SWEDISH COUNTIES' RELATIVE EFFICIENCY IN SPECIALIZED SOMATIC CARE PRODUCTION

Data Envelopment Analysis as method of comparison in healthcare

Master Essay

Author: Reza Javid

Supervisor: Ulf Gerdtham

SPRING 2017

Lund University, Department of Economics

Abstract

With aging population and increasing demand for healthcare services, the financial aspects of healthcare production has gained importance. With that, international and national comparisons have followed suit and administrative boards gained power in decision-making processes. Though Sweden often performs well in international comparisons of quality and cost-effectiveness, the increasing costs of healthcare as share of GDP has been worrisome. Therefore, measuring resource efficiency has increased in extent and benchmarking between entire hospitals or specific medical fields has been an integrated part of quality improvement tasks.

Data Envelopment Analysis (DEA) which compares different Decision Making Units (DMUs) has been used by some scholars to find the most efficient hospitals within Sweden or within Nordic countries. In Sweden, healthcare is decentralized and provided mostly by the county 21 councils. Even private providers have to write contracts with the county councils in order to be permitted to operate within their geographical areas. County councils are the responsible authorities for the hospitals. For that reason, this master's thesis in economics has county councils rather than individual hospitals as DMUs for comparing specialized somatic care provision. One county council, Gotland, is excluded from the comparison as it differs from the others by being both county and municipality council. Even the data for Gotland has been inadequate, so the models used in this paper are based on 20 county councils.

The results show that there are scale effects in place as the bigger county councils, especially those with university hospitals, perform better than the smaller ones in terms of resource efficiency. The efficiency frontier also demonstrates a tendency for presence of variable returns to scale for the input variables capturing expenditures related to provision of specialized somatic care.

Key words: Data Envelopment Analysis, efficiency in healthcare, specialized somatic care, Swedish healthcare system

Table of contents

1. Background

During the latest decades, resource allocation in the healthcare sector has steadily become a very hot topic. Discussions have mostly been about long waiting times for both visits and operations/treatments, overcrowdings and relocated patients in the wards, absence due to sickness among the healthcare staff and employees who leave the healthcare sector all together and move to other sectors as they no longer can stand the work burden. Resources, or shortage thereof, are indirect themes that have caused these problems.

New Public Management (NPM) which has its origin in production industries and which first was used in the USA, was introduced within the Swedish public sector in 1980s and was the main management model during two decades. With NPM ample economic and quantitative measures followed and made possible to compare counties and hospitals based on resource efficiency. The main force behind it was the rising healthcare costs in both absolute values and as share of GDP. Between years 2000 and 2015 Sweden's increase in healthcare expenditure as share of GDP was one of the highest, especially after 2008 when the geriatric care was included in order to make it comparable with other OECD countries. A comparison between Sweden and some other chosen OECD countries is in the table 1.

Countries	2000	2008	2015	Δ 2000-2008	Δ 2008-2015	Δ 2000-2015
Sweden	7,41	8,31	11,01	12%	32%	48,6%
Denmark	8,10	9,51	10,33	17%	9%	27,4%
Norway	7,71	7,97	9,98	3%	25%	29,4%
Finland	6,84	8,08	9,45	18%	17%	38,2%
Germany	9,84	10,18	11,15	3%	10%	13,3%
United Kingdom	6,01	7,74	9,88	29%	28%	64,3%
France	9,54	10,10	11,07	6%	10%	16,0%
Italy	7,58	8,56	9,00	13%	5%	18,7%
Australia	7,60	8,26	9,45	9%	14%	24,2%
The Netherlands	7,06	9,51	10,69	35%	12%	51,5%
United States	12,51	15,29	16,92	22%	11%	35,2%
Japan	7,15	8,20	10,90	15%	33%	52,4%
Korea	4,00	5,82	7,39	45%	27%	84,8%
Canada	8,28	9,47	10,25	14%	8%	23,9%
Austria	9,22	9,64	10,32	4%	7%	11,9%
Switzerland	9,34	9,78	12,06	5%	23%	29,1%
Chile	6,29	6,69	8,13	6%	21%	29,2%

Table 1: Healthcare expenditure as share of GDP, 2000-2015, source: OECD

Efficiency and productivity is said to be two key concepts that would lead the Swedish healthcare sector forward. Based on the notion that there was underutilization of resources in healthcare, the amount of hospital beds were reduced drastically by more than 60% between 1986 and 2006. However one major part of the decrease was due to a new law in 1992 that transferred the responsibility for care of elderly people from counties to municipalities (SKL, Appendix 1). As hospitals belong to the counties the geriatric care divisions were reduced by more than 2/3 so that dischargeable elderly patients would be moved more quickly to municipality-operated accommodations. Though, the reduction of hospital beds continued steadily even after that transfer. However, the number of specialist doctors at hospitals per 100000 inhabitants increased by around 30% between 1995 and 2011 (Socialstyrelsen, Appendix 2).

The organization of Swedish Municipalities and Counties (SKL) started the comparison barometer *Öppna Jämförelser* (Open Comparisons) which compare counties, municipalities and hospitals and a certain number of production and economic parameters in order to enthrone those with highest quality and/or efficiency. *Open Comparisons* has become an important and frequently used tool in political debates about both management models and the political parties enforcing them. The National Board of Health and Welfare (Socialstyrelsen) has also many registers that can be used in comparing quality and efficiency of care within and between counties councils, hospitals and specialties.

The Swedish government assigned a national enquirer, Göran Stiernstedt, to investigate the state of the Swedish healthcare with special emphasis on resource efficiency. The investigation that was dubbed to "Efficient Care, SOU 2016:2" got quick recognition and was spread and debated in the country. However, it has yet to be presented as proposition by the government before the parliament. Both according to that investigation and some other comparisons, Sweden's hospitals have the lowest efficiency among the Nordic countries.

In recent years, there has also been a shift in competence mix among healthcare employees in Swedish counties with increasing number of doctors and nurses and decreasing or constant number of assistant nurses and paramedics, an issue that also was raised by the national enquiry about healthcare efficiency, SOU 2016:2. According to statistics from the national board of health and welfare, Socialstyrelsen, it was the doctors and physiotherapists who increased most between 1995 and 2014, as can be seen in table 2.

Yrkesgrupp	1995 (per 100000 people)	2014 (per 100000 people)	Procentuell förändring
Mid-wives	5 758(65)	7 249(74)	26%
Physiotherapists	8 423(95)	12 867(132)	53%
Physicians	25 527(289)	40 637(417)	59%
Nurses	84 982(962)	107 988(1109)	27%

Table 2: Changes in number of healthcare employees in Sweden per profession, between 1995 and 2014, source: database of the National Board of Health and Welfare

As doctors and nurses have on average higher wages than assistant nurses and paramedics, this has contributed to an overall increase of healthcare costs as percentage of GDP. While the global average of healthcare costs as percent of GDP went from 8,5% in 1995 to 9,9% in 2014, Sweden's healthcare costs went from 8,0% to 11,9% during the same period of time (Word Bank, Health expenditure, total (% of GDP)).

Anell et al, 2011, looked into the efficiency levels of healthcare in Sweden and found that the technical efficiency was significantly low in both inpatient and outpatient care before 1990s but started to bounce upwards from the beginning of 1990s. According to them, the productivity increase was notable especially in county councils that had introduced case-based payment methods (Anell et al., 2011 & Gerdtham et al., 1999).

Some decades ago healthcare production was calculated in terms of some unadjusted measures, such as number of visits, number of episodes of care and number of care days. It meant that no attention was paid to the heterogeneity that was present among the caregiving units. Units that took care of complicated cases with long length of stay (LOS) were often deemed as relatively inefficient in comparison to those with more but less demanding episodes of care. In an attempt to make the comparison between units more just, Diagnosis-Related Groups (DRGs) were introduced within the Swedish healthcare sector in mid-1990s (Rehnberg, 2016).

One discussion topic has been the division between inpatient and outpatient care. The latest national enquiry on efficiency of healthcare, SOU 2016:2, came to the conclusion that Sweden is too dependent on inpatient hospital-bound care while the outpatient care is very limited, not least in comparison to other countries. Outpatient care is divided into two parts, 1. Non-hospital primary care, 2.

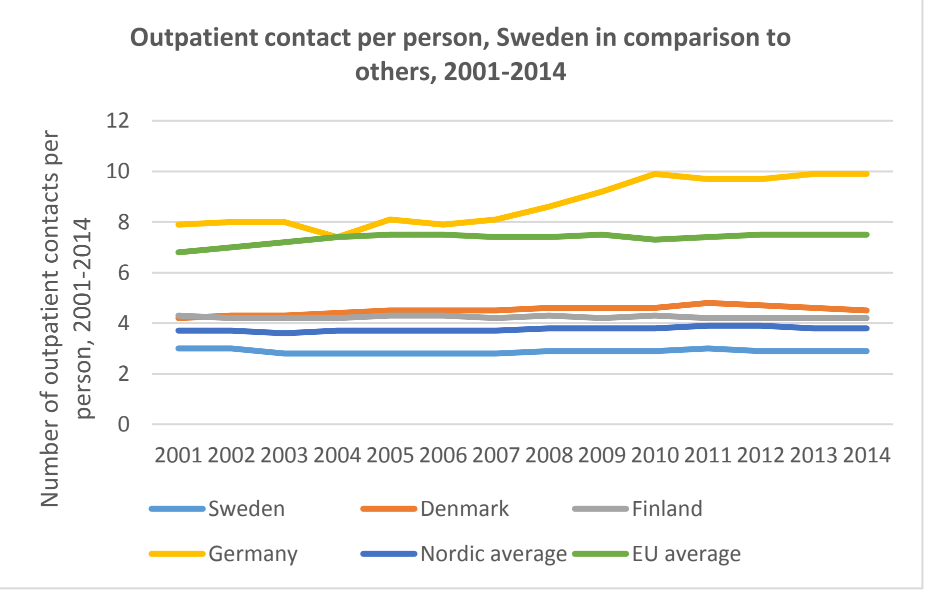


Diagram 1: Number of outpatient contacts per person, 2001-2014, source: WHO

Hospital-bound receptions with length of stay shorter than one day. Anell et al, 2011, discussed the extent of primary care in Sweden in their *Health System Review* and concluded that the primary care was on rise since the beginning of 1990s (Anell et al., 2011: 135). However, available data show that the rise has not been significant as Sweden continues to be the country with fewest number of outpatient contacts per person among both Nordic and EU-member states. That can be seen in diagram 1.

In this thesis, only the hospital-bound part of the outpatient care is included as it is part of "specialized care" and its costs are calculated together with hospital-based inpatient care. This means that the difference between counties in extent of primary care utilization as an alternative to hospital-bound outpatient care will be missed from the analysis.

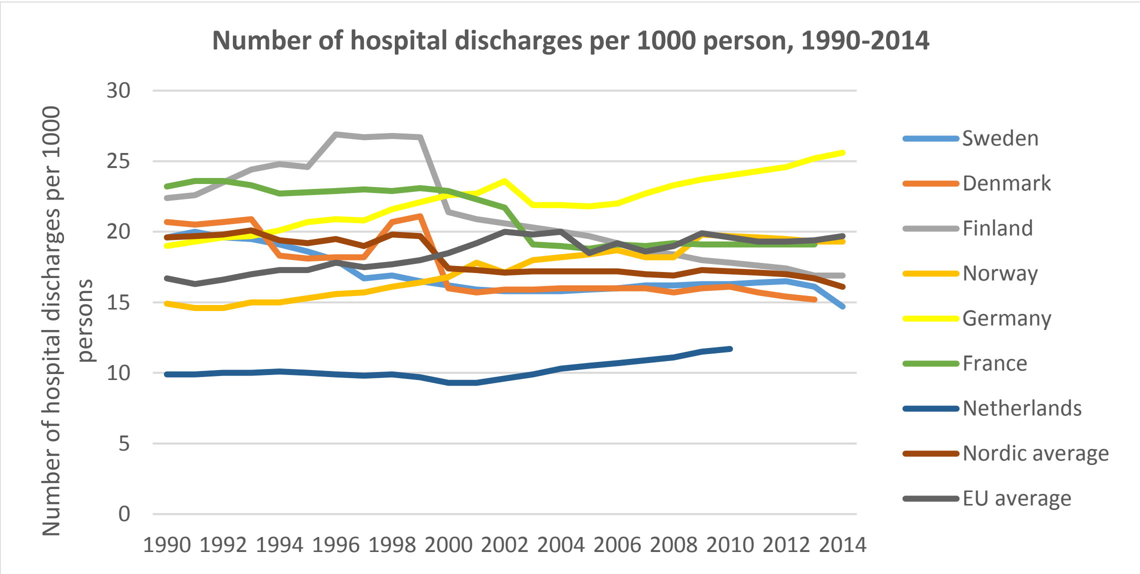


Diagram 2: Number of discharges from inpatient care per 1000 persons, 1990-2014, source: WHO

The data on primary care in table 1 and inpatient care based on discharges from hospitals in table 2 show that Sweden has very low consumption of primary care and lower than EU- and Nordic averages inpatient care consumption. This can be interpreted as comparably low production of healthcare, even though Sweden is among the countries with highest numbers of doctors and nurses per 1000 persons.

In order to capture the entire picture, it is important to put primary care consumption in relation to hospital-based specialized care consumption. At the same time, the division within hospitals on inpatient and outpatient care is of interest as a transfer of easier cases from inpatient to outpatient care can decrease total costs for hospitals and county councils.

Therefore a ratio between inpatient and outpatient care for each of the counties can be of interest and useful.

Based on data from production and efficiency levels in Sweden which is lagging behind most other comparable countries, the need for efficient and sustainable systems seems to be urgent. In that sense, it is of value to compare the counties among themselves and find out the relatively efficient counties so that others can learn from them and improve their own efficiency levels. The method is oftentimes known as benchmarking. Diagnosis-Related Groups (DRGs) that adjust the healthcare production for their resource consumption is an important tool for reaching that target.

There has been criticism voiced against too much focus on efficiency and the concept has lately become perceived by the public as cost reductions and *per se* a decrease in number of employees. Though data show that the number of employees, both in absolute and per capita terms have increased, the negative connotation of the concept continues to create unease among policy-makers. However, studies done by Janlöv, 2010, and Rehnberg, 2010, on the relation between patient satisfaction and efficiency show positive correlations (Janlöv, 2010 & Rehnberg, 2010).

As DRG, in Sweden the revised version NordDRG, divides the diagnoses based on resource needs it has gone from being used only for categorization to even being basis for resource allocation. From the mid-1990s more and more of Sweden's counties left the budget-based reimbursement programs and embraced internal quasi-markets with buyer/purchaser relations. Gerdtham et al., compared productivity among counties with budget-based and those with buyer/purchaser reimbursement models and found that counties that had shifted to buyer/purchaser relations had higher productivity (Gerdtham et al., 1999). Since their study the Swedish healthcare sector has gone through major changes with more deregulation so that private healthcare providers have become a much bigger part of the healthcare sector. This has strengthened DRG as model for categorization and reimbursement. Thus, DRG will be used in this thesis as an adjustment method in order to make the counties councils' healthcare production comparable.

There are ample comparison methods, both quantitative and qualitative, with focus on both financial and non-financial measures such as quality registers that Socialstyrelsen is responsible for. However, Data Envelopment Analysis (DEA) has not be one of the most used methods in the context of healthcare in Sweden. One of the first major studies based on DEA was *Mått på välfärdens tjänster (Measures on welfare services)* accomplished by Björn

Brorström et al. in 2006 where they penned an anthology on productivity and efficiency in municipal and county activities (Brorström et al, 2006).

1.2 Purpose and questions

The main purpose behind the chosen thesis topic is to look at the Swedish counties' efficiency in the relative efficiency map and follow them over years in order to see if their placements are stable over time or different counties score differently in efficiency at different years. Gotland has been excluded due to shortage of data and difference in responsibility and organization sphere as it is the only county which functions as both county and municipality and thus play two roles while other counties have many independent municipalities within themselves.

Beside the purpose of comparing the Swedish county councils in terms of efficiency in production of specialized somatic care, an aim of the thesis is also to examine whether there are challenges and issues that hinder DEA technique to do a just comparison. By that, I aim to give other future researches a helping hand so that they take those challenges and issues into account once launching their researches.

The questions to be answered are as follows:

- ✓ Are there differences in efficiency between Swedish counties and regions concerning specialized somatic care, based on efficiency measurement with Data Envelopment Analysis (DEA)?
- ✓ Are the counties consistent in relation to the efficiency frontier or do they change places between years?
- ✓ Does size of the counties play an important role for efficiency score?
- ✓ Does a change in the number of input and output variables cause efficiency scores to change?
- ✓ Is DEA robust as a model or does it change the efficiency values between iterations?

1.1 Delimitation

In the beginning the aim was to look at the entire healthcare sector within each county but as shortages of data in many areas became apparent I chose to delimit the thesis to include only specialized somatic care for each county and region. Counties and regions are sometimes abbreviated to only "counties" as *region* is a new denomination given to some counties either because they have more responsibility for local development of their geographical areas or that some earlier counties have gone together and built a bigger entity without changes in their responsibilities. Even the umbrella organization of the counties and regions, SKL, use the terms interchangeably and in many cases let *county* be the denomination for all.

Specialized somatic care consists of both inpatient and outpatient care. In this thesis, data from both parts will be used. This will be done in two sessions; Model A and Model B, for comparative reasons, in order to measure whether inclusion of exclusion of outpatient care changes the relative efficiency of the counties. That may shed light on differences in inpatient versus outpatient intensity of the healthcare produced in each of the counties.

2. Method

This thesis is built on non-experimental, observational study, based on data accumulated by the umbrella organization of Swedish counties and municipalities, SKL, and the Swedish national board of health and welfare, Socialstyrelsen. The thesis is delimited to the specialized somatic care, including both inpatient and outpatient care. As different counties have different patient compositions Nord-DRG has been used to adjust the counties' healthcare production and make them comparable. Socialstyrelsen has average DRG-points and number of episodes of care for each of the counties. For the outpatient care, there are some discrepancies between data from SKL and those from Socialstyrelsen concerning number of visits by patients. There is also shortage of data for average DRG-point per county for most of the years taken in this thesis. Therefore, the national average DRG-point of 0,0624 which was calculated for the outpatient care in 2015 has been used for all of the years and counties to convert the number of visits to number of DRG-points and thus make it comparable with the other output variable, case-mix-adjusted DRG-points in the inpatient care.

2.1 Production theories

Healthcare production is not entirely similar to industrial production of goods. Healthcare is not a “good” in terms of people demanding it as much as possible. Healthcare, rather, is something that people are obliged to seek when sickness and diseases affect them. Thus, the maximum production of healthcare is not the goal because the goal is maintaining maximum healthiness. If it is possible to achieve the maximum healthiness without needing to be admitted to a hospital, then that should be strived for. It means that the goal is achieved in two stages, where inpatient and outpatient specialized somatic care are output variables in the first stage and input variables in the second stage. Healthiness is the output variable in second stage. The first stage, in which sheer quantitative production data is calculated and analyzed, measures *efficiency* while the second stage which takes into account even qualitative data measures *effectiveness*. In this thesis, measuring *relative efficiency* is the main target.

In producing healthcare, similar to goods production, there are inputs that together produce the output(s). Cobb-Douglas classical production function is the most famous and built on two inputs; capital and labour. The mathematical equation is: $Q = AK^{\alpha}L^{1-\alpha}$ where K stands for capita, L for labour and A is a constant representing total factor productivity - i.e. the part of the output that is not explained by either capital or labour – α is the parameter that shows the rate of capital's contribution to production while 1-α shows the labour's (Borjas, 2010:170).

The unit cost of capital is $r = \alpha A \left(\frac{K}{L}\right)^{1-\alpha}$ while the unit cost of labour is $w = (1-\alpha) A \left(\frac{K}{L}\right)^{\alpha}$. If this basic formula is used, then for healthcare it means that all forms of staff- and service-related contributions are summed to one variable, *labour*, while all forms of material inputs are assumed to be represented by *capital*. However this basic Cobb-Douglas function would be too simplistic as there are many inputs that contribute to healthcare production. Beside the fact that there are different forms of inputs, even one input takes different forms, such as healthcare employees who range from doctors, to nurses, assistant nurses and so on, with their own specific tasks and discernible wage levels. Thus, the competence mix, which differs across wards and specialties, is of huge importance. Even the medical technology differs both across and within specialties based on complexity of the cases. This means that the results and conclusions of this thesis should be interpreted cautiously as the 20 counties of Sweden in some respects differ in divisions of production on medical specialties and level of complexity of the cases as well as technological equipments used.

The basic Cobb-Douglas function with $\alpha+\beta=1$ assumes *constant returns to scale (CRS)* from the inputs, which many studies, such as: Kristensen 2008 concerning Danish hospitals; Wang et al., 2006 concerning Australian hospitals; and Marini & Miraldo, 2009, concerning British hospital, have all concluded is not the case in real life. Like many other sectors, healthcare sector's production follows variable returns to scale (VRS), with increasing returns to scale (IRS) in the beginning, before reached optimum, and decreasing returns to scale (DRS) after the optimal production solution where the ratio between output and input is as largest. In a simplified model, if we let nursing hours represent all inputs needed for providing medical services, the relationship between input and output variable can be graphically demonstrated as in figure 1.

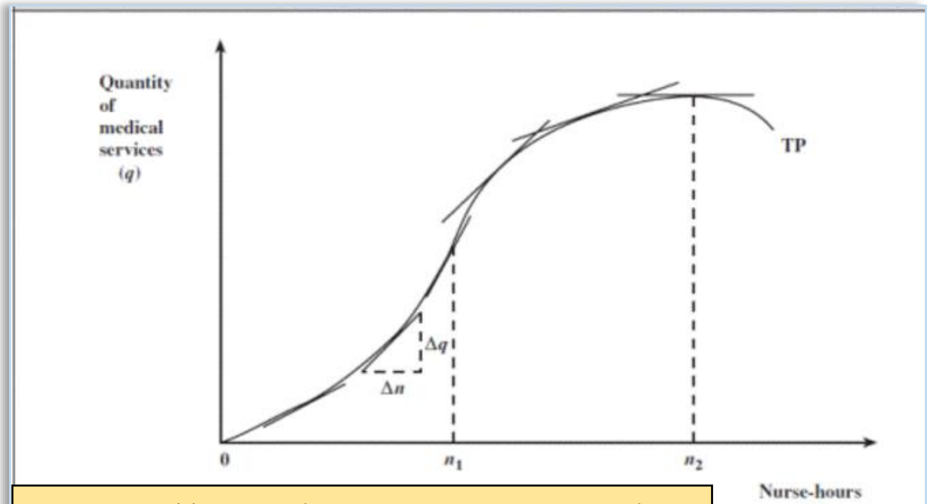


Figure 1: Healthcare production curse, source: TDMU.edu

2.2 Productivity, efficiency and effectiveness

Sweden's healthcare system concerning quality of care is often ranked high in international comparisons, not least among OECD countries. However, Sweden's healthcare expenditures as share of GDP has been steadily increasing during the latest decades resulting to decreased efficiency. Data from OECD show that Sweden's healthcare expenditures as percentage of GDP increased most of the years between 2000 and 2015 (OECD, 2015). That development is illustrated in diagram 3.

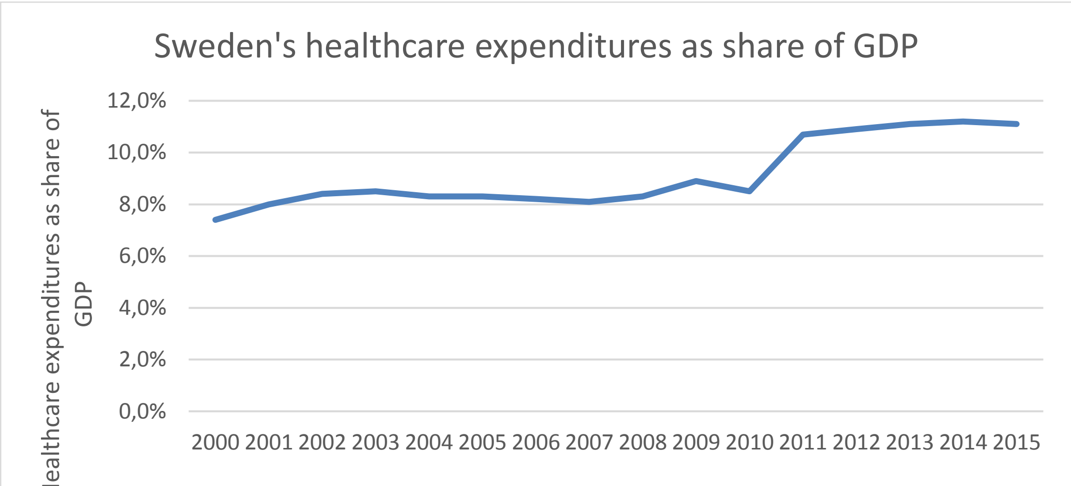


Diagram 3: Sweden's healthcare expenditures as share of GDP, 2000-2015, source: OECD

Since 1997 the Swedish healthcare system is governed by three overarching principles (HSL, 1982:763). Those three principles are together called the ethic platform (regeringen.se):

1. **The principle of equal value**

   All human beings have an equal entitlement to dignity and should have the same rights, regardless of their status in the community.

2. **The principle of need and solidarity**

   Those with greatest needs are given precedence in treatment and care

3. **The principle of cost-effectiveness**

   When a choice has to be made between different treatment options, there should be a reasonable relationship between the costs and the effects, measured in terms of health outcomes and quality of life.

As resources are allocated on the priority order of the above mentioned three principles, it shows that effectiveness is one of the cornerstones of Swedish healthcare sector. The relationship between effectiveness and efficiency is not linear but it can be interpreted as acknowledgment of efficiency as important factor because high efficiency (low waste) mostly is associated with high effectiveness (high attainment). The relationship between the two concepts is depicted in figure 3. The ratio between effectiveness and efficiency is called *productivity* (OEECoach.com). Since the piece of legislation went into effect, SKL has put more focus on measuring efficiency and comparing counties with the purpose of encouraging them to increase their resource effectiveness.

Efficient resource allocation in healthcare requires both productivity enhancement, with the help of innovations, and optimal mixture of input variables because output variables often are uncontrollable due to most of the patients being admitted acutely. The acute admissions have dominated the planned admissions for most of the modern healthcare history. The share of acute admissions have even increased during the latest years, which has resulted in longer waiting times at emergency receptions and overcrowding at inpatient wards (Socialstyrelsen, 2015:16 & 70). As output is mostly uncontrollable in the context of Sweden's tax-funded healthcare system with universal coverage, it is the inputs that are used as tools for enhancing efficiency.

Cost minimization, like profit maximization when output is a controllable variable, can be calculated by the help of *marginal rate of technical substitution* (MRTS) which denotes increase of capital needed in order to keep output constant given a unit decrease of labour. Cost is minimized when the increase in capital in order to offset a unit decrease of labour is equal to the ratio of unit cost of labour over unit cost of capital: $MRTS_{KL}x = \frac{w}{r}$. That state is called Pareto Optimum. (Connolly & Munro, 1999:25).

In the specialized somatic care with two levels, i.e. *outpatient* care where patients visit the hospitals and are consulted or treated during the day so that they return home, and *inpatient care* where patients are admitted to the wards and stay at the hospital at least one night, the optimal resource allocation can be achieved in a way that can be depicted in a production possibility curve, as in figure 2. Y1 denotes *casemix-adjusted episodes of care in inpatient specialized somatic care* while Y2 stands for *DRG-points produced in outpatient specialized somatic care.* Then optimum is reached when $MRTS_{KL}Y_1 = MRTS_{KL}Y_2$.

It is important to distinguish efficiency from effectiveness as they point to different stages of a process. Unfortunately misunderstanding and interchangeable usage of the concepts is common. Efficiency is closely related to productivity and aims to minimize the usage of inputs while effectiveness has the purpose of maximizing the end effects. Efficiency denotes *doing things right* while effectiveness denotes *doing the right things.*

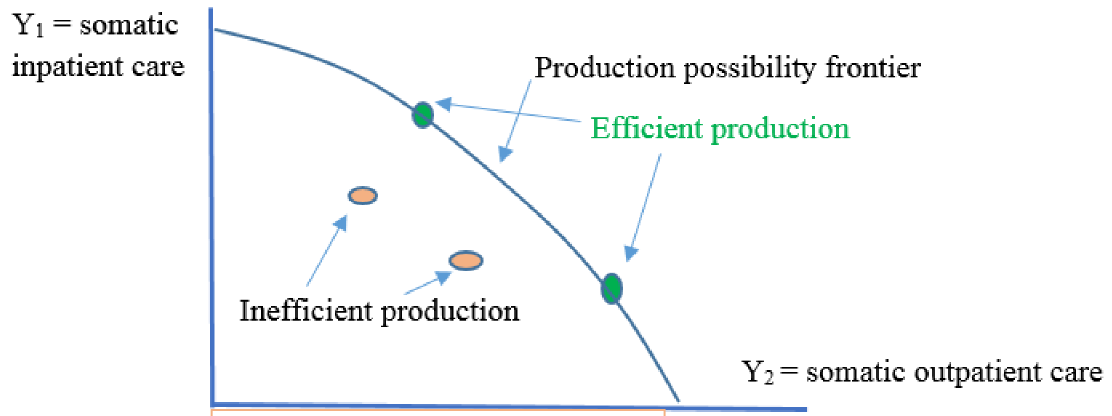


Figure 2: Production possibility curve

As this paper has input minimization as measurement basis, efficiency is the target. It means that ultimate changes in the quality of life and health status among patients resulted from the inpatient and outpatient specialized somatic care within the counties are not discernible from the results of this paper. For that purpose, it would be needed to measure effectiveness.

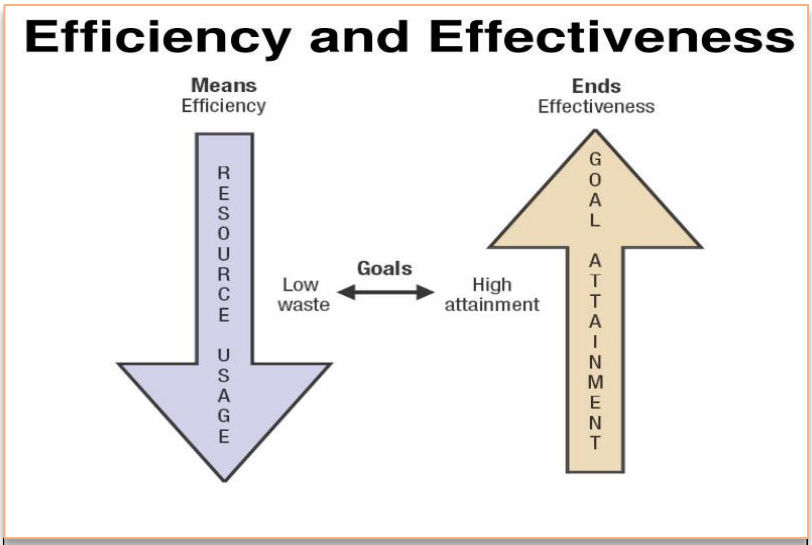


Figure 3: Efficiency vs effectiveness, source: Ralf-Heiser.info

The orientation of the DEA method used in this thesis is "input minimizing" rather than "output maximizing" which is customary in the production industries.

2.2.1 Different types of inefficiency

Efficiency, as described in earlier section, is focusing on inputs in order to minimize waste subject to given amount of outputs. However, the reason behind inefficiency can be many and it is important to find the right sources in order not to be tilting at windmills in pursuit of efficiency. For finding inefficiencies in the units compared, it is important to be sure that the reason behind inefficiencies are less than optimal use of available resources. If the reason is inherent differences in the input variables across compared units, then any attempt to make the seemingly inefficient units may lead to failure and despair.

If the units that are compared use exactly the same variables with the same characteristics and produce differently efficiently, then the relatively inefficient units face *technical inefficiency*. It means that the inefficient units have a gap between their actual production level and what is possible to produce, given their current level of inputs. Though, the absolutely maximum level of possible production cannot be read from the comparison and that can be even higher than the most efficient units in the model have managed to achieve. If the units compared face known maximum output levels that different between them, then a difference in production can be due to the difference in their sizes, i.e. *scale inefficiency* (Sherman & Zhu, 2006: 52)..

If instead of physical units, such as number of physicians, number of nurses, number of beds, etc. the input variables are in monetary terms, then any differences in production may be due to differences in price of the same input variables across the compared units. If for example the average wage of employees at county A is 35000 while it is 30000 in county B, and the same number of employees in both counties produce the same amount of healthcare, county A will still be more expensive. The reason is *price inefficiency* (Sherman & Zhu, 2006: 53) and if not correctly understood, managers might wrongly assume that employees in county A are lazier than in county B and suggest actions that will not solve the problem. The input variables in this thesis, as outlined in the next section, are based on monetary values so price inefficiency may arise.

When multiple inputs and outputs are involved, the mixture of the input variables become an important issue. If in the example above, the two counties A and B used several inputs with the same price and potential across those two counties but still got different output levels, then they might have different mixtures of inputs. The compared units that are relatively inefficient in comparison to some other ones are then affected by *allocative inefficiency* and must change their mixture of inputs in order to reach production levels of the efficient units (Sherman & Zhu, 2006: 54).

2.3 Choice of variables

As output variables I have chosen:

1. Number of episodes of care and adjusted them with the average Diagnosis-Related Groups (DRG) points per county as different counties have patients with differences in care needs, and
2. Number of contacts with hospital-bound outpatient care, both physical and digital contacts, and adjusted them with average national DRG weight for outpatient healthcare contacts.

As input-variables I have chosen the following four economic variables:

1. *Staff- and service-related costs*
2. *Material costs and costs for depreciation of values for physical capital*
3. *Internal costs, and*
4. *Costs incurred by purchase of somatic care, usually from private hospitals.*

For the purpose of finding answers to the thesis' main questions, Data Envelopment Analysis (DEA) has been run more than once for each county in each year. In first session, i.e. Model A, only the inpatient care production was used as output variable while staff- and service-related costs were split into two input variables. In the second session, i.e. Model B, the approach described above was used.

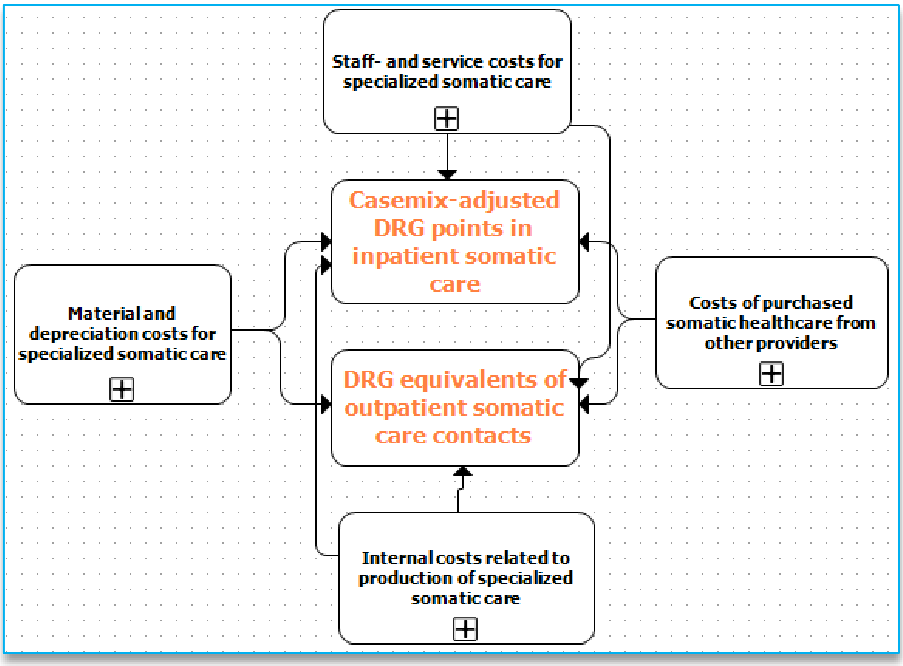


Figure 4: Chosen input and output variables in the final model

The above-mentioned expenditure measures contain most of the healthcare-related costs in specialized somatic care and should be sufficient in providing a view over the cost state of each county council. DEA analysis will be done for six years in a range of 10 years in order to follow the development of the relative efficiency for each DMU in relation to others.

As there are some diagnoses and operations categorized to “regional care” or “national care” and are prescribed to specific university hospitals, most of the counties have an economic entry for *purchased healthcare*. However, on the other hand, they also have *sold healthcare* in which the university hospitals responsible for regional or national care have the lion’s shares. I have subtracted the revenues from the sold somatic healthcare proportionately from all input variables for each county. For example, if material costs made up 25%, staff and service-related costs 50%, internal costs 15% and purchased care 10% of a county’s total costs, I subtracted 25% of the revenue from sold care from material costs, 50% of it from staff and service-related costs, 15% from internal costs and 10% from costs due to purchased care.

2.4 Data Envelopment Analysis (DEA)

Data Envelopment Analysis (DEA) is a non-parametric statistical comparison technique that first was developed by A. Charnes, W.W. Cooper and E. Rhodes in 1978 in an article by the name of “*Measuring the Efficiency of Decision Making Units”* with the purpose of measuring efficiency in not-for-profit firms in the public sector (Charnes et al., 1978*).* Since then, all units that are compared with the help of DEA are called Decision Making Units (DMUs), which either maximize their production given a fixed amount of inputs or minimize their costs given a fixed level of production.

The advantage with DEA is that from the beginning it was developed with the public sector in mind, distinguishing it from most other methods that first were introduced within the frame of manufacturing industries for production of goods and later on were applied to the public sector. The authors described their thoughts behind the model such that absolute monetary values of the inputs and outputs are not the most important aspect when comparing DMUs. That was one of the reasons why they first applied the model to not-for-profit organizations. Nevertheless, DEA has caught the eyes of the management in the for-profit sectors of the economies and been applied to DMUs for goods production. One such revised model is Quangling Wei’s and Tsung-Sheng Chang’s *Optimal System Design DEA* which is used for resource allocation within for-profit organizations with many units (Wei & Change, 2011).

If we suppose that there are *n* DMUs the model (Wen, M., 2015, p. 2) is mostly consisting of properties below:

DMU_i: the *i*th DMU, where i=1,2,…n

DMU_0: the target DMU

$x_i = (x_{i1}, x_{i2},\dots x_{ip})$: the input vector of DMU_i, where i=1,2,…,n

$x_0 = (x_{01}, x_{02},\dots x_{0p})$: the input vector of the target DMU_0.

$y_i = (y_{i1}, y_{i2},\ldots, y_{iq})$: the output vector of DMU_i, where $i=1,2,\ldots,n$

$y_0 = (y_{01}, y_{02},\ldots, y_{0q})$: the output vector of the target DMU_i

$u \in R^{p*1}$: the vector of input weights, and

$v \in R^{q*1}$: the vector of output weights

2.4.1 Sources of Variation

There are many sources of variation in a DEA formulation so it is important to define the model in use as precisely as possible so that it fits the data being analyzed (Hayes, 2005). The first of the sources of variation is ***formulation*** such that DEA can has either:

- *Primal form*, with rows as representing the model, or
- *Dual form* in which columns are representing the model.

When there are many DMUs to be compared, the dual form is the most common approach. In this paper 20 county councils are compared in respect to relative efficiency so the formulation of the DEA here is the *dual form.* The second source of variation that it important to define is the ***orientation*** with either:

- *Output-oriented DEA*, where the main focus is maximizing production and profit, or
- *Input-oriented DEA,* where the main target is minimizing usage of resources given certain levels of output.

The main purpose of this thesis is to compare counties of Sweden with respect to their somatic healthcare production subject to the output levels treated as non-discretionary and thus minimizing inputs as the main target. Some specialties, especially surgical ones, have a higher portion of their visits and episodes of care as elective (planned) so for those parts it would be possible to have an output-oriented DEA. However the elective visits and episodes of care make up only a small portion of the total, thus an input-oriented DEA is preferred and more appropriate. Therefore, the DEA here is "input-oriented".

The third important source of variation is ***returns to scale*** (Burda & Wyplozs, 2005:51) as the inputs can either have:

- *Constant returns*, so that the output/input ratio is constant over time, irrespective of the amount of inputs, or
- *Variable returns,* so that the contribution of the inputs to outputs changes over time, increasing sometimes and decreasing other times.

In healthcare, like most other sectors, it is expected that there is non-linear relationship between inputs and outputs such that one unit increase or decrease in inputs not always results into proportional change in outputs. There are many reasons, such as limited space, operation rooms, shared medical equipment, and etcetera. Ample studies from hospitals in different countries, such as: Wang et al., 2006, from Australian hospitals; Kristen, 2008, from Danish hospitals; and Marini & Miraldo, 2009, concerning British NHS hospitals, have all concluded that there are economies of scale, at small hospitals and diseconomies of scale at large size hospitals. Economies of scale means increasing returns to scale while diseconomies of scale denotes decreasing returns to scale. Therefore, the DEA in this paper is assumed to follow *variable returns to scale* approach as it is assumed that Swedish hospitals do not differ significantly from those of the studied countries.

The fourth source of variation in a DEA is the ***manager's ability to control*** the variables as they wish. Thus, variables can be either:

- *Discretionary*, so that they are fully controllable and changeable, or
- *Non-discretionary*, so that managers at the counties cannot fully control them.

In this thesis, the outputs, which depend on the care-seeking patterns of patients and the circumstances of diseases in the country, are treated to be uncontrollable and thus non-discretionary. In recent years, there have been reports of over-consumption of inpatient care in Sweden, especially inpatient care, which has resulted into Socialstyrelsen developing a register for *avoidable inpatient care* in order to encourage the counties to prevent those episodes of care where the primary health-centers are better options than hospitals to visit. That shows that seeking patterns are not fully controllable but effectible. Input variables are controllable and thus discretionary. In assessing efficiency with DEA, both discretionary and non-discretionary variables are considered, but in determining whether to maximize or minimize the function, only the discretionary variables are included (Hayes, 2005: 71). Consequently, in this paper, only the input variables can be changed at will and are discretionary so the model is input-oriented.

The fifth and last source of variation is the **interaction** between the input variables and also between the output variables. Thus, the model can either be:

- *Additive*, in which input or output variables add up when changed, or
- *Multiplicative*, in which input or output variables are multiplied to each other once changed.

The weights of the variables are chosen by the program itself and the operator can put some limitation conditions such as requiring the weights to be non-negative or strictly positive. In some cases, the *a priori* weights for a variable chosen by the Excel Solver program itself might be unrealistic so further restrictions may be needed in order to limit its over- or underestimation (Hayes, 2005: 49).

The mathematical formula used in DEA handles the weighted ratio between sum of outputs and sum of inputs ranging from 0 to 1.00 with the restriction that both inputs and outputs are strictly positive. When the outputs are undesired "bads", such as pollution, noise, etc., such that the aim of the DEA is to find relatively efficient input levels resulting into diminished outputs, then the output-minimizing DEA is used. In that case, the weighted output/input ratio will fall between -1 and 0. Though, in this thesis the outputs are "goods" and not "bads" so the output-minimizing method is not of interest and will not be further discussed. In this, input-minimizing DEA, the most effective DMUs will have efficiency score 1.00 or very close to it while the least efficient ones will have efficiency scores close to 0. The DMUs that have optimal efficiency in comparison to other DMUs, and thus are not able to further increase their efficiency levels, will have efficiency value 1.00 and be on the *Efficiency Frontier*. The DEA model here uses optimization technique of Excel Solver where the output and input variables can be restricted to be non-negative.

2.4.2 The Mathematical Model

The first ones who developed the DEA were Charnes, Cooper and Rhodes so the model was dubbed CCR and focused on output maximization. That model (Charnes, et al. 1978, p. 430) has the formula:

$$\max h_0 = \frac{\Sigma_{r=1}^{s} u_r y_{r0}}{\Sigma_{i=1}^{m} v_i x_{i0}}$$

Subject to:

$$\max h_0 = \frac{\Sigma_{r=1}^{s} u_r y_{r0}}{\Sigma_{i=1}^{m} v_i x_{i0}} \leq 1,$$

$$j = 1, 2, \ldots . n; \qquad u_r, v_i \geq 0 \qquad r = 1, 2, \ldots s \qquad \& \quad i = 1, 2, \ldots m$$

J=1,2…n stands for the DMUs, y for outputs and x for inputs. It is assumed that there are r=1,2…s different outputs and i=1,2…m different inputs. Each output and input has its own vector of weights represented by u and v respectively. DEA has thus the aim of maximizing the weighted sum of outputs in relation to the weighted sum of inputs. As this paper is interested in minimizing inputs rather than maximizing outputs, a revised model first developed by Banker, Charnes and Cooper, in 1984, called BCC model, is used:

$$\theta_B = \min \theta,$$

Subject to:

$$\sum_{j=1}^{n} x_{ij}\lambda_j \leq \theta x_{ij_0}, i = 1,2,\ldots p$$

$$\sum_{j=1}^{n} y_{rj}\lambda_j \geq y_{rj_0}, where\ r = 1,2,\ldots q$$

$$\sum_{k=1}^{n} \lambda_k = 1$$

$\lambda_k \geq 0$, such that k = 1,2,…,n

If there are non-discretionary input variables in an input-oriented DEA model, then some restrictions can be added such that: $\sum_{j=1}^{n} x_{ij}\lambda_j \leq x_{ij_0}$, $i \in ND$ where ND denotes non-discretionary, i.e. uncontrollable input variables (Angulo-Meza, et al., 2016). In this paper, however, all four input variables are assumed to be discretionary and affect the efficiency value θ. Therefore, this restriction is not added.

An important aspect to be taken into consideration is that there might be DMUs close to the boundary that are relatively efficient but still have a small distance to the frontier, i.e. non-zero slacks; input excesses $s_i^- \neq 0$ and/or output shortfalls $s_r^+ \neq 0$. Those DMUs are said to be weakly efficient. The DMUs with θ* = 1 and non-zero slacks are said to be weakly efficient while DMUs with θ* = 1 and $s_r^+ = s_i^- = 0$ are said to be strictly efficient. In order to get rid of the problem with slacks, the BCC model proposes to take the slacks to their maximal values, such that:

$$\max \sum_{i=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+$$

Subject to:

$$\sum_{j=1}^{n} x_{ij}\lambda_j + s_i^- \leq \theta x_{ij_0}, i = 1,2,\ldots,p$$

$$\sum_{j=1}^{n} y_{rj}\lambda_j + s_r^+ \geq y_{rj_0}, where\ r = 1,2,\ldots q$$

$$\sum_{k=1}^{n} \lambda_k = 1$$

$$\lambda_k \geq 0, \qquad k = 1,2,.., n$$

$$s_i^- \geq 0, \qquad i = 1,2,\ldots, p$$

$$s_r^+ \geq 0, \qquad r = 1,2,\ldots, q$$

The resulting problem that should be solved, based on the two steps above, will therefore be:

$$\text{mix } \theta - \varepsilon(\sum_{i=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+)$$

Subject to:

$$\sum_{j=1}^{n} x_{ij}\lambda_j + s_i^- \leq \theta x_{ij_0}, i = 1,2, \ldots, p$$

$$\sum_{j=1}^{n} y_{rj}\lambda_j + s_r^+ \geq y_{rj_0}, där\ r = 1,2, \ldots q$$

$$\sum_{k=1}^{n} \lambda_k = 1$$

$$\lambda_k \geq 0, \qquad k = 1,2,.., n$$

$$s_i^- \geq 0, \qquad i = 1,2,\ldots, p$$

$$s_r^+ \geq 0, \qquad r = 1,2,\ldots, q$$

DEA has the requirement that the variables are uniform, so that all DMUs perceive them in the same manner and value them the same way. This means that for example, a cost of 1000 is given exactly the same value across DMUs. Also, the preferences of the DMUs concerning the variables should be uniform so that if minimization of a specific input variable is more desired than that of another input variable, then that perception should prevail across all DMUs. If one county council values staff- and service-related costs as more important than material costs, while other county councils do the opposite, the difference in perception will not be captured by the DEA. This can be problematic in real life, especially when it comes to the difference in wages across counties and also differences in rental charges between densely and sparsely populated areas.

A DEA model can be solved in Excel either with Simplex Linear Programming (LP) or Non-linear Generalized Reduced Gradients (GRG). A non-linear problem can have more than one possible region, or a collection of similar values for decision making, where all requirements are fulfilled. Within each possible region, there can be more than one top concerning maximization problem or more than one bottoms in relation to minimization problem. There can be false tops or bottoms, which are known as saddle points. Taking these properties into account, non-linear optimal solutions give few guarantees (solver.com). In this thesis, both models will be run and compared but attention will be given to the risks for false optimal points by the non-linear model.

2.5 Data collection

This thesis is delimited to the somatic specialized healthcare and therefore all data that have been used are about the specialized somatic care, both inpatient and outpatient care. The specialized somatic care is provided almost exclusively at hospitals, but in some parts of Sweden some medical teams have been set up to visit patients at home and prevent non-necessary admissions to hospitals. One such team is *Närsjukvårdsteamet i Västra Skaraborg* that has helped decrease hospital admissions in western part of Skaraborg within the county of Västra Götaland. The team includes representatives from both hospital, primary care and the municipalities where the enrolled, often elders with multiple diseases, reside. The national enquiry SOU 2016:2 has recommended more such teams across the country and some new ones have been established in Västra Götaland in order to decrease the flow of patients to the inpatient wards. However such nascent projects have not been taken into consideration and data have not collected on them in this paper, but it should be mentioned that their unequal presence in the counties can affect the production of specialized somatic care unequally.

For data collection, statistical databases of SKL and Socialstyrelsen have been used in order to extract desired data. From SKL, data have been extracted about the economy and production of the counties while from Socialstyrelsen data have been extracted about the casemix-adjusted number of inpatient somatic episodes of care. The casemix-adjusted number of episodes of care contains only somatic care so Major Diagnosis Categories (MDCs) 19-20 that contain psychiatric care are excluded. SKL has both economic and production variables separately for the somatic and psychiatric care respectively so there has not been any need for exclusion as only the data for somatic care has been handled. The reason behind taking only somatic care, rather than all healthcare, is that psychiatric care is very individual and much harder than somatic care to forecast demands for. The other output variable, concerning somatic outpatient care, has been retrieved from SKL's production reports and then been converted to DRG equivalents based on average weight calculated in an SKL report for 2015. All input variables have been retrieved from SKL's database economy database where costs are given in terms of millions of Swedish Kronor (SEK).

3. Results

3.1 Background and preconditions

In order to compare the counties in terms of efficiency, I have collected data for the years 2006, 2008, 2010, 2012, 2014 and 2015 from the national umbrella organization of Swedish counties and municipalities (SKL) and the national board of health and welfare (Socialstyrelsen). The reason behind choosing those years is that there were no comparable and reliable data on the counties' healthcare production and economy from earlier years than 2006. Data on input variables are retrieved from SKL's statistical tables on healthcare production and financial performances while data on one of the two output variables, casemix-adjusted inpatient episodes of somatic care, has been retrieved from Socialstyrelsen's database because Socialstyrelsen is the authority that is responsible for healthcare and for developing and promoting NordDRG.

The Swedish healthcare system is decentralized with 21 independent counties responsible for most of the healthcare and 290 municipalities responsible for care of the elderly people since a legislative reform in 1992 called "Ädel-reformen" (the Noble Reform). As not so many other countries have that distinction, international comparisons of healthcare expenditures and costs sometimes give false impressions. Since Ädel-reformen, Swedish healthcare has gone through significant changes and development phases. The number of hospital beds have been more than halved (Appendix 1) and average length of stay has decreased from 27,6 days in 1990 to 5.4 days in 2016 (Socialstyrelsen, 2017). However, the average length of stay in 1990 included geriatric care so the just comparison would be from 1995-1996 forward. Between 1996 and 2016, the average length of stay decreased from 7.6 to 5.4 days, which is a 29% reduction (Socialstyrelsen, 2002 & 2016). Such a dramatic change should have resulted into cost reduction and efficiency gains, which really didn't happen. One of the reasons is that at the same time the number of physicians per 1000 inhabitants increased by almost 30% between 1995 and 2011 (appendix 2) so one can argue if it can be interpreted as more doctors were producing less healthcare.

The results of the models used in this thesis are about specialized somatic care. Swedish hospitals where specialized somatic care is provided are mainly divided into three categories:

- *University hospitals* consisting of 7 large hospitals or hospital groups where highly specialized care is provided. Those hospitals are: *Akademiska university hospital* in Uppsala county, *Karolinska university hospital* in Stockholm county, *Linköping* *university hospital* in Östergötland county, *Sahlgrenska university hospital* in Västra Götaland county, *Skåne university hospital* in Skåne county, *Umeå university hospital* in Västerbotten county and *Örebro university hospital* in Örebro county.

- *County hospitals*, around 20 middle-sized hospitals with emergency wards
- *County parts hospitals,* the smallest hospitals, mostly without emergency care. The number of this form of hospitals is around 40.

For provision of highly specialized care, Sweden is administratively divided into 6 healthcare regions (Appendix 3). 5 of the regions have one university hospital each, while one, Uppsala-Örebro healthcare region, has 2 university hospitals.

As there is difference in level of integration and cooperation among the healthcare regions, the national enquirer for division of Sweden into regions proposed a total elimination of smaller counties and their full integration into the 6 healthcare regions. That would mean that those regions would be responsible for not only highly specialized care provided at university hospitals but also all healthcare and other tasks currently held by the individual counties. The result would become that the country no longer consisted of 21 independent counties but rather 6 regions (Dagens Medicin, 2015). The reason was given that the current fully integrated big regions, Stockholm, Skåne and Västra Götaland, have advantages over the small counties with loose cooperation for healthcare within the framework of healthcare regions, in terms of sophisticated administrative resources and knowledge platforms at both regional and national discussions over priorities (SOU 2016:48, p. 17). Efficiency, beside potential for competition and closer integration, was given as one of the major reasons behind establishment of big regions out of the small counties (ibid. p. 84).

Depending on the type of hospitals a county owns and/or operates, the average DRG-points per county differ. Counties with university hospitals where highly specialized care is provided have on average higher DRG-points per episode of care than counties without university hospitals. They also have higher number of patients from other counties so their share of sold healthcare is higher. However, it is important to note that some smaller hospitals specialized on specific disease types can have high average DRG-points as those care types demand high level of competence and significant amount of resources, not least sophisticated medical technology. DRG, NordDRG in Sweden, is based on actual data on cost per patient (KPP) collected by SKL from the counties and the weight 1.00 which is the national average of all diagnoses corresponds a monetary value revised annually. For year 2017 the value is 51420 SEK (Socialstyrelsen, 2017).

For each of the counties in this thesis, the average inpatient DRG weight is calculated by summarizing its inpatient episodes of care with their corresponding DRG-weights and dividing them on the total number of episodes of car. For outpatient care, the number of care contacts have been multiplied to the national average 0.0624 for 2015. The formula for calculation of casemix-adjusted DRG weight in inpatient care is:

$$Ij \ = \frac{\sum_{i=1}^{n} (\ w_i \ N_{ij})}{N_j}$$

Where j= county j=1,2,….20

I_j = casemix for county j

i = NordDRG i where i=1,2,…n

N_j = number of somatic inpatient episodes of care

For both output variables to be comparable, I have converted the outpatient healthcare contacts/visits to casemix-adjusted DRG points. The national board of health and welfare has comprehensive data on DRG in inpatient care but limited when it comes to outpatient care. Therefore I have used their national average DRG-weight of 0.0624 per visit in 2015 and applied it to all years and all counties. It might not be the best way to do it but a better alternative was not available. Nevertheless, the difficult cases almost always lead to admission into the inpatient care so the main differences in difficulty of the cases are present in inpatient care while outpatient care is assumed to be quite similar across counties in the country. Therefore, using the national average for conversion of visits to DRG-points may not be far from reality.

3.2 Model A (first session): 1 output and 5 input variables

The results of the first session with 1 output and 5 input variables are in table 3. As can be seen, only one county, i.e. Stockholm, is on the efficiency frontier every year, with full efficiency as there is no slack. *Västerbotten* is on the efficiency frontier all years but has a small slack in 2014 that is invisible in the table but can be witnessed ones the number of decimals are increased. That means that *Västerbotten* is weakly efficient in 2014 but fully efficient in all other years. *Sörmland* has some small slacks in 2008, 2014 and 2015 making it weakly efficient while Kalmar has the same situation in 2008 and 2015. For most part, there seem to be a trend in the sense that the counties in the northern part of Sweden; *Dalarna, Gävleborg, Jämtland, Västernorrland* and *Norrbotten,* with huge land areas but small populations, have relatively low efficiency in producing somatic inpatient care, in almost all studied years. The only exception is *Västerbotten* which has a university hospital and provides most of the highly specialized care for the population in northern half of the country. As the relative efficiency score for each of the counties does not deviate so much from year to year, it can be taken as a proof for DEA being a robust comparison method.

Although not crystal clear, the counties with university hospitals and thus responsibility for highly specialized care tend to perform better than average in terms of relative efficiency. One reason can be that in this session, only the specialized somatic inpatient care is included as output variable so these counties that produce a lot of specialized and highly specialized somatic care logically get higher DRG-points per episode of care and thus have high production numbers in relation to their costs.

Relative efficiency values with 1 output and 5 input variables

DMU Order	County	2006	2008	2010	2012	2014	2015
1	Stockholm	1.00	1.00	1.00	1.00	1.00	1.00
2	Uppsala	1.00	1.00	1.00	0,75	0,79	1.00
3	Sörmland	0,99	1.00	1.00	1.00	1.00	1.00
4	Östergötland	0,90	0,97	0,87	0,85	0,90	0,89
5	Jönköping	1.00	0,95	0,96	0,95	1.00	1.00
6	Kronoberg	0,84	0,79	0,82	0,76	0,87	0,85
7	Kalmar	1.00	1.00	0,98	1.00	1.00	1.00
8	Blekinge	0,86	0,82	0,95	0,90	0,81	0,78
9	Skåne	0,80	0,86	0,99	1.00	1.00	1.00
10	Halland	1.00	1.00	1.00	1.00	1.00	0,79
11	Västra Götaland	1.00	1.00	1.00	1.00	0,98	0,98
12	Värmland	0,87	0,84	0,81	0,86	0,80	0,84
13	Örebro	1.00	1.00	1.00	1.00	1.00	0,95
14	Västmanland	0,85	0,93	0,77	0,85	0,69	0,71
15	Dalarna	0,94	0,87	0,86	0,89	0,77	0,73
16	Gävleborg	0,88	0,83	0,86	0,90	0,86	0,84
17	Västernorrland	0,75	0,74	0,66	0,75	0,71	0,66
18	Jämtland	0,96	0,94	0,89	0,85	0,93	0,85
19	Västerbotten	1.00	1.00	1.00	1.00	1.00	1.00
20	Norrbotten	0,78	0,80	0,78	0,90	0,73	0,73

Table 3: relative efficiency scores through DEA for Swedish counties, 2006-2015

In order to minimize the risk of giving advantage to inpatient-intensive counties, it is very interesting to compare this model with the model in the second session where both inpatient and outpatient somatic healthcare productions are included. Any disadvantage that smaller counties without university hospitals might have in Model A is eliminated in Model B.

A closer analysis shows that there is a weak correlation between the counties' service-related costs as share of their total costs on one hand and their placement in efficiency frontline on the other hand. Because service-related costs in absolute terms make up a small portion of the total costs, almost 3%, I suspect that DEA gives unproportionately high weight to this input variable. The reason can be that DEA interprets the variables with small values as very important for the production to take place, such as saffron in a saffron bun. In order to prevent such an unproportionate high weight given to service-related costs, I have added this input variable to staff costs in order to make a new aggregated variable *staff- and service-related costs*. The reasoning is that service-related costs also mostly consist of employee-related costs. As a result of this, there are four input variables left in the new revised model:

- Staff and service-related costs,
- Material costs,
- Internal costs, and
- Costs for purchased healthcare from other providers

For the outpatient care, the somatic healthcare production is measured in terms of care contacts, instead of episodes of care. Healthcare contacts can be either physical visits at receptions, visits by healthcare staff at the patients' homes or non-physical contacts per telephone or internet. They can also consist of visits to single care-givers or group visits. When it comes to categorizing of outpatient care contacts by healthcare professional groups, they are mostly divided between *visits to physicians* and *visits to care-givers other than physicians*, in which *visits to nurses* dominate. According to a calculation by SKL, the relative cost of a visit to other professions than physicians is about 40% of a visit to a physician (SKL, 2015). As counties in Sweden are quite independent in structuring their healthcare provision, the division of visits between the above mentioned professional groups can differ significantly between the counties, i.e. DMUs. This model may miss to capture any efficiency derived from a specific type of contacts.

As the production of inpatient somatic care is casemix-adjusted with the help of Diagnosis-Related Groups, DRGs, I convert even the other output variable measuring healthcare production in outpatient care to DRG-equivalent values so that the two variables have the same scale. Otherwise, the short outpatient visits rending into much bigger number of visits in total might be overestimated in comparison to inpatient episodes of care. The conversion has been based on the Report *DRG statistics 2015* by SKL, where the average outpatient healthcare contact is given a value equivalent of 0.0624 DRG points. That means that on average, on inpatient episode of care is about 16 times more resource intensive than an outpatient healthcare contact. For other years than 2015, no such a DRG equivalent value could be found, therefore that same value of 0.0624 has been applied to all other years; 2006, 2008, 2010, 2012, 2014 and 2015, assuming that on average the bundles of outpatient care contacts in all counties are the same.

3.3 Model B (Second session): 2 output and 4 input variables

Results from the new DEA model, in table 4, with 2 output and 4 input variables show that most of the counties have been on or very close to the efficiency frontier, between 2006 and 2015. It also shows that many counties that had been ineffective in the beginning of the measurement period have got improved relative efficiency scores and moved closer to the frontier. In 2006 and 2008 the number of relatively inefficient counties was 11, which means that 9 were on the efficiency frontier. In 2014 and 2015 that had reversed so that 8 were relatively inefficient and 12 were efficient and on the efficiency frontier.

Relative efficiency scores for counties, with 4 input and 2 output variables							
DMU order	**County**	**2006**	**2008**	**2010**	**2012**	**2014**	**2015**
1	**Stockholm**	1.00	1.00	1.00	1.00	1.00	1.00
2	**Uppsala**	1.00	1.00	1.00	0,79	0,80	1.00
3	**Sörmland**	0,94	1.00	1.00	1.00	1.00	1.00
4	**Östergötland**	0,91	1.00	0,93	0,96	0,91	0,93
5	**Jönköping**	1.00	0,94	0,95	0,91	1.00	1.00
6	**Kronoberg**	1.00	0,98	0,94	0,88	0,92	0,92
7	**Kalmar**	1.00	1.00	1.00	1.00	1.00	1.00
8	**Blekinge**	0,94	0,93	1.00	0,91	0,94	0,95
9	**Skåne**	0,88	0,97	1.00	1.00	1.00	1.00
10	**Halland**	0,99	0,99	1.00	1.00	1.00	1.00
11	**Västra Götaland**	1.00	1.00	1.00	1.00	1.00	1.00
12	**Värmland**	0,88	0,91	0,88	1.00	1.00	1.00
13	**Örebro**	1.00	1.00	1.00	1.00	1.00	1.00
14	**Västmanland**	1.00	1.00	1.00	1.00	1.00	1.00
15	**Dalarna**	0,79	0,78	0,80	0,84	0,82	0,82
16	**Gävleborg**	0,88	0,80	0,85	0,99	0,96	1.00
17	**Västernorrland**	0,76	0,78	0,84	0,89	0,98	0,90
18	**Jämtland**	1.00	0,97	0,96	0,91	1.00	0,92
19	**Västerbotten**	1.00	1.00	1.00	1.00	1.00	1.00
20	**Norrbotten**	0,76	0,78	0,80	0,87	0,74	0,80

Table 4: Relative efficiency scores by DEA, of Swedish counties, 2006-2015

The results in table 4 demonstrate that northern counties, except for Västerbotten with a university hospital, have all problem with inefficiency in producing specialized somatic healthcare in all the measured years. Among the relatively smaller counties, of which only Örebro has university hospital, Sörmland and Kalmar show high efficiency scores. For Uppsala, the low efficiency scores in 2012 and 2014 are mostly caused by clearly increased internal costs. The results deviate from the measurement of costs per DRG point when all the input variables are summed without weighting and their sum is divided on sum of aggregated DRG points for somatic inpatient and somatic outpatient care. The cost per produced DRG point in such an unweighted calculation can be seen in diagram 4, where on average, Dalarna has had the highest costs per produced DRG point while Stockholm comes at second place and Norrbotten on third.

The reason behind Stockholm and Skåne having efficiency score 1.00 and being on the efficiency frontier despite high costs per DRG point should be that they are relatively big counties that are in the high end of the production line where decreasing returns to scale is present. They perform at optimum for their position and no other county would have performed better in their place in order to become their reference DMUs. In the middle of the country, Värmland has had lower costs than the national average per produced DRG point while Västmanland has higher than national average. Despite that, Västmanland has been relatively more efficient than Värmland each year as Värmland has been relatively inefficient in 5 of the 6 studied years. This is the evidence for how the different weights to different input and output variables lead to unpredicted efficiency scores. Though, diagram 4 shows a certain level or correlation between costs per DRG point and efficiency score, not least for the smaller counties in norther Sweden, who have high costs and low efficiency.

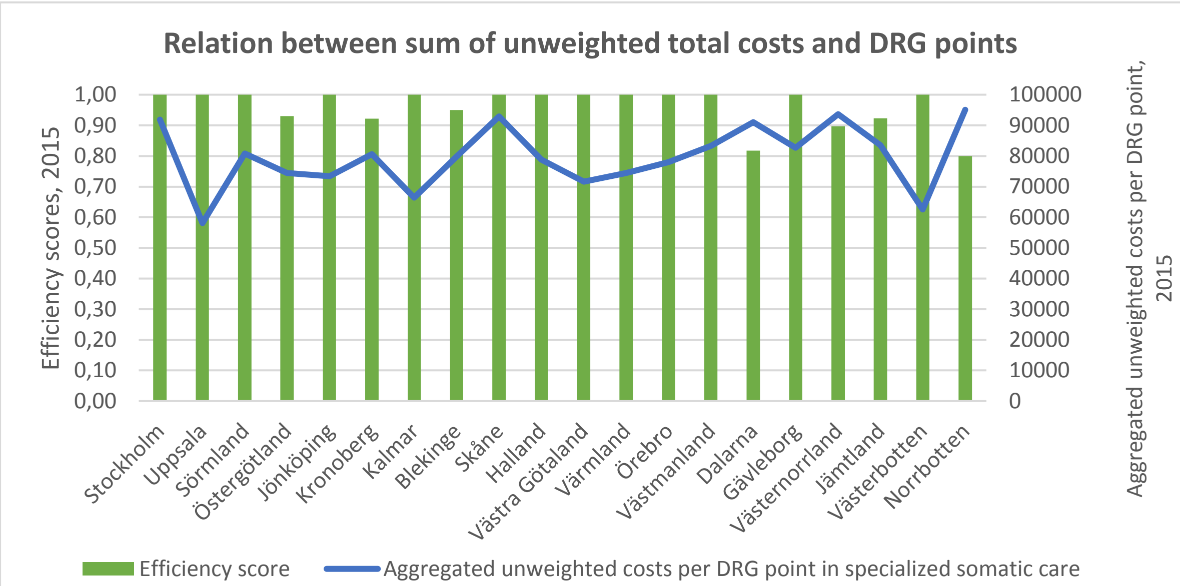


Diagram 4: Relation between efficiency score and aggregated unweighted costs per DRG point, 2015

The ratio of number of inpatient casemix-adjusted episodes of care per outpatient DRG equivalent healthcare contacts does not either seem to be correlated with the performance of the counties in the DEA efficiency measurement. An analysis of 2014 gives the following non-correlated diagram 5.

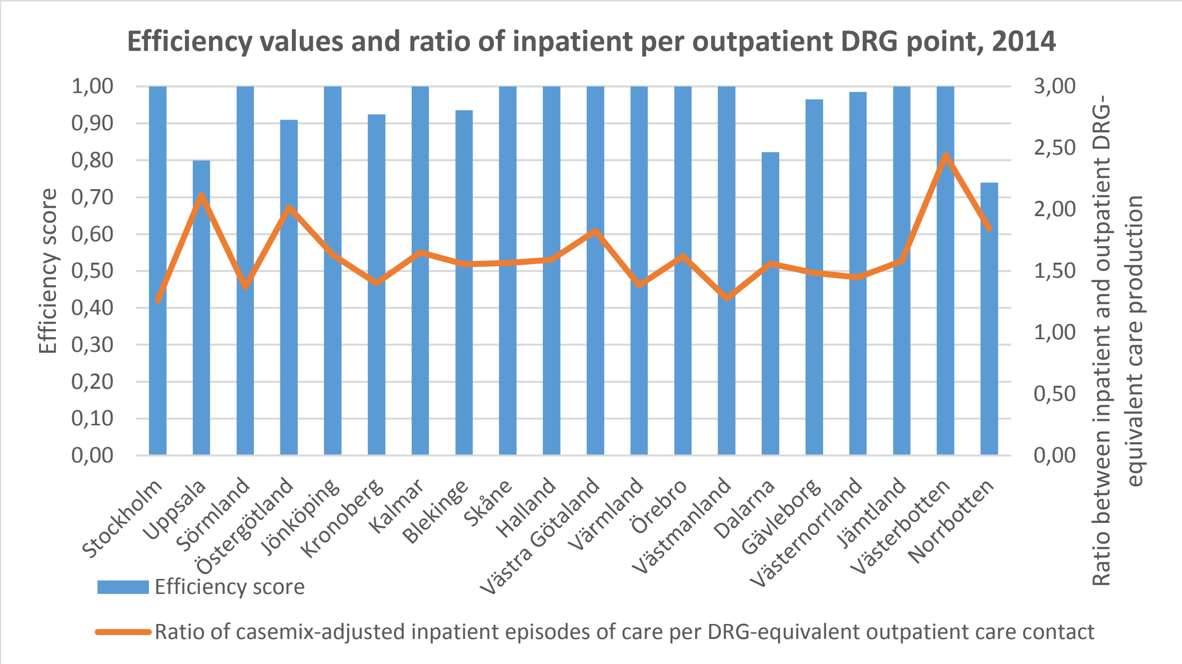


Diagram 5: Efficiency score and ratio of inpatient and outpatient healthcare production, 2014

One of the reasons behind changes in efficiency scores between the two DEA models, by borrowing words from Trick 2011, is that DEA assumes that the inputs and outputs have been correctly identified. Usually, as the number of inputs and outputs increase, more DMUs tend to get an efficiency rating of 1 as they become too specialized to be evaluated with respect to other units. On the other hand, if there are too few inputs and outputs, more DMUs tend to be comparable. In any study, it is important to focus on correctly specifying inputs and output (Trick, 2011). In model A there was 1 output variable which was easier to compare the DMUs upon and thus the efficiency scores were differing more. In model 2, as the number of output variables increased the weight shares between the two variables became of importance and it became more difficult for the model to compare the target DMU with respect to other DMUs and thus more DMUs got closer to or on the efficiency frontier.

The fact that the ratio between the inpatient and outpatient care does not predict the of the counties' placements in terms of efficiency can be regarded as a proof for robustness of the weighting mechanisms within the DEA model. Nevertheless, it is important to take into consideration the conversion of outpatient contacts to DRG equivalent values because without that conversion the inpatient and outpatient values would be in quite different scales.

When it comes to relation between efficiency score and input variables' share of total costs, there seems to be no covariation. The only input variable that indicates some form of covariation is "internal costs" as share of total costs. The results for 2015 are as in diagram 6.

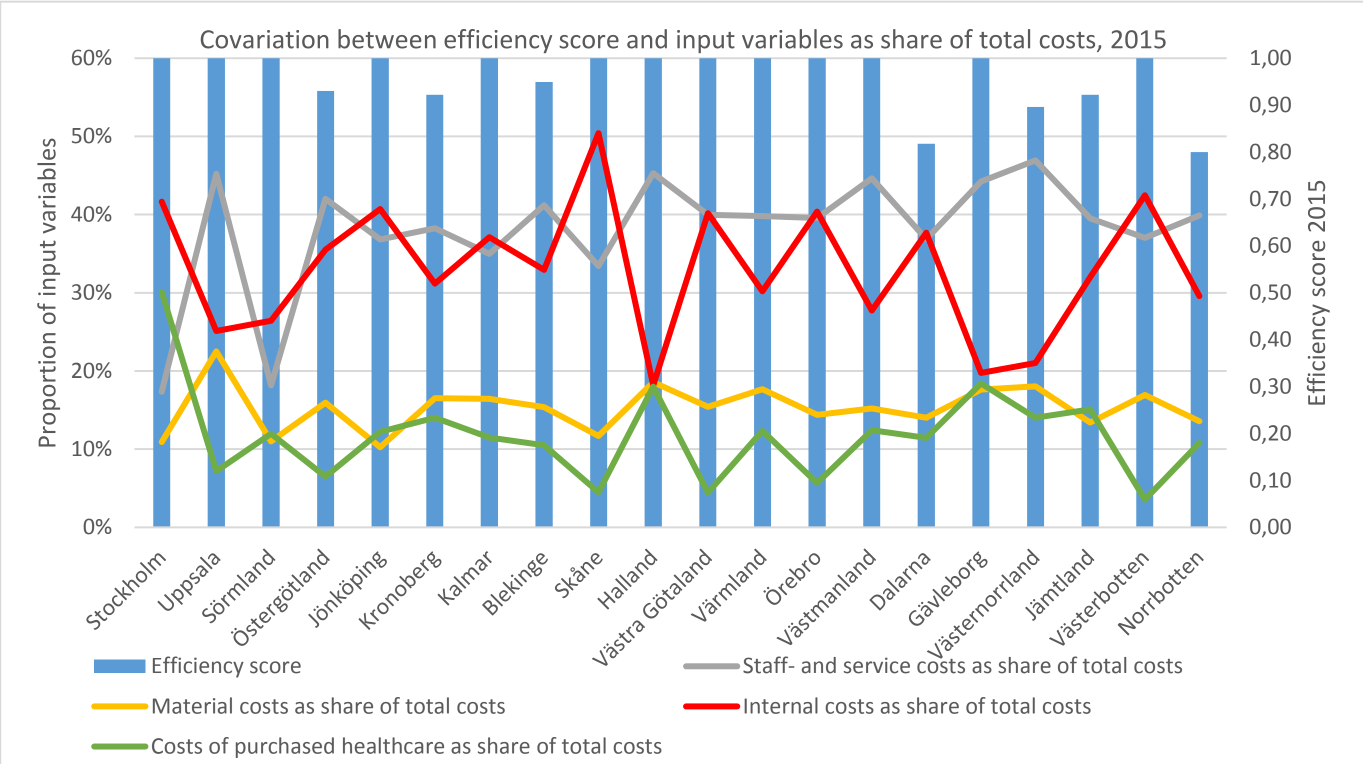


Diagram 6: Illustration of covariation between efficiency score and proportion of input variables, 2015

Even for other studied years, the results are similar and do not indicate existence of covariation between efficiency score and input variables as share of total costs. The lack of clear covariation between the efficiency score and input variables can be positive as it does not indicates that none of the variables is decisive for the final results of the entire model.

3.4 Reference DMUs

The counties that have optimal efficiency are at the efficiency frontier and have efficiency score θ=1.00. For these counties λ_j=1.00 in relation to their own vector of inputs and vector of outputs while λ_i=0 in relation to other DMU_i where i=1,2,…,n. It means that they are efficient in comparison to other DMUs in the model and do not need to follow the production models of other DMUs in order to become more efficient. The counties that have θ<1.00 are under the efficiency frontier, and in order to move to the efficiency frontier, they need to adapt their blend of input variables according to another or many other DMUs' schemes. A relatively inefficient county may get either one or more reference DMUs to try to imitate in order to become efficient and move to the efficiency frontier. The efficiency scores for each of the individual counties in relation to other counties for the DEA model for 2015 can be seen in the table below. It is distinguishable that the counties that are at the efficiency frontier have efficiency scores 1.00 and thus do not have any other counties as reference DMUs in order to ameliorate their efficiency and move to the frontier. The inefficient counties all get one or more efficient counties as reference DMUs to follow input and output mixture strategies of in order to become efficient and move to the efficiency frontier. Geographical abbreviations are described in Appendix 4.

Refe-rence	λ SLL	λ ULL	λ LS	λ LiÖ	λ JLL	λ KLL	λ LKL	λ LB	λ RS	λ RH	λ VGR	λ LIV	λ RÖL	λ RV	λ LD	λ GLL	λ RVN	λ RJH	λ VLL	λ RNB
SLL	1.00																			
ULL		1.00		0,30													0,09	0,05		0,19
LS			1.00																	
LiÖ																				
JLL				0,31	1.00			0,02							0,29			0,21		0,36
KLL																				
LKL						0,22	1.00	0,16							0,55					
LB																				
RS									1.00											
RH						0,06				1.00							0,40	0,07		0,05
VGR				0,07				0,02			1.00									
LIV						0,21						1.00					0,17			
RÖL													1.00							
RV						0,10		0,31						1.00	0,09		0,02			
LD																				
GLL																1.00				
RVN																				
RJH																				
VLL				0,41															1.00	
RNB																				

Table 5: Reference sets for efficient and inefficient counties, 2015

The production of somatic specialized healthcare follows a linear equation line, with variable returns to scale. The horizontal axis represents the vector of inputs while the vertical axis shows the vectors of outputs. The smaller counties in terms of population and healthcare production are coalesced in the bottom left corner with relatively low costs and low number of produced DRG points. Stockholm, which is Sweden's biggest county in terms of population with more than 20% of the country's population living there, is alone at the top right corner of the line. Except for Västra Götaland and Skåne who come at 2nd and 3rd places respectively in terms of population (Appendix 5), the other counties have small differences.

Referencing method of DMUs is based on the idea of getting an inefficient DMU to the efficiency frontier with as little change and effort as possible. Therefore, as it can be witnessed in the diagram 5, none of the relatively inefficient DMUs have Stockholm as reference DMU due to the large distance between the inefficient DMU in question and Stockholm in terms of production and costs. The reference DMUs are the efficient DMUs nearest to the inefficient target DMU. On the contrary, Jönköping and Halland are the two efficient DMUs that lie quite in the middle of the 20 DMUs used in the study, which means that they have short distances to most of the other DMUs. Based on that, these two DMUs are the individually most frequent referenced DMUs that inefficient DMUs are recommended to imitate.

The goal by DEA model is to take a specific DMU, that is relatively inefficient, and find reference DMUs that the DMU in question should strive to resemble in terms of input utilization and/or output production. Östergötland County, which in 2015 was among the relatively inefficient counties, had the following reference DMUs to look for inspiration from.

Variable Name	Value	Lower Limit	Target Results	Higher limit	Target Results
Stockholm λ Östergötland	0,00	0,00	0,93	0,00	0,93
Uppsala λ Östergötland	0,30	0,30	0,93	0,30	0,93
Sörmland λ Östergötland	0,00	0,00	0,93	0,00	0,93
Östergötland λ Östergötland	0,00	0,00	0,93	0,00	0,93
Jönköping λ Östergötland	0,31	0,31	0,93	0,31	0,93
Kronoberg λ Östergötland	0,00	0,00	0,93	0,00	0,93
Kalmar λ Östergötland	0,00	0,00	0,93	0,00	0,93
Blekinge λ Östergötland	0,00	0,00	0,93	0,00	0,93
Skåne λ Östergötland	0,00	0,00	0,93	0,00	0,93
Halland λ Östergötland	0,00	0,00	0,93	0,00	0,93
Västra Götaland λ Östergötland	0,07	0,07	0,93	0,07	0,93
Värmland λ Östergötland	0,00	0,00	0,93	0,00	0,93
Örebro λ Östergötland	0,00	0,00	0,93	0,00	0,93
Västmanland λ Östergötland	0,00	0,00	0,93	0,00	0,93
Dalarna λ Östergötland	0,00	0,00	0,93	0,00	0,93
Gävleborg λ Östergötland	0,00	0,00	0,93	0,00	0,93
Västernorrland λ Östergötland	0,00	0,00	0,93	0,00	0,93
Jämtland λ Östergötland	0,00	0,00	0,93	0,00	0,93
Västerbotten λ Östergötland	0,40	0,40	0,93	0,40	0,93
Norrbotten λ Östergötland	0,00	0,00	0,93	0,00	0,93
Efficiency score for Östergötland (θ)	**0,93**	**0,93**	**0,93**	**0,93**	**0,93**

Table 6: Reference set for Östergötland County in 2015

As the production sets within each of the counties change over time and the relative size of each one changes likewise, the reference DMUs for the inefficient target DMUs also change.

Due to that awareness, one of the purposes of this paper has been to visualize changes over time and come to conclusions on whether the changes have been significant. Therefore a comparison between the starting year, 2006, and the last year of study, 2015, has been done. The reference sets for the DMUs in 2015 were visualized in table 5 and the corresponding results for 2006 are in table 7 below.

Refer-ence	λ *SLL*	λ *ULL*	λ *LS*	λ *LiÖ*	λ *JLL*	λ KLL	λ LKL	λ LB	λ RS	λ RH	λ VGR	λ LIV	λ RÖL	λ RV	λ LD	λ GLL	λ RVN	λ RJH	λ VLL	λ RNB
SLL	*1.00*		*0,03*			0,00	0,00			0,04		0,00			0,02					
ULL		*1.00*		*0,93*	*0,00*	0,00	0,00	0,15	2,53	0,22	0,00	0,33		0,00		0,09	0,13	0,06		0,32
LS																				
LiÖ																				
JLL					*1.00*		0,00					0,03				0,51	0,13	0,23		0,04
KLL			0,62	0,18		1.00		0,12				0,51			0,24	0,21	0,61			
LKL							1.00			0,25										
LB																				
RS																				
RH																				
VGR											1.00					0,01				
LIV																				
RÖL					0,00			0,24	0,03				1.00				0,00	0,04		0,25
RV		0,00												1.00						
LD																				
GLL																				
RVN																				
RJH																				
VLL	0,00		0,17	0,16					1,36	0,11					0,50		0,11		1.00	
RNB																				

Table 7: Reference sets for efficient and inefficient counties in 2006

As can be seen in table 7, there are 9 counties with efficiency score 1.00 but 3 of them also have small reference values to other counties so they are weakly efficient. That means that only 6 counties are efficient without any slacks.

A comparison between table 5, year 2015, and table 7, year 2006, shows that in 2006 it was Uppsala County (ULL) and Kronoberg County (KLL) that were the efficient counties that most inefficient counties were recommended to imitate in order to become efficient. In 2015, the two counties mostly suggested as reference DMUs were rather Jönköping County (JLL) and Halland Region (RH). However, ULL was reference DMU for four counties even in 2014 while JLL was reference DMU for 7 other counties in 2006. That means that as most of the counties have quite similar sizes the reference sets do not change much over time. DEA reference DMUs for other studied years; 2008, 2010, 2012 and 2014, are in Appendices 8-11. They all show the same patterns of referencing relatively inefficient DMUs to the efficient DMUs closest to them. As long as some counties maintain their places on the efficiency frontier, the inefficient DMUs in their vicinity will have them as reference DMUs. What can be learnt from it is that relatively inefficient counties should try to learn from efficient counties that are of their own size because their production conditions are comparable and similar. Their technological capabilities might also be similar or comparable.

3.5 Simplex Linear Programming vs Non-linear GRG

In this thesis, the Excel Solver has been the main software used in order to calculate the relative efficiency values of the counties. The data have been analyzed repeatedly with DEA. For two reasons, the optimization through Solver is run twice for each county in each year in order to see whether 1) The Simplex Linear Programming (LP) technique differs from the Non-linear Generalized Reduced Gradient (GRG), and 2) If the number of inputs and number of outputs significantly change the relative efficiency values of the counties. In model A, there were 5 input variables; staff costs, material costs, internal costs, service costs and cost for purchased healthcare from other counties, and one output variable; casemix-adjusted inpatient episodes of care. In model B, a new output variable, DRG-adjusted number of visits in outpatient care was added to the model while the number of inputs was reduced by one as service costs were included to staff costs so that they became one aggregated variable.

In model A with 1 output and 5 input variables, the efficiency scores for each DMU was calculated by both Simplex Linear Programming (LP) and Non-linear GRG techniques. The scores did not change, except for in a few cases when Non-linear GRG gave values above 1.00 for some efficient counties. That seemed illogical as there are constraints that restrict the efficiency scores to be between 0 and 1.00. Therefore, my conclusion was that the LP model is more robust than the non-linear GRG model. One reason is that the non-linear GRG model can wrongly take a local saddle point as global maximum or minimum. That problem is described in more detail in section 2.4. Due to that reasoning, the best DEA technique is Simplex Linear Programming (LP).

In the second session with the DEA model containing 2 output and 4 input variables, the deviation of Simplex LP-generated results from those of Non-linear GRG were more pronounced. The Non-linear GRG results changed for the same target DMUs between iterations without any changes made. Meanwhile the results generated from Simplex Linear Programming was stable over the course of iterations if no changes were made to the constraints and their contents. Therefore, the final results from the second model are all based on Simplex LP technique of the DEA model.

4. Discussion and conclusion

4.1 Analysis

The costs of healthcare have increased almost incessantly during the latest decades resulting into a lively debate in Sweden over potential inefficiency. Though, mostly it is Sweden as a country that is compared to other countries and there emerges a picture of decreasing number of hospital beds, decreasing length of stay and still the situation seem to be very problematic year after year. Those problems reemerge despite increasing number of doctors and nurses per 1000 persons both in absolute terms and relative to other countries. Based on that, a national enquiry was given the task to review the Swedish healthcare system and find potential areas for efficiency improvements. The enquiry has talked of Sweden having too much focus on hospitals and inpatient care while the primary care is very weak in international comparison. Therefore a transfer from hospital to health centers is proposed in order to prevent the healthcare costs from increasing further.

As Sweden has a decentralized healthcare system with 21 counties that are independent and fund their expenditures with taxes and governmental grants, inefficiency is hardly gained at once on national level. That comes only on local and regional levels and therefore a comparison between counties is vital. DEA is a technique that makes the comparison possible by treating the counties as Decision-Making Units (DMUs). The results in this thesis from DEA through Microsoft Excel's Solver add-in, have given input and output variables weights to reflect the variables' relative strength in explaining variance in production.

In DEA, the weights of the variables is of central importance. In this thesis, the efficiency scores do not have any consistent positive or negative correlation with any of the input variables. The one variable that gives impression of some form of covariation is "internal costs" as share of total costs but even that is not obvious. I interpret the absence of correlation between efficiency scores and any individual input variable as a proof for robustness of the model because it does not give unproportionately big weight to any of the variables. The absence of correlation also ensures that the efficiency scores are not vulnerable to changes in any of the inputs.

The optimal size of counties and hospitals have often been a debate issue as proponents and opponents of centralization raise different arguments. Proponents talk of economic efficiency through scale effects and "enough patient base" for a highly specialized and qualitative care while opponents talk about nearness and accessibility. Economy has become a focal area, not least after recent deregulations and privatizations in the healthcare sector. One more discussion point has become the dominance of the three biggest counties on national policy setting, which led to a special enquiry on reorganization of other smaller counties to three big ones so that the country would consist of six big regions. In that debate, a DEA-based efficiency comparison between the counties should be interesting.

The results in this thesis show that the bigger counties in general perform much better than the smaller ones in terms of efficiency scores. Stockholm and Västra Götaland which are the two biggest counties are on the frontier all six studied years while Skåne which is the third biggest county is on the frontier 4 of the six studied year. On the other hand, the sparsely populated counties in the northern part of Sweden perform consistently badly in terms of efficiency. The only exception is Västerbotten where the university hospital *Norrlands universitetssjukhus* is situated. Without the university hospital, it is probable that even Västerbotten would be among the inefficient counties.

In general, over the six studied years, counties with bigger population tend to be more efficient than those with smaller populations. One reason can be that the small counties do not have enough patient population and that some staff and material might be underutilized but it can also mean that the bigger counties with more stable financial status use the latest technologies which the smaller counties cannot afford. That was one of the main arguments behind the national enquiry that proposed geographical reformation of Sweden to fewer and bigger regions by pointing out scale advantages for the three biggest counties; Stockholm, Västra Götaland and Skåne. The eventual differences in technologies means that it is important to take into consideration that the efficiency scores demonstrate only relative and not absolute efficiency. Sherman and Zhu 2006 outlines that:

> When we focus on service organizations we generally cannot determine what the engineered, optimum or absolute efficient output-to-input ratio is. Consequently we cannot determine whether a service unit is absolutely efficient. We can, however, compare several service unit output-to-input ratios and determine that one unit is more or less efficient than another - benchmarking. The difference in efficiency will be due to the technology or production process used, how well that process is managed, and/or the scale or size of the unit.

The results in this thesis can be used as tools for learning from each other and perhaps imitation of the technologies used in the efficient counties by the relatively inefficient counties. Though, they are not enough to draw conclusions on whether a specific county is optimally efficient in comparison to its maximal capacity. If technologies used differ significantly, one can demand that those counties with better technologies should produce more than those with inferior technologies, subject to same cost patterns. In that case, the counties' actual production should be compared to their optimal production in order to conclude whether they are absolutely efficient or not. For that reason, a DEA-based comparison between hospitals with the same level of technology, e.g. university hospitals, would be a more certain approach.

The model and its variables are based on assumption of uniformity across DMUs, i.e. all contents of the variables are perceived and valued similarly across county councils. One issue not discussed or taken into account in this thesis is *price efficiency*, or lack thereof (Sherman & Zhu, 2006). As all my four input variables are expressed in monetary terms, SEK, rather than physical units such as number of physicians or number of beds, it does not capture any differences in price levels across counties. According to national Statistics from Statistics Sweden, there were apparent differences in average wage levels between the county councils in 2016. That can be seen in Appendix 6. Even the rental costs per square meters 2014 and 2015 differed significantly across the country, which can be witnessed in Appendix 7. Due to price differences, the results should be interpreted cautiously.

4.2 Shortages and debatable issues

The DEA has proven to be a quite usable technique in comparing some DMUs with multiple input and output variables. In this thesis, I have tried to take into consideration different aspects and sources of variation so I have run DEA models with different criteria in order to find out the Swedish counties that have relatively high efficiency in production of specialized somatic care so that they can be benchmarks for others. However, there have been restrictions that have hampered full analysis of the model.

One important aspect that can be problematic is that DMUs here consist of counties of different sizes. The counties are administrative and regional governmental bodies that, in a decentralized healthcare system such as Sweden's, have high level of independence. The strategies in terms of which input variables to focus on and which types of outputs that are most desirable can differ across the counties. Therefore the condition of uniformity in valuation of the variables across all DMUs might be questionable.

Another problem that arises is that each of the DMUs have different number of hospitals that operate separately and independently from each other. This becomes troublesome, especially considering the returns of scale which is depending on the size of a DMU. Stockholm which has more and bigger hospitals than e.g. Kronoberg becomes one unit while Kronoberg also becomes one unit. This means that the economies or diseconomies of scale present within each hospital is not totally mirrored in the bigger aggregated DMU unit that is sum of many different hospital units. In this sense, the results and relative efficiency scores could have been very different if the DMUs consisted of the individual hospitals rather than their respective county councils. This issue will be studied in a second study where I will have individual hospitals instead of counties as DMUs.

Except for the problems mentioned above, the DEA technique in this thesis has produced interesting results about the relative efficiency levels of the counties of Sweden in terms of production of somatic specialized healthcare. In the model with one output variable there was no need for weighting of outputs and thus there is no need to suspect that the weights are unrealistic. In the second model, where the number of outputs was increased to two, the relative weighting of the variables is important to consider. Because of the ambiguity between the two editions, their comparability may be questionable. However, as none of the input variables was correlated to efficiency scores, I find no reason to worry. The lack of correlation between inpatient/outpatient production ratio on one hand and efficiency score on the other hand also gives reassurances for the final results to be trustable.

4.3 Conclusion

Beside some data-based conclusion about the relative efficiency of the county councils in terms of provision of specialized somatic healthcare to the inhabitants, the purpose of the thesis has been to test whether Data Envelopment Analysis (DEA) is a reliable method to measure relative efficiency within the scope of healthcare. Due to time and resource shortages, it has not been possible to visit county councils or have direct contact with representatives in order to assemble their views. Therefore, the only data sources are some national organizations' statistical databases. As counties might have differences in collection procedures, not least due to different software programs in use, the data can be susceptible to quality shortcomings for optimal comparison.

In the beginning of the thesis, I had some pre-perceptions that the bigger counties are more efficient than the smaller ones. One of the reasons was that an essential part of the costs of the counties consists of fixed costs that every county has so the bigger counties get lower average costs as they produce more. However the assumption of variable returns to scale made me assume that the two or three biggest counties may have reached the state where the efficiency falls to lower than optimal level and thus the counties themselves fall below the efficiency frontier. The results show otherwise, and the reason can be that Sweden is relatively sparsely populated and even the biggest counties may not have reached that *suboptimal state*. If counties of a bigger country such as Germany or France were compared, such state could have been attained by some big counties. A comparison of healthcare systems in 30 European countries by Asandului et al. 2015 showed that Sweden had constant returns to scale while Germany and France had decreasing returns to scale, thus confirming my assumption. Though, important to mention that the assumption is based on resource allocation and planning from one central unit, rather than independent hospitals.

It is vital to notice that the output variables in this paper are not end-products, they are rather intermediary products. End-products are the wellbeing and health status of the people treated. Therefore, in terms of societal efficiency, a two-stage model would be more appropriate. Asandului et al. compared the efficiency of the healthcare systems in 30 European countries by having healthcare expenditures as input variables and self-estimated health status as output variable. The input variables they used were *number of hospital beds per 10000 inhabitants, number of physicians per 10000 inhabitants* and *Healthcare expenditures as share of GDP*. The output variables were *Life expectancy (years), Infant mortality rate* and *Health-adjusted life expectancy (HALE)*. Their results showed Sweden's healthcare system as one of the most efficient ones in Europe as Sweden was one of only 6 countries on the efficiency frontier, i.e. with efficiency score of 1.00. Denmark and Finland, which in Nordic hospital efficiency comparisons perform better than Sweden, were deemed as relatively inefficient (Asandului et al., 2014). One reason can be that *number of hospital beds* is translated into monetary terms by the DEA model the authors have used, so that Sweden which has the lowest number of beds per 10000 inhabitants gets advantage and countries such as Germany and Austria with high number of hospital beds per 10000 inhabitants get disadvantage in terms of efficiency.

As aggregated expenditures do not detail where the costs have been incurred, especially if they have been direct healthcare costs or costs related to prevention and public health, no quick conclusions can be drawn. Nevertheless, the results from Asandului et al.'s study appeases the worrying indications of inefficient hospitals in Sweden compared to other Nordic countries as concluded by Kittelsen et al. 2015 and notified by the special enquirer Göran Stiernstedt in the public enquiry SOU 2016:2 on healthcare efficiency in Sweden. It also means that Sweden might be very efficient in primary prevention, i.e. disease prevention and public health, while it is lagging behind in secondary prevention, i.e. treatment at health centers and hospitals. The current Swedish government has emphasized the focus on primary prevention by launching the public enquiry "Knowledge-based and equitable healthcare – preconditions for a learning healthcare sector SOU 2017:48".

An assumption in this paper has been that all counties on average have similar distribution of healthcare production over the medical fields; medicine, surgery and psychology. Any differences should be captured by the DRG-system which gives higher weight to more demanding areas. However, in reality, that might not be fulfilled as highly specialized areas are often centralized to some counties and hospital in order to have enough patient population to utilize the specialized staff and sophisticated equipments and thus be efficient in resource utilization. A DEA-based study by Adel Mohammed Al-Shayea 2011 on King Khalid University Hospital in Saudi Arabia that compared different departments showed apparent differences in efficiency between the departments (Al-Shayea, 2011). If one can draw parallels to Swedish hospitals, then a comparison on lower level between hospitals and medical fields is necessary for being able to draw robust conclusions. That is a topic for another DEA-based study in which hospitals or hospital departments are used as DMUs.

Due to lack of complete view over the technologies used at the hospitals whose production data are the basis for this thesis, I find it difficult to point of the source of inefficiencies at the relatively inefficient county councils. It is possible that some of the county councils in some years may have higher wages than national average or maybe have bought some equipments that cost a lot so that their internal costs increase temporarily, which I suspected to be the case for Uppsala in 2012 & 2014. In that case, the inefficiency is a price inefficiency that is temporary and should be worrisome.

If, because of their differences in sizes, the counties face different possible production levels in a sector with variable returns to scale, then it is important to compare a county with someone of the similar size. DEA in this thesis has reference DMUs close to the target DMUs so that they do not face the problem of scale inefficiency. Based on that notion, I find the results in this thesis reliable.

A continuation of the study and its results should focus on discerning the sources of differences in efficiency with the target of finding technical and allocative inefficiencies. For moving from inefficient state to the efficiency frontier, the inefficient county councils should try to address and improve their eventual technical and/or allocative efficiencies.

References

Books

Banker RD, Charnes A, Cooper WW (1984) Some models for estimating technical and scale efficiencies in data envelopment analysis. Management Science 30:1078–1092

Borjas, George J., 2010, Labour Economics – fifth edition, McGraw Hill Companies Inc. Printed in Singapore

Charnes, A; Cooper, W.W. & Rhodes, E., 1978, *Measuring the Efficiency of Decision Making Units*, European Journal of Operational Research, North-Holland Publishing Company

Connolly, Sara & Munro, Alistair, 1999, Economics of the Public Sector, Pearson Education Limited, Edinburgh Gate

Wen, Meilin, 2015, Uncertain Data Envelopment Analysis, Springer-Verlag Berlin Heidelberg

Articles and reports

Al-Shayea, Adel Mohammed, 2011, *Measuring Hospital's units Efficiency: A Data Envelopment Analysis Approach*, International Journal of Engineering & Technology IJET-IJENS Vol: 11 No: 06

Anell, Anders; Glenngård, Anna H & Merkur, Sherry, 2012, Sweden – Health System Review, Health Systems in Transition, Vol. 14, No. 5 2012, World Health Organization 2012, on behalf of the European Observatory on Health Systems and Policies

ANGULO-MEZA, Lidia; SOARES-DE MELLO, João Carlos Correia Baptista and FIGUEIREDO-GOMES-JUNIOR, Silvio. 2016, A Multiobjective Approach for Non-discretionary Variables in Data Envelopment Analysis, Dyna rev.fac.nac.minas [online]. 2016, vol.83, n.195, pp.9-15. ISSN 0012-7353., retrieved from: http://dx.doi.org/10.15446/dyna.v83n195.45396.

Asandului, Laura; Romanb, Monica & Fatulescua, Puiu; 2014, *The efficiency of healthcare systems in Europe: a Data Envelopment Analysis Approach*, Procedia Economics and Finance 10 (2014) 261 – 268

Björn Brorström, Hans-Olof Hagén, Eva Hagsten, Gustaf Kastberg, Birgitta Magnusson, Bo Malmberg och Richard Murray, 2006, *Mått på välfärdens tjänster – en antologi om produktivitet och effektivitet i kommunala verksamheter*, Finansdepartementet, Borgström, Agneta., 2007, Sweden has the fewest number of hospital beds in Europe ”*Sverige har lägst antal vårdplatser i Europa”,* Läkartidningen, retrieved 12 April 2017 from: http://www.lakartidningen.se/OldWebArticlePdf/6/6069/LKT0706s396_397.pdf

Development of Healthcare in 1990s "Hälso- och sjukvårdens utveckling under 1990-talet", 2007, Nätverken, retrieved from: http://natverken.se/media/7027/Norrbotten%20-%20H%C3%A4lso-%20och%20sjukv%C3%A5rdens%20utveckling%20under%2090-talet.pdf

Geographical Division Committee's final report ”Indelningskommitténs slutbetäkande”, SOU 2016:48, Government of Sweden, retrieved from: http://www.sou.gov.se/wp-content/uploads/2016/06/SOU-2016_48.pdf

Gerdtham, U-G., Rehnberg, C., Tambour, M., 1999, *The impact of internal markets on health care efficiency: Evidence from health care reforms in Sweden*, Centre for Health Economics, Stockholm School of Economics, Stockholm, Sweden, Working Paper Series in Economics and Finance, No 170

Hayes, Robert M, 2005, *Data Envelopment Analysis (DEA*, UCLA Department of Information Studies

Healthcare employees' union on the situation about childcare: *"Löpande band-tänk",* 2013, Mitt i, retrieved from: https://mitti.se/nyheter/sjukvard/ny-rapport-tuff-sommar-nar-bb-sophia-stangde/

Healthcare Expenditure and Financing, 2016, Organization for Economic Cooperation and Development (OECD): http://stats.oecd.org/index.aspx?DataSetCode=HEALTH_STAT

Kristensen, Troels; Olsen, Kim Rose & Kilsmark, Jannie, 2008, *Economies of scale and optimal size of hospitals: Empirical results for Danish public hospitals*, University of Southern Denmark – Syddansk Universitet, Health Economics Papers 2008:13

Many have unnecessary acute healthcare ”*Många söker onödig akutsjukvård"*, Sveriges Radio, 2011-09-08, retrieved from: http://sverigesradio.se/sida/artikel.aspx?programid=83&artikel=4684500

Marini G; Miraldo M., 2009, *Economies of scale and scope in the English hospital sector*. Discussion paper 2009/05, retrieved 6 June 2017 from: http://eprints.imperial.ac.uk/bitstream/10044/1/4202/1/Miraldo%202009-05.pdf

Medical Care Production and Cost, Horbachevsky Ternopil State Medical University, retrieved 11 June 2017 from: http://intranet.tdmu.edu.ua/data/kafedra/internal/magistr/classes_stud/English/First%20year/Health%20Economics%20and%20marketing%20of%20medical%20services/07.%20Medical%20Care%20Production%20and%20Costs.htm

OEE Coach, 2017, *The relationship between efficiency, effectiveness and productivity*, retrieved in 5th July 2017 from: http://oeecoach.com/efficiency-effectiveness-productivity/

Sherman, H.D., Zhu, J., 2006, *Improving Service Performance using Data Envelopment Analysis (DEA),*

Socialstyrelsen, Rapport 2015, Waiting time and patient flows at acute care receptions "*Väntetider och patientflöden på akutmottagningar",* retrieved from: https://www.socialstyrelsen.se/Lists/Artikelkatalog/Attachments/19990/2015-12-11.pdf

Solver, *Standard Excel Solver Limitation - limitations of nonlinear optimization,* Frontline Solvers, retrieved 8 June 2017 from: http://www.solver.com/standard-excel-solver-limitations-nonlinear-optimization

Statistics Sweden, 2017, *Salaries in County Councils 2016*, retrieved from: https://www.scb.se/contentassets/cebc46583b904474b83276ea0d8e394f/am0105_2016a01_sm_am51sm1701.pdf

The Swedish healthcare law "Hälso- och sjukvårdslagen"(HSL 1982:763), Riksdagen, retrieved from: https://www.riksdagen.se/sv/dokument-lagar/dokument/svensk-forfattningssamling/halso--och-sjukvardslag-1982763_sfs-1982-763

Trick, Michael A., 2011, Using Linnear Programming, Michael Trick's Operations Research Page, Cornegie Mellon University, retrieved 7 July 2017 from: http://mat.gsia.cmu.edu/classes/mstc/dea/node3.html

Wang, Jian; Zhao, Zhong & Mahmood, Amir, 2006, *Relative Efficiency, Scale Effect, and Scope Effect of Public Hospitals: Evidence from Australia*, Forschungsinstitut zur Zukunft der Arbeit Institute for the Study of Labour, IZA DP No. 2520

Wei, Quanling & Chang, Tsung-Sheng, 2011, *Optimal profit-maximizing system design data envelopment analysis models*, Computers & Industrial Engineering Volume 61, Issue 4, November 2011, Pages 1275–1284

World Health Organization (WHO), European Health Information Gateway:

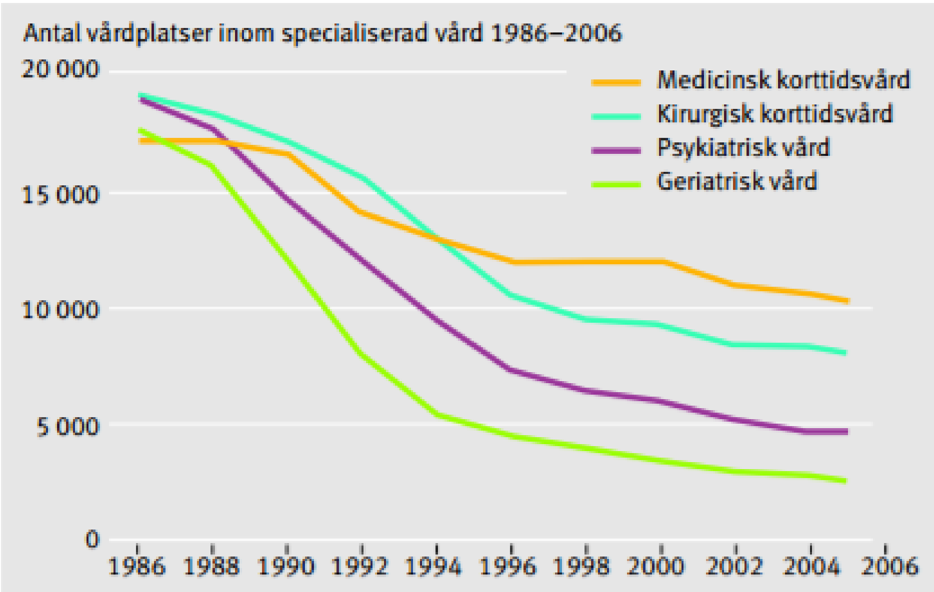
- Inpatient care discharges per 100, retrieved 12 June 217 from: https://gateway.euro.who.int/en/indicators/hfa-indicators/hfa_534-6010-inpatient-care-discharges-per-100/
- Outpatient Contacts per person per year, retrieved from: https://gateway.euro.who.int/en/indicators/hfa-indicators/hfa_543-6300-outpatient-contacts-per-person-per-year/

Åsgård, Samuel, 2015, *Regeringens utredare vill skrota sjukvårdsregioner*, Dagens Medicin, retrieved at 2017-07-06 from: https://www.dagensmedicin.se/artiklar/2015/10/01/regionutredare-vill-skrota-sjukvardsregioner/?login=true

Appendices

Appendix 1

Number of hospital beds in Sweden, 1986-2006.



Figur 2. Utveckling av antalet vårdplatser i Sverige under perioden 1986–2006. Källa: Sveriges Kommuner och Landsting

Appendix 2

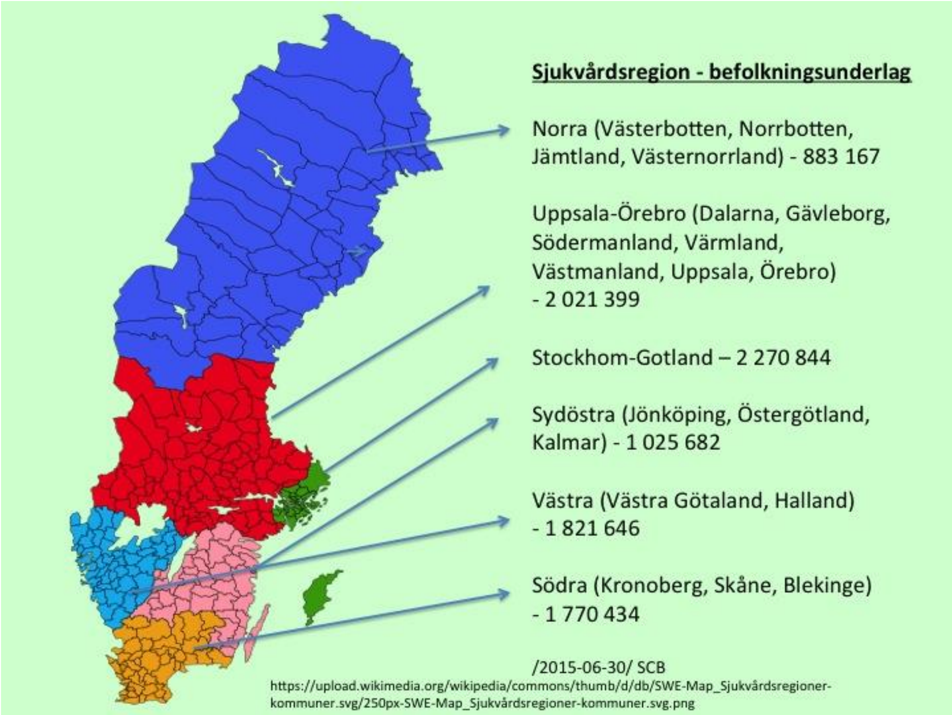
Number of specialist doctors per 100000 inhabitants between years 1995 and 2011. Source: Socialstyrelsen

Utveckling över tid, antal per 100 000 invånare 1995-2011

Sjukvårdsregion	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Stockholm	249	249	250	257	260	262	271	280	288	292	299	308	316	317	318	319	320
Sydöstra	178	179	178	185	188	190	195	203	207	209	213	221	227	232	240	241	247
Södra	219	220	218	219	225	231	236	240	248	253	256	260	265	266	267	270	273
Västsvenska	204	204	205	210	212	215	221	228	235	241	245	249	253	255	259	263	265
Uppsala/Örebro	199	199	200	204	206	212	214	217	221	227	232	235	239	238	245	248	251
Norra	186	189	190	195	196	199	204	208	213	220	224	230	234	241	246	245	248
Län																	
Stockholms län	251	250	252	259	262	264	273	283	290	295	302	310	318	319	320	321	321
Uppsala län	285	274	288	290	300	313	313	330	339	351	360	361	345	337	343	357	364
Södermanlands län	166	170	165	168	172	176	176	182	191	199	198	200	205	200	201	207	205
Östergötlands län	209	206	205	217	219	222	226	237	235	230	237	252	257	260	268	269	274
Jönköpings län	156	161	157	161	161	162	164	172	178	188	192	197	202	208	215	216	223
Kronobergs län	172	173	178	187	191	191	198	206	206	214	215	215	230	227	228	234	230
Kalmar län	155	156	159	162	169	174	183	186	195	199	199	201	212	215	223	225	233
Gotlands län	189	205	175	196	186	204	209	202	205	205	219	227	238	242	243	253	272
Blekinge län	191	193	195	178	194	205	207	216	218	228	231	238	238	240	236	243	247
Skåne län	239	240	237	239	243	248	254	258	267	271	275	280	283	284	285	289	291
Hallands län	164	163	163	165	174	183	191	196	203	212	214	211	221	222	231	229	239
Västra Götalands län	206	206	207	212	213	217	222	228	235	241	245	249	254	255	259	262	264
Värmlands län	178	182	185	189	189	191	190	192	194	200	203	204	206	199	208	213	215
Örebro län	228	229	229	232	235	242	245	253	257	260	266	264	274	271	273	279	282
Västmanlands län	179	185	182	180	184	185	196	191	187	186	189	192	212	216	220	219	221
Dalarnas län	176	173	164	178	176	182	183	186	195	197	203	207	210	217	223	226	219
Gävleborgs län	175	175	175	176	172	176	177	173	170	179	190	194	202	205	221	210	222
Västernorrlands län	156	163	169	166	163	166	180	187	191	200	198	201	206	211	215	205	209
Jämtlands län	185	189	198	200	197	194	202	200	203	214	221	225	225	243	248	252	258
Västerbottens län	240	239	245	253	258	265	263	270	274	281	294	304	307	309	319	324	334
Norrbottens län	164	165	152	162	165	169	170	170	177	179	180	186	192	198	198	200	192
Hela riket	**210**	**211**	**211**	**216**	**219**	**223**	**228**	**234**	**240**	**246**	**250**	**256**	**262**	**263**	**267**	**270**	**273**

Appendix 3

Swedish healthcare regions and their populations. Source: Suiprev, retrieved from: https://suiprev.wordpress.com/tag/sjalvmordsstatistik/



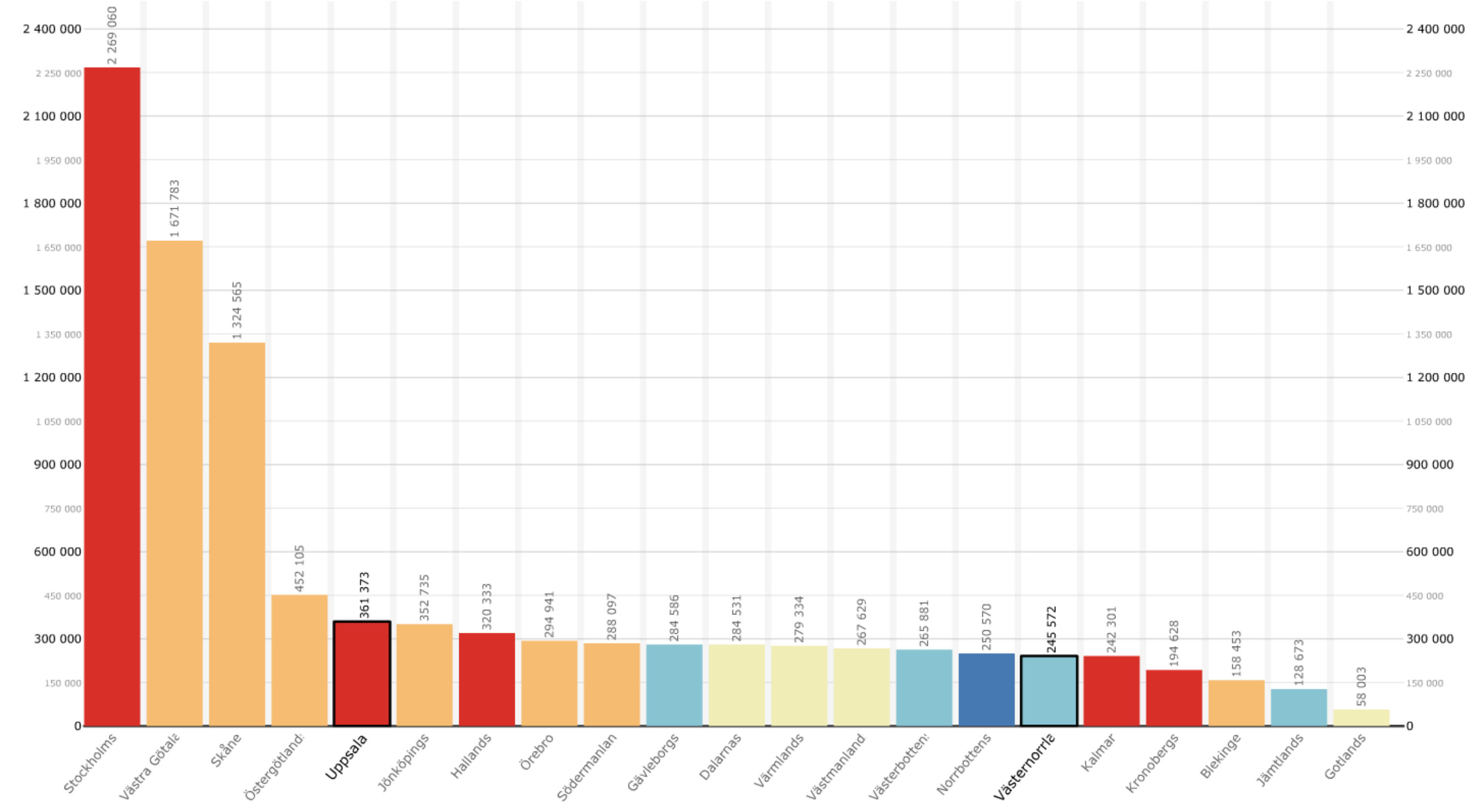
Appendix 4

Geographical abbreviation of Sweden's counties

Definition of geographical abbreviations		
Abbreviation	**Complete name, Swedish**	**County name in English**
SLL	Stockholms Läns Landsting	Stockholm County
ULL	Uppsala Läns Landsting	Uppsala County
LS	Landstinget Sörmland	Sörmland County
LiÖ	Landstinget i Östergötland	Östergötland County
JLL	Jönköpings Läns Landsting	Jönköping County
KLL	Kronobergs Läns Landsting	Kronoberg County
LKL	Landstinget Kalmar Län	Kalmar County
LB	Landstinget Blekinge	Bleking County
RS	Region Skåne	Skåne Region
RH	Region Halland	Halland Region
VGR	Västra Götalandsregionen	Västra Götaland Region
LIV	Landstinget i Värmland	Värmland County
RÖL	Region Örebro Län	Örebro County Region
RV	Region Västmanland	Västmanland Region
LD	Landstinget Dalarna	Dalarna County
GLL	Gävleborgs Läns Landsting	Gävleborg County
RVN	Region Västernorrland	Västernorrland Region
RJH	Region Jämtland-Härjedalen	Jämtland-Härjedalen Region
VLL	Västerbottens Läns Landsting	Västerbotten County
RNB	Region Norrbotten	Norrbotten Region

Appendix 5

Population size of Sweden's county councils, 2016. Source: Statistics Sweden, population statistics



Appendix 6

Average wage differences across county councils, 2016. Source: Statistics Sweden

1. County councils, 2016. Average monthly salary in SEK by county councils and sex

	Antal[1]			Månadslön		
Landsting	Kvinnor	Män	Totalt	Kvinnor	Män	Totalt
Hela riket	186 800	52 200	239 000	33 700	42 700	35 700
Stockholms läns landsting	22 300	6 900	29 200	36 400	44 200	38 200
Uppsala läns landsting	8 800	2 700	11 500	34 700	45 900	37 400
Södermanlands läns landsting	5 100	1 500	6 700	34 000	43 300	36 100
Östergötland läns landsting	10 000	2 500	12 400	33 500	45 000	35 800
Jönköpings läns landsting	7 800	2 000	9 800	33 200	44 500	35 500
Kronobergs läns landsting	4 400	1 300	5 700	33 100	40 300	34 700
Kalmar läns landsting	5 400	1 500	6 900	32 700	43 400	35 100
Blekinge läns landsting	3 700	1 000	4 700	32 800	41 200	34 600
Region Skåne	25 700	7 100	32 800	33 600	41 700	35 300
Hallands läns landsting	6 200	1 600	7 800	33 200	44 400	35 500
Västra Götalands läns landsting	36 300	9 700	46 000	33 200	41 700	35 000
Värmlands läns landsting	5 900	1 500	7 400	33 000	42 600	34 900
Örebro läns landsting	7 300	2 100	9 500	32 900	41 900	34 900
Västmanlands läns landsting	5 200	1 300	6 500	33 800	44 200	35 900
Dalarnas läns landsting	6 300	1 800	8 100	33 500	42 500	35 500
Gävleborgs läns landsting	5 200	1 400	6 600	32 900	41 900	34 800
Västernorrlands läns landsting	5 000	1 500	6 500	32 800	39 000	34 200
Jämtlands läns landsting	3 000	900	3 900	32 600	41 100	34 600
Västerbottens läns landsting	7 500	2 300	9 800	33 300	41 700	35 200
Norrbottens läns landsting	5 800	1 500	7 300	33 300	42 500	35 200

1) Antalsuppgifterna avser lönepopulationen. Se förklaring i stycket *Objekt och population* under avsnittet *Fakta om statistiken.*

Appendix 7

Yearly rents per square meters in SEK for newly built houses in different regions of Sweden, 2014-2015, Source: Statistics Sweden

YEARLY RENTAL COSTS PER SQUARE METER IN SEK FOR NEWLY BUILT HOUSES, 2014-2015

REGIONS	**Ownership type**	**2014**	**2015**
STOCKHOLM REGION	Publicly owned	1701	1985
	Private companies and organizations	1708	1837
	Total	1704	1883
GOTHENBURG REGION	Publicly owned	1757	1699
	Private companies and organizations	1683	1900
	Total	1716	1794
MALMÖ REGION	Publicly owned	1558	1429
	Private companies and organizations	1545	1811
	Total	1550	1560
MUNICIPALITIES WITH >75000 INHABITANTS, EXCEPT STOCKHOLM, GOTHENBURG AND MALMÖ REGIONS	Publicly owned	1587	1573
	Private companies and organizations	1536	1645
	Total	1568	1601
MUNICIPALITIES WITH <75000 INHABITANTS, EXCEPT STOCKHOLM, GOTHENBURG AND MALMÖ REGIONS	Publicly owned	1469	1565
	Private companies and organizations	1419	1437
	Total	1450	1528

Appendix 8

Reference DMUs for the county councils, 2008

Reference	λ SLL	λ ULL	λ LS	λ LiÖ	λ JLL	λ KLL	λ LKL	λ LB	λ RS	λ RH	λ VGR	λ LIV	λ RÖL	λ RV	λ LD	λ GLL	λ RVN	λ RJH	λ VLL	λ RNB
SLL	1,00					0,01														
ULL		1,00				0,10		0,02	1,97	0,14	0,00	0,33				0,29	0,12	0,04		0,16
LS			1,00			0,05		0,08		0,40					0,26	0,07				
LiÖ				1,00					0,32											
JLL																				
KLL																				
LKL					1,09	0,39	1,00	0,06		0,44		0,47			0,51	0,33	0,70	0,37		0,45
LB																				
RS																				
RH																				
VGR											1,00									
LIV																				
RÖL					0,18			0,41					1,00							
RV												0,01		1,00			0,06	0,02		
LD																				
GLL																				
RVN																				
RJH																				
VLL									1,60	0,06					0,23	0,08			1,00	0,14
RNB																				

Appendix 9

Reference DMUs for county councils in 2010

Reference	λ SLL	λ ULL	λ LS	λ LiÖ	λ JLL	λ KLL	λ LKL	λ LB	λ RS	λ RH	λ VGR	λ LIV	λ RÖL	λ RV	λ LD	λ GLL	λ RVN	λ RJH	λ VLL	λ RNB
SLL	1,00																			
ULL		1,00		0,20								0,09				0,19	0,04			
LS			1,00			0,13									0,41	0,02				
LiÖ																				
JLL																				
KLL																				
LKL				0,70		0,56	1,00					0,63		0,00	0,03	0,37	0,53	0,32		0,30
LB					0,63			1,00							0,10					
RS				0,02		0,01			1,00											
RH					0,16					1,00						0,28		0,02		0,09
VGR											1,00	0,01						0,02		0,02
LIV																				
RÖL					0,51								1,00		0,47				0,00	0,35
RV												0,14		1,00			0,28			
LD																				
GLL																				
RVN																				
RJH																				
VLL				0,56															1,00	
RNB																				

Appendix 10

Reference DMUs for county councils in 2012

Reference	λ SLL	λ ULL	λ LS	λ LiÖ	λ JLL	λ KLL	λ LKL	λ LB	λ RS	λ RH	λ VGR	λ LIV	λ RÖL	λ RV	λ LD	λ GLL	λ RVN	λ RJH	λ VLL	λ RNB
SLL	1,00																			
ULL																				
LS		0,19	1,00			0,15									0,04					
LiÖ																				
JLL																				
KLL																				
LKL							1,00													
LB																				
RS				0,12					1,00											
RH					0,42	0,10		0,09		1,00					0,24			0,16		0,32
VGR											1,00									
LIV				0,48		0,23		0,11				1,00				0,86	0,80			
RÖL					0,52	0,14		0,19					1,00		0,60					0,35
RV								0,03						1,00				0,12		
LD																				
GLL																				
RVN																				
RJH																				
VLL		1,30		0,57	0,08			0,12								0,10	0,04	0,10	1,00	0,10
RNB																				

Appendix 11

Reference DMUs for county councils in 2014

Reference	λ SLL	λ ULL	λ LS	λ LiÖ	λ JLL	λ KLL	λ LKL	λ LB	λ RS	λ RH	λ VGR	λ LIV	λ RÖL	λ RV	λ LD	λ GLL	λ RVN	λ RJH	λ VLL	λ RNB
SLL	1,00																			
ULL																				
LS		0,01	1,00												0,22					
LiÖ																				
JLL		0,14			1,00	0,12		0,09							0,22					
KLL																				
LKL						0,26	1,00	0,04							0,14	0,01				
LB																				
RS				0,11				0,07	1,00						0,03	0,11	0,01			0,03
RH										1,00							0,20			
VGR											1,00									
LIV						0,24		0,09				1,00				0,43	0,55			
RÖL		0,36											1,00		0,20					
RV														1,00						
LD																				
GLL																				
RVN																				
RJH				0,45				0,16										1,00		0,81
VLL		0,91		0,85															1,00	0,25
RNB																				