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Productivity of Czech small and medium enterprises: Lagging behind their potential

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Productivity of Czech Small and Medium Enterprises: Lagging Behind Their Potential

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Abstract:

This paper analyzes microeconomic production functions of Czech small medium enterprises. We use the data from 2002 to 2005 of thirty manufacturing industries (agriculture and services are not included), each divided into five subgroups according to the number of employees. We employ stochastic frontier analysis (SFA) to make statistical inference on the production process.

Our results demonstrate that Czech SME depend in their functioning more on labour than on capital. The impact of investment or intangible assets such as software or patents is negligible. SFA strongly supports the presence of a systematic gap between common practice and best practice: the majority of firms significantly differ from top performers. Finally a simple test for time effect shows that between 2003 and 2005 Czech SME moved towards higher efficiency.

Keywords: production, efficiency measurement, stochastic frontier analysis, small and medium enterprises.

JEL: D24, L25.

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1 Introduction

The term small and medium enterprises has recently gained more attention in general media, eventually reflecting the key contribution of SME to a healthy economy. In the Czech Republic however, where small entrepreneurs had to build from scratch after 1989, research in this field has remained largely untouched. Our paper aims to partly fill this gap, in that it captures main characteristics of the production function of SME.

We can regard small and medium businesses from two points of view: static and dynamic. Firstly, we look at their structural position in the economy. Although general public better knows giant brands, the SME matter because they form an economy's fundamentals. They can be compared to ants, who impact little individually but hugely altogether. Small entrepreneurs build the economy from the bottom, so that they are the true discoverers of market niches that call for filling.

Besides their economic impact on the creation of value (GDP), they play a key social role as well. Although many of them start as self-employed, later on as they grow they eventually become important local or national employers. Usually SME lack sufficient sources of capital and rely on more labour intensive production processes, or even they concentrate in industries which are inherently labour intensive. This biases their productivity in terms of value added per employee towards worse ranking (which can be misleading), yet it leads to their prominent position as dynamic and flexible job creators.

It follows from table 1 that in modern market economies, SME employ between one half to three quarters of the workforce in manufacturing. It is true that the breakdown point at 250 employees (or any other number) is artificial, nonetheless it becomes apparent that size of businesses matters—not least to people employed there.¹

These figures clearly illustrate the interest of SME for economists. In the rest of our paper, we first present several characteristics of the SME sector. It is clear that there are economies to scale and also its resources need not be allocated in an optimal structure. Section 3 outlines the methodology used to estimate the production function and efficiency of SME: stochastic frontier analysis (SFA). The results are presented in section 4.

Estimating the production function on the macroeconomic level is a common economic exercise, and appeared in several papers on the Czech economy. To name just one example: Hájek [7] tracked the determinants of economic growth given by the model of Solow. Yet our approach differs significantly from that of Hájek and similar studies, since we are deriving the model from microeconomics and use the enterprise data. By plugging in data aggregated into industries, the model of course shifts towards macroeconomics, but we will argue that this is both a reasonable and necessary simplification.

2 Small and Medium Enterprises

2.1 Definition

Simple though it appears, the mere size criterion can still be relevant for economic analysis. We shall illustrate it in the following section, but prior to that we give proper definition of the term SME.

Small and medium enterprises, abbreviated as *SME*², are defined as companies not exceeding specific size limits. The official definition of the European Union is given in table 2. It is not

¹Exceptions are twofold. Post-soviet countries that have not yet undergone full transition show negligible SME sectors, eg Belarus, Georgia or Ukraine. However in this countries lots of prospective entrepreneurs take part in the informal economy, not captured by official statistics, so that the true percentage is higher. The other exception is the USA, where the share on labour force is 53 per cent, but with 500 employees as the yardstick. It illustrates that the world's biggest economy has quite different dimensions from Europe.

²Sometimes the abbreviation 'SME' stands for 'small and medium-sized entrepreneurs'.

Country	GDP/capita	SME 250	Country	GDP/capita	SME 250
Austria	29619	66	Italy	19218	80
Belarus	2523	5	Japan	42520	72
Belgium	27572	69	Luxembourg	45185	71
Brazil	4327	60	Netherlands	27395	61
Bulgaria	1487	50	Poland	3391	63
Croatia	4454	62	Portugal	11121	80
Czech Republic	5015	64	Romania	1501	37
Denmark	34576	69	Russian Federation	2614	13
Estonia	3752	65	Slovak Republic	3651	57
Finland	26814	59	Spain	15362	80
France	27236	67	Sweden	27736	61
Georgia	737	7	Taiwan, China	12474	69
Germany	30240	60	Turkey	2865	61
Greece	11594	87	Ukraine	1190	5
Hungary	4608	46	United Kingdom	19361	56
Ireland	19528	67			

GDP/capita = Real GDP per capita in USD. SME 250 = Share of the SME sector on the total formal labour force in manufacturing when 250 employees is taken as the cutoff for the definition of an SME. Data are for the 1990's. Unfortunately for some other important world economies the cutoff 250 is not available.

Table 1: Share of SME on employment in selected countries (Ayyagari *et al.* [2]).

a clearly disjunctive definition, if related to employment only. The complication emanated from the fact that in the EU SME have become an important tool for economic policy measure. Note that a firm must satisfy the first condition and either one of the last two conditions at the same time in order to be classified as SME. The simplest classification, such as that of the World

Enterprise Category	Headcount	Turnover	Balance Sheet Total
Micro	< 10	≤ €2 million	≤ €2 million
Small	< 50	≤ €10 million	≤ €10 million
Medium-sized	< 250	≤ €50 million	≤ €43 million

Table 2: Definition of SME according to the EU legislation.

Bank, relies solely on the number of employees—the WB uses 250 as the limit. Lots of countries created their own definitions, eg Switzerland or the USA take 500 employees as the cutoff.³

2.2 SME around the World

According to a widespread argument, a strong sector of competitive small and medium enterprises heavily depends on the quality of business environment. As is known, economic institutions can play a double role: they can both improve and impede the efficiency of markets and thus increase or decrease the competitiveness of firms. Some sources point to the negative role of state bureaucracy—but bureaucracy is only one of a dozen factors selected by the World Bank that impinge on the efficiency of firms.

³Large portions of subsidies which are distributed to SME each year in the EU can truly lead to heated political debates over the definition of size categories. Recently France proposed to extend the mark to 500 employees, presumably to create a loophole for state aid to larger companies—which is otherwise banned by the European law.

We can think of several intuitive arguments which support this hypothesis: In the first place, complicated bureaucracy acts as a sure deterrent to start up a business at all, just as does persistence of organized crime or anti-competitive practices. Secondly, additional costs incurred due to obstacles to business form the larger share of a company's costs the smaller the company actually is, so that smaller firms are harmed more. Thirdly, chaotic economic institutions add to overall uncertainty in doing business, against which it is harder to hedge for smaller firms than for larger firms.

Two studies have addressed the issue of firm's size and institutional setting on the global scale. Schiffer & Weder [15] explored the hypothesis that size explains part of the variance in responses to the World Bank global survey of business environment. Companies were asked to judge the severity of the following obstacles: (1) Financing, (2) infrastructure, (3) taxes and regulations, (4) policy instability or uncertainty, (5) inflation, (6) exchange rate, (7) functioning of the judiciary, (8) corruption, (9) street crime, theft or disorder, (10) organized crime or mafia, and (11) anti-competitive practices by government or private enterprises.

In the overall sample of roughly 10.000 firms, the authors found that small firms on average viewed the obstacles to doing business as more severe than large firms, ie SME perceived more obstacles than did large firms. The significance of this strong finding declined (though not disappeared) when they split up the sample to regional groups⁴. In particular, in the then OECD countries firms report the same level of obstacles irrespective of their size. Yet the effect remained significant in two regions: Latin America and the Carribean; and transition economies, where Czech Republic belonged at the time of the survey in 1990's.

Schiffer & Weder do not elaborate much on the fact that the significance of the finding varied within the regional subsamples. But they might have overlooked the quite considerable implication of their results: namely that more of the "free market" leads to less "size discrimination". In other words, this would support the argument that liberal market reforms do equalize conditions for market players and that SME deserve special political treatment—how to cut the red tape in order to open SME to competitive (and more efficient) markets.

Another study by Ayyagari *et al.* [2] tested two mutually exclusive hypotheses. Firstly, large SME sectors may stem out from high exit costs and government subsidies, so that they are prevented to grow or to disappear (negative reasoning). Alternatively they argued that large amount of SME could result from low barriers to entry and better credit availability (positive reasoning). The authors test a large cross-country dataset from the 1990's. They do not find any conclusive support for the former hypothesis, but a significant backing for the latter.

We can translate the result of their investigation to a simple imperative: governments must not crack down on natural entrepreneurship if their want to foster a thriving SME sector. Their finding also contains another dimension: The study suggests that financial aspects (entry costs and credit availability) matter more for creation of SME than other institutional factors do.

It is of our concern throughout this paper to quantify the conditions of efficiency, which are of vital importance for the advancement of small and medium-sized firms in the environment of globalised competition. I.e. in cases when competition to SME comes both from outside and inside.

Entrepreneurs often start from scratch and thus embody the ability and will to learn and create. In his case study on Turkey, Taymaz [17] concludes that "most firms start small", moreover, they are most often challenged there by their distinct systemic disadvantage: both their scale and efficiency are suboptimal. It follows that these businesses have to achieve higher rates of growth in order to survive, notwithstanding their resultant lower profits or lower wages. That small firms grow faster is exactly the finding of the recent study by Mohnen & Nasev [11], who analyzed German SME. Taymaz notes that the Schumpeterian selection process is quite drastic, given high mortality rate among entrants.

⁴Groups were as follows: OECD countries; transition economies; Latin America & the Carribean; East Asia & Pacific; South Asia; Africa.

The rate of technical change gained much attention in economic literature, but productivity dynamics of this kind is not the subject of our paper and we skip more details at this point.

2.3 Czech SME Sector: Foundations so Tiny

Until 1989, Czechoslovakia had one of the toughest regime concerning private enterprise among the communist countries. Private businesses were violently nationalized or collectivized in the 1950s. Any entrepreneurial activities were forced to the informal economy. The prompt revival of the SME sector in Czechoslovakia in the first years after the fall of the “iron curtain” is thoroughly analysed in the study by Vladimr Benáček [5]. Benáček claims that from the start the impact of the emerging small ventures, both legal and informal, was largely underestimated by official statistics and substantially contributed to an economically smooth transition.

Year	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
# of firms	99.77	99.78	99.80	99.71	99.81	99.85	99.81	99.84	99.85	99.85
# of employees	59.82	57.91	58.84	59.42	59.73	61.34	61.63	61.48	61.63	61.38
Gross output	52.91	53.03	53.63	51.53	51.44	52.46	52.79	52.29	52.42	51.45
Value added	57.36	52.25	53.17	51.93	51.33	52.98	54.46	53.02	53.68	52.62
Payroll	n/a	53.93	54.57	54.42	55.72	55.82	55.90	55.61	55.88	55.41
Investment	n/a	41.53	41.06	40.48	37.81	44.52	49.88	51.43	52.57	54.42
Export	36.40	36.25	36.54	36.15	35.74	34.16	34.0	34.3	40.7	43.5
Import	48.00	48.84	50.74	49.43	47.12	50.33	49.8	52.5	54.7	54.6
GDP	n/a	n/a	31.54	31.17	31.63	34.59	34.86	34.69	34.60	34.36

100% = Czech economy of the given year. Investment = Acquisition of tangible and intangible assets, refer to appendix A. Included are all entrepreneurial activities in manufacturing, construction, commerce and a part of services.

Table 3: Share of SME on macroeconomic indicators.

Table 3 quotes statistics on SME published by the Ministry of industry and trade in its “Report on the development of SME and its support in 2006”.⁵ We make several straightforward observations. SME account for one third of the Czech GDP and for close to two thirds of employment. This share remained more or less stable over the last ten years. This holds for the accounting value added as well, which stayed close to 53 per cent throughout the ten years.

On the contrary, three indicators changed significantly and suggest that the SME sector has come through an intensive consolidation. On one hand its share on exports and imports has gone up seven and six percentage points respectively, meaning that SME are now more involved in international trade. Moreover the breakthrough appears around the years 2004/2005, when Czech Republic entered the EU. On the other hand, SME invest relatively more, or they are rather correcting the underinvestment from the earlier period.

The following chapters will focus on cross-sectional analysis. Besides structural results, we are particularly concerned with what stands behind the table 3. We estimate the SME-specific production function, derived from the microeconomic background, to reveal the sensitivity of productive inputs. Above all, we investigate the relationship between labour, capital and investment. We noted in relation with table 3 that SME have recently experienced a massive investment surge, which should result in higher capital endowment and better productivity. This effects on efficiency scores are handled by a separate model in the last part of the paper.⁶

⁵Downloaded at [<http://www.mpo.cz/dokument32006.html>] on January 5, 2008.

⁶However we are also aware that table 3 is related to a broader group of SME than that represented by our dataset.

3 A Stochastic Model of the Production Function

3.1 A Model of Production

The starting point of our analysis is the neoclassical production function.⁷ We consider a p -dimensional vector of inputs $\mathbf{x} \in \mathbb{R}_{0,+}^p$ and an r -dimensional vector of outputs $\mathbf{y} \in \mathbb{R}_{0,+}^r$. Production function characterizes the technology available to the firm and describes how all inputs inclusive capital, labour, land, materials, know-how etc. are transformed into outputs. This is written as

$$\mathbf{y} = f(\mathbf{x}),$$

so that $f(\mathbf{x})$ represents the complete technical relationship between inputs. We assume $f(\mathbf{x})$ to have all standard properties; we mention their application later in the text.

Production function defines only one part of the economic world: It constitutes the constraint subject to which every firm has to operate. The other part consists of preferences and scarcity and is captured in prices of input and output vectors. Because firms act so as to maximize their profits, knowledge of $f(\mathbf{x})$ would not be sufficient for economic analysis. The way we track prices is discussed in section 3.3

Production function is an ideal concept when no frictions exist. In real world inefficiencies occur and not all producers are able to reach the maximum possible output: $\mathbf{y} < f(\mathbf{x})$, meaning that some firms will operate inside the area constrained by the production function. Furthermore once a firm achieves maximum output it can still be inefficient in terms of prices, since it may use a combination of inputs and/or produce a vector of outputs that do not maximize the profit at prevailing market prices.

Both technical and economic inefficiency are now widely used concepts in economics, but their exposition is not the purpose of this paper. In our analysis we mark those industries as inefficient which simply do not achieve the best practice.

3.2 Estimator of Technical Efficiency

In the next sections, we build a framework to estimate $f(\mathbf{x})$ and the extent of inefficiency among SME. The method we use is called stochastic frontier analysis, or SFA. We adapt the model for technical efficiency from Kumbhakar & Lovell [10, equation 3.2.18]:

$$y_i = f(\mathbf{x}_i, \boldsymbol{\beta}) \cdot \exp\{v_i - \tau_i\}, \quad (1)$$

where $\boldsymbol{\beta}$ is the vector of parameters of $f(\cdot)$, v_i is the random disturbance term and $\tau_i \geq 0$ is the inefficiency term. A general unknown production function is adjusted to differently productive firms by a multiplicative inefficiency term τ which is of one sign only. With data in the form of matrices X, Y , we look for estimates $\hat{\boldsymbol{\beta}}$ and $\hat{\tau}_i$.

This approach was pioneered by Aigner & Chu [1], Aigner, Lovell & Schmidt and Meeusen & van den Broeck and is thoroughly depicted in Kumbhakar & Lovell [10, p. 72-81]. The initial production function is assumed to be:

$$f(\mathbf{x}_i, \boldsymbol{\beta}) = \exp\{\beta_0\} \cdot \prod_{j=1}^p x_{ij}^{\beta_j}.$$

Then we can rewrite the model (1) as the log-linear Cobb-Douglas production function to ob-

⁷Detailed concepts of production functions can be found in Sato [14] and Johansen [8], a condensed overview in Nadiri [12].

⁸Throughout this section we assume only one output.

tain:

$$\begin{aligned} \log y_i &= \beta_0 + \sum_{j=1}^p \beta_j \log x_{ij} + (v_i - \tau_i) \\ v_i \dots &\text{ iid, } \mathcal{L}(v_i) \sim \mathcal{N}(0, \sigma_v^2). \end{aligned} \quad (2)$$

Ordinary least squares (OLS) yield estimates of β_j s, but we would also like to separate β_0, v_i, τ_i to obtain producer-specific efficiency scores. In order to get these, we need two additional assumptions: (1) τ_i is *iid*, $\mathcal{L}(\tau_i) \sim \mathcal{N}^+(0, \sigma_\tau^2)$, and (2) τ_i and v_i are independent on each other and on the regressors. Denoting $\epsilon_i = v_i - \tau_i$, $\sigma = \sqrt{\sigma_\tau^2 + \sigma_v^2}$ and $\lambda = \frac{\sigma_\tau}{\sigma_v}$, the following maximum likelihood estimator (MLE) can be derived:

$$\mathcal{L}(\epsilon, \sigma^2, \lambda) = \prod_{i=1}^n \frac{2}{\sigma \sqrt{2\pi}} \cdot \exp \left\{ -\frac{\epsilon_i^2}{2\sigma^2} \right\} \cdot \Phi \left(-\frac{\epsilon_i \lambda}{\sigma} \right), \quad (3)$$

where $\phi(\cdot)$ and $\Phi(\cdot)$ are standard normal density and distribution functions. Further it is possible to derive the conditional distribution of τ_i given ϵ_i , which is truncated normal:

$$g(\tau_i | \epsilon_i) \sim \mathcal{N}^+ \left(\mu_{*i} = -\frac{\epsilon_i \sigma_\tau^2}{\sigma^2}; \sigma_*^2 = \frac{\sigma_\tau^2 \sigma_v^2}{\sigma^2} \right).$$

From this distribution point estimators of τ_i can be obtained as either the mean $E(\tau_i | \epsilon_i)$ or the median $M(\tau_i | \epsilon_i)$. Both results have to be transformed back to the exponential form of (1) to obtain the estimate of technical efficiency $\hat{\mathcal{E}}_i = \exp \{-E(\tau_i | \epsilon_i)\}$, the same holds for the mode. One more complication is that we assumed inefficiency to have multiplicative form, which we then transformed by taking logarithm. Thus it makes more sense to construct an estimator which is based on efficiency already transformed back, ie in exponential form. In other words we can write:

$$\exp \{-E(\tau_i | \epsilon_i)\} \neq E(\exp \{-\tau_i\} | \epsilon_i).$$

This problem was resolved by Battese & Coelli and is mentioned by Kumbhakar & Lovell [10]. Instead of mean or mode, they proposed an improved point estimator:⁹

$$E(\exp \{-\tau_i\} | \epsilon_i) = \left[\frac{1 - \Phi \left(\frac{\sigma_* - \mu_{*i}}{\sigma_*} \right)}{1 - \Phi \left(-\frac{\mu_{*i}}{\sigma_*} \right)} \right] \cdot \exp \left\{ -\mu_{*i} + \frac{1}{2} \sigma_*^2 \right\}. \quad (4)$$

3.3 The Economic Dimension

Deliberations in section 3.2 deal just with technology. In section 3.1 we stressed that economics primarily focuses on allocation efficiency. Hence we ought to analyze revenue and cost functions to capture economic performance of SME.

The underlying idea for derivation of an estimator is similar to the previous section, only the algebra is more complicated. A comprehensive overview can be found in Kumbhakar & Lovell [10]. But we do not pursue their exposition because we do not have sufficient data to apply it, since our dataset is given in monetary units¹⁰. With such data we cannot construct profit functions and decompose overall efficiency into technical and allocation efficiency. Instead we have to give up some of the microeconomic detail.

This move is less drastic that it appears. It is difficult to imagine that even with the most detailed data for individual firms we could reasonably use the standard construct of uniform

⁹In the original article [3], the authors defined the estimator for panel data, where τ_i was constant over time but v_{it} was allowed to vary among periods.

¹⁰The only exception is one of the proxies for labour in the production function: number of employees.

exogenous input and output prices. Today with incredibly diverse forms of capital we always have to aggregate to a certain degree.

As a consequence our empirical analysis will plug in aggregated data, so that our estimate which we denoted $\hat{\epsilon}_i$ includes both components, ie it measures overall efficiency. In other words, we estimate a profit function, although our starting point (2) is not a proper profit function, but a production function. We show that this simplification can still deliver interesting results.

4 Efficiency of Czech SME

4.1 Data Description

Czech Statistical Office (CSU) publishes a yearly summary on economic activity of Czech small and medium enterprises, which can be found under reference number 8007-[year]. This publication contains several indicators along with condensed size and sector groups.

These data are obtained by a statistical enquiry, which covers all firms with 100 or more employees, 55 per cent of companies with 10–99 employees and about 2,6 per cent of the micro-segment (below 10 employees). Individual data are aggregated and are not made available.

Following an official request, CSU provided us with slightly more detailed data than one can find in the publicly available booklet. Our dataset has four dimensions:

1. thirty-item two-digit OKEC¹¹ classification, including OKEC codes 10 to 41¹², ie agriculture and services are not included;
2. size classification with breakdowns at the following number of employees: 0-10-20-50-100-250;
3. eleven economic indicators listed in table 4, for complete definitions of indicators refer to appendix A;
4. years 2002 through 2005, so that the short time span restricts us to cross-sectional analysis, ie we will assume that technology did not change in time.

Indicator and the corresponding variable in the model		
Number of active firms		
<i>OUT</i>	Output	} Output
<i>REV</i>	Sales revenue	
<i>VAD</i>	Accounting value added	
<i>TAS</i>	Tangible assets	} Capital
<i>IAS</i>	Intangible assets	
<i>INV</i>	Acquisition of tangible and intangible assets	
<i>EMP</i>	Number of employees	} Labour
<i>AEM</i>	Average number of employees	
<i>PAY</i>	Payroll	
<i>OPE</i>	Other personnel expenses	

Table 4: Indicators on SME provided by the Czech Statistical Office.

¹¹European Union uses the abbreviation NACE: Nomenclature Générale des Activités Économiques dans les Communautés Européennes.

¹²OKEC 12 is not included. Full list of industries is available at [[http://www.czso.cz/csu/klasifik.nsf/i-odvetvova_klasifikace_ekonomickych_cinnosti_\(okec\)](http://www.czso.cz/csu/klasifik.nsf/i-odvetvova_klasifikace_ekonomickych_cinnosti_(okec))] in Czech or at [http://ec.europa.eu/comm/competition/mergers/cases/index/nace_all.html] in English.

The dataset turns our initial estimation idea to:

$$\begin{aligned} y_i &= f(\mathbf{x}_i; \boldsymbol{\beta}) \\ VAD_i &= f(TAS_i, IAS_i, INV_i, AEM_i, PAY_i, OPE_i; \boldsymbol{\beta}), \end{aligned} \quad (5)$$

with $n^{(2002)} = 135$, $n^{(2003)} = 135$, $n^{(2004)} = 134$ and $n^{(2005)} = 136$, totalling 540 observations.

4.2 Estimation of the Parameters: SFA Results

4.2.1 Identifying a Model

Stochastic frontier analysis can yield twofold distinct results: (1) Sensitivity of factors of production, ie estimation of $\boldsymbol{\beta}$; and (2) estimation of individual efficiency scores. We first concentrate on the former point, which can be consistently solved by standard ordinary least squares (OLS). The latter point is investigated in section 4.3 by means of MLE.

Equation (5) for our variables gives:

$$VAD_i = \beta_0 \cdot TAS_i^{\beta_1} \cdot IAS_i^{\beta_2} \cdot INV_i^{\beta_3} \cdot AEM_i^{\beta_4} \cdot PAY_i^{\beta_5} \cdot OPE_i^{\beta_6} \cdot \exp\{\nu_i - \tau_i\}. \quad (6)$$

We enhance equation (6) in three ways. Firstly, we expect absolute values to result in heteroskedasticity, ie non-constant variance. This was confirmed by our preliminary tests, hence we normed the variables by output.

Secondly, INV include acquisition of assets whose period of usage is longer than one year and that usually take some time to be realized. Accordingly we use lagged values $INV_{-1,i}$, so that we will only be able to model just three years out of the four, 2003 through 2005.

Thirdly, we can think of PAY as the multiple of AEM and average pay per employee, $APAY$. By including $\left(\frac{AEM_i}{OUT_i}\right)^{\beta_4} \cdot \left(\frac{PAY_i}{OUT_i}\right)^{\beta_5}$, we are in fact counting AEM twice. Therefore we test the significance of AEM separately, as indicated by square brackets.

These considerations yield the following model:

$$\begin{aligned} \frac{VAD_i}{OUT_i} &= \beta_0 \cdot \left(\frac{TAS_i}{OUT_i}\right)^{\beta_1} \cdot \left(\frac{IAS_i}{OUT_i}\right)^{\beta_2} \cdot \left(\frac{INV_{-1,i}}{OUT_{-1,i}}\right)^{\beta_3} \cdot \left[\left(\frac{AEM_i}{OUT_i}\right)^{\beta_4}\right] \\ &\cdot \left(\frac{PAY_i}{OUT_i}\right)^{\beta_5} \cdot \left(\frac{OPE_i}{OUT_i}\right)^{\beta_6} \cdot \exp\{\epsilon_i\}. \end{aligned} \quad (7)$$

This model production function (7) is of course estimated in its log-linear form.¹³

¹³It must be stressed that the proposed equation is *not* derived from a macroeconomic production function, which gives output in monetary terms. As the discussion in section 3.3 points out, our initial model is based on purely microeconomic model of production, where the production function returns physical units of output. In this framework, any applied work would then aim at a profit function in the ideal case. However, in practice we have to combine this microeconomic basis with an aggregate approach where the function is money-valued. Above all, we use the multiplicative Cobb-Douglas production function.

The proposed equation reflects the cost structure of firms. Accounting value added is the value of output less cost of materials (see appendix A). The inputs on the right hand side are: (1) share of capital on output; (2) share of labour on output, which is also money-valued, ie multiplied by payroll; and finally (3) investment.

The third component captures the share of investment on the output. The idea here is to provide a rough measure of how much firms innovate. Therefore an alternative specification would include the share of investment on capital (ie capital renewal) rather than on output, so that we would like to have $\left(\frac{K}{Y}\right)^a \left(\frac{I}{K}\right)^b$ instead of $\left(\frac{K}{Y}\right)^a \left(\frac{I}{Y}\right)^b$. But consider the following algebra with obvious simplified notation:

$$\left(\frac{K}{Y}\right)^a \left(\frac{I}{Y}\right)^b = \left(\frac{K}{Y}\right)^a \left(\frac{I}{Y}\right)^b \left(\frac{K}{K}\right)^b = \left(\frac{K}{Y}\right)^{a+b} \left(\frac{I}{K}\right)^b,$$

so that the results of our specification can also be readily interpreted in this manner. Of course this derivation is inaccurate for past investment, since past investment is counted in present capital. But our claim is that we can stick to the simple specification because of the simple intuition behind and because it performs reasonably well with the data. Finally it must be noted that there is vast room for testing of numerous changes in the model specification.

4.2.2 Standard Regression

We evaluate ordinary least squares regression for (7) in the statistical package \mathcal{R} .¹⁴

	Estimate	Std. Error	t value	Pr(> t)
(Intercept)	0.3249	0.6681	0.49	0.6276
<i>TASn.03</i>	0.0596	0.0399	1.49	0.1375
<i>IASn.03</i>	-0.0127	0.0186	-0.68	0.4955
<i>INVn.02</i>	0.0410	0.0365	1.12	0.2636
<i>AEMn.03</i>	0.1559	0.1185	1.32	0.1907
<i>PAYn.03</i>	-0.9431	0.1330	-7.09	0.0000
<i>OPEn.03</i>	1.2971	0.1785	7.27	0.0000

Residual standard error: 0.2859 on 125 degrees of freedom
Multiple R-Squared: 0.4354, Adjusted R-squared: 0.4083
F-statistic: 16.06 on 6 and 125 DF, p-value: 1.237e-13

Table 5: OLS for the model (7), data for 2003.

	Estimate	Std. Error	t value	Pr(> t)
(Intercept)	2.0138	0.3081	6.54	0.0000
<i>TASn.04</i>	0.0697	0.0288	2.42	0.0169
<i>IASn.04</i>	0.0364	0.0130	2.81	0.0058
<i>INVn.03</i>	0.0353	0.0341	1.04	0.3017
<i>AEMn.04</i>	0.3888	0.0522	7.45	0.0000
<i>PAYn.04</i>	-0.5764	0.0942	-6.12	0.0000
<i>OPEn.04</i>	0.6820	0.0662	10.30	0.0000

Residual standard error: 0.2535 on 125 degrees of freedom
Multiple R-Squared: 0.6269, Adjusted R-squared: 0.609
F-statistic: 35.01 on 6 and 125 DF, p-value: < 2.2e-16

Table 6: OLS for the model (7), data for 2004.

	Estimate	Std. Error	t value	Pr(> t)
(Intercept)	1.5003	0.4124	3.64	0.0004
<i>TASn.05</i>	0.1431	0.0313	4.57	0.0000
<i>IASn.05</i>	0.0019	0.0150	0.13	0.8968
<i>INVn.04</i>	-0.0806	0.0293	-2.76	0.0067
<i>AEMn.05</i>	0.4121	0.0751	5.49	0.0000
<i>PAYn.05</i>	-0.5513	0.1309	-4.21	0.0000
<i>OPEn.05</i>	0.4907	0.0682	7.20	0.0000

Residual standard error: 0.2753 on 125 degrees of freedom
Multiple R-Squared: 0.4789, Adjusted R-squared: 0.4538
F-statistic: 19.14 on 6 and 125 DF, p-value: 9.91e-16

Table 7: OLS for the model (7), data for 2005.

Results are presented in tables 5, 6 and 7. We added n to the names of explanatory variables to indicate that they were normed by *OUT* before taking logarithms.

R-squared indicates that we are able to explain between 40 and 60 per cent of the original data variation. This does not seem much, and less so since estimating the model (6) with lagged

¹⁴For more information refer to the webpage [<http://www.r-project.org/>].

investment yields R-squared above 90 percent. But after performing some basic diagnostics, (7) appears more favourable than the equation in the non-normed form: It performs better in terms of both normality¹⁵ and homoskedasticity¹⁶.

4.2.3 Production Function of Czech SME

Let us discuss the findings from the previous section. One point of view is the significance of estimated parameters. Two variables are of lower significance: (lagged) investment and intangible assets.

We know that investment, defined as acquisition of long term assets, is at first a considerable expense, which should later turn profitable. Fluctuation of the coefficient between positive and negative values suggests that one-year lag is not always enough for the investment to generate positive revenue. Table 3 documents the investment surge among small and medium enterprises, which in conjunction with our results implies two possible hypotheses: (1) SME invest in standard “hard” technologies, while research is not stressed enough. (2) Investment turns profitable only after a few years, which makes it especially troublesome for SME to spend money there.¹⁷

Insignificance of intangible assets means that no high-tech revolution occurred in the past years in the SME sector, and that SME do not properly exploit patents or trademarks. It is quite clear that the production of vast majority of small and medium companies is not based on leading-edge or even innovative technology. Nonetheless, we would expect that once a company possesses any of these, we would recognize it as an advantage.

The other point of view is the sign of the estimated coefficients, which must be interpreted carefully. We find that payroll has negative influence on value added. Since the theory says that differences in wages should reflect quality of the workforce, higher salaries should result in more value added. Hence the mechanism we expect follows the relationship high skill — high wage — high value added and vice versa. Profit maximizing firms have to find a balance between high wages and high value added, because wages are costs. In our multiplicative specification of the cost function where labour input is money valued, both the number of employees and their payroll contribute to the value added. The employer wants of course to keep both *AEM* and *PAY* low while maintaining high value added, and we want to find out which one is kept relatively lower.

Our regression cannot confirm that higher wages alone imply higher value added, because it does not include average wage per employer which would be the relevant variable. On the contrary, the joint result on *AEM* and *PAY* tells us much about firms’ cost minimization technique: The coefficient of *AEM* is positive and of *PAY* is negative, and hence (following the result above) we conclude that firms rather choose large numbers of low-wage workers for a given level of value added.

The interpretation of other personnel expenses *OPE* is rather vague, because it can contain a variety of distinctly different expenses (see appendix A). We include it mainly to separate regular wages from these extra costs, so that the coefficient on *PAY* is more accurate. The positive

¹⁵Among the plenty of tests available, we decided for Kolmogorov-Smirnov and Shapiro-Wilk. Model (6) with lagged *INV* shows no normality, since *p*-values are of order 10^{-5} to 10^{-6} . The same holds for (7) in 2003, but model (7) yields *p*-values 0.078/0.017 for 2004 and 0.078/0.021 for 2005. Thus the transformation by *OUT* shifted the results by a considerable amount towards normality.

¹⁶We assumed that nonspherical disturbances could stem from the size variation and use Breusch-Pagan to test for this effect. In the case when residual are not normally distributed, we use the studentized Breusch-Pagan test, as advised by Kennedy [9, p. 130]. Model (7) yields *p*-values 0.096 in 2005 (compared to 0.016 for the other model) and 0.228 versus 0.467 in 2004. We infer that the source of the presumably largest problems with non-constant variance is not statistically significant.

¹⁷We tested the second hypothesis by lagging *INV* by two and three years for 2005, other things equal. With the three year lag, we finally arrived at a positive coefficient, yet none of the lags was statistically significant (with *p*-values 0.842757 for *INV*₋₂ and 0.2707 for *INV*₋₃).

coefficient could prompt us to deduce two points: (1) Outsourcing tasks beyond regular contracts is relatively more efficient. (2) Because the variable includes payments for high-skilled jobs such as expert testimonies, it supports our previous hypothesis on the relationship between amount of labour employed and payroll.

Yet on the other hand, the presence of expenses such as royalties or expert testimonies in *OPE* in fact slightly weakens our previous point that intangible assets are unimportant. Hence we cannot draw any definite strong conclusion from this variable.

We sum up the discussion in a proposition:

Proposition 4.1 *SME production function characteristics.*

- ★ *Our regressions confirm that Czech SME depend more on labour than on capital. Their profitability is determined by the ability to employ lots of people and to pay them little.*
- ★ *SME are not able to reap the benefits of intangible assets, such as software or patents.*
- ★ *The effect of previous investment turns out hazy: it influences the production either negatively or not at all.*
- ★ *The above points mean that by large, SME fundamentals of the Czech economy have not yet converted to an innovation based production process.*

4.3 Effects of Size and Time

4.3.1 Model Specification

In this section we focus on the estimation of efficiency of individual industries by using the parametric approach. As shown in section 3.2, the starting point is now the equation (3). The solution of this maximum likelihood maximization is implemented in the freely available program FRONTIER by T. Coelli [6], which moreover offers several extension to this basic model.

FRONTIER is able to compute two specifications. The first reads for time $t = 1, \dots, T$:

$$\begin{aligned}
 y_{it} &= \beta_0 + \sum_{j=1}^p \beta_j \cdot x_{ijt} + (v_{it} - \tau_{it}) & (8) \\
 v_{it} &\dots \text{ iid, } \mathcal{L}(v_{it}) \sim \mathcal{N}(0, \sigma_v^2), \\
 \tau_{it} &= \tau_i \cdot \exp\{-\eta \cdot (t - T)\}, \\
 \tau_i &\dots \text{ iid, truncations at zero of } \mathcal{N}(\mu_\tau, \sigma_\tau^2).
 \end{aligned}$$

As in the previous text, we would plug in logarithms of the data rows.

The second specification available in FRONTIER for $t = 1, \dots, T$:

$$\begin{aligned}
 y_{it} &= \beta_0 + \sum_{j=1}^p \beta_j \cdot x_{ijt} + (v_{it} - \tau_{it}) & (9) \\
 v_{it} &\dots \text{ iid, } \mathcal{L}(v_{it}) \sim \mathcal{N}(0, \sigma_v^2), \\
 \tau_i &\dots \text{ iid, truncations at zero of } \mathcal{N}(\zeta_{it}, \sigma_v^2), \\
 \zeta_{it} &= \delta_0 + \sum_{h=1}^d \delta_h \cdot z_{it},
 \end{aligned}$$

the data again being logarithms. This specification allows the inefficiency to be modelled by other factors than time, meaning that z are variables influencing efficiency and δ is the respective vector of parameters to be estimated. The idea is simple: once we have estimated efficiency,

we would like to explain it and run a second-step regression. Yet a more efficient procedure is to estimate both parameter vectors in a single step, as is done by FRONTIER.

Coelli [6] remarks that the models (8) and (9) are not nested, so they cannot be tested against each other.

What deserves special attention is the distribution of the inefficiency term τ . In section 3.2 we assumed $\mathcal{L}(\tau_i) \sim \mathcal{N}^+(0, \sigma_\tau^2)$, so that the distribution was half normal. In equations (8) and (9) we specify the distribution to be truncation of a non-central normal distribution, though still at zero. The impact on implementation is modest, since it only results in a more complicated likelihood function. Yet it considerably modifies the modelling framework.

With $\mu_\tau = 0$, most firms should lie on, or be close to, the efficient frontier. On the contrary, if the underlying density is modelled as non-central with $\mu_\tau > 0$, the centre of gravity is moving towards inefficiency. By this we in fact allege that there is systematic inefficiency, which we can track either by time or by particular explanatory variables z_d . In other words, we claim that the best practice and the common practice are not identical.

# of employees		min	1Q	median	3Q	max	mean
Not restricted		0.3310	0.7257	0.8034	0.8684	0.9697	0.7878
2003 to 2005	<10	0.3310	0.7793	0.8878	0.9330	0.9697	0.8457
	10-19	0.5401	0.7267	0.8073	0.8683	0.9313	0.7886
	20-49	0.5185	0.7348	0.8049	0.8483	0.9003	0.7768
	50-99	0.5793	0.6869	0.7949	0.8269	0.9364	0.7647
100-250		0.5446	0.6926	0.7669	0.8144	0.9148	0.7560

Table 8: Box plot statistics for maximum likelihood efficiency scores using (8).

Before we turn to tests of hypotheses, we list table 8, which contains box plot statistics for the MLE estimates of efficiency scores using (8), where μ_τ and η are set to zero. This time the scores are joint for 2003 to 2005. There are two compelling reasons why we used all the years together: (1) wrong skewness of residuals in 2005, and (2) employment of the non-central truncated normal distribution for τ . By this increase of the number of observations, the quality of the resulting estimate should substantially improve and offer a solid basis for inference.¹⁸

4.3.2 Estimating the Common Practice

We apply the model (8), where we specify x to be the same six variables as in (7). We use $t = 2003, 2004, 2005$. In order to have exactly the same industries in each of the years, we had to cross some more rows to get $3 \times 131 = 393$ observations. We get estimated efficiency $E\hat{\mathcal{E}}_i = \exp\{-\hat{\mu}_\tau\} = \exp\{-0.39522\} = 0.677$. This yields the expected mean efficiency level of two thirds.

Let us formulate the first hypothesis to test: Under the null $\mu_\tau = 0$, under the alternative $\mu_\tau \neq 0$. In FRONTIER we solve (8), where we set $\eta = 0$. For the test itself we use the likelihood-ratio test, which is specified as in Battese & Coelli [4]:¹⁹

$$-2 \cdot \{\log \mathcal{L}(H_0) - \log \mathcal{L}(H_A)\} \xrightarrow{\text{asymptotically}} \chi^2(J),$$

where the degrees of freedom J are equal to the number of restrictions, ie we have $J = 1$. $\log \mathcal{L}$ are the values of the log-likelihood function for the respective case. We get:

$$\hat{\chi}^2 = -2 \cdot (-23.30802 + 19.71990) = 7.17624 \rightsquigarrow p = 0.01478.²⁰$$

¹⁸For detailed discussion of computational aspects see Simar & Wilson [16] and Ritter & Simar [13].

¹⁹Two other options could be used: the Wald test and the Lagrange multiplier test, see Kennedy [9, p. 61].

We conclude that on the significance level $\alpha = 0.05$ we reject the null.

Proposition 4.2 Systematic inefficiency. *The production function of Czech small and medium enterprises (7) is likely to contain systematic inefficiency, meaning that the common practice is significantly different from the best practice.*

4.3.3 Testing Size Effects

We would like to test the hypothesis that there is a significant relationship between size and efficiency. By size we mean the SME definition in terms of employees. Table 8 suggests that the relationship indeed is inverse, which is a bit perplexing.

We use EGR , the group according to the number of employees, as the single z variable in model (9). Hence $EGR \in \{1, 2, 3, 4, 5\}$, as corresponds to breakdown points 0-10-20-50-100-250. We get estimated efficiency $E\hat{\mathcal{E}}_i = \exp\{-\hat{\xi}\} = \exp\{-0.06569 \cdot EGR\}$. This means that average efficiency level goes down from 94% for the smallest firms to about 74% for the largest firms.

To test the significance of this result, our hypothesis is as follows: Under the null $\delta_1 = 0$, under the alternative $\delta_1 \neq 0$. The test statistics is the same as in the previous section:

$$\chi^2 = -2 \cdot (-43.07255 + 40.67602) = 4.79306 \rightsquigarrow p = 0.05715.$$

Contrary to the previous section, we cannot reject the null, so that the effect of EGR is insignificant.

Proposition 4.3 Size effect. *Although the suggested relationship between a firm's size and its efficiency is inverse, we do not find it statistically significant.*

4.3.4 Testing Time Effects

Our last test checks the presence of a significant time effect. We are aware that our specification does not rely on an advanced model for technical change. Moreover since we use data in monetary units, we are estimating the combined effect of technical *and* allocation efficiency anyway. We only want to test whether efficiency scores are different among years.

We use the specification from equation (8). The test is again the likelihood-ratio. It makes sense to test the null of $\eta = 0$ against the alternative of $\eta \neq 0$ for two cases: once with $\mu_\tau = 0$ and once with $\mu_\tau \neq 0$. In the former case, we get $p = 0.01174$, and in the latter we compute $p = 0.01105$. Because we already concluded that $\mu_\tau \neq 0$ (proposition 4.2) and because we reject the null on the significance level $\alpha = 0.05$, we derive that the best model is with $\hat{\eta} = 0.06441$ and $\hat{\mu}_\tau = 0.36851$.

To get an idea about the magnitude of this estimated effect, we use equation (8) which yields that the inefficiency index fell from $1.12 \times \tau_i$ in 2003 to $1 \times \tau_i$ in 2005. The estimated time effect was about twelve per cent.

Proposition 4.4 Time effect. *In the course of the three observed years, efficiency of Czech SME increased.*

5 Conclusions

Stochastic frontier analysis (SFA) works as an enhanced regression; it looks for the parameters which govern the production process and then estimates efficiency as the margin between fitted and observed values. We used it to find out the characteristics of the production function

²⁰ p -value was computed as: $p = 2 \times \min\{\Pr(C \geq \hat{\chi}^2), \Pr(C < \hat{\chi}^2)\}$, where the random variable C is governed by $\chi^2(J)$.

of Czech small and medium manufacturing enterprises (ie, agriculture and services are not included).

We were able to gather several propositions about Czech manufacturing SME in the form of stylized facts. SFA estimates production and profit functions and due to its statistical formulation, it offers procedures for testing hypotheses. We used ordinary least squares and the accompanying standardized diagnostics to find out an acceptable specification which we then handed over to maximum likelihood estimators.

We confirmed that Czech manufacturing SME are more dependent on labour employment rather than on capital usage. Further, the investment surge documented in table 3 was not mirrored in our estimates. There are more feasible explanations: (1) It takes more time for the investments to start generating profits, so that our dataset is too old to capture this effect. (2) Investment is not evenly spread across industries; while it improves efficiency of successful and growing companies, it turns out globally insignificant. If true, this reasoning means that recent investments lead to divergence in efficiency score and that there is a dramatic shift in the structure of Czech SME on the way. (3) If we assess the contribution of past investment to value added as insignificant, it might stem from the fact that some of the investment projects were and are not prosperous. In other words we can imagine that SME have not yet learnt to invest effectively. (4) Table 3 contains a broader group of SME than our dataset, namely the construction industry, commerce and part of services. It is possible that these sectors cared for a larger part of the observed jump in investment. Finally we note that these points are not mutually exclusive, hence in fact all of them can be partially true.

Similar conclusions can be made for the role played by intangible assets, which include goodwill, software, patents, copyrights, trademarks and tradenames. That their presence in the production function is insignificant means that Czech manufacturing SME are not yet innovation driven on a large scale.

At last we performed three specific tests: We found the presence of systematic inefficiency highly significant. By this we mean that instead of being close to the efficient frontier, the majority firm operates on a considerably lower level of efficiency. However we were not able to accept the hypothesis which would explain this inefficiency by the size of enterprises. Even if confirmed, the size effect would work in the opposite direction than expected: larger firm performing worse.

As with every empirical study, we are well aware of the fact that practice requires compromise. One that we encountered throughout the paper was as follows: The methods are constructed to trace technical and allocation efficiency separately, but we have to use data in monetary units which disables the separation of the two effects. Still we argued that it does not hinder us from using them and that they are capable of yielding meaningful results.

We are aware that this analysis could well be extended, an example of which is an explicit treatment of technological progress. This issue is left for further research.

A Data Definition

We give complete definitions of the data obtained from the Czech Statistical office. These definitions are available online.²¹ For reference purposes, we list both the Czech expression and the English translation.

Gross profit on merchandise sold = revenue from goods acquired for resale less costs of resold merchandise.

1. **Number of active firms** (počet aktivních podniků).

Number of firms which were active at least on one day during the reference period.

²¹[\[http://dw.czso.cz/pls/metis/TUCUK_N.ZAC\]](http://dw.czso.cz/pls/metis/TUCUK_N.ZAC).

2. **Output** (výkony celkové).
Sum of: (1) sales revenue from own products, (2) gross profit on merchandise sold (3) received leasing installments, (4) change in inventories and (5) self-constructed asset revenue.
3. **Sales revenue** (tržby za vlastní výkony a zboží).
Sum of: (1) sales revenue from own products and (2) revenue from merchandise sold.
4. **Accounting value added** (účetní přidaná hodnota).
Output less cost of materials used in manufacturing. The latter consists of (1) the value of purchased and already used material, energy and of supplied materials which are not storable, and (2) of the value of purchased services.
5. **Tangible assets** (dlouhodobý hmotný majetek).
Includes mainly land, plants, capital equipment, orchards and vineyards, herd and draught animals and all other assets with supposed period of usage longer than one year.
6. **Intangible assets** (dlouhodobý nehmotný majetek).
Immaterial assets worth more than 60 thousand CZK and with supposed period of usage longer than one year. Above all this indicator includes goodwill, software, patents, copyrights, trademarks and tradenames.
7. **Acquisition of tangible and intangible assets inclusive land save financial assets** (pořízení dlouhodobého majetku včetně pozemků bez dlouhodobého finančního majetku celkem).
Includes purchased assets, expenses connected with self-constructed long-term assets, and the value of assets obtained by voluntary conveyance.
8. **Number of employees** (počet zaměstnaných osob).
Number of people who are permanently or temporarily employed by the firm, irrespective of their country of citizenship. Employment means that employers perform continuous work for the employer. Generally, all employers who receive regular pay are included here, and employers who temporarily left their job and do not receive any wage at the same time (eg parental leave) are not counted.
9. **Average number of employees** (Průměrný evidenční počet zaměstnanců).
The previous item recalculated in order to capture fluctuations. Number of employees on individual days of one month is divided by the number of days in the respective month, and this monthly figure is averaged for to obtain the yearly indicator.
10. **Payroll (without other personnel expenses)** (mzdy bez ostatních osobních nákladů).
Salaries and payments in kind provided to employers belonging to the item "number of employees". Includes regular pay, supplementary pay, bonuses and other components of salaries. Gross wages are indicated, ie before social and health insurance contribution and income tax is deducted.
11. **Other personnel expenses** (ostatní osobní náklady).
Payments that are not connected with regular employment contract, indicated as gross payments. These will typically be: remuneration for work contracted beyond the employment contract, remuneration for expert testimonies or for intermediation, royalties and other patent fees, severation or termination pays, salaries of judges.

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