
	  • Transparency of policymaking
	  • Undue influence
	  • Wastefulness of government spending
	• Infrastructure
	  • Quality of airports
	  • Quality of ports
	  • Quality of roads
	• Macroeconomic environment
	  • Government budget balance
	  • Government debt
	  • Gross national savings
	  • Inflation
	• Higher education and training
	  • Extent of staff training
	  • Quality of the education system
	  • Tertiary education enrollment rate
		World Economic Forum with Columbia University

Appendix B. Results of TFE regressions.

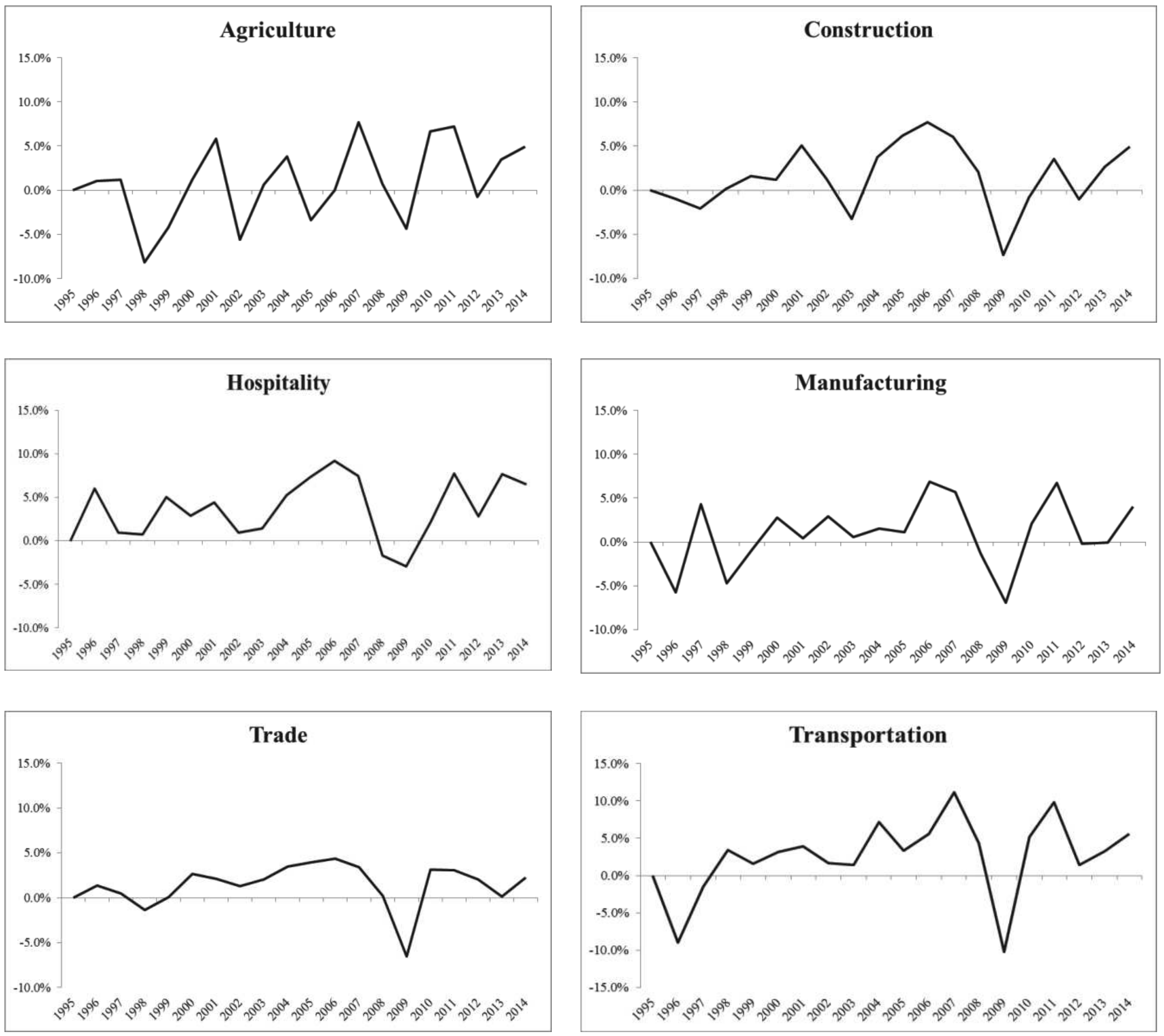
	Agriculture		Construction		Hospitality	
	Coefficient	St. Err.	Coefficient	St. Err.	Coefficient	St. Err.
labour	0.197***	0.042	0.49***	0.046	0.240**	0.041
capital	0.193***	0.035	0.415***	0.038	0.043***	0.004
t						
1996	0.010	0.029	-0.010***	0.003	0.060	0.037
1997	0.022	0.033	-0.030	0.032	0.069***	0.003
1998	-0.060**	0.029	-0.029	0.033	0.077***	0.004
1999	-0.102***	0.029	-0.013	0.029	0.127***	0.004
2000	-0.091***	0.030	-0.001	0.032	0.156***	0.022
2001	-0.032	0.031	0.049	0.046	0.200***	0.023
2002	-0.088***	0.031	0.061	0.043	0.210***	0.023
2003	-0.082**	0.032	0.029	0.035	0.224***	0.022
2004	-0.043	0.032	0.066*	0.034	0.277***	0.023
2005	-0.077**	0.034	0.128***	0.037	0.349***	0.022
2006	-0.077**	0.035	0.205***	0.034	0.442***	0.024
2007	0.000	0.037	0.265***	0.035	0.516***	0.026
2008	0.007	0.036	0.286***	0.038	0.500***	0.024
2009	-0.036	0.036	0.213***	0.040	0.470***	0.024
2010	0.030	0.037	0.204***	0.033	0.491***	0.024
2011	0.103***	0.038	0.240***	0.034	0.569***	0.042
2012	0.095***	0.039	0.230***	0.037	0.596***	0.032
2013	0.130**	0.039	0.256***	0.037	0.673***	0.039
2014	0.179***	0.044	0.306***	0.040	0.738***	0.032
σ_u	0.273***	0.013	0.291***	0.01	0.265***	0.007
σ_v	0.047***	0.011	0.000	0.00	0.000	0.000
Log-Likelihood	350.578		406.705		480.405	
N	800		800		800	

Note. Significance: ***:1% level; **: 5% level; *:10% level.

	Manufacturing		Trade		Transportation	
	Coefficient	St. Err.	Coefficient	St. Err.	Coefficient	St. Err.
labour	0.446***	0.045	0.459***	0.042	0.273***	0.028
capital	0.543***	0.020	0.533***	0.030	0.091***	0.020
t						
1996	-0.058***	0.012	0.014	0.026	-0.089***	0.014
1997	-0.015**	0.006	0.019	0.028	-0.105***	0.022
1998	-0.062***	0.011	0.005	0.029	-0.070**	0.028
1999	-0.070***	0.011	0.006	0.031	-0.054	0.033
2000	-0.043***	0.008	0.033	0.034	-0.023	0.035
2001	-0.039***	0.011	0.054	0.035	0.016	0.038
2002	-0.009	0.024	0.067*	0.036	0.033	0.041
2003	-0.003	0.003	0.087**	0.037	0.047	0.044
2004	0.012*	0.006	0.122***	0.038	0.119***	0.044
2005	0.023***	0.006	0.162***	0.039	0.152***	0.048
2006	0.092***	0.007	0.205***	0.040	0.208***	0.047
2007	0.148***	0.007	0.239***	0.042	0.32***	0.054
2008	0.135***	0.022	0.242***	0.042	0.363***	0.057
2009	0.066***	0.016	0.177***	0.042	0.261***	0.053
2010	0.086***	0.018	0.208***	0.040	0.313***	0.054
2011	0.154***	0.017	0.238***	0.040	0.411***	0.047
2012	0.151***	0.020	0.259***	0.041	0.426***	0.063
2013	0.150***	0.020	0.260***	0.042	0.459***	0.063
2014	0.191***	0.022	0.283***	0.042	0.515***	0.067
σ_u	0.17***	0.004	0.117***	0.033	0.245***	0.000
σ_v	0.000	0.000	0.089***	0.014	0.000	0.409
Log-Likelihood	834.692		611.048		406.705	
N	800		800		800	

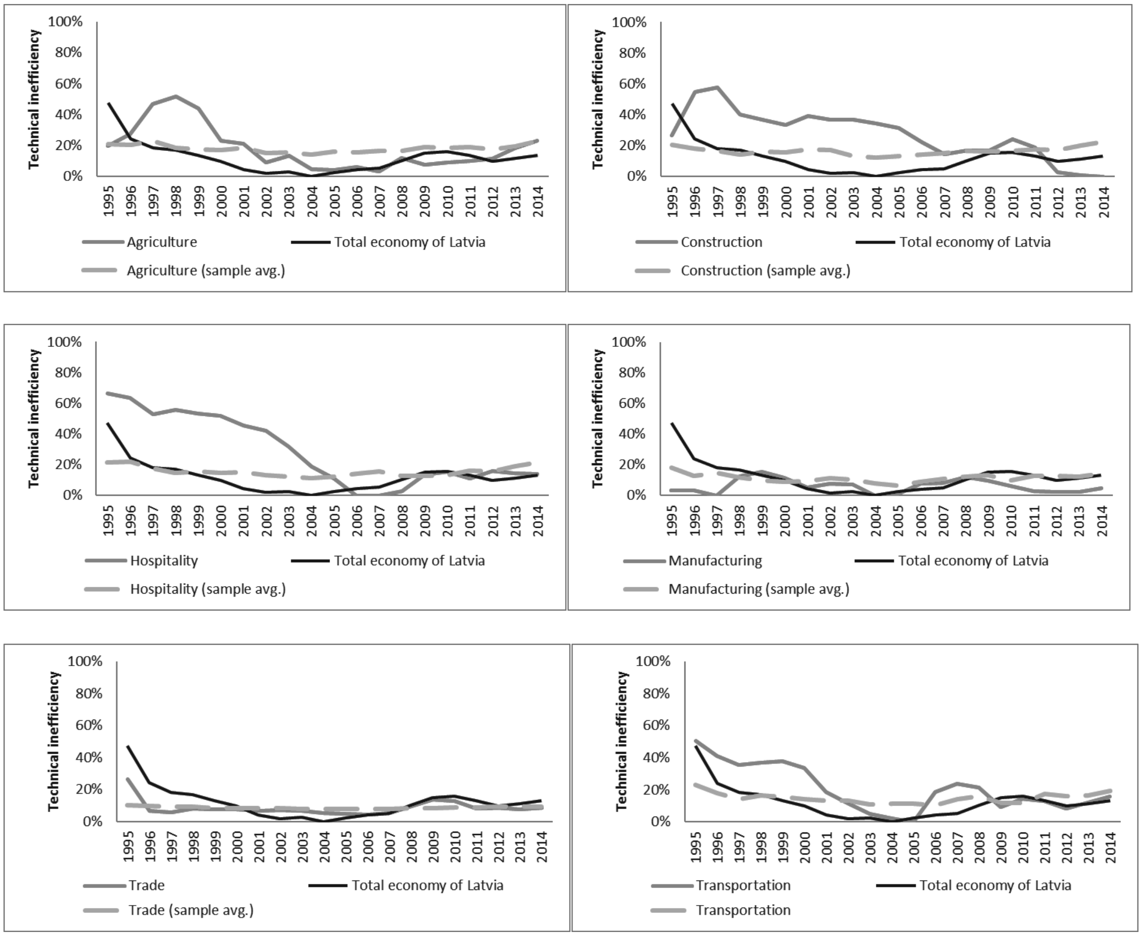
Note. Significance: ***:1% level; **: 5% level; *:10% level. Country specific intercepts (alphas) are not reported to save space.

Appendix C. World technical progress estimates (1995-2014).



*For all graphs: Y axis – technical change in %; X axis - years

Appendix D. Comparison of inefficiency scores from 1995 to 2014.



Appendix E. Results from TFE regressions with inefficiency determinants.

	Agriculture		Construction		Hospitality	
	Coefficient	St. Err.	Coefficient	St. Err.	Coefficient	St. Err.
labour	0.180***	0.039	0.443***	0.039	0.240***	0.028
capital	0.149***	0.036	0.358***	0.034	0.042***	0.004
t						
1996	0.013	0.036	0.030	0.024	0.025***	0.000
1997	-0.008	0.036	0.035	0.026	0.073***	0.000
1998	-0.038	0.036	0.053*	0.026	0.091***	0.001
1999	-0.070*	0.036	0.058*	0.026	0.184***	0.002
2000	-0.059	0.037	0.071**	0.026	0.170***	0.020
2001	-0.025	0.036	0.095***	0.028	0.204***	0.020
2002	-0.049	0.036	0.110***	0.030	0.238***	0.026
2003	-0.044	0.037	0.130***	0.030	0.234***	0.016
2004	0.007	0.037	0.171***	0.031	0.299***	0.008
2005	-0.062*	0.038	0.216***	0.032	0.363***	0.016
2006	-0.062	0.038	0.275***	0.032	0.440***	0.016
2007	0.008	0.040	0.320***	0.032	0.496***	0.016
2008	0.009	0.040	0.320***	0.033	0.517***	0.017
2009	-0.073*	0.040	0.245***	0.033	0.522***	0.023
2010	0.011	0.041	0.219***	0.033	0.501***	0.017
2011	0.075*	0.042	0.245***	0.035	0.543***	0.017
2012	0.096**	0.042	0.249***	0.036	0.582***	0.018
2013	0.104**	0.043	0.249***	0.036	0.631***	0.019
2014	0.115***	0.043	0.280***	0.037	0.675***	0.019
Coefficients						
EFI	-0.064***	0.024	-0.133***	0.075	-0.024***	0.006
R&D	-1.913***	0.430	-2.366***	0.009	-0.837***	0.056
FDI	-0.036	0.056	-0.031	0.011	-0.000	0.002
Exports	-0.018	0.013	0.004	0.004	0.001	0.002
Constant	2.507*	1.399	6.801***	0.608	-0.191	0.362
σ_u	0.022***	0.017	0.154***	0.256	0.265***	0.007
σ_v	0.153***	0.004	0.099***	0.006	0.090***	0.000
λ	0.820		1.556		2.949	
γ	0.402		0.708		0.897	
Log-likelihood	350.21		467.27		590.08	
N	800		800		800	
Alphas	40***		40***		40***	

Note. Significance: ***:1% level; **: 5% level; *:10% level. Country specific intercepts (alphas) are not reported to save space, in the last row we report number of significant alphas; for example, "40***" means that all country specific intercepts are significant at 1% level. $\lambda = \sigma_u/\sigma_v$. $\gamma = \sigma_u^2/(\sigma_u^2 + \sigma_v^2)$

	Manufacturing		Trade		Transportation	
	Coefficient	St. Err.	Coefficient	St. Err.	Coefficient	St. Err.
labour	0.425***	-0.035	0.422***	-0.042	0.193***	-0.033
capital	0.572***	-0.026	0.488***	-0.03	0.127***	-0.025
t						
1996	0.000	0.020	0.009	0.022	-0.060**	0.026
1997	0.023	0.021	0.020	0.023	-0.051	0.033
1998	0.010	0.021	0.008	0.023	-0.044	0.038
1999	0.019	0.021	0.013	0.024	-0.036	0.043
2000	0.050**	0.022	0.033	0.025	-0.011	0.047
2001	0.044**	0.022	0.054**	0.025	0.015	0.050
2002	0.051**	0.022	0.074***	0.026	0.015	0.053
2003	0.065***	0.023	0.094***	0.027	0.037	0.056
2004	0.099***	0.023	0.128***	0.027	0.089	0.058
2005	0.119***	0.023	0.164***	0.028	0.121**	0.060
2006	0.150***	0.024	0.200***	0.030	0.157**	0.062
2007	0.185***	0.025	0.235***	0.031	0.221***	0.064
2008	0.153***	0.025	0.237***	0.032	0.234***	0.066
2009	0.070***	0.027	0.174***	0.032	0.161**	0.067
2010	0.129***	0.027	0.202***	0.032	0.215***	0.068
2011	0.160***	0.028	0.229***	0.033	0.244***	0.070
2012	0.161***	0.029	0.249***	0.034	0.273***	0.071
2013	0.161***	0.029	0.255***	0.035	0.294***	0.072
2014	0.180***	0.030	0.276***	0.036	0.324***	0.073
Coefficients						
EFI	-0.093***	0.028	-0.110***	0.023	-0.153***	0.017
R&D	-0.667**	0.340	-0.743***	0.227	-2.645***	0.291
FDI	-0.058	0.042	-0.030	0.029	-0.018	0.024
Exports	-0.042***	0.009	-0.026***	0.009	-0.021***	0.007
Constant	3.103**	1.573	4.502***	1.358	8.888***	0.990
σ_u	0.072***	0.067	0.111***	0.105	0.149***	0.135
σ_v	0.076***	0.003	0.076***	0.004	0.065***	0.002
λ	0.943		1.453		2.279	
γ	0.471		0.679		0.839	
Log-likelihood	802.70		697.91		707.62	
N	800		800		800	
Alphas	21*** 14**		40***		40***	

Note. Significance: ***:1% level; **: 5% level; *:10% level. Country specific intercepts (alphas) are not reported to save space, in the last row we report number of significant alphas; for example, "40***" means that all country specific intercepts are significant at 1% level. $\lambda = \sigma_u/\sigma_v$. $\gamma = \sigma_u^2/(\sigma_u^2 + \sigma_v^2)$

Appendix F. Results from 2-stage DEA regressions.

Table F.1. Tobit regressions on inefficiency scores (dependent variable) predicted by DEA model, manufacturing industry.

EFI	-0.009***	(0.001)	-0.008***	(0.001)	-0.008***	(0.001)	-0.007***	(0.001)
R&D			-0.016**	(0.008)	-0.016**	(0.008)	-0.018**	(0.008)
FDI					0.000	(0.000)	0.000	(0.000)
Exports							-0.000	(0.000)
Constant	1.043***	(0.052)	1.008***	(0.054)	1.008***	(0.055)	0.999***	(0.055)

Note. Significance: ***:1% level; **: 5% level; *:10% level. Standard errors in parenthesis.

Table F.2. Tobit regressions on inefficiency scores (dependent variable) predicted by DEA model, trade industry.

EFI	-0.008***	(0.001)	-0.004***	(0.001)	-0.003***	(0.001)	-0.002**	(0.001)
R&D			-0.081***	(0.008)	-0.083***	(0.008)	-0.088***	(0.008)
FDI					-0.001**	(0.000)	-0.001	(0.000)
Exports							-0.001***	(0.000)
Constant	0.890***	(0.056)	0.712***	(0.056)	0.696***	(0.056)	0.669***	(0.056)

Note. Significance: ***:1% level; **: 5% level; *:10% level. Standard errors in parenthesis.

Appendix G. Inefficiency equations for manufacturing sub-industries.

	Medium-high technology						Low technology	
EFI	-0.292**	(0.116)	-1.035**	(0.430)	-1.121**	(0.459)	-0.092	(0.073)
R&D			-0.147***	(0.037)	-0.157***	(0.036)		
FDI					-0.081**	(0.040)		
Constant	-2.309***	(0.142)	5.132**	(2.045)	5.935***	(2.020)	-2.238***	(0.117)

Note. Significance: ***:1% level; **: 5% level; *:10% level. Standard errors in parenthesis.

Appendix H. Results from TFE regressions for GCI sub-variables.

Table H.1. Institution sub-variables that have significant impact on inefficiency.

	Construction		**Trade**		**Transportation**	
Judicial independence	-0.201***	(0.065)	-0.559***	(0.110)	-0.605***	(0.087)
Wastefulness of gov. spending	-0.245**	(0.113)	-0.002	(0.147)	0.082	(0.126)
Constant	-1.658***	(0.418)	-1.970***	(0.311)	-2.174***	(0.336)
Judicial independence	-1.368*	(0.762)	-0.374***	(0.135)	-0.302**	(0.118)
Transparency of policymaking	-2.216	(2.402)	-0.283	(0.179)	-0.430**	(0.170)
Constant	7.336	(7.253)	-1.582***	(0.387)	-1.409***	(0.413)
Judicial independence	-1.986*	(1.161)	-1.305***	(0.452)	-0.355***	(0.123)
Wastefulness of gov. spending	1.405	(1.509)	-1.378***	(0.490)	0.205	(0.141)
Transparency of policymaking	-1.820	(1.226)	-1.646***	(0.518)	-0.515***	(0.185)
Constant	3.106	(3.665)	9.503***	(2.588)	-1.490***	(0.423)

Note. Significance: ***:1% level; **: 5% level; *:10% level. Standard errors in parenthesis

Table H.2. Infrastructure sub-variables that have significant impact on inefficiency.

	Construction		**Trade**		**Transportation**	
Quality of roads	-0.258***	(0.066)	-0.582***	(0.067)	-0.656***	(0.063)
Constant	-2.226***	(0.314)	-1.918***	(0.319)	-1.725***	(0.301)
Quality of port infrastructure	-0.445***	(0.089)	-0.402***	(0.073)	-0.644***	(0.074)
Constant	-1.316***	(0.435)	-1.620***	(0.360)	-1.609***	(0.365)
Quality of air infrastructure	-0.479***	(0.107)	-0.947***	(0.110)	-0.696***	(0.089)
Constant	-0.957*	(0.562)	0.284	(0.574)	-1.057**	(0.469)

Note. Significance: ***:1% level; **: 5% level; *:10% level. Standard errors in parenthesis.

Table H.3. Macroeconomic environment sub-variables that have significant impact on inefficiency.

	Construction		Trade		Transportation	
Government debt	0.033***	(0.008)	0.062***	(0.020)	0.065***	(0.021)
Gross national savings	-0.620***	(0.131)	-0.559***	(0.208)	-0.564**	(0.230)
Constant	0.438	(1.215)	-6.949***	(2.019)	-7.011***	(1.895)

Note. Significance: ***:1% level; **: 5% level; *:10% level. Standard errors in parenthesis.

Table H.4. Higher education and training sub-variables that have significant impact on inefficiency.

	Construction		Trade		Transportation	
Tertiary educ. enrolment rate	-0.006**	(0.003)	-0.248***	(0.065)	-0.207***	(0.047)
Extent of staff training	-0.525***	(0.114)	-0.981*	(0.564)	-2.493***	(0.795)
Constant	-0.740	(0.558)	4.389	(3.340)	10.455***	(4.023)
Tertiary educ. enrolment rate	-0.178***	(0.060)	-0.412***	(0.106)	-0.179***	(0.049)
Quality of educ. system	-1.207*	(0.648)	-3.641***	(1.048)	-1.011*	(0.517)
Constant	4.636	(3.245)	16.547***	(5.479)	3.216	(2.595)
Tertiary educ. enrolment rate	-0.277***	(0.071)	-0.403***	(0.108)	-0.208***	(0.048)
Extent of staff training	-2.656**	(1.214)	0.592	(0.836)	-2.461***	(0.867)
Quality of educ. system	-0.822	(0.708)	-4.092***	(1.360)	-0.062	(0.603)
Constant	15.922***	(5.932)	15.353***	(5.745)	10.581**	(4.188)

Note. Significance: ***:1% level; **: 5% level; *:10% level. Standard errors in parenthesis.