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THE USE OF DATA ENVELOPMENT ANALYSIS TO ASSESS THE R&D EFFECTIVENESS OF THE CZECH MANUFACTURING INDUSTRY

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Abstract. The article deals with the application of Data Envelopment Analysis on research and development (R&D) effectiveness assessment of Czech manufacturing industry. The aim of this paper is to analyze effectiveness of resources spent in R&D, i.e. how effectively are resources transformed into marketable outputs of R&D. As variables are used R&D personnel, R&D expenditure and Sales of products of R&D to another entity. Data envelopment analysis is based on assessing the quantity of consumed inputs by the produced outputs and estimation of production possibility frontier by techniques of linear programming. Two models are calculated: an input oriented model with variable returns to scale and an input oriented model with constant returns to scale. Described approach to evaluation of R&D effectiveness can also be used in other sectors of economy as well as other countries. It was found that the most effective sector of Czech manufacturing industry is a manufacture of wood and paper while automotive industry is the least effective.

Keywords: research and development, effectiveness, competitiveness, Data Envelopment Analysis, manufacturing industry, Czech Republic.

JEL Classification: O32, C67.

Introduction

Effectiveness of R&D plays a key role in competitiveness not only in manufacturing industry but also in the whole Czech economy regarding the fact that manufacturing industry is the main source of Gross Domestic Product (GDP) of the Czech Republic. In the literature occurs several ways of competitiveness assessment. Competitiveness at the macroeconomic level is usually assessed by a set of indicators. The Global Competitiveness Report 2012–2013 assesses the competitiveness of countries through more than 100 indicators. Potential Competitiveness Rankings 2010 evaluates the ability of national economies to increase GDP per capita in the future (Schwab 2012). One possibility how to increase GDP is increase productivity. Constant productivity increase through simple cost reduction in manufacturing, which usually involves reducing the number of jobs, is not a sustainable way. Investment in R&D and innovating processes, products and services is one way how to achieve productivity increase with the subsequent effect of enhancement customers' consumption, without increased unemployment. Therefore, one of the indicators for measuring competitiveness of the economy is the level of investment in R&D. Competitiveness evaluation is economically relevant because it enables to identify all strengths and weaknesses of a national economy and it provides the basis for the creation of efficient economic stimulation instruments (Navickas, Malakauskaitė 2010).

The aim of this paper is to provide a comparative study of Czech manufacturing industry based on evaluation of technical efficiency of R&D personnel and R&D expenditure to sales of R&D products. The chosen topic is relevant regarding the objectives of the Europe 2020 strategy and Competitiveness Strategy of the Czech Republic 2012-20 (Strategie mezinárodní konkurence–schopnosti ČR 2011).

Achievement of the Lisbon Strategy objective, i.e. increase R&D expenditures at 3% of GDP by 2010, failed in the Czech Republic as well as other EU member states. A literature review of scientific papers relating to R&D investments was performed in order to meet the aim. To evaluate the technical efficiency of individual manufacturing industry sectors a data envelopment analysis was used. The data source was Czech Statistical Office data sets. The facts are further divided according to CZ-NACE.

1. Theoretical approach to R&D investments

Many theoretical and empirical studies have dealt with economic aspects of R&D expenditure and investments. For example Meliciani (2000), Timmer (2003), Gonzalez and Gascon (2004) describe the effects of R&D investments. Innovations have a positive effect on the corporate productivity and economic growth. It is important to know whether R&D expenditure and investments have adequate returns. The effectiveness of R&D expenditure stimulation through indirect support was modeled in several studies, e.g. Atkinson (2007), Baghana and Mohnen (2009), Tassey (1996, 2007). Recommendations point to the need for restructuring the system of indirect support to increase corporate R&D expenditures. Simulations of European Tax Analyzer, that compared tax burden of companies, showed that support of the Czech Republic is the most useful one (Elschner, Ernst, Licht, Spengel 2011). In many publications for managers (Pitra 2001, 2006; Drucker 1992; Košturiak, Chaľ 2008), there are mentioned concepts of innovation, invention, innovation management and their positions in strategic management. Innovation is a result of consistent and conscientious work of R&D personnel. Innovation is not just about the products, also production processes can be innovated. Continuous innovations are crucial for increasing competitiveness. Increasing number of competitive companies within the region improves the stability of the region, the social climate, increases GDP and contributes to raising the standard of living. Support for R&D, raising R&D expenditure and investment in all sectors are consistent with the Europe 2020 strategy and Competitiveness Strategy of the Czech Republic 2012-20. However, the effectiveness of these expenditures is still not quite resolved.

Literature aimed at innovation describes that R&D activities are influenced by many factors. Supply of qualified R&D personnel and high-quality infrastructure are important factors for research centers (Cantwell, Piscitello 2005). Product customization of R&D to a particular market is influenced by its size (Mansfield, Romeo, Switzer1983; Patel, Vega 1999). For multinational enterprises, using their technological strengths and weaknesses of individual branches, a supportive potential of the host country is crucial (Kuemmerle 1997; Le Bas, Sierra 2002). Globalization of R&D leads to input specification (Lall 1979; Defever 2006).

2. Methods for evaluating the effectiveness of R&D investment

The question of investment generally relates to investment effectiveness. For the evaluation of real investments there are many methods, such as pay back method, net present value method, internal rate of return method, economic value added, etc. Measuring the effectiveness of R&D investments is much more complicated. In the literature, there are several approaches to R&D investment effectiveness measurement. First, is stochastic frontier analysis (SFA) defined by Aigner, Lovell and Schmidt (1977) a Meeusen and Van den Broeck (1977). SFA is based on estimation of stochastic frontier production function by econometric methods. SFA approach to R&D investment effectiveness measurement was used by e.g. Wang (2007).

Another approach is data envelopment analysis (DEA) defined by Charnes, Cooper and Rhodes (1978) which is based on estimation of production function by techniques of linear programming. Data envelopment analysis was used for evaluation of effectiveness of R&D investment in work of Lee and Park (2005). Czech authors Staníčková and Malecký (2011) used DEA to evaluate the competitiveness of regions. Another interesting application of the method DEA provides Cook, Seiford and Zhu (2004), who evaluated influence e-business activities on a performance of banks or Post and Spronk (1999) that also used DEA to a performance benchmarking of UK universities. DEA models are based on the fact that for a given problem a set of options consisting of all possible (acceptable) combinations of inputs and outputs exists. This set is given by a production possibility frontier. Production units which combination of inputs and outputs lies on this frontier are efficient units because it is not expected that there could be actually a unit that will produce the same output with less inputs or higher outputs with less inputs (Jablonský, Dlouhý 2004).

Multiple criteria decision-making methods represent a valuable tool in reaching rational decisions about R&D investments in the light of multiple criteria and conditions of risks and uncertainty. The objective of the multi criteria variant evaluation is, in most cases, a selection of the optimal (compromise) variant and creating a platform for complex decision-making processes typical for R&D investments. The multi criteria analysis is essentially a mathematical model. The application should lead to a selection of the optimal variant from a group of variants feasible in a given situation. Optimal variants are expressed by means of a set of criteria that serve to select the optimal variant. Choosing the right criteria is an important step towards an objective assessment of all variants, and consequently is the determination of how much weight should be given to each criterion in accordance with its importance. For example Analytical Hierarchy Process with Group Decision Making methods was used in the work of authors Sargent and Sargent (2010). Jung and Seo (2010) used Analytic Network Process approach for the evaluation of R&D projects. The Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) was applied by Chen and Zhang (2011).

3. Legislative framework for research and development in the Czech Republic

In the Czech Republic, the legislative support of R&D contains both direct and indirect support. Direct support is decentralized. The central administrative office for research and development is Ministry of Education, Youth and Sports. The advisory body of Czech government is the Research, Development and Innovation Council. R&D is also supported by the Academy of Sciences of the Czech Republic, Ministry of Defence, Ministry of Health, Ministry of the Interior, Ministry of Agriculture, Ministry of Industry and Trade and Ministry of the Environment. Act on the Support of Research and Development published as Act. No. 130/2002 Coll. has been twelve times modified by 2013. Currently, another two amendments are being prepared. Basic research is supported by the Grant Agency of the Czech Republic, applied R&D by the Technology Agency of the Czech Republic. Both agencies are funded as well as the ministries from the state budget. In the Czech Republic, indirect support for R&D (R&D tax incentives) has been used since 2005 on the basis of the Law on Income Tax Act. No. 586/1992 Coll., which allows tax allowances for investment in R&D. From January 1, 2015, new amendment of the Law on Income Tax will come into force; this amendment will extend and refine the use of indirect support for R&D in companies. There is also a rule, that the same project cannot draw simultaneously indirect support and direct support.

Foreign investors can benefit from government consulting agency – Czech Trade. With the government support science&technology parks and incubators are set up. Investments into R&D can be supported also by EU Structural Funds Potential and Innovation.

4. DEA models

Two models are computed – an input oriented model with constant returns to scale (CCR model; Charnes, Cooper, Rhodes 1978) and an input oriented model with variable returns to scale (BCC model; Banker, Charnes, Cooper 1984).

The proposed model includes 15 sectors of manufacturing industry. Each of these sectors is considered as a homogeneous production unit (decision-making unit, DMU), $k = 15$. In this model, there are 2 inputs – $i = 2$ (*number of R&D personnel, R&D expenditure*) and 1 output – $j = 1$ (*sales of products of R&D*). DMU_k consumes X_{ik} of the input i and produces Y_{jk} quantity of the output j. DMU_q consumes x_{jq} of the input i and produces yiq quantity of the output j.

Mathematical model of primary input oriented CCR model (Jablonský 2002):

$$\max z = \sum_{i}^{2} u_i y_{iq}, \quad (1)$$

on conditions:

$$\sum_{i}^{2} u_i y_{iq} \leq \sum_{j}^{1} v_j x_{jk}, \quad (2)$$

$$\sum_{j}^{1} v_j x_{jq} = 1, \quad (3)$$

$$u_i \geq \varepsilon, \quad (4)$$

$$v_j \geq \varepsilon. \quad (5)$$

Mathematical model of primary input oriented BCC model (Jablonský 2002):

$$\max z = \sum_{i}^{2} u_i y_{iq} + \mu, \quad (6)$$

on conditions:

$$\sum_{i}^{2} u_i y_{iq} + \mu \leq \sum_{j}^{1} v_j x_{jk}, \quad (7)$$

$$\sum_{j}^{1} v_j x_{jq} = 1, \quad (8)$$

$$u_i \geq \varepsilon, \quad (9)$$

$$v_j \geq \varepsilon, \quad (10)$$

$$\mu \text{ – arbitrary}. \quad (11)$$

Where, u_i and v_j are individual weights assigned so as to maximise the efficiency of the unit and μ is a dual variable associated with the convexity condition $e^T \lambda = 1$. ε is infinitesimal constant which ensures that all weights of inputs and outputs will be positive.

The coefficient of technical efficiency z derived from the DEA model is relative, expresses efficiency of the DMU within the studied group of DMUs. If equal to one, it means that in the group there is no more effective unit. If the value of z is less than 1, there is at least one more DMU which is more effective.

The data source for input and output variables was obtained from a secondary sources. Relevant provider of secondary data is Czech Statistical Office (CSO). The effectiveness of R&D was computed for manufacturing companies. Data on specialized research centers are not included. Approximately just 0.65% Czech manufacturing companies do their own research and development. The highest, and during the period increasing, number of companies involved in R&D is in manufacture of machinery and equipment n.e.c. In the second place there is a manufacture of basic metals, of fabricated metal products, except machinery and equipment. The smallest number of companies involved in R&D is in manufacture of wood and of products of wood and cork, except furniture.

Variables are defined as follows:

- *R&D personnel* include researchers, technicians, administrative staff and other supporting staff. The number of employees at 31 December in Head Count refers to registered number of active R&D personnel employed (full or part-time) at the end of reference year (CSO 2012).
- *R&D expenditure* consists of all R&D current and capital expenditure made within the industry. We calculate only R&D expenditures that come from the business enterprise sector (private funds of enterprises, financial institutions, and employers) (CSO 2012).
- *Sales of products of R&D* – results and outputs of R&D sold to other companies and organizations. The main activity of these business subjects is the production of goods and services for the purpose of sale for economically significant price.

5. Discussion

One of the indicators evaluating competitiveness of a country is the level of investments in R&D. A volume of spent funds monitors an indicator GERD (Gross domestic expenditure on R&D). There is a stable but slow increase in R&D expenditure in the EU-27. Since 2006, total R&D expenditure in the EU-27 has increased by 9.7% to 2.03% of GDP in 2011. In the Czech Republic, R&D expenditure increased by 24% to 1.84% of GDP during 2006–2008 (Eurostat 2012).

Innovation in manufacturing and of processes are mainly results of applied research. However, research and development is not just a privilege of academic and scientific institutions, but it more and more expands directly to the business sector. Selected research sample - the manufacturing sector belongs to the part of Czech economy that is constantly productive. Manufacturing industry had 60% share on R&D activites in 2011, this share represents €1.06 billion (Štamnpach 2013).

For understanding the relations among the variables a correlation analysis was performed in the first step, see Table 1. Sales of products of R&D are more positively influenced by human rather than financial resources.

Calculated results of CCR and BCC model were averaged for the period 2008–2011 and an order for each model was set, see appendix 1. Comparison of CCR and BCC models for evaluating the R&D effectiveness showed a comparable order of one third of sectors of manufacturing industry.

Table 1. Correlation coefficients between the variables in the period 2008–2011

Variable	2008	2009	2010	2011
R&D personnel Sales of products of R&D	0,7530	0,7303	0,7008	0,7440
R&D expenditure Sales of products of R&D	0,3158	0,2326	0,1046	0,0922

Source: own calculation based on the CSO data.

Manufacture of wood and paper, manufacture of basic pharmaceutical products and pharmaceutical preparations, manufacture of motor vehicles, of trailers and semi-trailers, manufacture of other transport equipment, manufacture of furniture, other manufacturing, repair and installation of machinery and equipment had the same order according to CCR model as well as BCC model. The disproportion of two points occurred only once in the manufacture of machinery and equipment n.e.c. According to the BCC model, this industry shared the first position with the manufacture of wood and paper, according to CCR model it was on the third position. In other cases, the difference between the CCR model and BCC model, was only one position.

The most effective sector of manufacturing industry, according to both models, was manufacture of wood and paper, which in real terms represents 16[*] companies (0.7% of all Czech companies engaged in the R&D or 1.3% of Czech manufacturing companies engaged in the R&D in 2011). Also the most efficient is manufacture of machinery and equipment n.e.c., according to the BCC model. This part of the manufacturing industry is represented by 266 companies (11.8% of Czech companies engaged in the R&D or 21.9% of Czech manufacturing companies engaged in the R&D in 2011). On the contrary the least efficient was manufacture of motor vehicles, of trailers and semi-trailers represented by 60 companies (2.7% of Czech companies engaged in the R&D or 4.9% of Czech manufacturing companies engaged in the R&D in 2011). Inefficiency of the automotive industry contrasts with other statistical data. The automotive industry is a sector where the major share of R&D investment is realised and is the driver of the Czech economy. Export of vehicles is one fifth of total exports of the Czech Republic.

In 2009, 79 foreign investors set up research centres in the Czech Republic. Among 26 major foreign investors (in 2012), which set up research centres, there are 14 operating in the automotive industry, e.g. Behr, Bosh, Mercedes Benz.[**] Number of automotive companies which use R&D

[*] Data on the number of companies is taken from the Czech Statistical Office report – Research and Development Indicators 2011 (CSO 2012).

[**] Czech Trade data.

tax incentives has increased from 10 to 16 in a given period, an amount of invested money has increase from €53 349 416 € to €111 227 103 €. 26.6% of automotive companies involved in R&D use R&D tax incentives. According to DEA models, the most effective industry is manufacture of wood and paper; from this sector only 5 companies used indirect support in 2008 – 201. Invested financial resources significantly increased from €173 359 to €1 281 957. 31.25% manufacturers of wood and paper involved in R&D use R&D tax incentives. Automotive industry employs 141 times more R&D personnel and spends 88 times more financial resources per one sold outcome (patent, licence etc.) of R&D than companies manufacturing wood and paper.

Conclusions

Investment in R&D is one of the priorities of government policies of developed and developing economies. R&D and innovation activities are a prerequisite for increasing competitiveness of companies, regions and countries. Efficient R&D is one of the priority objectives of the Czech economy. The volume of funds spent on R&D is presented in various forms of statistical indicators. In this paper, the R&D performance of sectors of manufacturing industry was compared. Secondary data of CSO were compared by time series and the effectiveness was evaluated by two DEA models – an input oriented model with constant returns to scale and an input oriented model with variable returns to scale. The results of CCR and BCC models, when compared as ranking, were about the same. The most effective sector of manufacturing industry was manufacture of wood and paper while automotive industry was the least effective. Results are limited by the fact that only three variables were calculated.

Influence of legislation on the effectiveness of invested resources into R&D is a possible topic for further research. It is difficult to incorporate this aspect into DEA models, because it is hard to measure and it is necessary to define relevant measures/indicators first. It can be assumed that the low efficiency of automotive industry according to DEA models, which has the most research centres and the highest total investment in R&D, is partially caused by the fact that these companies receives most of the direct support – Structural Funds and grants financed from the state budget and thus their economic activities are not under so much pressure as the companies funding R&D on their own.

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References

Aigner, D.; Lovell, C. A. K.; Schmidt, P. 1977. Formulation and estimation of stochastic frontier production function models, *Journal of Econometrics* 6: 21–37. http://dx.doi.org/10.1016/0304-4076(77)90052-5

Atkinson, R. 2007. Expanding the R&E tax credit to drive innovation, competitiveness and prosperity, *The Journal of Technology Transfer* 32(6): 617–628. http://dx.doi.org/10.1007/s10961-007-9046-y

Baghana, R.; Mohnen, P. 2009. Effectiveness of R&D tax incentives in small and large, *Small Business Economics* 1: 91–107. http://dx.doi.org/10.1007/s11187-009-9180-z

Banker, R. D.; Charnes, A.; Cooper, W. 1984. Some models for estimating technical and scale inefficiencies in data envelopment analysis, *Management Science* 30: 1078–1092. http://dx.doi.org/10.1287/mnsc.30.9.1078

Cantwell, J.; Piscitello, L. 2005. Recent location of foreign-owned research and development activities by large multinational corporations in the European regions: the role of spillovers and externalities, *Regional Studies, Taylor and Francis Journals* 39(1): 1–16. http://dx.doi.org/10.1080/0034340052000320824

Charnes, A.; Cooper, W.; Rhodes, E. 1978. Measuring the efficiency of decision-making units, *European Journal of Operational Research* 2: 429–444. http://dx.doi.org/10.1016/0377-2217(78)90138-8

Chen, W.; Zhang, Y. 2011. Research on evaluation of high-new-tech enterprises R&D projects investment risk, in *Information Management, Innovation Management and Industrial Engineering (ICIII), 2011 International Conference on,* vol. 1: 428–431. IEEE.

Cook, W.; Seiford, L.; Zhu, J. 2004. Models for performance benchmarking: measuring the effect of e-business activities on banking performance, *Omega* 32(4): 313–322. http://dx.doi.org/10.1016/j.omega.2004.01.001

CSO. Odbor statistik rozvoje společnosti. 2012. Ukazatele výzkumu a vývoje 2011 [online], [cited 29 May, 2013]. Available from Internet: http://www.czso.cz/csu/2012edicniplan.nsf/kapitola/9601-12-r_2012-0301. Kód e-9601-12.

Defever, F. 2006. Functional fragmentation and the location of multinational firms in the enlarged Europe, *Regional Science and Urban Economics* 36(5): 658–677. http://dx.doi.org/10.1016/j.regsciurbeco.2006.06.007

Drucker, P. 1992. *Management: budoucnost začíná dnes.* Praha: Management Press. 128 p.

Elschner, C.; Ernst, C.; Licht, G.; Spengel, C. 2011. What the design of an R&D tax incentive tells about its effectiveness:a simulation of R&D tax incentives in the European Union, *The Journal of Technology Transfer* 36(3): 233–256. http://dx.doi.org/10.1007/s10961-009-9146-y

Eurostat. Eurostat Data Explorer. Eurostat [online], [cited 20 June, 2013.] Available from Internet: http://epp.eurostat.ec.europa.eu/portal/page/portal/science_technology_innovation/data/database.

Gonzalez, E.; Gascon, F. 2004. Sources of productivity growth in the Spanish pharmaceutical industry, 1994–2000, *Research Policy* 33: 735–745.

Jablonský, J. 2002. *Operační výzkum: kvantitativní modely pro ekonomické rozhodování.* Praha: Professional Publishing. 323 p.

Jablonský, J.; Dlouhý, M. 2004. *Modely hodnocení efektivnosti produkčních jednotek*. Praha: Professional Publishing. 183 p.

Jung, U.; Seo, D. W. 2010. An ANP approach for R&D project evaluation based on interdependencies between research objectives and evaluation criteria, *Decision Support Systems* 49(3): 335–342. http://dx.doi.org/10.1016/j.dss.2010.04.005

Košturiak, J.; Chaľ, J. 2008. *Inovace: vaše konkurenční výhoda*. Brno: Computer Press. 176 p.

Kuemmerle, W. 1997. Building effective R&D capabilities abroad, *Harvard Business Review* March–April: 61–70.

Lall, S. 1979. Transfer pricing and developing countries: Some problems of investigation, *World Development* 7(1): 59–71. http://dx.doi.org/10.1016/0305-750X(79)90008-1

Le Bas, C.; Sierra, C. 2002. Location versus home country advantages' in R&D activities: some further results on multinationals'locational strategies, *Research Policy* 31(4): 589–609. http://dx.doi.org/10.1016/S0048-7333(01)00128-7

Lee, H.; Park, Y. 2005. An international comparison of R&D efficiency: DEA approach, *Asian Journal of Technology Innovation* 13(2): 207–221. http://dx.doi.org/10.1080/19761597.2005.9668614

Mansfield, E.; Romeo, A.; Switzer, L. 1983. R&D price indexes and real R&D expenditures in the United States, *Research Policy* 12: 105–112. http://dx.doi.org/10.1016/0048-7333(83)90007-0

Meliciani, V. 2000. The relationship between R&D, investment and patents: A panel data analysis, *Applied Economics* 32: 1429–1437. http://dx.doi.org/10.1080/00036840050151502

Meeusen, W.; Van den Broeck, J. 1997. Efficiency estimation from Cobb-Douglas production functions with composed error, *International Economic Review* 8: 435–444.

Navickas, V.; Malakauskaitė, A. 2010. Methodological problems and limitations of competitiveness evaluation, *Business: Theory and Practice* 11(1): 5–11.

Patel, P.; Vega, M. 1999. Patterns of internationalisation of corporate technology: location vs. home country advantages, *Research Policy* 28(2–3): 145–155. http://dx.doi.org/10.1016/S0048-7333(98)00117-6

Pitra, Z. 2006. *Management inovačních aktivit*. Praha: Professional publishing. 438 p.

Pitra, Z. 2001. *Zvyšování podnikatelské výkonnosti firmy*. Praha: EKOPRESS. 305p.

Post, T.; Spronk, J. 1999. Performance benchmarking using interactive data envelopment analysis, *European Journal of Operational Research* 115(3): 472–487. http://dx.doi.org/10.1016/S0377-2217(98)00022-8

Sargent, T. A.; Sargent, R. G. 2010. *The investment comparison tool (ICT): A method to assess research and development investments* [online], [cited 23 August, 2013.] Available from Internet: http://surface.syr.edu/eecs/174/

Schwab, K. 2012. The global competitiveness report 2012–2013 [online], [cited 2 May, 2013.] Available from Internet: http://www3.weforum.org/docs/WEF_GlobalCompetitivenessReport_2012-13.pdf.

Staníčková, M.; Malecký, L. 2011. Hodnocení konkurenceschopnosti visegrádské čtyřky prostřednictvím aplikace CCR vstupově orientovaného modelu analýzy obalu dat, *Scientific Papers of the University of Pardubice* 22(4): 176–188.

Strategie mezinárodní konkurenceschopnosti ČR. 2011 [online], [cited 10 June, 2013]. Available from Internet: http://www.businessinfo.cz/files/dokumenty/mpo_strategie_konkurenceschopnost_2020.pdf.

Štampach, M. 2013. Soukromý výzkum a vývoj v podnicích, *Statistika* & *My* 3: 30.

Tassey, G. 1996. Choosing government R&D policies: Tax incentives vs. direct funding, *Review of Industrial Organization* 1: 579–600. http://dx.doi.org/10.1007/BF00214824

Tassey, G. 2007. Tax incentives for innovation: time to restructure the R&E tax credit, *The Journal of Technology Transfer* 1: 605–615. http://dx.doi.org/10.1007/s10961-007-9045-z

Timmer, M. P. 2003. Technological development and rates of return to investment in a catching-up economy: The case of South Korea, *Structural Change and Economic Dynamics* 14: 405–425. http://dx.doi.org/10.1016/S0954-349X(03)00028-6

Wang, E. C. 2007. R&D efficiency and economic performance: A cross-country analysis using the stochastic frontier approach, *Journal of Policy Modeling* 29: 345–360. http://dx.doi.org/10.1016/j.jpolmod.2006.12.005

APPENDIX 1. The effectiveness of sectors of manufacturing industry in 2008–2011
(*Source*: own calculation based on the CSO data)

Sector of manufacturing industry	2008		2009		2010		2011		Average		Ranking	
	CCR	BCC	CCR	BCC	CCR	BCC	CCR	BCC	CCR	BCC	CCR	BCC
Manufacture of food products and beverages	0,42	0,52	0,18	0,37	0,68	0,81	0,5	0,94	0,4450	0,6600	6	7
Manufacture of textiles, of wearing apparel, of leather and related products	0,21	0,47	0,07	0,13	0,37	0,37	0,12	0,26	0,1925	0,3075	14	13
Manufacture of wood and paper	1	1	1	1	1	1	1	1	1,0000	1,0000	1	1
Petrochemical and chemical industry	0,78	1	0,24	0,51	0,8	1	0,26	0,65	0,5200	0,7900	4	5
Manufacture of basic pharmaceutical products and pharmaceutical preparations	0,46	0,58	0,16	0,33	0,2	0,25	0,12	0,29	0,2350	0,3625	12	12
Manufacture of rubber and plastic products	0,37	0,47	0,3	0,63	0,52	0,64	0,27	0,57	0,3650	0,5775	9	8
Manufacture of other non-metallic mineral products	0,56	0,71	0,22	0,46	0,6	0,63	0,27	0,42	0,4125	0,5550	8	9
Manufacture of basic metals	0,28	0,35	0,08	0,17	0,38	0,39	0,09	0,14	0,2075	0,2625	13	14
Manufacture of fabricated metal products, except machinery and equipment	0,37	0,73	0,49	1	1	1	0,6	1	0,6150	0,9325	2	3
Manufacture of computer, electronic and optical products	0,42	0,67	0,26	0,68	0,59	0,62	0,42	0,76	0,4225	0,6825	7	6
Manufacture of electrical equipment	0,51	1	0,37	1	0,47	0,55	0,45	0,92	0,4500	0,8675	5	4
Manufacture of machinery and equipment n.e.c.	0,59	1	0,32	1	0,91	1	0,51	1	0,5825	1,0000	3	1
Manufacture of motor vehicles, of trailers and semi-trailers	0,15	0,29	0,07	0,26	0,07	0,09	0,04	0,1	0,0825	0,1850	15	15
Manufacture of other transport equipment	0,46	0,59	0,18	0,38	0,27	0,34	0,13	0,34	0,2600	0,4125	11	11
Manufacture of furniture, other manufacturing, repair and installation of machinery and equipment	0,36	0,57	0,2	0,57	0,38	0,49	0,21	0,55	0,2875	0,5450	10	10

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