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Productivity of Czech state administration with focus on IT technology and costs connected with use of modern technologies

Bachelor's Thesis

Author of the Thesis: Pavel Fuchs

Study program: Economics and Finance

Supervisor: Petr Pleticha, M.Sc.

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Declaration

1. I hereby declare that I have compiled this thesis using the listed literature and resources only.
2. I hereby declare that my thesis has not been used to gain any other academic title.
3. I fully agree to my work being used for study and scientific purposes.

In Prague on 25. 07. 2021 Pavel Fuchs

References

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Abstract

Czech state government is often criticized because of slow implementation of new information technologies (IT). Furthermore, IT-related government contracts are frequently overpriced and the official analyses say only little about the projects' efficiency. The paper inquiries into relatively homogenous level of local government represented by municipalities of extended competence. These jurisdictions have to guarantee extensive portfolio of services, however they have relative freedom of investment decision making. We used Data Envelopment Analysis and assigned each municipality with efficiency score. We found out that higher investment in IT does not stand for improved efficiency and indicates inefficiencies in public spending. We also described an ambiguous effect of the size of the district and a significant negative effect of amount of clerks.

Abstrakt

Česká státní správa je často kritizována kvůli pomalému zavádění moderních informačních technologií. Veřejné zakázky slibující posun v digitalizaci úřadů jsou navíc mnohdy předražené. Oficiální studie jsou povrchní anebo zaměřené na konkrétní (neúspěšné) projekty. Práce se zabývá relativně homogenním vzorkem lokální státní správy, obcemi s rozšířenou působností. Tyto municipality zajišťují rozsáhlé portfolio centrální vládou určených služeb, ale investice si řeší poměrně autonomně. Použili jsme Data Envelopment Analysis a přiřadili každé obci skóre popisující její efektivitu. Vyšší investice do informačních technologií se neodrazila ve vyšší efektivitě zkoumaných obcí. Dospěli jsme také k nejednoznačnému vlivu velikosti okresku a poměrně zásadnímu negativnímu efektu počtu zaměstnanců.

Keywords

efficiency, government, local municipality, DEA, information technologies, IT, digitalisation

Klíčová slova

efektivita, státní úřady, státní správa, lokální, DEA, informační technologie, IT, digitalizace

Název práce

Efektivita složek české státní správy se zaměřením na IT technologie a náklady spojené s jejich využíváním.

Acknowledgement

I would like to express my gratitude to the supervisor, whose inspiring guidance reflected in the thesis. I could not forget secretaries of local municipalities, ministry officers, employees of non-governmental organisations and researchers, who assisted me to get oriented in the complicated environment of the Czech state administration. Last but not least, I thank to Michal Heller, who helped me to concentrate in severe periods of persisting lockdowns.

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1. Introduction

The influence of modern information technologies on efficiency has been discussed for several decades. At the earliest, IT came under strong criticism because of stagnated productivity during the implementation of new instruments in 1980's (Solow, 1987). Nowadays, there are no doubts about the contribution of IT (Brynjolfsson, Hitt, 2000), the problems are in the methodology and the mismeasurement of real benefits (Jones, Heaton, Rudin, Schneider, 2012). The aim of the study is to contribute in the discussion about the influence of information technologies on the Czech government. The paper uses the extensive dataset describing the performance of the local government.

Czech Supreme Audit Office claims that high investments in IT contracts have not led to fundamental changes in its efficiency or in communication between the state and citizens through online services. (NKÚ, 2020) The evaluation of the new projects or the performance of individual offices is executed without profound analysis (e.g. imperfect questionnaire survey with absent data, Ministry of the Interior, 2019). In addition, the correct comparison of non-profit organizations, which are not oriented merely on the financial return, is generally regarded as more complicated (Geys, Moesen, 2009a).

Our attention is focused on the Czech municipalities of extended competence. This relatively new tier of Czech local government was introduced in 2003. Main benefit for the research resides in the relatively high quantity of homogenous units, which have given a lot of obligations from the central government. However, the decision-making about investments and means how to guarantee these compulsory services is in the hands of responsible managers. The Ministry of the Interior introduces the possibility to select any office of citizen's choice for an increasing part of services (e.g. new ID card). The municipalities which provide better services are more attended by inhabitants from other districts.

We will use Data Envelopment Analysis, a suitable and popular non-parametric technique for the evaluation of the productivity of non-profit organizations on the accessible data from two years (2018, 2019). The input is defined as total expenses spent for the local administration. The outputs are defined as services provided by the municipality (e.g. amount of published identity cards or driving licenses, acts of spatial planning or administration of register of births and deaths).

The scores of efficiency are then compared with the investment into various components (hardware, software, training courses) related to information systems. In compliance with literature (Sung, 2007; Loikkanen, Susiluoto, 2005; Geys, Moesen, 2009a), we perform several OLS and Tobit models. Due to gradual implementation of new technologies (Willcocks, Lester, 1996), we use data from previous five years. Our research tries to answer, whether higher IT investment improves the productivity of the local government. We consider also other important variables as the size of the district or the expenses spent on wages. The ideal size of the jurisdiction is debated theoretically (Tullock, 1969), as well empirically (Šťastná, Gregor; 2015). We suppose problematical utilization of new IT technologies on the basis of performance of the central government. Our interest is also directed at regional differences.

1.1 Problems of the implementation of new technologies in Czech state administration

The issues of the Czech government with implementation of new information technologies are discussed for a long time. Independent experts speak about structural problems (ČTK, 2021a). Collapses of information systems are frequent and are anticipated in advance. Census (2021) had to be prolonged, selling of toll stickers was postponed, and troubles did not even avoid the registration for anticovid vaccination (ČTK, 2021b; Kasík, 2021).

Journalists often investigate government contracts in the IT segment. Services ordered by state are frequently overpriced (Břešťan, 2020). After the announcement of the costs of a new system for toll administration, IT specialists organized a weekend hackathon to demonstrate inefficiency of the government. This affair caused the change of the minister of transport; main offices are newly obliged to report every planned IT contract (higher than 6 million CZK) to the cabinet in advance (ČTK, 2020). Non-governmental organisations and media seek inspiration for instance in Estonia, where the state government was massively innovated till 1997 because of state security and attraction of foreign investors (Bulan, 2020; 602, 2020)

Czech Republic Supreme Audit Office called attention to (e.g.) 390 million CZK wrongfully used for computerization of state administration (NKÚ, Hykšová, 2015), absent strategy for IT management of Ministry of traffic (425 million CZK wasted; NKÚ, Neuvirt, 2016), system for administration of state subsidies (383 million CZK; NKÚ, Reisiegel, 2016), medical information systems (364 million; NKÚ, Kubíček, 2018) or service of tax collection (428 million CZK; NKÚ, Reisiegel, 2019).

The attention is predominantly concentrated on central offices. The contracts are not suitable for econometric analysis. The sample is restricted (frequently to just one observation). The composition and tasks of ministries are quite heterogeneous. The comparison is rather possible in an international context. On the contrary, the behaviour of local municipalities can show everyday functioning of the government on the homogenous sample (Šťastná, Gregor, 2015). Citizens meet with this segment the most frequently, and an effective operation can improve their regular experience.

1.2 The structure of the thesis

In next chapter we focus on literature occupied with the Solow productivity paradox, papers explaining how new technologies help raise productivity and why the attempts are not always successful. We also discuss literature about decentralization of state government and then the paper concentrate on the studies dealing with the productivity of local jurisdictions. In chapter 3, we introduce suitable methods for the measurement of the efficiency of public organizations, especially Data Envelopment Analysis. In chapter 4, we present the organization of Czech state government, problems of financing and distinguish terms such as self-government, state administration, and delegated jurisdiction. This overall context helps to comprehend the datasets which is closely described in Chapter 5. Two steps-model is introduced in Chapter 6. We use DEA in the first stag e, and OLS or Tobit subsequently. The conclusion, limitations and possible next research are presented in Chapter 7.

2. Literature review

2.1 IT productivity paradox

The change of productivity with respect to the development of information technologies is one of the key questions of today's society. The various empirical analyses provided vague results (Brynjolfsson, 1993; David, 2000). The productivity paradox is often named after Robert M. Solow, the author of the witticism (1987): "You can see the computer age everywhere but in the productivity statistics." The paradox was on a macro level partly explained by swift productivity growth in the late 1990s, when the potential of IT was finally capitalized. (Sung, 2007). The inefficiency is caused by three types of issues: mismeasurement, mismanagement and poor usability (Jones, Heaton, Rudin, Schneider, 2012). The problem was exposed mainly on the output side, which is especially in service industries notoriously hard to measure (Geys, Moesen, 2009a). The main contribution of IT is in the improvement of factors such as accessibility and convenience. On the contrary, expenses connected with new technologies (the number of computers purchased) are easily measurable. For instance, the introduction of ATMs in the US during the 1970s was reflected with no productivity growth because standard methods were not able to reflect increased comfort of clients (Brynjolfsson, Hitt, 1998; Haynes, Thompson, 2000). The research showed (Kern et al., 2009), how the majority of metrics is inconvenient for observation of the effectivity for instance in hospital care. Moreover, no profits on aggregated level can be caused by redistribution of benefits towards more innovative entrepreneurs or whole branches (Brynjolfsson, 1993).

The problems of measurement were partially resolved by more detailed data, their collecting is ironically possible by the development of the information technologies (Brynjolfsson and Hit, 1998). The attention was concentrated on micro data and various sector analyses (Jorgenson, 2001; Brynjolfsson and Hit, 1996, 2000; Stiroh, 2001).

The mismanagement can be excused and resolved by progressive development. Authors show (David, 1990) that the electrification of manufactories in early 20th century had small effect on the productivity. Firstly, new electric motors just replaced steam engines. The shift came when space-saving potential of new machines was used and whole configuration of the factory was changed. Similar situation is present in some of current offices, where paper based processes are just digitized without the utilization of new possibilities (i.e. interconnection of databases).The effect of modern technologies is higher in organizations with more educated staff and autonomous work teams (Brynjolfssonn, Hitt, 2003).

Underestimation of approachable design for the end user of IT systems can cause reduction of productivity (Landauer, 1995). Every investment in IT products should follow multiple amounts to later adjustment and redesign, training and implementation with existing processes (Willcocks, Lester, 1996).

The progress of computers is often measured by the increasing of the compounding capacity (Brynjolfsson, 2000), which is manifold bigger than the stagnated rate of economic productivity. The power of computers in fields as storing, retrieving, organization and transmitting data is more important, but much more complex. The understanding of processes by clerks and managers is also necessary, Almutairi (2007) focused on individual performance of staff in Kuwaiti Public Organizations, where the usage of information systems lead to higher productivity jointly with variables as the amount of experiences.

The IT productivity paradox is discussed in all fields of public services, especially when some big financial stimulus is announced. The frequent criticism is related not only to wastage of funds, but also to safety problems especially in fields where personal data of citizens are stored or critical infrastructure is operated. (Jones, Heaton, Rudin, Schneider, 2012)

Public investment into new information technologies can have an effect on the overall community. The study of Bae and Lee (2007) focused on the adoption of the local municipality webpage in five counties of the Los Angeles area. The inroduction of this mean of communication was in positive correlation with the logarithm of average income in the area. The authors explain the dependency by better communication between local businesses and government, the webpage reduces transaction and communication costs. Additionally, the webpage supports information sharing about the locality and improved knowledge and trust in the area.

Most of the researches use IT-related expenditure to proxy the state of IT, which does not include the intensity of IT use. The paper of Nakil Sung (2007) focused on Korean local governments had the opportunity to use the Information Index, published for local Korean jurisdictions since 1999. The index includes the number of PCs, usage of bulletin boards or homepage visits. The DEA analysis shows that rural counties engage more servants and spend more money than urban jurisdictions. Some public outputs are not distributed equally, cities have a higher water supply or sewage and refuse disposal, which complicates analysis of the efficiency. In the second stage, several Tobit models are used with statistically significant coefficient of the IT index. Local municipalities work closer to the production frontier if they accomplish a higher degree of IT use. This work is unique for our purposes and research because of similar specialization on the local government and IT effectivity.

2.2 Efficiency with respect on Czech environment and public organisations

Economic efficiency defined as the highest quantity of outputs for minimized level of inputs is just one of public interests. This, jointly with problematical quantification of variables, makes measuring public sector efficiency more complicated in contrast with behaviours of private companies oriented on profit. We can mention other aims of state administration as appropriateness, responsiveness, adequateness. (Dunn, 2004; Koopmans, 1951; Lovell, 1993)

The research focused on the same sample was performed in 2015 (Šťastná, Gregor, 2015). The municipalities of extended competence were chosen for the sake of homogeneity, which absence is one of the crucial problems in efficiency estimation. The study compares productivity of local governments in the transition period (1995-1998) after the end of socialism and the post-transition period (2005-2008). It includes the change in administrative arrangement of the Czech Republic and the authorization of the municipalities with extended competence. The authors use stochastic frontier analysis with a broad dataset of outputs present in the area (education, sport and cultural facilities, or environmental variables) or produced by the local government. The input is determined just as current expenditures, due to volatility of capital spending influenced by co-financing from the European Union. The paper observes convergence to the best practice frontier. The size of the municipality represented by the population robustly raises the cost inefficiency and small municipalities improved their efficiency better between two periods. Also left-wing orientated representatives were associated with cost inefficiency (demonstrable just in the first, transition period). The mobility and isolation of the municipality also have a significant and growing effect on the effectiveness.

Some studies focus on the efficiency in specific area such as maintenance of the road network or waste disposal, the interest can be caused by debate of public control of fiscal spending (Kalseth, Rattsø, 1998). Other specific studies discussed efficiency of nursing homes (Kalseth, 2003) or secondary education (Borge, Naper, 2006). The influence of democratic participation was investigated i.e. by Borge, Falch, Tovno, 2007, where authors took advantage of special efficiency measures for Norwegian local governments compiled from a large number of indicators. The aggregate output measure consider six service sectors, interesting indicators are e.g. share of single rooms in nursing homes, teaching hours per student or play and outdoor area per child.

The comparison of various approaches in the measuring of the efficiency of local municipalities was performed e.g. by Geys, Moesen (2009a). The authors warn about results affected by selected method (free disposal hull, data envelopment analysis, stochastic efficiency frontier). The sample of Belgian municipalities were judged by mentioned methods; the cardinal differences in the absolute effectivity are caused by various efficiency frontiers (see part methodology), but the relative performances are positively correlated. Same authors (Geys, Moesen, 2009b) researched the sources of Flemish local government inefficiency with evidence for small influence of population variables (i.e. income inequality, unemployment). The opposite holds for the fiscal state of the jurisdiction (historical debt and financial surplus). Belgian municipalities were examined (cross-sectional data from 1985) also by De Borger et al. (1994) with utilization of FDH (Free Disposal Hull) and Tobit model in second stage. The efficiency was positively influenced by the size of the jurisdiction and the averaged level of education. Income level and grants from the state had a negative effect.

The research of 353 Finnish municipalities (Loikkanen, Susiluoto, 2005) detected efficiency differences among jurisdictions, stable over time. The most efficient municipalities were located in the developed centre of the country and they were rather smaller. Big cities performed really fluctuating results. Similarly with other studies, a two-step approach was applied. The difference in the efficiency scores were clarified with several OLS and Tobit models. Big proportion of clerks from the age group 35-49 years, compact urban structure and great education level have a positive impact. On the other hand, position on the periphery, larger population, higher income of citizens, unemployment and also outsourcing of services (purchases from other municipalities) tend to decrease efficiency.

Municipalities are good experimental space for observation of efficiency due to homogeneity. The literature about IT efficiency on the local level of government is limited for the present. The issue is the acquisition of relevant data, which we attempt to overcome with new instruments accessing economic activities of governments. Similar study was performed in South Korea (Sung, 2007, see above) taking advantage of local IT index computed for each office.

Our review should not miss brief reference to the decentralization of state government, which can have large effect on the efficiency of the municipalities. The transfer of tasks from central administration to local municipalities is debated in many countries (Moses, 2005). The states try various alternatives, change number of tiers of government, the area of districts and assigned authorities. Smaller compact jurisdiction can provide better public goods for their population, but the fragmentation can also cause economic issues. (Oates, 1999; Tullock, 1969). The difficulties can spring i.e. from inadequate fiscal base or inexperienced clerks and managers, who cannot specialize in one agenda. Larger offices can exploit economies of scale.

3. Methodology

Data Envelopment Analysis (DEA) is a popular non-parametric method used for measuring efficiency. The foundations were laid by Farrell (1957), later improved by Charnes (1978) and Banker (1984). This technique is widely applied in cases when Decision Making Units (DMU) create multiple outputs using multiple inputs. The method does not request input/output prices. DEA is suitable for cases where defining weights of inputs/outputs and specification of the production function are problematical. Above mentioned properties explain the popularity in the studies of public sector (Seiford, Thrall, 1990).

3.1. Graphical formulation of Data Envelopment Analysis

The method can be easily understood graphically. In next section we will follow description similarly performed by Loikkanen and Susiluoto (2005) or Thanassoulis and Concceção (2018) and others. We focus on basic case, which can be solved in two-dimensional space. (Image 3.1)

Decision Making Unit can be production firm, which buys inputs and sell outputs. Data Envelopment Analysis is suitable also for non-profit organizations (our case), because we are not forced to specify the prices of inputs and outputs or relationships among them (e.g. which output is more important).

It is complicated to estimate all real inputs of municipality. We will use total expenses of municipality spent for local administration (similar solution of input, e.g. Loikkanen and Susiluoto 2005; Šťastná, Gregor, 2015).

The outputs of municipalities are performed services (e.g. issued cards, the administration of registers). Our model includes several outputs, which creates problem in multidimensional space. In this section we imagine, that the municipality produces just one output.

In our Image 3.1, there are four Decision Making Units (DMUs) (municipalities A, B, C, D) Our four DMUs thus use only one input X to produce one output Y. The relationships between used amount of input and production of output are described by points A, B, C, D. We can simulate either constant (CRS) or variable (VRS) returns to scale.

If we assume CRS, the efficient DMU is only B. This can be graphically described as the greatest tangent of the angle from the point O. Therefore, the efficiency frontier is the line crossing O and B. Other DMUs (A,C,D) are inefficient. Inefficient municipalities should approach the efficiency frontier. For example unit D have two options how to increase efficiency. The efficiency frontier can be reached by the maximisation of output (point I), with the same amount of input or vice versa by the minimisation of input (and preserving the output – point F).

The efficiency score, if we focus on input minimization, is found out as ratio of distances: $(F – Y_D)/(D- Y_D)$, The possible output maximization is defined as $(I-X_D)/(D- X_D)$. Under CRS, the value of the input-oriented efficiency coefficient is inverse value of the output-oriented one.

The VRS efficiency frontier creates real “envelope” above judged units. It goes through the units A, B, C, in our case. The only inefficient DMU is unit D, with the inefficiency measured as $(E-Y_D)/(D-Y_D)$ in case of input minimisation or $(H-X_D)/(D- X_D)$. The issues which can be caused by the type of returns (CRS or VRS) were already mentioned in literature review (Geys, Moesen; 2009a).

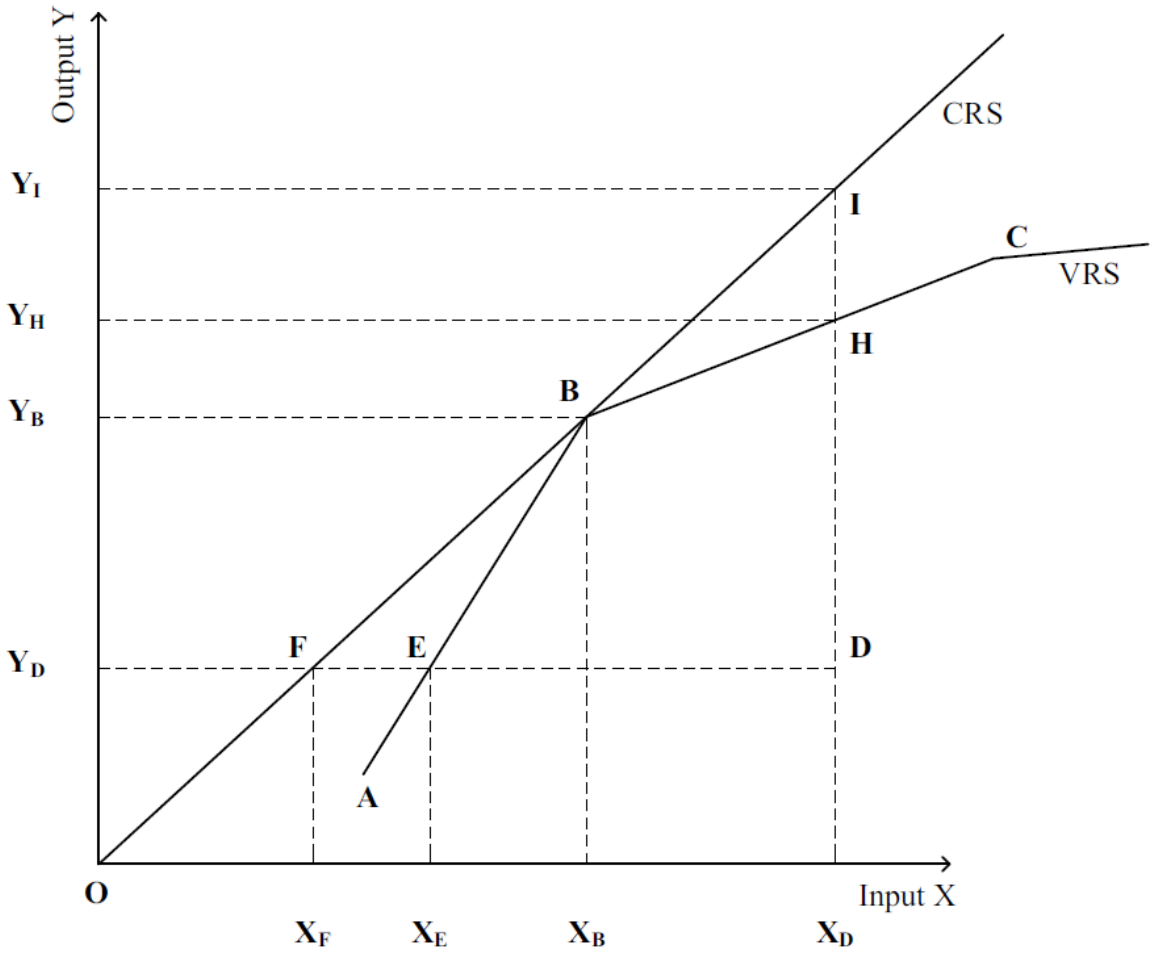

Image 3.1. Based on Loikkanen and Susiluoto (2005). If we assume constant returns to scale (CRS), only municipality B has the best ration between input and output. For example municipality D should produce (from amount of input X_D) output Y_I to be identically efficient. Second approach for municipality D is to produce same output (Y_D) and minimize the input (X_F).

The assumption of variable returns to scale (VRS) slightly changes the situation. The efficiency frontier gradually connects municipalities A, B and C. These three are now efficient and only the municipality D has smaller efficiency score than 1. It is possible to produce Y_H for output maximization (with same intput X_D) or decline input to X_E (and keep output Y_D).

3.2 Mathematical representation of Data Envelopment Analysis

We could see relatively straightforward explanation of basic Data Envelopment Analysis case in previous section (3.2.). The mathematical representation is relatively complicated and plenty of empirical papers disregard this part (e.g. Loikkanen and Susiluoto 2005). The DEA is a linear programming method. We will mainly follow Santos et al. (2013) and Charnes et al. (1978) during the introduction to mathematical defining of the DEA.

We have the group of n DMUs, x_{ik} denotes ith input of the kth unit, y_{rk} stands for rth output of the kth unit. The efficiency (E_a) of a particular DMU_a is described as the ratio of a weighted sum of its s outputs and a weighted sum of its m inputs:

$$E_a = \frac{\sum_{r=1}^{s} w_{ra} y_{ra}}{\sum_{i=1}^{m} v_{ia} x_{ia}}$$

The weights (also called virtual multipliers) w_{rk} and v_{ik} are chosen with respect to maximize efficiency of unit.

The restrictions of the maximization problem are following:

1. Strict positivity of virtual multipliers w_{rk} and v_{ik}

2. All efficiency scores cannot overcome certain value, the procedures usually use one or 100%.

3. This linear fractional program would have an infinite number of solutions, for example multiples of solving w_{rk} and v_{ik}, i.e. kw_{rk} and kv_{ik} would solve the problem. Setting the denominator to one or 100 % avoids this situation.

The linear programming maximisation problem for every single unit is:

$$\max E_a = \frac{\sum_{r=1}^{s} w_{ra} y_{ra}}{\sum_{i=1}^{m} v_{ia} x_{ia}} \tag{3.1}$$

$$st. \quad w_{ra} \geq \varepsilon > 0 \qquad r = 1 \dots s \tag{3.2}$$

$$v_{la} \geq \varepsilon > 0 \qquad l = 1 \dots m \tag{3.3}$$

$$E_a = \frac{\sum_{r=1}^{s} w_{ra} y_{ra}}{\sum_{i=1}^{m} v_{ia} x_{ia}} \leq 1 \qquad k = 1 \dots n \tag{3.4}$$

$$\sum_{i=1}^{m} v_{ia} x_{ia} = 1 \tag{3.5}$$

We can use the Charnes and Cooper transformation for solution of the fractional linear program (Charnes, Cooper, 1962), which provides the linear program:

$$\max E_a = \sum_{r=1}^{s} w_{ra} y_{ra} \tag{3.6}$$

$$st. \quad \sum_{i=1}^{m} v_{ia} x_{ia} = 1 \tag{3.7}$$

$$\sum_{i=1}^{m} v_{ia} x_{ik} - \sum_{r=1}^{s} w_{ra} y_{rk} = 1 \quad k = 1 \dots \tag{3.8}$$

$$w_{ra} \geq \varepsilon > 0 \quad r = 1 \dots s \tag{3.9}$$

$$v_{ia} \geq \varepsilon > 0 \quad i = 1 \dots m \tag{3.10}$$

The weights are unknown and restricted by a small number ε, typically 10^{-6}. This satisfied that all inputs and outputs are respected in the evaluation. We evaluate each unit with a portfolio of weights, which maximises unit´s efficiency, on the condition that all other units, rated with same portfolio of weights, have efficiency not greater than unity.

We try to find the composite unit, which has same or bigger output and uses fewer inputs. The composite units are finite linear combinations of efficient units which are placed on the efficiency frontier, which creates the envelope.

The resolution of the problem is the expansion of our example in Image 3.1, where the production frontier is the line. The production possibilities set is closed convex polyhedral cone in R^{s+m} in the positive orthant (when we reflect the simplest case of constant return to scale).

The shape of the frontier can be further discussed (Geys, Moesen, 2009a). Another popular technique, which left the assumption of the convexity, is the Free Disposal Hull (see Image 3.2).

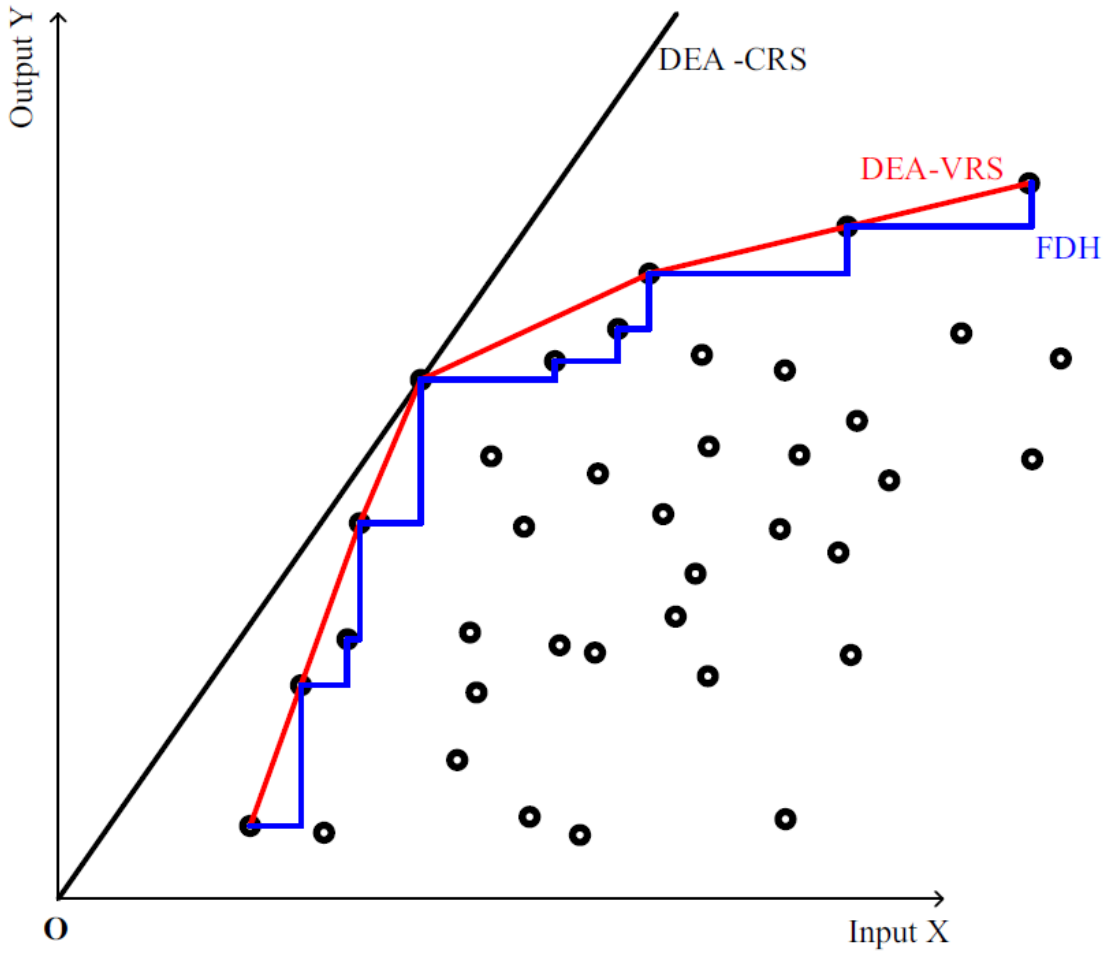

Image 3.2 Based on Geys, Moesen (2009a). The results of Data Envelopment Analysis are influenced by the assumptions about returns to scale or convexity of the efficiency frontier. We have already described the differences between constant and variable returns to scale (see Image 3.1). Free disposal hull leaves the assumption of convexity of the efficiency frontier. We can presume also other types of returns to scale (e.g. increasing, not shown in the image). Chosen condition influences the number of efficient units on the efficiency frontier (CRS<VRS<FDH), but the relative performances of decision making units are still positively correlated. The efficiency scores acquired through DEA are then described typically by OLS or Tobit models. We will perform both CRS and VRS Data Envelopment Analysis and inquire into differences (see Chapter 6.1).

4. The role of municipalities of extended competence

This paper uses several data sources describing the performance of Czech municipalities of extended competence (see Chapter 5). These jurisdictions appear to be relative good environment (Šťastná, Gregor, 2015) for examination of public sector efficiency, especially due to homogeneity, quantity and broad portfolio of services. The services are predominantly specified by the central government (Ministry of the Interior, 2021b). The representatives and managers can make decisions about investment, staff and equipment relatively independently, though. (Durasová, 2016)

On the other side, the financing of the municipalities is complicated and comes from different sources (Regulation 358/2020Sb., Matej, 2017). The legal acts, whose counts are used as outputs in our analysis, are paid indirectly. Some services can have positive financial impact for the municipality, some are unprofitable (Ministry of the Interior, 2021b; Ministry of the Interior, 2018). Moreover, the municipality executes two different roles (self-government and state administration), which financing is mismatched. It creates tension between municipalities and central government (SMO, 2009). Our data were obtained because of the ongoing discussion (Ministry of the Interior, 2018) about the financing of local municipalities. This section summarizes interesting facts about financing and functioning of the municipalities of extended competence and helps to comprehend next chapters.

4. 1 State administration in the Czech Republic

After the establishment of the independent Czech Republic in 1993, the system of the three tiers of government was composed: central government, 76 district authorities and 6259 municipalities. The number of municipalities can vary every year due to separation or joining mainly on the level of the smallest villages. Afterwards, the territorial reform was performed in two steps. First, 14 regions were founded (European NUTS 3). Second, district authorities were dissolved; their responsibilities (and part of the employees) were passed to 205 municipalities of extended competence. (Štastná, Gregor, 2015; Durasová, 2016)

The municipality of extended competence is assigned with a portfolio of various services specified by plenty of parliament laws. Fundamental tasks are administration of civil registers, issuance of ID cards, driving licenses, decisions in building proceedings, register of vehicles, but also preparation for unexpected disasters in the area (Ministry of the Interior, 2018). These activities are provided for inhabitants of district, which composes from the municipality itself and tens of other municipalities in the area. The municipalities with extended competence regularly claim they have insufficient funds for these services (SMO, 2009; Čermáková, 2011). This is the reason, why the counts of performed acts started to be published annually (Ministry of the Interior, 2021c) and we use them as the outputs in our Data Envelopment Analysis.

4.2. Self-government, state administration, delegated jurisdiction

The situation on the input side of our efficiency analysis is much more complicated. In the modern concept of administration, it is necessary to separate self-government, state administration and delegated jurisdiction, especially in the case of our sample (Bird, 2000; Ministry of the Interior, 2004). The office of the municipality of extended competence performs self-government and delegated state administration simultaneously.

Self-government signifies decision-making about problems in the area by its members. On the local scale of the municipality, inhabitants (via elected representatives and with numerous limitations) can influence i.e. public spaces or provided (cultural, educational, social or sport) services. The state administration is the system of activities realized by the state, either directly by special state authorities or through the agency of other organizations (delegated jurisdiction).

Our outputs represent the state administration. The issue is to describe which expenses were utilized for services connected with the state administration (and should be used as inputs) and which were used to self-government. This is nearly impossible, e.g. because same staff (accounting department) guarantee the operation of both.

The wages of clerks are considered as the most important expense of the offices; average share of the staff occupied with state administration is 64 %. (estimate, Čermáková, 2011). The costs of state administration were also investigated by voluntary survey on the sample of 65 municipalities (144 approached) (Ministry of Interior, 2019). The overhead costs (power supplies, equipment) are roughly 32 % of labour expenses. If working hours of managers, secretaries, IT and accounting departments were fairly included, the costs would rise by 16 %.In our case, we filtered the parts of the municipalities' budgets which are mainly spent for the state administration knowing the complexity of the situation and used them as the input of our Data Envelopment Analysis.

4.3 Financing of local municipalities

The financing of Czech local municipalities elicits controversies among diversely populated districts. The income is composed mainly from tax revenues and local charges (67.5%, 2016), a considerably smaller amount is acquired as transfers from other public budgets, profits of own activities and companies or revenues of privatisation. (Regulation 358/2020Sb.)

The real estate tax obtained in the territory is exclusive revenue of the municipality (small part of the budget), other taxes raised in the Czech Republic (value added tax, corporate and personal income tax) are distributed on the basis of a complex formula, which is regularly modified. Till 2021, budgetary allocation determines 25.84% of tax revenues to municipalities. (This share is gradually increasing from 20.59% 2007, 21.40% 2008-2012, 23.58% 2013-2020. Matej, 2019)

The total amount is subsequently divided among 6 259 municipalities. The fundamental element in the calculation is the population of the municipality. Nevertheless, this figure is modified by coefficient. Thus, the revenues of larger municipalities are increased. This adjustment should solve increased costs of services which are used by citizens from other smaller municipalities; a typical illustration is the augmented traffic encumbrance in larger cities.(Matej, 2017)

Till 2007, the exceeding of the sharp frontier in the number of inhabitants caused considerable increasing of revenues. That resulted in abusive practices such as acquisition of new inhabitants in municipalities situated tightly below one of the specific frontier (ČTK, 2005). Nowadays the coefficient is growing more gradually. In addition, the calculation takes into consideration the surface area and the number of students in school established by the particular municipality. The main part of municipality's revenues is thus not dependent on the provided services for citizen, but on the assumption that bigger municipality provides more services.

Local charges are also important part of the budget. The municipality can keep charges collected during performing the services of state administration (our outputs in efficiency analysis). To give an example, the regular replacement of an identity card is free. Specific cases (as the necessity of overnight preparation, voluntary card for child facilitating travelling into other European countries) are imposed with various charges from 100 to 1 000 Czech crowns. (Ministry of the Interior, 2021d) The execution of the state administration is also partly compensated by specific grant. (Ministry of the Interior, 2021b)

5. Data

Our research combines two relatively independent datasets about the operation of Czech local municipalities with extended competence. Firstly, we used a dataset published annually during the preparation of the State budget Act which provides information about the number of legal operations arranged by a particular municipality, the count of inhabitants in the municipality and in the district. Secondly, we downloaded a dataset from Monitor, an application of the Ministry of Finance of the Czech Republic, where we can find detailed structured budgets of particular municipalities.

5.1. Information about performed acts, population

Population of the municipality can partly influence the state of the office in communal elections. *pop18, pop19*

Population of the district includes also inhabitants of surrounding municipalities using the services of the municipality of extended competence. *pop_dist18, pop_dist19*

Processed births Records about newly born children are predominantly processed in municipalities where maternity hospitals are located. Registration in the place of the child's residence is exceptional. *birth18, birth19*

Marriages The municipalities have predominantly prepared one ceremonial room. Wedding ceremony is possible anywhere by prior arrangement, which is linked with special fees to municipal budget. The number of marriages can increase popular location (event-place) in the territory of the municipality. *marr18, marr19*

Deaths are registered in the place of residence. *death18, death19*

Determination of paternity is an operation necessary to perform more frequently in case when parents are not married. The proportion of child born to unmarried couple has increase till 1980's (roughly one half of toddlers). *pater18, pater19*

Published identity cards Inhabitants can choose the preferred municipality for the application till 2016. The Ministry of Interior perceives inequality among municipalities. Citizens use the office in their real residence (which can differ from permanent address), close to the place of work or take advantage of places, where waiting time is shorter. *id18, id19*

Published driving licenses The municipalities can determine whether the issuing is joined with publishing of other cards (e.g. above mentioned Identity cards). Some smaller offices prefer the preservation of the issuing in the department of transportation. Uneven use of the offices can be seen in the image 5.3. *dl18, dl19*

Guardianship is care of inhabitants who are divested of legal capacity and have no co-operative relatives. Thereafter, e.g. representation before the court is ensured by the municipality. It is one of the most demanding activities of the municipalities. *guard*18, *guard19*

Acts of spatial planning Building procedure and urban planning faces the issue of difference of every single case. We use data about acts of special planning, which predominantly precede procedure of building permission, the office controls just several basic facts and the acts are mutually (at least) comparable. *plann18, plann19*

5.2 Information from budgets of particular municipality

The budgets of all tiers of Czech state government are regularly published on the website monitor.statnipokladna.cz (formerly ARISweb). Unfortunately, the supply of data is not compulsory and some municipalities do not use this database (and publish simplified records individually). We had to discard these jurisdictions.

Czech public organisations have to maintain the required budget structure. Each operation should be distinguished by two classifications. The section denotes sectoral classification (Why sources were spent.); the items describe a way of utilisation (How sources were spent.). Their names are binding (cannot be modified or changed). We state the codes of used section and items, based on the regulation of the budget structure.

We used section **6171 – Activities of local administration** (sum of individual items). This distinction should filter other operations directed for example to the management of own property as school and cultural facilities. (see Chapter 4). *cost18, cost19*

The research concentrated on several special items:

5011 Wages of employees The managers of office have relative freedom in the number of employees, salaries are specified by law, increase gradually with years of experience, plus individual bonuses. We use wages as proxy of number of clerks (data not accessible), assuming similar price level, metropolitan region and main big cities are excluded due to other reasons (see below), per capita terms (compared to district population). *wages18pc, wages19pc*

5162 Electronic communications services This item includes payments for Internet access, telephone and data services, (minority) related products as purchase of new SIM cards. *elservis*

5168 Data processing and services related to information and communication technologies Training of employees related to IT is subject of this item (special exception, all other training courses are recorded in item 5167). There are also classified external adjustment and correction of informational systems. *ITservis*

5172 Software (short-term) Expenditures on the purchase of computer programs (software) or databases. In case they are acquired as intangible assets. Costs up to 60,000 CZK or usability does not exceed one year. This item also concludes technical improvement (upgrade) of computer programs till the amount 60,000 CZK in an individual case. *softshort*

6111 Software (long-term) is the part of capital expenditures/investment purchases. Computer programs, which do not fulfil conditions of item 5172. That implies expenditures exceeding 60,000 CZK and usability for more than a year. *softlong*

6125 Hardware These are computers, computer networks, devices and networks intended to detect unauthorized intrusion of persons into protected areas, devices for determining geographical position (navigation), telephones, digital cameras (except for these used for artistic purposes), scanners and things used for their functioning (computer printers, speakers and headphones connected to computers, compact discs, audio cassettes, video cassettes, etc.). *hardware*

5.3 Pre-processing and cleaning

The data included information about 205 municipalities of extended competence. The area of the capital city was not included. Prague is not a municipality of extended competence, even though twenty two city districts function similarly. We also eliminated six municipalities with special position and grants. These are 3 biggest cities and additional 3 cities located in suburban areas, which provide services for non-standard districts. They have second detached department in the main city (e.g. the relatively small office of the town Černošice is partly detached in Prague because of accessibility for citizens of the district). Some cities ignore publishing dataset about budgets in a uniform system (mostly larger jurisdictions). Total sample narrowed down to 158 municipalities.

Costs related with informational technologies fluctuate dynamically. We entered the conversation with secretaries of selected municipalities, who described circumstantial realization of key projects. The implementation takes several years (Which is in accordance with literature describing the necessity of funding not only the purchase of new technology, but also adaptation of existing systems, Willcocks, Lester, 1996). Precise invoicing (discussed with analysts as Mejstřík or Tesárková) can be hardly assumed, the mistakes among items can occur. These are the reasons, why we use the total amount invested into informational technologies in five years preceding examined year (included) in per capita of district terms. This variable should demonstrate the long-term setting of the office, whether the managers put emphasis on new technologies.

We use the majority of the variables from the first source as outputs in our DEA analysis, combined with information about costs as input. The summary of the variables is presented in the Table 5.1. For second stage (OLS and Tobit) variables describing IT investment were summed for five following years and divided by number of inhabitants in the district (per capita). Wages were also related to population. The data for the second step is presented in the summary (Table 5.2., after pre-processing Table 5.3). We use log transformation of these in the models, the log transformation of the IT investment can be seen in two histograms (Image 5.1, Image 5.2).

2018					
	mean	std.dev.	std.err	min	max
pop	13331.97	7903.10	628.74	2784	37444
pop_dist	32837.11	18652.59	1483.92	8649	91735
birth	260.00	429.03	34.13	0	1798
marr	96.53	49.70	3.95	24	267
death	260.56	240.64	19.14	12	990
pater	112.86	81.66	6.50	0	413
id	3682.79	1989.37	158.27	1003	10390
guard	19.18	22.09	1.76	0	114
plann	323.37	223.22	17.76	0	1289
dl	1293.79	656.77	52.25	427	3343
cost (CZK)	77315894.29	36611838.00	2912681.00	28839892	182139057

2019					
	mean	std.dev.	std.err	min	max
pop	13314.25	7880.41	626.93	2784	37525
pop_dist	32893.22	18715.95	1488.96	8676	91899
birth	257.27	429.52	34.17	0	1770
marr	95.00	46.84	3.73	18	239
death	256.58	235.12	19.14	16	955
pater	110.94	77.55	6.17	394	394
id	3050.13	1691.71	134.59	732	10005
guard	20.49	22.99	1.83	0	119
plann	315.19	226.01	17.98	24	1292
dl	1152.97	636.41	50.63	292	3340
cost (CZK)	80412017.00	37939280.00	3018287.00	30543974	188350047

Table 5.1 Summary of population (municipality and district), performed acts and total costs of local administration for year 2018 and 2019. Author's calculations.

		2014	2015	2016	2017	2018	2019
wages	mean	31092716.94	32377692.70	33768289.57	35844589.20	40074603.05	43088829.38
	st.dev.	14911579.28	15516819.74	16173329.24	16888315.08	18926597.05	20382740.12
	st.err.	1186301.55	1234451.90	1286680.99	1343562.21	1505719.21	1621563.74
	min	11505911.00	12385464.65	13127868.00	13712675.00	15456163.20	16788394.00
	max	79926714.00	82647314.00	86806038.00	89555211.00	100328362.00	108926208.00
elservis	mean	445821.73	417486.89	409354.78	399944.73	402859.39	425406.65
	st.dev.	251553.63	233510.01	257648.51	246503.27	230886.22	269923.53
	st.err.	20012.53	18577.06	20497.41	19610.75	18368.32	21473.96
	min	98875.00	101785.00	86376.20	77505.52	100112.07	95263.17
	max	1646849.98	1645069.38	1647475.42	1672256.20	1645413.17	1681774.04
ITservis	mean	934190.56	1222177.53	1401940.38	1478637.76	1645164.90	1948865.79
	st.dev.	858838.37	926485.94	998909.77	993672.28	1091023.63	1303147.82
	st.err.	68325.51	73707.26	79468.99	79052.32	86797.18	103672.87
	min	0.00	0.00	0.00	0.00	0.00	47684.29
	max	5083834.82	5432070.10	6935649.58	6176903.26	6386925.88	8719421.61
softshort	mean	163224.62	227118.62	201858.10	157809.38	167170.82	200537.32
	st.dev.	209639.92	314327.76	265402.59	190951.41	241121.07	318078.07
	st.err.	16678.06	25006.57	21114.30	15191.28	19182.56	25304.93
	min	0.00	0.00	0.00	0.00	0.00	0.00
	max	1402431.10	2128441.69	1948610.00	1071973.23	1653863.46	2645045.60
softlong	mean	217315.02	1166543.67	237182.18	269249.52	1337014.57	953226.10
	st.dev.	442445.94	1290610.72	382565.89	517362.16	2074687.77	2137473.64
	st.err.	35199.11	102675.48	30435.31	41159.12	165053.30	170048.27
	min	0.00	0.00	0.00	0.00	0.00	0.00
	max	2731199.92	5720532.75	2083693.90	4119409.00	10454881.74	12795750.00
hardware	mean	214977.71	978692.29	247676.04	295852.76	1143434.90	574251.93
	st.dev.	575689.49	1357653.58	623862.31	608644.00	2068533.54	1331845.73
	st.err.	45799.40	108009.12	49631.82	48421.12	164563.69	105955.96
	min	0.00	0.00	0.00	0.00	0.00	0.00
	max	3412306.80	5872665.00	6462748.88	4000447.11	20314954.30	9765151.04

Table 5.2. Summary of variables describing wages of staff and IT investment for years 2014 -2019. CZK. Author's calculations.

SUM 2015-2019 divided by population of the district (2019)						
Total IT pc	mean	611.02		softshort pc	mean	32.01
	st.dev.	283.19			st.dev.	27.76
	st.err.	22.53			st.err.	2.21
	min	179.78			min	1.23
	max	2086.43			max	194.09
elservis pc	mean	70.39		softlong pc	mean	144.89
	st.dev.	34.33			st.dev.	161.46
	st.err.	2.73			st.err.	12.84
	min	18.33			min	0.00
	max	224.03			max	1063.77
ITservis pc	mean	255.51		hardware pc	mean	108.27
	st.dev.	128.37			st.dev.	92.99
	st.err.	10.21			st.err.	7.40
	min	3.13			min	0.00
	max	829.92			max	584.85
2019 values divided by population of the district (2019)						
wages pc	mean	1398.48				
	st.dev.	320.41				
	st.err.	25.49				
	min	849.72				
	max	2328.71				

Table 5.3. Summary of per capita variables, IT components were computed as sum from years 2015-2019, wages of clerks are just per capita term (year 2019), CZK. Author's calculations.

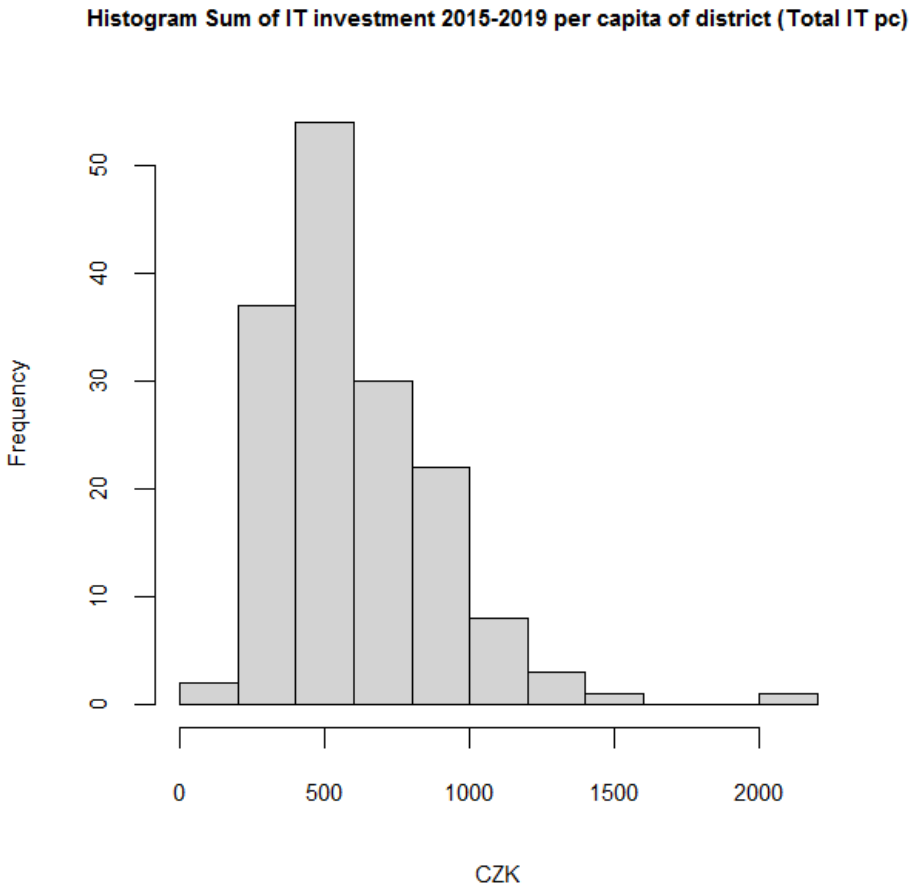

Image 5.1 Histogram of Total IT pc. Author's calculations.

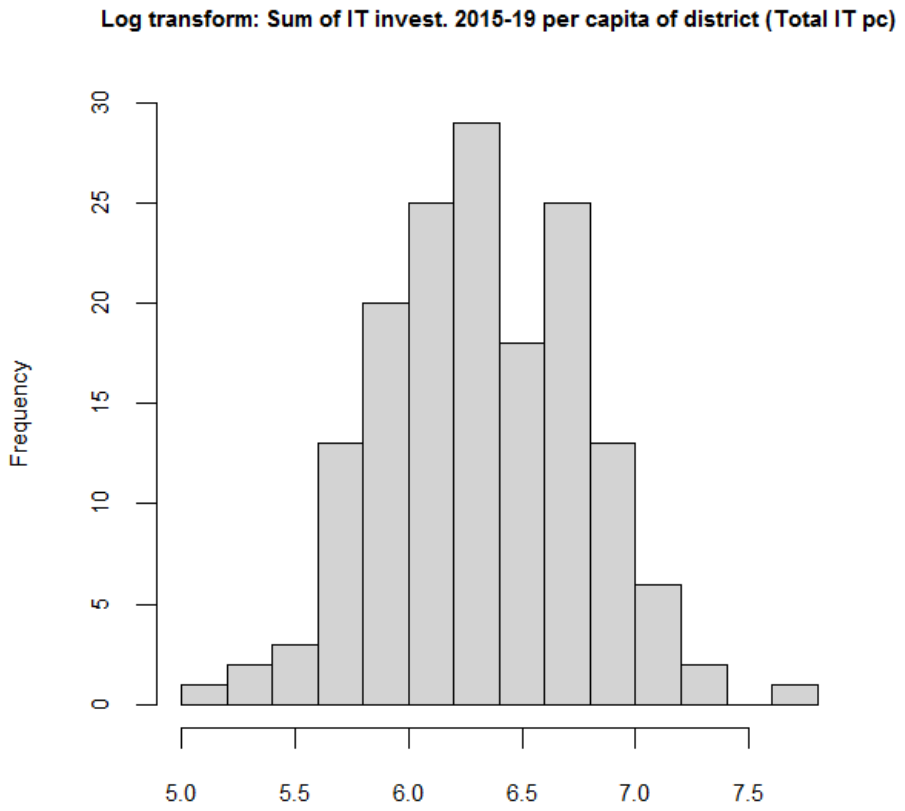

Image 5.2 Log transformation of Total IT pc. Author's calculations.

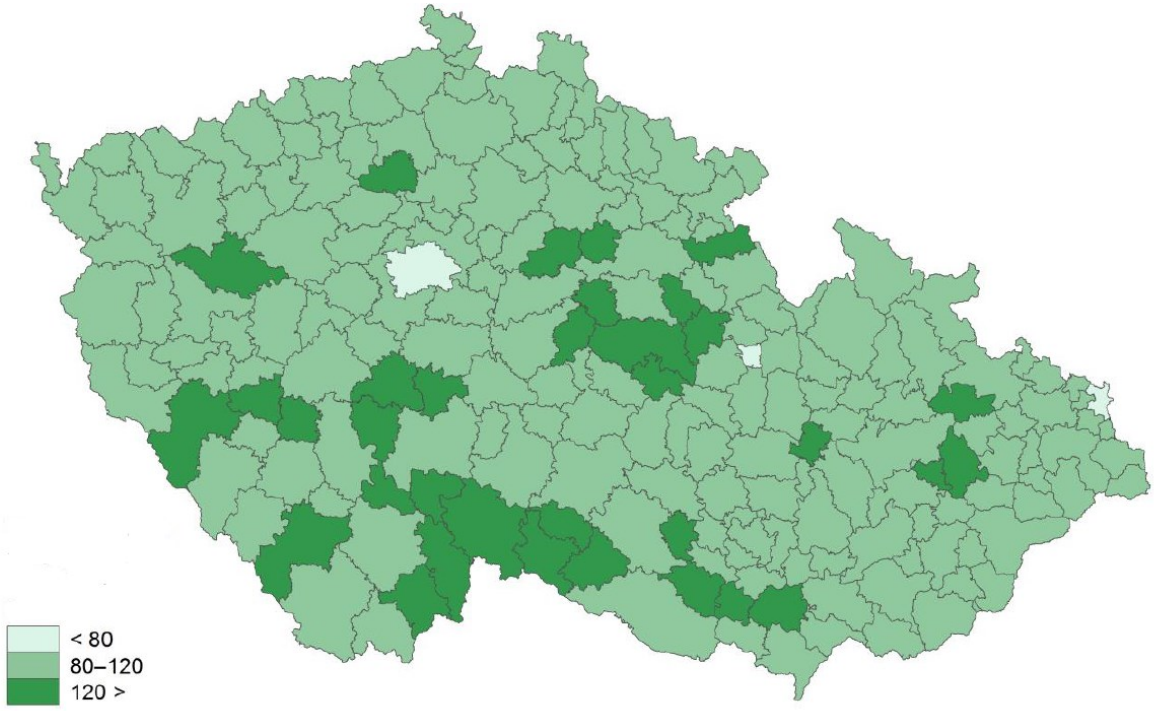

Image 5.3. The Ministry of the Interior is aware that some municipalites arrange more operation than others. There is still extending portfolio of services which the citizen can solve in every office (especially isssuing on new identity cards or driving licenses). This is very helpful for our reasearch because the effectivity of the office is partly determined by the interest of the client (similarity with the production firm). In the picture: The share of issued driving licenses in first half of year 2018. The difference compared to countrywide mean (%). Unfortunately, the way of the computation is unclear (absolute numbers, per capita terms?; Ministry of the Interior, 2019)

6. Model, applying the methodology, results

Our empirical analysis has two stages. Firstly, we use Data Envelopment Analysis and assign the efficiency score to each municipality. We calculated the efficiency for year 2019 and simultaneously for year 2018 to verify the stability of our model. We also focus on different approaches to returns to scale and describe the necessity to be careful about assumptions (Geys, Moesen, 2009a).

The efficiency score is then used as dependent variable in several models (OLS, Tobit), where we try to find the impact of IT investment. Auxiliary variables (with great importance though) are the size of the municipality district or funds spent on wages. We were also looking for the regional effects.

6.1 First stage: The efficiency scores (Data Envelopment Analysis)

6.1.1. Inputs and outputs of the model

We used **all annual expenses in section 6171 – Activities of local administration** (*costs19, costs18*) as **an input variable**.

$$inputs = cost$$

The **outputs** are represented by a vector of variables **comprising activities of several fundamental departments** of each office. The departments are established by the city council and differ to some extent in every jurisdiction. Thus we try to select the outputs to notice a maximum of the spectrum of services.

Vector of outputs:

$$outputs = birth + marr + death + pater + id + guard + plan + dl$$

Information about processed birth, marriages, deaths and paternity follow the activity of the registration department. Publishing of identity cards is frequently solved in separated department; similarly exact title of the division looking after guardianship differs. Spatial planning is the activity of the building department. Driving licenses can be issued in transport department, or jointly with other personal cards.

6.1.2 The results of the DEA

We perform the input oriented Data Envelopment Analysis on the data from years 2019 and 2018. In each year we also focus on the condition of returns to scale and research the alternation among constant and variable returns to scale.

The efficiency scores from two subsequent years do not have the ambition to examine the changes of the efficiency. The environment of the state administration develops slowly and the greater interval is needed to recognise the changes (used e.g. in Šťastná, Gregor, 2015). We rather supposed similar results, which would confirm the stability of our model. The correlation between models (2018 x 2019) with constant returns to scale is 0.7711, for variable returns to scale even 0.8176. (see Table 6.1)

The issue of the returns to scale was presented in Chapter 2 and 3 respectively. We can consider there is some variability in returns to scale, but we have no detailed information. (The discussion is relatively demanding. The ambiguousness of this problem is the main reason, why many countries from time to time look for a new administrative division, Moses, 2005; Oates, 1999; Tullock, 1969). The VRS DEA has (from the definition) the issue, that relatively large percentage of the municipalities

is completely efficient, just because the method wraps up the set of the units by convex efficiency frontier into the "envelope". Some municipalities especially on the tails can be inefficient in reality, but the method tries to make smooth efficiency frontier and assign them with a full efficiency score.

The basic assumption of constant returns can be better option in some cases. We wanted to avoid premature conclusion and chose to follow e.g. Geys and Moesen (2009a) and perform analysis of both models. In next part we deal primarily with models from year 2019, the data from previous year gave similar results and are used just as verification.

6.1.3 Comparison of DEA model, year 2019, CRS x VRS

Our sample is composed from 158 jurisdictions. The CRS model determined 22 efficient municipalities, mean efficiency score is 0.759, with median value 0.7787. The least efficient municipality is evaluated with the score 0.3522. If we consider variable returns to scale, the number of efficient municipalities is considerably higher, which was expected. 37 municipalities have maximal efficiency score. Similarly other monitored values have risen: mean 0.819, median 0.8405 or minimum 0.4210. We also inquired the representation in ranges divided by tenths of efficiency score, which is partly similar and varies mainly in range immediately under the absolute efficiency i.e. <0.9,1). (see Tables 6.2, 6.3)

Moreover, the correlation of efficiency scores for CRS x VRS was relatively high: 0.8517 for year 2019, computed also for year 2018, when reached 0.9083. (see Table 6.1)We were interested in the mean size of the most efficient district, which is 32 362 inhabitants for CRS and relatively higher (46 740) for VRS. (Taking into account the mean value for the whole sample 32 893). It can indicate increasing returns to scale or just error caused by raised number of efficient municipalities (as described in 6.1.2)

The relative similarity of our models was inquired also graphically. We plot the municipalities in order of cost efficiency (2019, where can be seen higher count of effective municipalities in VRS model (Image 6.1, Image 6.2)**.** The correlation of efficiency scores between subsequent years is captured in Image 6.3. From the definition, VRS scores are always same or higher than CRS for same data, this can be seen in Image 6.4. In next subsection, we will concentrate and discuss mainly the scores acquired by model considering constant returns to scale, the OLS and Tobit models in next subsection were computed also for VRS efficiency scores, with relatively similar results.

Correlation of efficiency scores among different approaches and years				
	2019 CRS	2019 VRS	2018 CRS	2018 VRS
2019 CRS	x	**0.8517**	**0.7711**	*0.7197*
2019 VRS		x	*0.704*	**0.8176**
2018 CRS			x	**0.9083**

Table 6.1 Correlation of efficiency scores among different approaches and years.
Author's calculations

Efficiency **2019**					
CRS constant returns to scale					
Number of efficient municipalities		22	out of		158
Mean efficiency		0.759			
Eff. Range	Number	%		Min	0.3522
<0.3, 0.4)	1	0.63		1st Qu.	0.6428
<0.4, 0.5)	8	5.06		Median	0.7787
<0.5, 0.6)	21	13.29		3rd Qu.	0.8596
<0.6, 0.7)	27	17.09		Max	1.0000
<0.7, 0.8)	34	21.52			
<0.8, 0.9)	36	22.78			
<0.9, 1)	9	5.70			
Eff = 1	22	13.92			

Efficiency **2018**					
CRS constant returns to scale					
Number of efficient municipalities		18	out of		158
Mean efficiency		0.776			
Eff. Range	Number	%		Min	0.3527
<0.3, 0.4)	1	0.63		1st Qu.	0.6474
<0.4, 0.5)	5	3.16		Median	0.7834
<0.5, 0.6)	16	10.13		3rd Qu.	0.9156
<0.6, 0.7)	32	20.25		Max	1.0000
<0.7, 0.8)	29	18.35			
<0.8, 0.9)	31	19.62			
<0.9, 1)	26	16.46			
Eff = 1	18	11.39			

Table 6.2 The results of DEA models with the assumption of constant returns to scale. Author's calculations

Efficiency **2019**					
VRS variable returns to scale					
Number of efficient municipalities			37	out of	158
Mean efficiency			0.819		
Eff. Range	Number	%		Min	0.4210
<0.4, 0.5)	5	3.2		1st Qu.	0.7035
<0.5, 0.6)	13	8.2		Median	0.8405
<0.6, 0.7)	21	13.3		3rd Qu.	0.9621
<0.7, 0.8)	27	17.1		Max	1.0000
<0.8, 0.9)	36	22.8			
<0.9, 1)	19	12.0			
Eff = 1	37	23.4			

Efficiency **2018**					
VRS variable returns to scale					
Number of efficient municipalities			37	out of	158
Mean efficiency			0.819		
Eff. Range	Number	%		Min	0.3563
<0.3, 0.4)	1	0.63		1st Qu.	0.7002
<0.4, 0.5)	3	1.90		Median	0.8362
<0.5, 0.6)	9	5.70		3rd Qu.	0.9741
<0.6, 0.7)	26	16.46		Max	1.0000
<0.7, 0.8)	28	17.72			
<0.8, 0.9)	29	18.35			
<0.9, 1)	25	15.82			
Eff = 1	37	23.42			

Table 6.3 The results of DEA models with the assumption of variable returns to scale. Author's calculations

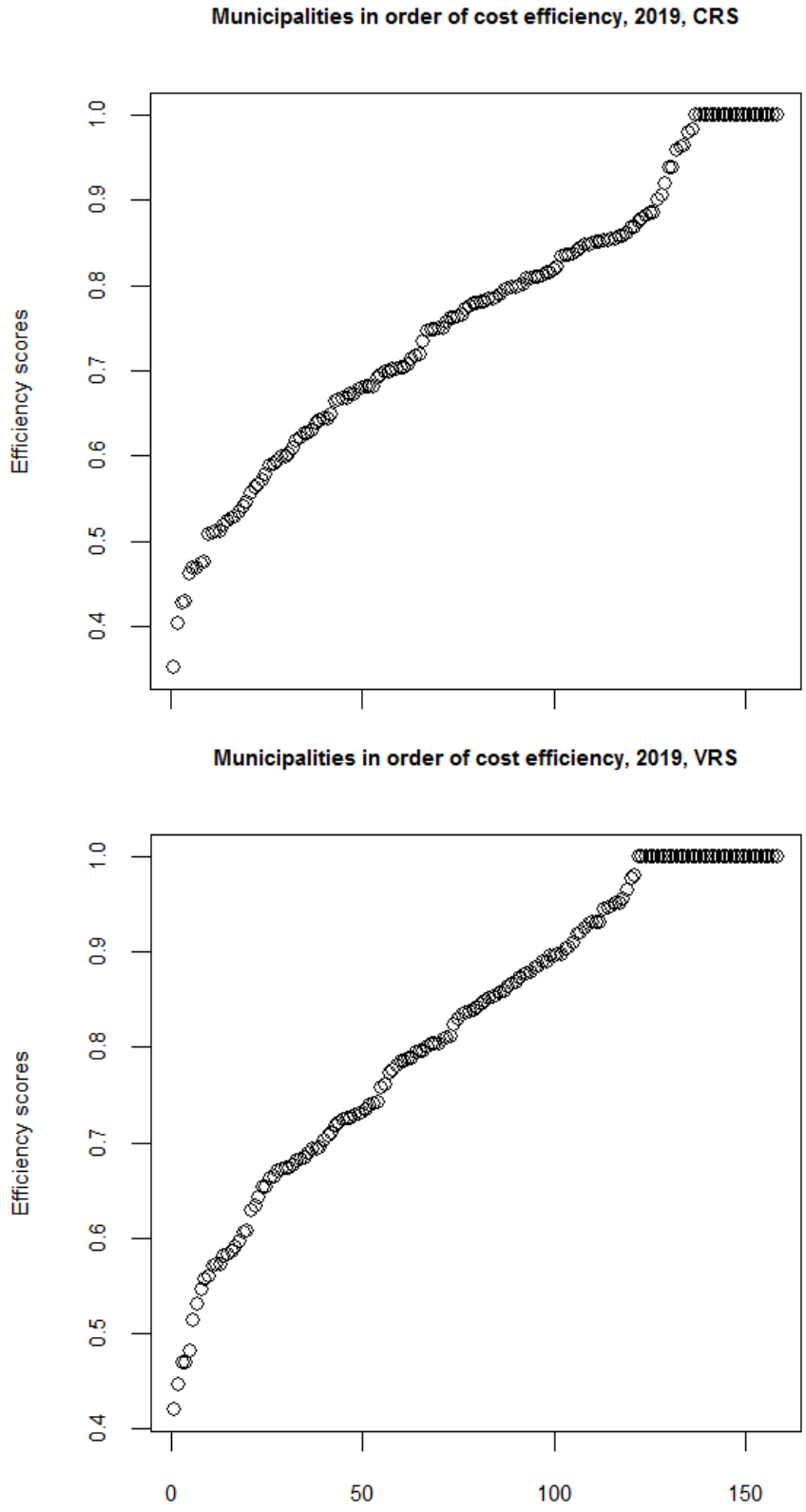

Image 6.1, 6.2 Municipalities in order of cost efficiency, comparison of CRS x VRS. Assumption of variable returns to scale increases the number of efficient municipalities (Efficiency score = 1,0) Author's calculations.

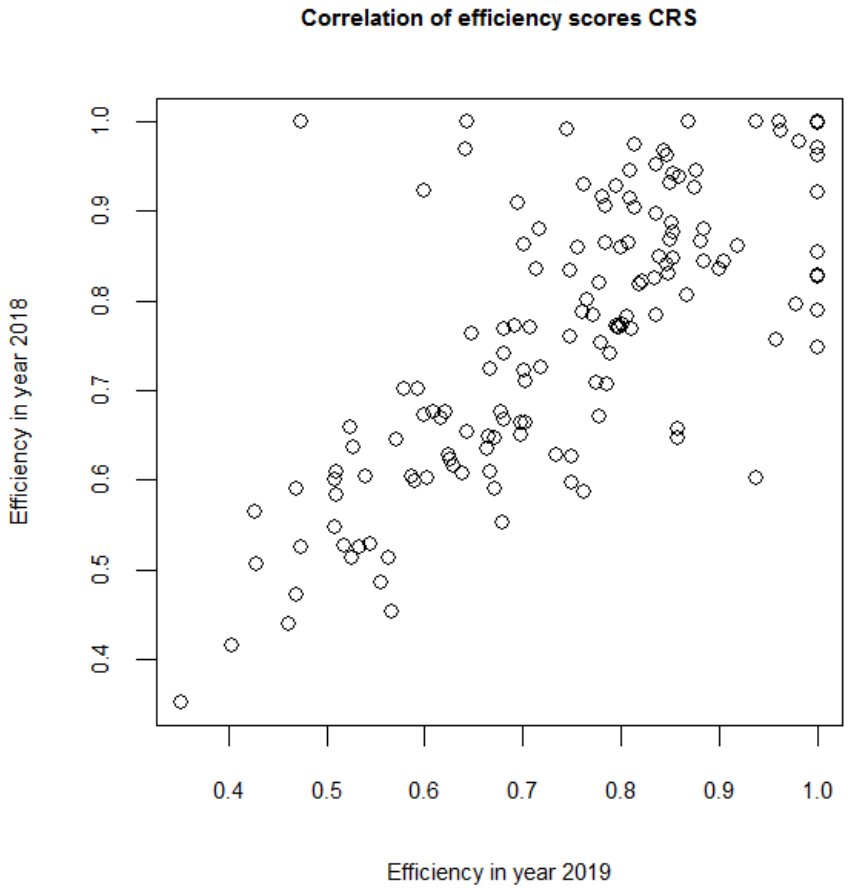

Image 6.3 Correlation of efficiency scores (2019x2018). Author's calculations

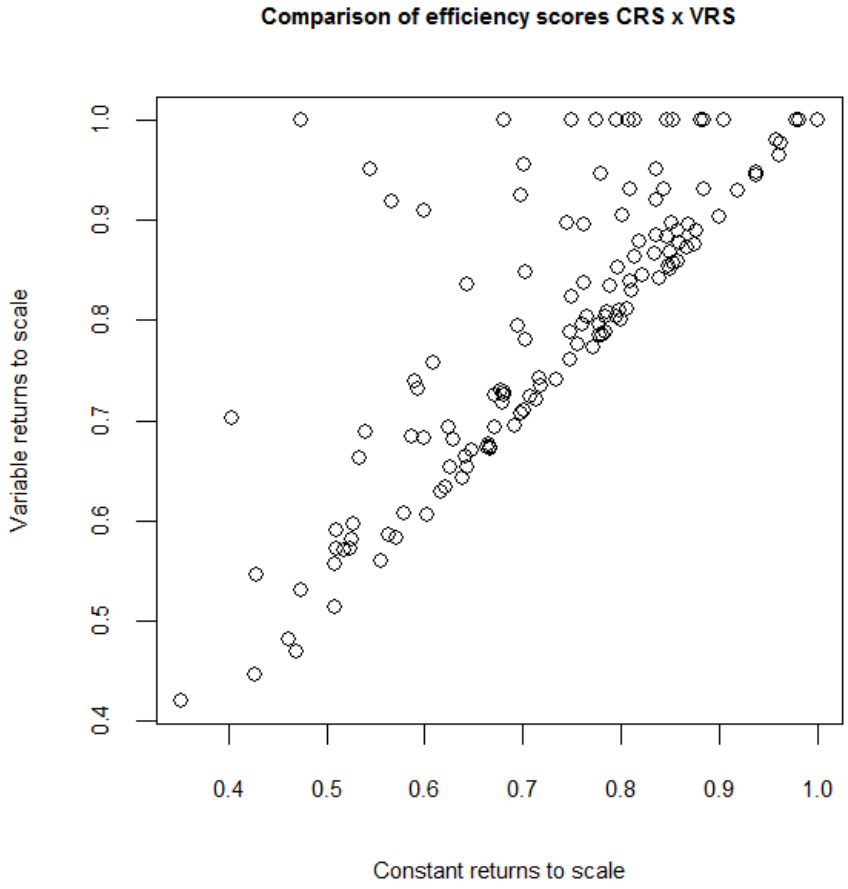

Image 6.4 Comparison of different approaches to returns to scale CRS x VRS. Author's calculations

6.2 Second stage: OLS and Tobit models

We try to find the relationship among efficiency scores and the investment into information technology in our sample of municipalities of extended competence. First, we use aggregated IT investment. Later we look for the effects of different components (hardware, software, and training of staff). The productivity of the office can be influenced by many other factors; we focused on size of the district/municipality, costs of clerks' wages and regional effects.

6.2.1 Total IT investment and the size of the district, wages of clerks

We use log transformation of our independent variables (see example of histogram in part data), to normalize our mainly skewed distributed data. This also helps as in comparison of individual effects. 1% effect in the independent variable is interpreted as (coefficient/100) change of efficiency.

The literature pays attention to the dependence of efficiency on the district size (population). Changes of the administrative division are executed regularly in many countries because of the effort to find the best size of jurisdiction. We attempt to describe the difference of efficiency scores by population of the district *(pop_dist)*.

Our first model has following pattern (**Model 1)**:

$$effscore = \beta_0 + \beta_1 \, log(pop\_dist) + \beta_2 log(ITtotalpc)$$

The results show significant negative effect of IT investment (see Table 6.4). This effect steadily repeats in next models. We can confirm our hypothesis that the IT investment in the Czech Republic is problematical and increased expenses do not project in the efficiency. We also should be careful about the interpretation of the negative influence of IT investment. The reduction of the investment would not automatically lead in the improvement of the efficiency and we do not encourage stopping the investment into information systems. We used total yearly costs as input in our first step (DEA) and our scores thus represent cost efficiency. The municipalities, which spent money disadvantageously, have then higher probability of unprofitable purchasing in each segment, not excepting IT. The effect of population was positive, but significant just in case of OLS model for constant returns to scale. Loikkanen, Susiluoto, (2005) found (for Finnish municipalities), that size of the population increase inefficiency. Similarly, Štastná and Gregor (2005) show negative effect of population, but draw attention to the discussion that the results can be ambiguous.

We tried to complete our model with other important determinants of efficiency. We wanted to bypass proxy variables and concentrate on real functioning of the office, but many information (in contrast e.g. to Norway, Borge, Falch , Tovmo, 2004) are not comfortably accessible. E.g. number of staff, number of separated office buildings (see discussion below) would be very beneficial in our case.

However, the amount of office workers is crucial factor. Is the office with more employees capable to work better? The clerks can concentrate on one or a few operations and are not stressed. The expenses spent on human labor are crucial cost of the municipalities, though. The representatives would be probably unable to save sources in other sections. One extra employee means significant additional costs, which is difficult to compensate. We solved the inaccessibility of exact amount of employees by variable *wages per capita*, which divide total expenses spent on wages by number of inhabitants in the district. We can assume that management in our sample have limited possibilities to increase individual wages above the sample mean (due to Czech law system determining the height of wage in public sector), but have possibility to hire more employees, if "proves" her/his necessity.

The locations with higher price level are mostly excluded from our sample (big cities and specific districts around them).

Our second model consists from these variables **(Model 2)**:

$$effscore = \beta_0 + \beta_1 \, log(pop\_dist) + \beta_2 log(ITtotalpc) + \beta_3 log(wagespc)$$

The effect of wages (see Table 6.4) is significant and negatively influences the effectivity. This variable is negatively correlated (-0.489) with the population of district (we can say that larger office need less clerks to secure more inhabitants of the district), which explain positive omitted variable bias of the population in our first model. The effect of the population is still insignificant.

6.2.2. The regional effect

Our effort (**Model 3,** table 6.5) was also to find some regional differences, we used factor variable ***region***:

$$effscore = \beta_0 + \beta_1 \, log(pop\_dist) + \beta_2 log(ITtotalpc) + \beta_3 log(wagespc) + \boldsymbol{\beta region}$$

Where ***region*** is a vector of 13 regions (NUTS3). We computed the mean efficiency of municipalities for each individual region and choose the region (Liberecký kraj) with the highest average efficiency as the baseline level. The regions have different economic background, which is related with unemployment or amount of university graduate. This difference projects also in results of election (Hartl, STEM, iRozhlas, 2010; Seznam zprávy, ČTK, 2021) and could influence the choice of representatives of the offices.

We could expect negative results in the regions faced with problems (Ústecký, Karlovarský; Ministry of Labour and Social Affairs, 2015). The results show significant results just in case of several regions and the results differ among different methods. We can see significant negative effect in case of some Moravian regions (Jihomoravský, Moravskoslezský, Olomoucký) The negative efficiency of Ústecký kraj was detected just in case of the assumption of variable returns to scale and OLS.

6.2.3 Interaction terms

Our next models research whether the size of the district or municipality influences the efficiency of IT investment. We assigned each municipality with factor (small, medium, large), according to number of inhabitants (Less than 10 thousand, among 10 and 20 thousand and more than 20 thousand for inhabitants of the municipality. Less than 20 thousand, among 20 and 50 and more than 50 thousand respectively for inhabitants of the district. See histograms in appendix.)

Model 4 and 5:

$$effscore = \beta_0 + \beta_1 \, log(pop\_dist) + \beta_2 log(ITtotalpc) + \beta_3 log(wagespc) + \boldsymbol{\beta(municipalityfactor)*}(log(ITtotalpc))$$

$$effscore = \beta_0 + \beta_1 \, log(pop\_dist) + \beta_2 log(ITtotalpc) + \beta_3 log(wagespc) + \boldsymbol{\beta(districtfactor)*}(log(ITtotalpc))$$

We did not find any additional effect of these two factors (Table 6.6). The regional perspective is more interesting. We investigated the effect of factor *region* on IT investment, once again the region with highest average efficiency (Liberecký kraj) as baseline. The significant negative effects of the IT investment are present for similar regions as in Model 3. (Table 6.7)

Model 6:

$$effscore = \beta_0 + \beta_1 \, log(pop\_dist) + \beta_3 log(ITtotalpc) + \beta_3 log(wagespc) + \boldsymbol{\beta(regionfactor)*}(log(ITtotalpc))$$

6.2.4. Different components of IT (software, hardware, training)

Our last model returns to the assumption, that the separation of the information technology investment into several items is extremely problematical. (see part 5.3)

Our **Model 7** (Table 6.8) is composed as:

$$effscore = \beta_0 + \beta_1\, log(pop\_dist) + \beta_3 log(ITtotalpc) + \beta_4 log(elservispc) + \beta_5 log(Itservispc) +$$

$$\beta_6 log(softshor\ pc) + \beta_7 log(softlongpc) + \beta_8 log(hardwarepc)$$

The significant effect was detected just in case of hardware (negative, constant returns to scale), long-term software (positive, variable returns to scale). This was also the only case of significant positive coefficient connected with IT technology in our models. We tend to the opinion, that the conclusion about more perspective software investment is premature and require next research, which could focus on other micro data acquired directly in the municipalities. We do not have information about parts of the information systems from each individual municipality (contrary to Korea, Sung, 2007).

Constant returns to scale 2019	log dependent variables											
	OLS_1			Tobit_1			OLS_2			Tobit_2		
	Estimate	SE		Estimate	SE		Estimate	SE		Estimate	SE	
Intercept	1.01706	0.38459	**	1.11666	0.43772	*	4.57844	0.53674	***	4.98782	0.61291	***
Pop. of district	0.04962	0.02487	*	0.04771	0.02833	.	-0.02358	0.02256		-0.03193	0.02562	
Tot. IT costs pc	-0.12137	0.03007	***	-0.13230	0.03439	***	-0.05637	0.02626	*	-0.05999	0.02972	*
Tot. wages pc							-0.44629	0.05391	***	-0.48662	0.06148	***
R^2	0.1905						0.4398					
Log-likelihood				26.3433						52.9384		

Variable returns to scale 2019	log dependent variables											
	OLS_1			Tobit_1			OLS_2			Tobit_2		
	Estimate	SE		Estimate	SE		Estimate	SE		Estimate	SE	
Intercept	1.50124	0.37457	***	1.39966	0.47334	**	4.92226	0.52592	***	5.27783	0.67357	***
Pop. of district	0.01281	0.02422		0.03963	0.03062		-0.05750	0.02210	*	-0.04561	0.02797	
Tot. IT costs pc	-0.12884	0.02928	***	-0.15224	0.03730	***	-0.06640	0.02576	*	-0.07767	0.03229	*
Tot. wages pc							-0.42870	0.05282	***	-0.48196	0.06730	***
R^2	0.1552						0.4083					
Log-likelihood				4.7402						27.3154		

Table 6.4 The results of Model 1 and Model 2, using OLS and Tobit. Notes: ***, ** and * denote statistical significance at 0.1%, 1% and 5% levels, respectively. The statistical significance at 10% level denotes (.).

Constant returns to scale 2019				log dependent variables		
	OLS_3	R^2 =0.4918		Tobit_3	Log-likelihood 60.0493	
	Estimate	SE		Estimate	SE	
Intercept	4.59936	0.58502	***	4.988640	0.640327	***
Pop. of district	-0.02657	0.02393		-0.034726	0.026048	
Total IT costs pc	-0.05525	0.02739	*	-0.059154	0.029795	*
Total wages pc	-0.43449	0.05875	***	0.473620	0.064365	***
Region:						
Jihočeský	-0.10810	0.05855	.	-0.99126	0.063690	
Jihomoravský	-0.12318	0.05747	*	-0.121994	0.062636	.
Karlovarský	-0.08523	0.07132		-0.061193	0.077794	
Královehradecký	-0.06733	0.06062		-0.058340	0.066258	
Moravskoslezský	-0.09441	0.06016		-0.086361	0.065530	
Olomoucký	-0.14753	0.06393	*	-0.141025	0.069405	*
Pardubický	-0.08084	0.05920		-0.072827	0.064528	
Plzeňský	-0.08857	0.06002		-0.064431	0.065598	
Středočeský	-0.01679	0.05680		0.005681	0.062229	
Ústecký	-0.10318	0.06420		-0.091446	0.069757	
Vysočina	-0.07619	0.06225		-0.067450	0.067833	
Zlínský	-0.07348	0.06269		-0.065403	0.068438	

Variable returns to scale 2019				log dependent variables		
	OLS_3	R^2 =0.4632		Tobit_3	Log-likelihood 34.8753	
	Estimate	SE		Estimate	SE	
Intercept	4.61738	0.57326	***	4.928529	0.698597	***
Pop. of district	-0.04737	0.02345	*	-0.034808	0.028355	
Total IT costs pc	-0.06496	0.02683	*	-0.077658	0.032360	*
Total wages pc	-0.38979	0.05757	***	-0.437751	0.069982	***
Region:						
Jihočeský	-0.12014	0.05737	*	-0.115961	0.069809	.
Jihomoravský	-0.13013	0.05632	*	-0.140555	0.068836	*
Karlovarský	-0.12269	0.06989	.	-0.107382	0.084593	
Královehradecký	-0.09588	0.05940		-0.036448	0.074831	
Moravskoslezský	-0.12807	0.05896	*	-0.100819	0.072687	
Olomoucký	-0.09207	0.06265		-0.127970	0.071754	.
Pardubický	-0.07914	0.05801		-0.079531	0.076047	
Plzeňský	-0.06872	0.05882		-0.073734	0.071007	
Středočeský	-0.04021	0.05566		-0.043829	0.072642	
Ústecký	-0.13193	0.06291	*	-0.007698	0.068786	
Vysočina	-0.04770	0.06100		-0.133785	0.076133	
Zlínský	-0.07635	0.06143		-0.064201	0.075462	

Table 6.5 The results of Model 3 (looking for regional effect) Notes: ***, ** and * denote statistical significance at 0.1%, 1% and 5% levels, respectively. The statistical significance at 10% level denotes (.).

Constant returns to scale 2019			
	OLS_4	R^2 =0.4463	
	Estimate	SE	
Intercept	4.195302	0.380484	***
log(Pop. of municipality)	-0.002600	0.021265	
log(Total IT costs pc)	-0.048775	0.025994	.
log(Total wages pc)	-0.430256	0.053745	***
Interaction Total IT costs pc with (municipality factor):			
medium	0.006425	0.009237	
large	0.000116	0.004677	

Constant returns to scale 2019			
	OLS_5	R^2 =0.4378	
	Estimate	SE	
Intercept	4.361775	0.621856	***
log(Pop. of district)	0.003866	0.043166	
log(Total IT costs pc)	-0.054257	0.026779	*
log(Total wages pc)	-0.455503	0.054777	***
Interaction Total IT costs pc with (district factor):			
medium	-0.009180	0.011044	
large	-0.000584	0.005555	

Table 6.6 The results of Model 4 and 5 Notes: ***, ** and * denote statistical significance at 0.1%, 1% and 5% levels, respectively. The statistical significance at 10% level denotes (**.**).

Constant returns to scale 2019						
	OLS_6	R^2 =0.5316		Tobit_6	Log-likelihood 60.1975	
	Estimate	SE		Estimate	SE	
Intercept	4.507263	0.584780	***	4.9048729	0.6402862	***
log(Pop. of district)	-0.026564	0.023895		-0.0347925	0.0260286	
log(Total IT costs pc)	-0,041502	0.028849		-0.0471449	0.0313856	
log(Total wages pc)	-0.433541	0.058733	***	-0.4722160	0.0643378	***
Interaction Total IT costs pc with:						
Jihočeský	-0.017437	0.009268	.	-0.0160013	0.0100796	
Jihomoravský	-0.019622	0.009202	*	-0.0193692	0.0100230	.
Karlovarský	-0.014515	0.011033		-0.0110276	0.0120149	
Vysočina	-0.012685	0.009787		-0.0112903	0.0106561	
Královehradecký	-0.010835	0.009712		-0.0092983	0.0106047	
Moravskoslezský	-0.015248	0.009606		-0.0139298	0.0104588	
Olomoucký	-0.023977	0.010173	*	-0.0229323	0.0110412	*
Pardubický	-0.012505	0.009425		-0.0111643	0.0102669	
Plzeňský	-0.014918	0.009615		-0.0112916	0.0104950	
Středočeský	-0.002748	0.009089		0.0008581	0.0099423	
Ústecký	-0.016988	0.010219	.	-0.0151682	0.0110989	
Zlínský	-0.010507	0.010094		-0.0092194	0.0110169	

Table 6.7 The results of Model 6. Notes: ***, ** and * denote statistical significance at 0.1%, 1% and 5% levels, respectively. The statistical significance at 10% level denotes (**.**).

Constant returns to scale 2019				log independent variables		
	OLS_7	R^2 =0.4450		Tobit_7	Log-likelihood 53.6316	
	Estimate	SE		Estimate	SE	
Intercept	4.350781	0.570342	***	4.738769	0.640339	***
Pop. of district	-0.008655	0.023763		-0.014749	0.026588	
Total wages pc	-0.495618	0.055388	***	-0.543305	0.062422	***
elservis pc	-0.002467	0.023198		0.003156	0.026019	
Itservis pc	0.011935	0.013230		0.115320	0.014744	
softshort pc	0.011016	0.002770		-0.000377	0.003072	
softlong pc	-0.000664	0.011253		0.013229	0.012538	
hardware pc	-0.003689	0.001687	*	-0.003905	0.001911	*

Variable returns to scale 2019				log independent variables		
	OLS_7	R^2 =0.4056		Tobit_7	Log-likelihood 27.1475	
	Estimate	SE		Estimate	SE	
Intercept	4.790323	0.562752	***	5.181511	0.706922	***
Pop. of district	-0.044372	0.023446	.	-0.029625	0.065462	
Total wages pc	-0.493566	0.054651	***	-0.568163	0.029196	***
elservis pc	-0.016334	0.022889		-0.011526	0.069050	
Itservis pc	0.012433	0.013054		0.008090	0.028569	
softshort pc	-0.001660	0.002733		-0.001679	0.016036	
softlong pc	0.019636	0.011103	.	0.027026	0.013685	*
hardware pc	-0.002453	0.001665		-0.002874	0.002101	

Table 6.8 The results of Model 7 (division of IT investment into several subsections) Notes: ***, ** and * denote statistical significance at 0.1%, 1% and 5% levels, respectively. The statistical significance at 10% level denotes (**.**).

7. Conclusion

This paper tried to describe the influence of IT investment on the efficiency of the Czech local government. Information technologies have complicated effect on the productivity, which lead to the partial distrust of scientist in last decades of 20th century. Contemporary perspective is much more optimistic. Nevertheless, the situation in the Czech Republic is affected by many disadvantageous purchases and inefficient behaviour of the central government, which we briefly wrote down.

For this reason, we were awaiting no or negative impact of IT investment. The selection of literature dealing with IT efficiency and evaluation of efficiency of public organisation was presented. Similarly we introduced the context of Czech state administration, problems of financing and data availability. The municipalities of extended competence were chosen as ideal homogenous sample. The Data Envelopment Analysis is one of established methods suitable for evaluating efficiency. The methodology was described with stress on the understanding of the graphical meaning.

The data representing key services of the municipality were chosen as outputs of our decision making units. The input was aggregated into costs spent on local administration. The efficiency considering both constant and variable returns to scale were quite correlated and we thus checked out that in the case of our sample the difference between chosen returns to scale is relatively slight. The main limitation of DEA is the fact, that all deviations from the efficiency are evaluated as inefficiency. Other methods, as Stochastic Frontier Analysis, decompose deviations into inefficiency and a stochastic term. In second stage, the negative effect of IT investment was proved through OLS and Tobit models. All our models detected the negative effect of the IT investment on the efficiency. This could have two explanations. First, the negative impact of IT investment indicates, that Czech local government is in the situation of wastage, similarly as the central government, where the affairs are more publicly well-known. We were focused on cost efficiency and the municipalities, who are inefficient generally, are also probably inefficient in IT. The results of our research should not indicate termination of the investment into new technologies. Second, the case of the municipalities can be a typical example of the Solow paradox and the efficiency scores were not capable to notice real-life operation of the offices. The municipalities with higher IT investment can still have e.g. more satisfied clients or less stressed staff.

This could be researched on other microdata, obtained directly in the offices. Some comparative studies should confront the utilities of similar information systems used by different municipalities (not only functions, but also the front end, which is frequently used by the officers).

We did not prove significant effect of the size of the district, represented by the population. This variable is important and challenging in the literature. We focused on the municipality performance just in the state administration, though; many papers deal with local government performance and try to find efficiency scores for broader spectrum of the activities (Aggregated efficiency in education, road maintenance, culture, social services, etc.) The small influence of the population was indicated already in DEA analysis. The municipalities can spent mainly subvention divided according to number of inhabitants and the variable returns to scale in our case were similar to constant returns to scale.

However, we have to pay attention to difference between population of the municipality (used for division of taxes) and population of the district, even though there is a correlation. (Smaller municipalities have mostly smaller districts.) The effect of the difference between these two variables could be tested in next research.

The organisation of the office is in a large part the decision of the representatives and can influence the efficiency. We do not have enough data, which could compare the effects of the management. Other effects could be discussed; already the situation of unavailable data (in international context) shows issues of the government. Information about the offices and buildings of the municipalities would be also very valuable. The offices often reside in several buildings, which can increase operational costs and worsen communication among staff or client's experience. The town halls are frequently situated in historical houses in city centres, with expensive operation resulting from cultural value.

One of the goals of this paper is to summarize accessible data about IT and productivity on the local government level in the Czech Republic. The demands were discussed with several civil servants of responsible Ministry of the Interior. The development of some IT-index (similar to Korean case; Nakil Sung, 2009) would be very beneficial for a next research and public surveillance. The accessible data about local municipalities should improve at least to the level of Norwegian measurement of efficiency, describing 6 fields with 17 indicators. The author also longs for the state administration which is capable to regularly analyse its performance through similar econometrics' methods as shown in this paper. The present analyses prepared by the central government are often limited and based on imperfect sample survey.

International comparison would bring interesting results, especially with similar small open European economies as Estonia. Up to the present, the confrontation of different development is restricted just on short articles with limited data sources. These evaluations in media are published regularly when some issues on the Czech side appears. The Estonian Ministry of finance offers similar web interface about the economic activities of local municipalities and the possibilities of research were discussed by the author with responsible clerks. The different arrangement of the tiers of government raises the issue of heterogeneity, which would be smaller in case of Central European countries, especially Slovakia, where the pressure on the digitalization is probably not so significant though.

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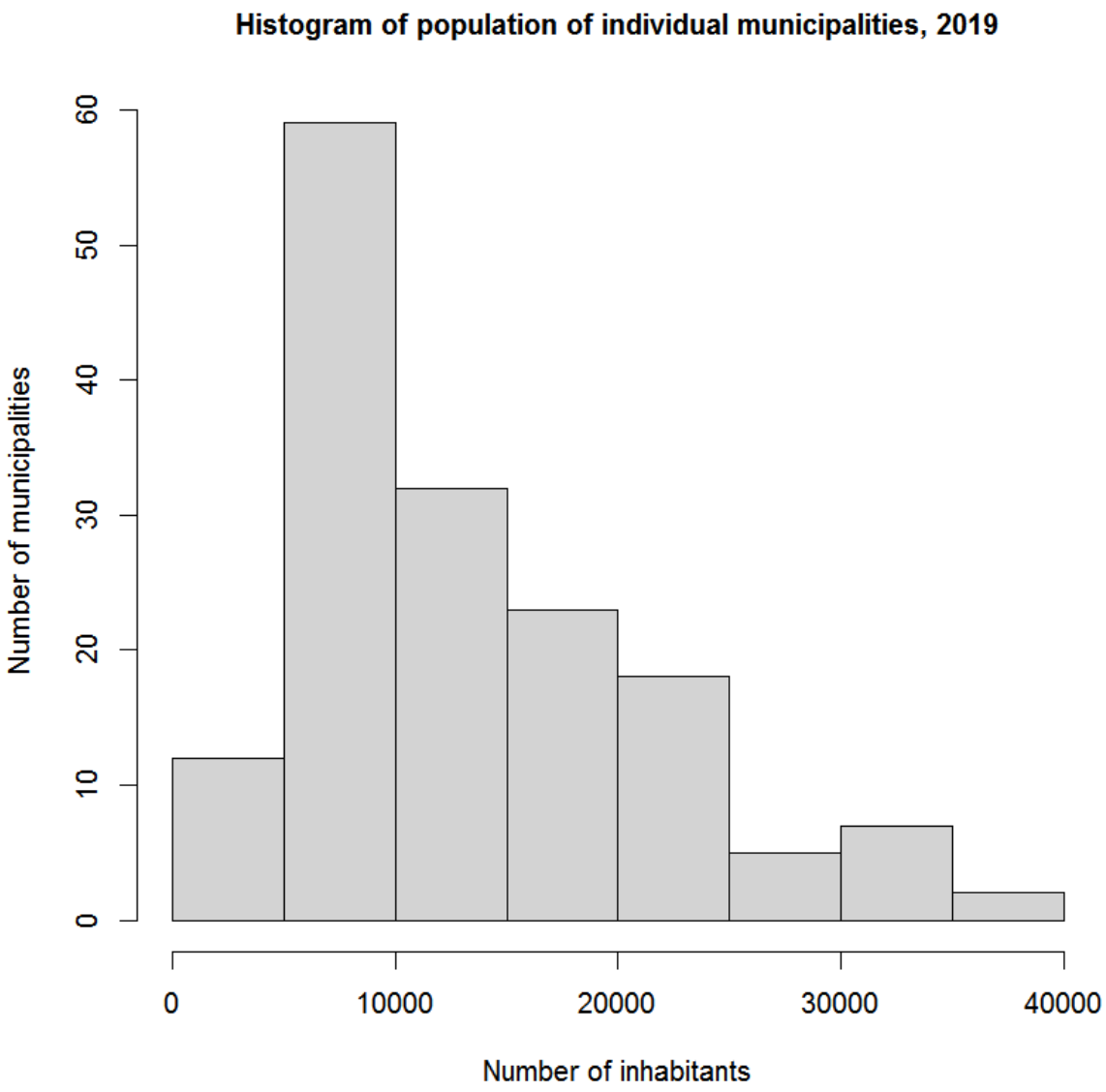
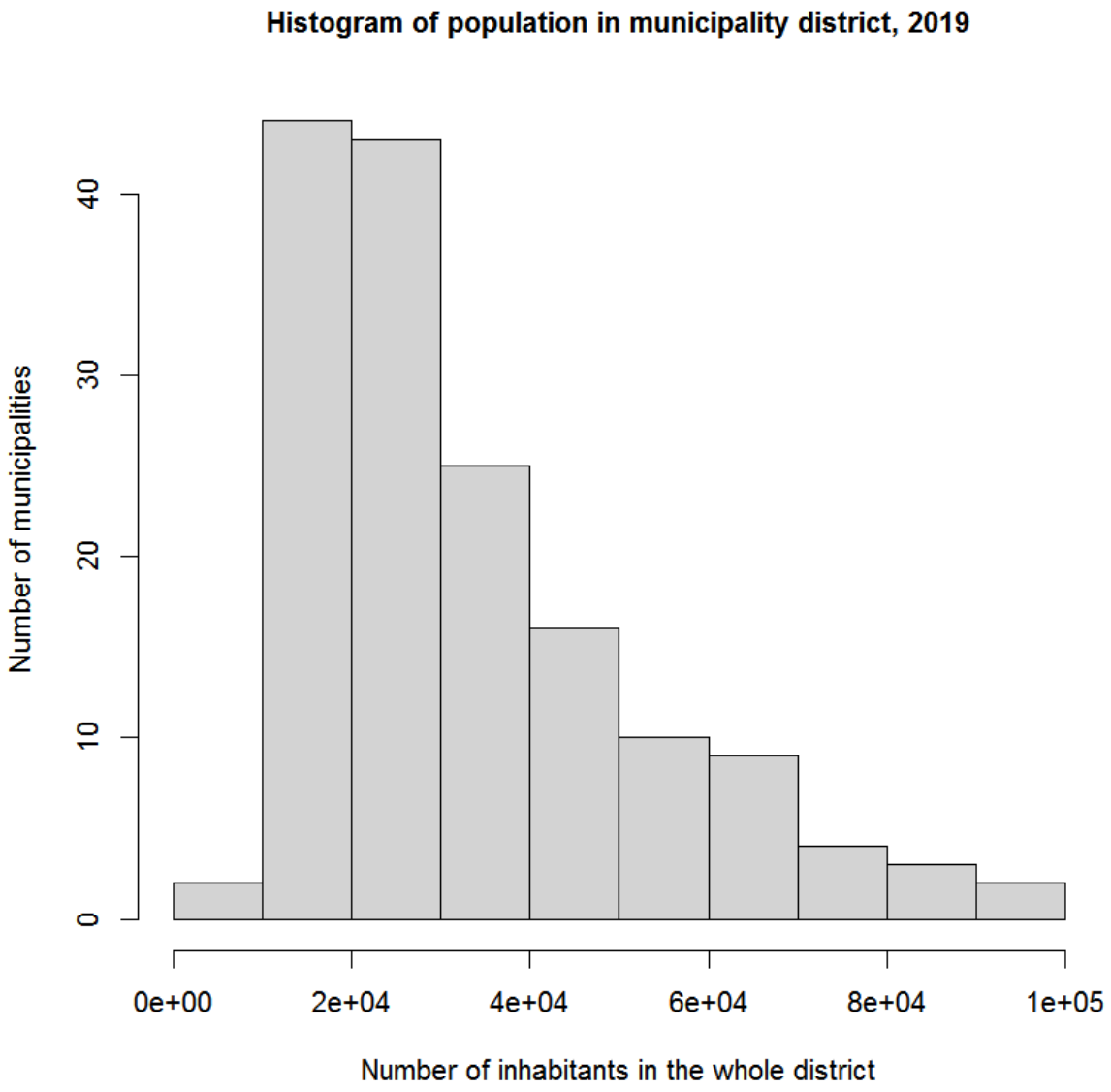
Appendix:

Mean efficiency in regions, CRS data, 2019	
Jihočeský	0.6845
Jihomoravský	0.7698
Karlovarský	0.6817
Královehradecký	0.8071
Liberecký	**0.8567**
Moravskoslezský	0.6731
Olomoucký	0.6802
Pardubický	0.7625
Plzeňský	0.7833
Středočeský	0.8517
Ústecký	0.7052
Vysočina	0.7771
Zlínský	0.7892

Appendix 1. The table of average efficiency scores for regions, the calculation was used for determination of the baseline in models with regional effect. Based on assumption of constant returns to scale, 2019 data



Appendix 2 The distribution of the size of the municipalities, we used 10 000 and 20 000 inhabitants as division into three categories (small, medium, large).



Appendix 3 The distribution of the size of the district, we used 20 000 and 50 000 inhabitants as division into three categories (small, medium, large).