HELSINKI CITY URBAN FACTS OFFICE:

web publications

2003 | 16

Ilkka Susiluoto

Effects of ICT on Regional Economic Efficiency

Web Publications
ISSN 1458-5707
ISBN 952-473-146-0

FURTHER INFORMATION
Ilkka Susiluoto, tel. +358 9 191 22185
www.ilkka.susiluoto@helsinki.fi

Effects of ICT on Regional Economic Efficiency

Ilkka Susiluoto
University of Helsinki
Department of Economics
31.7.2003
MUTEIS Impact Study

Table of contents

List of tables

List of figures

1. INTRODUCTION

Increase in the importance of knowledge in the economy, the advent of information industries, as well as other structural changes in the economy have transformed the preconditions for regional development. In many countries today, economic development shows tendencies towards regional concentration. Economically central modern regions often face a migration gain as well as growth of employment and income, whereas the opposite is the case in many peripheral areas. However this picture is by no means uniform, as it is enriched with mosaic-like elements and exceptions. Also some far-away regions have shown successful development, making them interesting objects of study. When we add the effects of recent developments at the international institutional level, the regional outcomes become difficult to predict.

Under these circumstances it is important to study the effects of the information sector on regional growth and development. To develop successfully, a region must have a sufficiently high economic performance level, whether this is seen as competitiveness or efficiency. While competitiveness may be defined in many different ways, one reasonable starting point would be the resource base. A region with a good endowment of basic resources like high level knowledge would have a good opportunity to compete successfully in the market.

This study is based on the concept of efficiency, which is closely related to competitiveness. Regional efficiency is defined as a region's ability to use its basic productive resources in an economic way, to produce well being. We recognise that the starting points of regions differ: for example a region with a good knowledge base must produce more than its poorer neighbour in order to be equally efficient. Otherwise it would waste its resources. So, differences in the initial endowments between regions are taken into account.

Now we can state the basic questions of the study: does ICT increase the economic efficiency of regions? If there is such an effect, does it give equal opportunities to all regions? How has it developed with time? Is it possible to present an estimate of the magnitude of the effect?

Investigating these questions means that two things must be done: efficiency of the regions has to be estimated and their connection with ICT has to be assessed. The first task is achieved in this study by using a programming method called Data Envelopment Analysis or DEA. For the second task Tobit random effects modelling is applied to panel data.

It is possible to approach the effect of ICT on regions in numerous ways, some of which are more qualitatively, others quantitatively inclined. Such differing approaches complement each other and form together a more coherent picture of the phenomenon studied. This report is part of the regional economic analysis of the MUTEIS study, and the methodology is based on quantitative estimation, measurement and modelling. In this respect the approach differs from the main strand of the MUTEIS project. Moreover, in order to make more general statistical inference possible and to give the results more validity, the scope has been widened to cover all economic NUTS 4-level regions of the countries in question.

Most of this report concentrates on the economic behaviour of Finnish regions during the period 1988-1999. This is largely because the Finnish data set was widest. In addition, a previous efficiency study existed for Finland, giving a good base for statistical analysis (Susiluoto and Loikkanen 2001b). The report also contains a short analysis of Swedish regions. Unfortunately no sufficient data set could be constructed for Ireland and the Netherlands, and these two countries were left outside the study.

We want to thank Thomas Paulsson and Mattias Olsson-Ruppel from Jönköping International Business School for help and good co-operation with the Swedish case. In particular, Mattias Ohlsson-Ruppel has kindly collected and compiled the Swedish data for us.

The report proceeds as follows. In chapter 2 the methodology of the study is briefly described. Chapters 3-5 address the Finnish case. In chapter 3, the Finnish DEA study is summarised and some main findings are presented. Chapter 4 then introduces the data used in the panel models. Chapter 5 gives the results of the Finnish panel study, showing the estimated nature of the relationship between ICT volume and regional economic performance. Chapter 6 then summarises the different parts of the Swedish study. Finally a summary of the whole report is presented in chapter 7.

2. ESTIMATING AND EXPLAINING REGIONAL ECONOMIC EFFICIENCY: THE DEA AND TOBIT PANEL METHODS

Efficiency rates were estimated for the 83 Finnish and 81 Swedish NUTS 4 regions. For Finland, the study period was 1988-1999, while for Sweden data was available only for years 1996 and 1998-2000. The obtained efficiency estimates were then exploited in the second part of our regional ICT study. More exactly, the efficiency rates were explained statistically, using ICT as well as various background variables as explanatory factors in a Tobit panel setting. In this chapter the DEA method is first explained (2.1), after which the panel method is briefly described (2.2).

2.1 The DEA method

In this section we first state some of the questions that were answered in the DEA study. Then we briefly present the method itself and summarise some earlier regional economic studies that have applied the DEA method.

Some main questions

How efficiently do regions use their own basic resources in their production? It is not self-evident that those regions with highest income per capita or highest value added are also the most efficient ones. We wanted to look at not only production levels but differences in the resources of regions as well. Still, we would expect that regions with a strong resource basis produce more local well being than regions with smaller resources.

Which factors are characteristic of those regions that have efficient business sectors? Is efficiency linked with size, i.e. can agglomeration benefits be found? What about localisation advantages, or the concentration of some sectors into the region? And how did the overall picture of regional efficiency develop during the research period?

The study only concerned the efficiency of the business sector. Public sector, private non-profit sector and housing were excluded. The results are based on the overall picture rendered by five different production models for Finland and four models for Sweden.

Earlier regional studies applying the DEA method

DEA is an application of linear programming, a non-parametric method, which does not estimate statistical dependencies between variables (as is done in ordinary production function analysis). Instead, DEA uses input and output data to compute a technically efficient production frontier, i.e. a ”surface” formed by the most efficient units. The best units receive an efficiency score one (or more practically, 100 per cent), while the other units receive scores below one, depending upon their position in comparison with the most efficient units. In our study the units were regions, so we obtained an efficiency number for each of the 83 Finnish regions (81 regions for Sweden) for each of the 12 years 1988-1999 (for Sweden 1996 and 1988-2000).

DEA is originally based on the work by Farrell (1957) and further elaborated by Charnes et al. (1978) and Banker et al. (1984). It has become especially popular in the study of public sector. These applications include efficiency studies concerning e.g. schools, hospitals and theatres, also private sector applications have been numerous.

In the last few years also several regional applications of DEA have emerged. Charnes et al. (1989) studied the economic performance of 28 China’s cities in 1983 and 1984. Chang et al. (1995) use DEA and the Malmquist productivity index approach to study the economic performance of 23 regions in Taiwan in 1983 and 1990. Tong applied DEA to investigate the changes in production efficiency of 29 Chinese provinces in two papers (Tong 1996, 1997). Bernard and Cantner (1997) calculate the efficiency of the 21 French provinces in 1978-1989. In a recent study, Maudos, Pastor and Serrano (2000) analyse the relationship between efficiency and production structure in Spain 1964-93. Some DEA studies have concerned agriculture. Weaver (1984) studied agriculture in the U.S., Mao ja Koo (1997) study the performance of agriculture in 29 Chinese provinces during 1984-93, while Millan and Aldaz (1998) analyse Spanish provinces 1977-88.

2.2. Using panel analysis, the Tobit method and random effects for explaining regional efficiency differences

Panel analysis

Panel data means that a pooling of observations is available on a cross-section of households, countries, firms, etc. over several time periods. This can be achieved by surveying a number of individuals and following them over time. Over the last three decades such statistical models combining cross section and time series data have become increasingly popular in economic research. This is due to certain general factors, like the better availability of disaggregated data, advances in computer technology and software programs as well as progress in the statistical methods needed (see Baltagi 1995, Ch. 1 and Matyas-Sevestre 1996, Ch. 2). A panel data set originally refers to a group of persons (consumers, employees, etc.), but often it also used to represent any group of individuals, which remains unchanged with time (for example regions or firms).

Why should then panel data be used in a statistical analysis? Some reasons are:

-the number of observations is much larger in panel data, resulting to more reliable parameter estimates. More variability among the variables, less collinearity, more degrees of freedom and more statistical efficiency is involved.

-panel data models allow us to construct and test more complicated models than just cross-section or time-series data

-effects may be identified and measured that are not detectable in simpler models

The Tobit approach

The DEA efficiency scores estimated in the first part of our study all lie in the 0-1 interval, and there is always at least one observation, which takes the upper limit 1. Moreover the observations typically tend to concentrate into the upper part of the range. The Tobit model is now a good alternative, because these facts may be taken into account. In a standard Tobit model the dependent variable is a nonnegative number. If we choose the dependent variable y_i to represent the inefficiency score (1-efficiency score) of region i, the model can be written as

$$y_i^* = x_i\,\beta + \mu_i$$

$$y_i = y_i^*,\ \text{if}\ y_i^* > 0\,,$$

$$y_i = 0,\ \text{otherwise}$$

In the equations above, x_i is a vector of explanatory variables and β is the vector of parameters to be estimated. y_i^* is a latent variable which can be viewed as a threshold beyond which the explanatory variables must affect in order for y_i to "jump" from 0 to some positive value. As the inefficiency score is in our study a continous variable limited to a minimum value of 0, the threshold has here no special interpretation. Still, such a model specification can be estimated by the maximum likelihood method (Kirjavainen and Loikkanen 1998).

Fixed effects or random effects model?

The specification task consists of modelling heterogeneous behaviour in a sensible way, also taking the need for parsimony into account. Heterogeneity may appear in the regression coefficients (which may vary across individual and/or time) and in the structure of residuals. No single, universally valid specification exists, but rather the choice of the appropriate specification depends on the type of problem and on the nature of the data. Two simple basic specifications are most popular: the fixed effects model and the random effects model. We here give only short descriptions of these two alternatives. For a systematic presentation of both, see Baltagi (1995) and Matyas-Sevestre (1996).

Technically, our starting point is a simple linear regression in which one variable, y, is explained in terms of endogenous variables, $x_1, \ldots, x_K$ and a non-observable random term u (we here follow Matyas and Sevestre 1996, Ch. 2.2). Given the panel nature of the sample, for individual i at time t we write:

$$y_{it} = \beta_{1it}\,x_{1it} + \ldots + \beta_{Kit}\,x_{Kit} + u_{it} = \underline{x}_{it}{}'\,\underline{\beta}_{it} + u_{it}$$

where the β_{Kit} are the unknown parameters to be estimated, $\underline{x}_{it}$ is the vector of the explanatory variables and $\underline{\beta}_{it}$ is the vector of regression coefficients. This expression corresponds to the most general specification of the panel data regression problem. It simply states that each individual has its own reaction coefficients, which are specific to each time period. However, such a model is useless, for it cannot be estimated in practise, as the number of parameters exceeds the number of observations.

For the model to be useful in practise and to acquire an explanatory power, it has to be structured. The first step for model parsimony is to assume that the reaction coefficients are the same for all individuals, except for a generic individual (fixed) effect. This is accomplished by allowing a different intercept for each individual. So, we obtain a simple fixed effects (FE) model, called the covariance model, by assuming:

$$\beta_{1it} = \beta_{1i}\text{, for all t, and}$$
$$\beta_{kit} = \beta_{k}\text{, for all i and t, k = 2, … , K}$$

The resulting model:

$$y_{it} = \beta_{1i} + \underline{\underline{x}}'_{it}\,\underline{\underline{\beta}} + u_{it}$$

is also called the dummy variables model. The idea in this simple fixed effects formulation is that all differences in ways of behaviour between individuals (in our study regions) can be captured in the coefficients β_{1i}, whereas the behaviour coefficients β_k are the same for all individuals and for every time period. This model has been very popular in applied research, for it is simple to estimate and it treats individual differences in a systematic way. This basic model can then be extended in many ways in the fixed effects direction.

The basic idea of the random effects (RE) model is to introduce an individual effect in the random term by splitting it into two parts or components: an individual component and an overall remainder, while assuming that all the reaction coefficients are fixed and the same for all individuals. Formally we make the assumption:

$$\beta_{kit} = \beta_{k}\text{, for all i and t, and}$$
$$u_{it} = \mu_i + \nu_{it}\,,$$

where μ_i is the random individual effect and ν_{it} is the remainder. The two components are assumed to be independent of each other, each one being identically distributed with zero mean and with a variance respectively of σ_μ^2 and σ_ν^2. The error components model is a prototype of all panel data models and it has been very popular in research.

Altogether in the error components model the individual or time specificities are introduced in the model by error terms. This means that the heterogeneity is incorporated into the model not by the expected value of the endogenous variable (which is the case in the fixed effects model) but via its variance. For details see Matyas – Sevestre (1996), Ch. 4.

The two models will lead to different conclusions about the data, so the question whether a fixed or a random effects model should be chosen is an important one. It is also a difficult methodological question and has been much discussed in the literature. Several arguments may be presented in favour of either one, including:

-if a large number of non-observable random causes lie behind the individual effects, a random effects model is more natural.

-if the number of statistical units (here regions) is large, while the number of time periods is small, a fixed effects model may become problematic

-fixed effects is a natural candidate if the sample is closed and exhaustive (regions, industrial sectors). But if the individuals are drawn from a large population, a random specification is appealing.

-if inference is restrained to the sample, fixed effects is a proper choice, in the contrary case a random effects model is suggested.

-a fixed effect model cannot estimate the effect of any time-invariant variable like sex, race or for that matter, existence of a university in a region (see Ch. 5 and 6). Alternatively, it is not possible estimate variables that are constant across units, like national growth rates in regional analysis.

Very often it becomes necessary to apply specification tests when deciding about the model type. (See Matyas and Sevestre 1996, Ch.2). Breusch-Pagan and Hausman specification tests were used in this study to find the proper specification. The Breusch-Pagan Lagrangian multiplier test compares the suitability of random effects and pooled OLS specifications by testing the hypothesis that there is no need to control for the random term μ. If the null hypothesis is not rejected, pooled OLS should be chosen. The Hausman test differentiates between random effects and fixed effects models by testing the consistency of RE specification (H_0: E($\mu_i X_{kjt}$)=0, for all i, k, j, and t). Rejection of the null hypothesis leads to a fixed effect model. As these two tests were not applicable in a Tobit panel setting, they were done after an ordinary random effects panel model. (See Matyas and Sevestre 1996, 298; Baltagi 1995, 61, 68). These tests clearly suggested a random effect approach both for the Finnish and the Swedish case.

Approach of the study

We finally now state our summary of the methodology in the second part of our study. We combine the different elements presented above. We apply the Tobit approach to a panel data to estimate a random effects model, which explains regional differences of economic efficiency (obtained in the first part of the study) with several variables. Our central explanatory variable *is ICT activity in the regions. Our panel consists of 83 regions (for Sweden 81), 12 years (for Sweden 4) and a group of economic phenomena.*

Finally, it is customary in econometric analysis to carefully specify one or at most a few statistical models, consistent both with the theory and data in question, and to derive all results from these. However in our work the approach has been different, as several specifications have been applied (see chapters 5 and 6). The reason is the multifaceted and practical nature of the research task. In addition to finding out just a few central estimates about the effect of ICT, our information need has been wider. We also wished to calculate, effects on the regions' efficiency ranking, effects on certain specific region types etc. For these purposes, many different models and estimations were needed.

3. DEA RESULTS FOR FINLAND: REGIONAL ECONOMIC EFFICIENCY 1988-1999

The primary output variable in the DEA calculations for Finland was real private sector regional value added 1988-1999 in 1995 prices. A second output variable comprised the real income that employed persons get for their participation in production within business sector workplaces. As input variables capital stock of the area, number of employed people, their education level and volume of the public sector were used. Regional local capital stock and real personal income were specifically computed for this study.

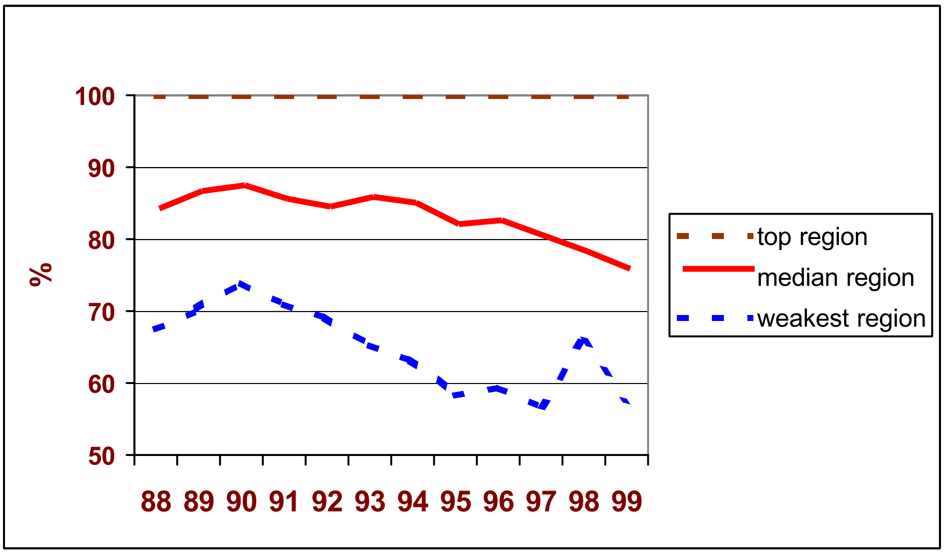
Regional differences in efficiency proved to be considerable. During the period 1988-1999, the Helsinki Region topped the list with the efficiency score 99,3. Sufficient size and a modern production structure are plausible explanations for this. The high efficiency rates of the Helsinki Region are in line with the strong growth of the region in the last few years. The Salo region, a town in southern Finland, ranked next to Helsinki in efficiency. An obvious reason behind Salo's success is the electronics industry and Nokia, whose strong growth in this region actually made it the most efficient at the end of the study period.

Tornionlaakso region in Northern Finland had the lowest score 67,1. Consequently, it can very roughly be stated that the weakest area produces about 33 per cent less outputs than the strongest for the same inputs. Alternatively, if the weakest area had been as efficient as the strongest one, it would have produced its outputs with 33 per cent less resources.

The size of a region is connected with efficiency. Among the ten highest-ranking areas, three (Helsinki, Tampere and Oulu) are among the country's biggest cities. Moreover, all the ten biggest regions by population ranked above median in 1988-99. It seems clear that large size brings certain advantages of agglomeration that raise efficiency. Another factor that can be discerned among the top ten regions is specialisation: six of them are specialised in paper and pulp industry. In these regions localisation advantages seem to be very strong.

Differences in economic efficiency have reflected themselves in regional development and recovery from the Finnish economic depression of early 1990's. Employment has developed more favourably in the more efficient regions. Efficient use of labour and other inputs to production increase the regions' capacity to employ. Also, there was an expected – although not very strong – negative correlation between efficiency and regional rate of unemployment in the 1990s. Efficient regions often also have a more favourable migration balance than inefficient ones.

Figure 3.1. Relative economic efficiency 1988-99 in Finland: top, median and weakest region



The most efficient areas mostly lie in the southern and western part of the country.
After the depression, a peripheral location has become a clearer obstacle to efficiency. The correlation between efficiency and location increased during the twelve years of the study. Yet the picture has also mosaic-like elements, and perhaps even increasingly so in the southern and central parts of the country.

Differences in efficiency between regions have grown in Finland. In 1988-90, the difference between the most and the least efficient regions was around 30 per cent, but in 1996-99 it was already about 40 per cent. During the depression, the position of the weakest areas weakened even further, and after it a group of efficient regions have improved their positions. For most regions, the DEA scores fell during the twelve years from 1988 to 1999. In other words, the majority of regions are increasingly lagging behind the strongest ones.

Figure 3.2. Employment growth in ten most efficient and ten least efficient Finnish regions 1988-1999, 1988=100

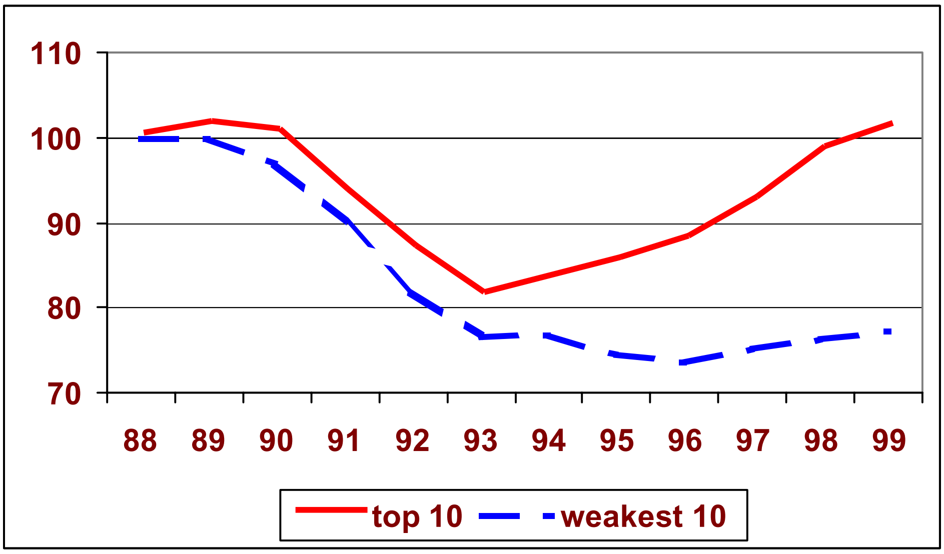


Table 3.1. Statistics of the results of DEA estimation for Finnish regions, 1988-1999

Average number of efficient regions	9
Average efficiency of regions, %	82.6
Average efficiency of weakest region, %	67.1
Average correlation of results between:	
the 12 years	0.730
successive years	0.867
the five DEA models	0.640

4. EXPLAINING FINNISH REGIONAL EFFICIENCY DIFFERENCES 1988-1999: DATA

We now move to the second part of our study of Finnish regions (the Swedish case is reported as a whole in chapter 6). The following variables were used for estimating the statistical dependence between regional economic efficiency, ICT and other explanatory variables. The variables describe some of the most important factors that can be expected to affect regional economic efficiency, even though the list is by no means perfect. In any case the list should be sufficient for us to detect the influence of the ICT sector on regional efficiency differences.

1. The variable to be explained is *the rate of private sector economic inefficiency:*

Inefficiency = 100 – efficiency

The relative efficiency rates for the period 1988-1999 were earlier obtained by Susiluoto and Loikkanen (2001b). Here inefficiency (instead of efficiency) is used in the estimation procedures because of modelling reasons. The lower efficiency is, the higher is inefficiency. In 1997-99 the lowest regional efficiency rate in Finland was 57 %, meaning 43 per cent inefficiency. So, with a constant resource base, the inefficient region produced 57 per cent of the GDP of the efficient region. It should be noted that in practise the efficiency differences between regions are not 100 percent but rather some 40 percent, and all the 83 NUTS 4 regions remain within these limits.

Part of the results in chapter 5, notably the figures, are however presented in the reverse direction. This means that we look at the efficiency (not inefficiency) increasing effect of ICT, as this is more natural considering our research task.

The explanatory variables were:

2. Share of the ICT sector in regional value added 1988-1999 is the most important explanatory variable. Aggregate ICT is mostly used, but also division into goods production and rest of ICT is attempted. MUTEIS definition of the sector is applied as closely as possible. It is assumed that increasing ICT would raise regional economic performance level.

3. Population of the region is a natural measure for size. We assume that the greater a region is the more efficient (less inefficient) it would be, or that positive agglomeration effects would prevail. We use logarithm of the population as the explanatory variable. This means that the determining factor is relative population change, not absolute change.

4. Rate of specialisation in production may also have an influence on efficiency. Specialisation is measured by the Herfindahl index:

$H = \Sigma p_i^{\ 2}$ where p_i is sectors i's share of total production

The Herfindahl index is often applied for measurement of specialisation. It was calculated without the ICT sector, because the share of ICT is a separate explanatory variable, and including it in the Herfindahl index would have brought double counting. The range of this index is (1/n, 1), n being the number of sectors (35), but for practical reasons it was be scaled to

(100/n, 100). It is assumed that specialisation in production increases efficiency, other factors constant.

5. A distance factor is needed to take the (dis)advantages of location into account. For Finland this variable was obtained by calculating a weighted average of road distances between all regions. For each region, the distance to every other region was weighted by the value added share of the destination region (its share of GDP), and the figures were summed for each origin region. The result describes the average domestic economic accessibility of a region, and it also changes with time. We assume that the more accessible a region is, the more efficient it tends to be.

6. The state of knowledge or education level can be measured in many plausible ways. Consequently several measures are alternatively used in this study. This is relevant, as we want to examine the effect on the results of applying alternative educational variables. It is natural to assume that increasing knowledge improves the performance of a regional economy.

Our basic choice for a measure of education or knowledge is the average per capita length of schooling. It is measured from all regional population over 15 years of age. In addition to covering the whole population the index has the advantage of changing with time, reflecting ongoing regional development. A disadvantage is that it gives all kinds of schooling an equal importance. The four other measures are:

-having a university in the region (a dichotomous variable)

-share of university students in the population

-share of university and vocational college students. This is used a few times as an alternative to the share of university students.

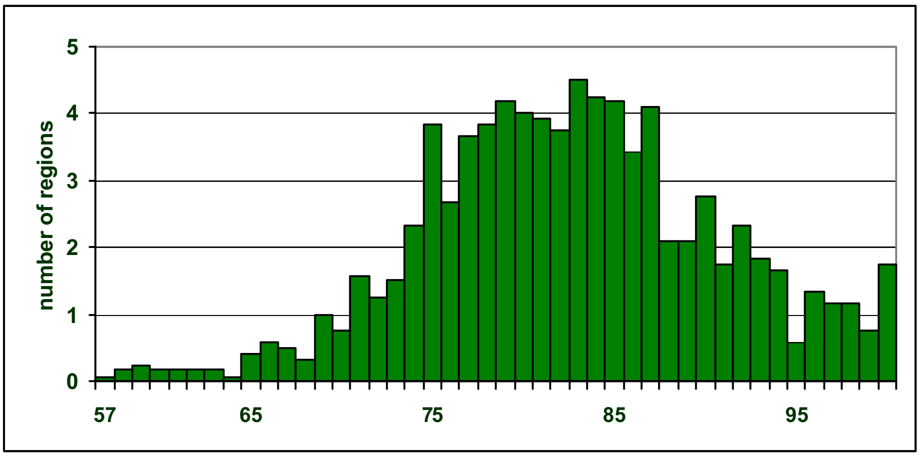
-an index of regional human capital, compiled from several measures describing number of students, academic degrees and demographic factors. It is available only for 1995, which is a disadvantage.

In addition to the above variables also some others were tried at an early stage of the estimations. These included absolute number of population, shares of various “modern” sectors in production, as well as alternative specialisation and accessibility measures. Also statistically significant dummies have been used throughout, although they are not reported below.

5. EXPLAINING FINNISH REGIONAL EFFICIENCY DIFFERENCES 1988-1999: RESULTS

In this chapter we present our findings about the effects of ICT on the efficiency of regions in Finland during 1988-1999. First, some results of the whole group of 83 NUTS 4 regions are described. Then we take a short look at the importance of the various explanatory factors used in the models as well as ICT goods and services. Third, some notes are presented about the effect of ICT on the relative rankings of the regions, what comes to their efficiency. After that the reactions of some region groups (large – small, efficient – inefficient, accessible – peripheral) are studied. Some observations are then given concerning the variability of results, when we use alternative knowledge variables in the explanation. Finally, we make some attempts to measure the direction of causality: does ICT explain efficiency, or do efficient regions rather draw ICT?

Figure 5.1. Average number of regions by efficiency percentage 1988-1999

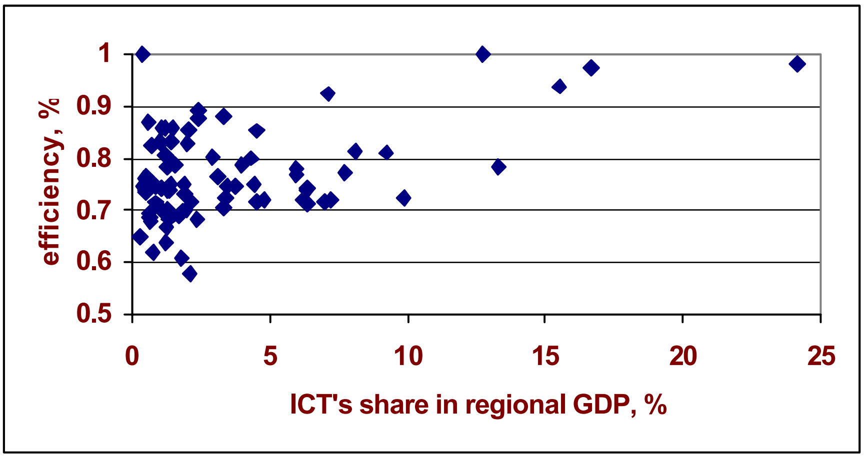


The efficiency distribution bears resemblance to a bell-shape, even though the tails are not symmetrical. Most regions lie between a relative efficiency rate 75 to 87 per cent. This means roughly stated that such a region would produce 75 to 87 per cent of the value added of a fully efficient region, given the same amount of resources.

Figure 5.1 also points out that even a change of only a few per cent in the efficiency rating could alter the relative position of a region significantly, if we are moving in the high-density part of the graph. We return to this question later.

Figure 5.2 gives us first information about the relationship between regional ICT volume and economic performance. Visually there seems to be some connection between these two phenomena: regions with highest ICT shares tend to be quite efficient, whereas those regions with only little ICT activity are often among the least efficient ones. One outlier is excluded from the figure, the Salo region in southern Finland with top efficiency and top ICT share (65 per cent). Figure 5.2 gives us reason to expect a positive relationship also in statistical analysis of the Finnish data.

Figure 5.2. Share of ICT and regional efficiency, 1999



5.1 General results

Development of the effect 1988-1999: the basic model

To see the results on a general level, we first apply a basic model including the following variables:

- inefficiency of private sector, explained by:

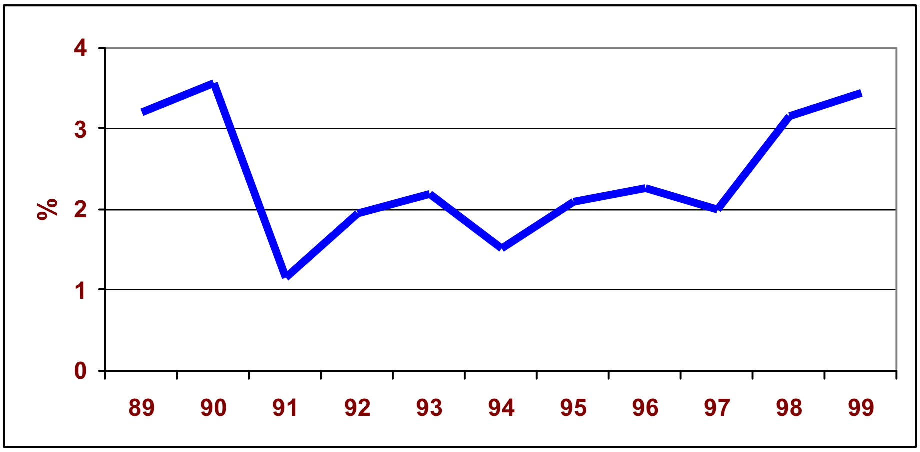
- share of total ICT in the region's value added
- logarithm of regional population (agglomeration measure)
- average economic distance (accessibility)
- Herfindahl specialisation index (general localisation measure)
- regional education level (knowledge level),
- statistically significant annual dummies

In figures 5.3 and 5.4 consequences of two different kinds of increases in regional ICT volume are studied. How much would regional efficiency typically grow, if the share of ICT in the regions would be increased?

In figure 5.3 we assume that the increase in ICT would be 5 % of regional value added total. For example, if 10 % of a region's value added is produced by ICT industries at the start, we assume that this increases to 15 % of total regional value added. By how many per cent would the efficiency of an average region increase? That is, how many per cent more value added would it produce with the same amount of resources (labour, capital, knowledge and public services input)?

In figure 5.4 our assumption about the increase in regional ICT is different. We now start from an improvement in the relative position of the region, what comes to the amount of ICT in the regional economy. More specifically, we assume that the increase would raise a region from a median position to 5th best in the whole group of 83 regions, what comes to the share of ICT. What is the effect on efficiency now?

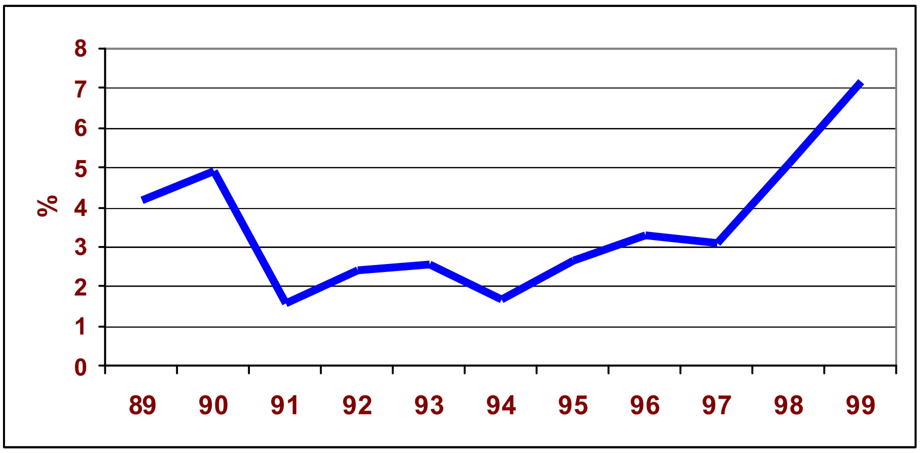
Figure 5.3. Percent increase in efficiency for a typical region, caused by increasing ICT's share in total output by 5 % of total regional output



Here we should note that the increase in efficiency includes both the direct contribution of ICT itself to regional performance level, as well as the indirect effects of ICT. The latter would mean that increasing ICT in the region would make also the production of other regional sectors more efficient. Unfortunately it is not possibly to separate these two effects in our study. Figures 5.3 and 5.4 are based on two-year panels from 1988-89 to 1998-99.

There seems to be an efficiency increase during the whole period 1988-1999 in both cases 5.3 and 5.4. This increase is largest at the beginning of the period 1988-90 and again in the growth period of the Finnish economy of the late 1990's. During the economic crisis in the first half of the 1990's the effect is smaller. Altogether the effect following the increase in the regions' relative ICT position (fig. 5.4) is somewhat larger than the increase following a 5 percent increase (fig. 5.3).

Figure 5.4. Percent increase in efficiency for a typical region, caused by increasing ICT's share from median position to 5th best.



Different explanatory variables and statistical confidence: model variants

Our results depend on the model we choose to estimate. In a study like this it may be difficult to find the best choices for variables, to describe the factors that affect efficiency. Secondly, we also want to get a picture on how reliable our results are in a statistical sense. In figure 5.5 (and in figure 5.11 below), several model variants are used to examine the following two questions:

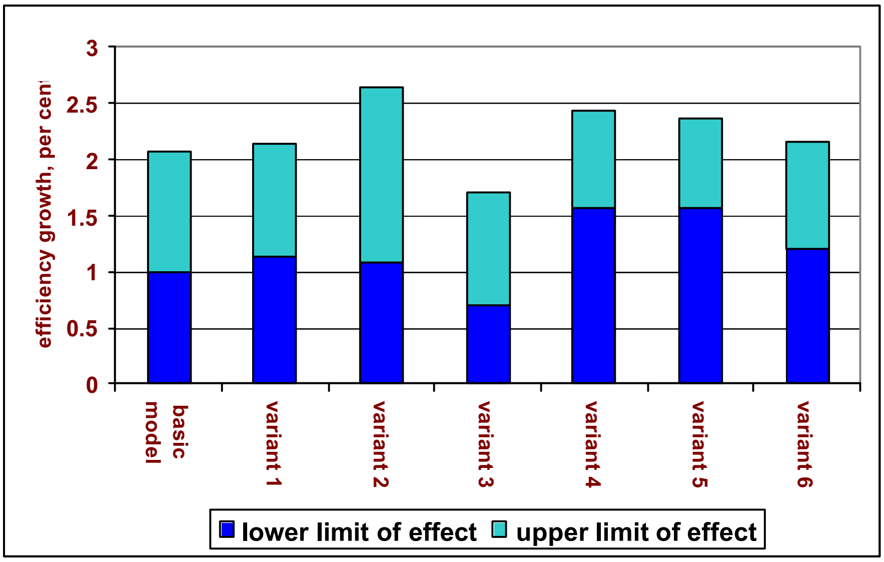
1) How much does our choice of explanatory variables affect the results? Do the general results remain if we use alternative ways of measuring the factors that effect regional efficiency? To see this we have not only estimated our basic model, but also several alternative models in figure 5.5. These are:

- the basic model
- variant 1: logarithm of population is replaced by total population
- variant 2: economic distance is replaced by a more general accessibility index
- variant 3: Herfindahl specialisation index is constructed with ICT included
- variant 4: years of education are replaced by university in the region
- variant 5: years of education are replaced by number of university students
- variant 6: years of education are replaced by regional human capital index

2) What is the statistical variation of the estimates? Can we remain reasonably certain that our results are not just due to statistical coincidence?

This question is answered in figure 5.5 by calculating 95 per cent statistical confidence levels for the effects. That is, we assess the limits within which the effects will remain with 95 % probability. In figure 5.5 these lower and upper limits are shown by the endpoints of the upper parts of the columns.

Figure 5.5. Percent increase in regional efficiency 1988-1999, caused by an increase in ICT equalling 5 % of regional value added total. Several Tobit panel models.



There is a clear similarity in all the results. In all cases there is a notable and statistically significant ICT effect: raising ICT in the regional economy increases the performance level or efficiency of the regions. There are some differences in results between the models, and it is seen that our basic model is by no means the one with the highest estimated effects. Variant 3 gives clearly lowest results. This was to be expected, as there the Herfindahl specialisation measure was constructed including ICT. Consequently, such a Herfindahl formulation would take for itself part of the explanation more plausibly attributed to ICT's share.

Even though the result is clear, statistical uncertainty forms a large part of the estimates (upper part of the columns). This means that we should not take the numerical values presented too literally, but rather they are quite tentative. Still we can now state our first conclusion:

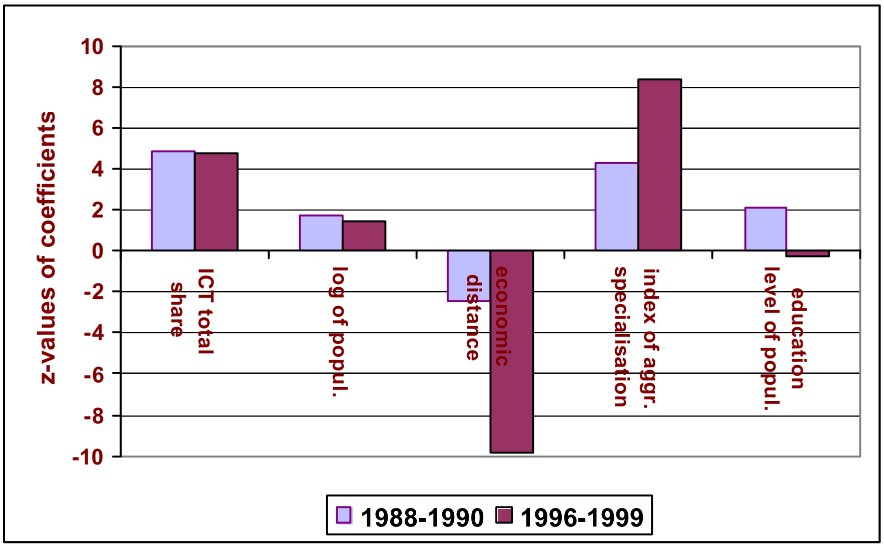
According to our results, increasing the share of ICT in the regional economies by 5 percent of total regional production brought an average efficiency increase of 1 – 2.5 percent. A similar result is obtained by improving a region's relative position, what comes to its ICT share. The effect was largest in normal economic times, in late 1980's and in the second half of 1990's. This result includes both the efficiency of ICT sector itself and its indirect effects on other sectors.

How do different factors affect regional efficiency?

What is the importance of different explanatory factors for regional economic performance, and has the role of these factors changed during the 1990's? Because the units of measurement differ between the variables (kilometres are used to measure distance, years for length of education etc.), we have to look at the z-values of coefficients rather than the coefficients themselves. This means that we look at the statistical certainty of the effects, instead of trying to compare their magnitudes. In figures 5.6 and 5.7, a z-value of more than +2 means that increasing the factor increases efficiency with greater than 95 % probability. On the contrary, a z-value less than –2 means, that the factor decreases efficiency. The greater the absolute z-value is, the more certain is also the effect. (It may be noted that we have changed the signs of the z-values in figures 5.6 and 5.7, for we were originally estimating inefficiency in our models, not efficiency).

As to the ICT effect, the results for 1988-90 and 1996-99 are practically the same (figure 5.6). In both sub-periods there very clearly exists an ICT effect. Population (agglomeration effect) and education (knowledge effect) are not statistically significant in the sub-periods, although they weakly tend to increase efficiency. The other two variables are interesting. The effects of economic distance as well as general rate of specialisation of the regional economy have become much clearer during the 1990's. The more accessible and the more specialised a region is, the higher efficiency tends to be. In particular, peripheral regions tend to be economically inefficient.

Figure 5.6. Factors explaining regional efficiency in late 1980's and late 1990's in Finland. Increasing effect on efficiency, z-values.



Z-values do not tell how large the effects are, but they only measure the certainty of the effect. But other results obtained in our estimations of figure 5.6 suggest that the magnitudes of effects of distance and specialisation have almost doubled during the 1990's. This is in line with the changes in z-values. The magnitude of the ICT effect has remained about the same.

5.2. Some specific questions

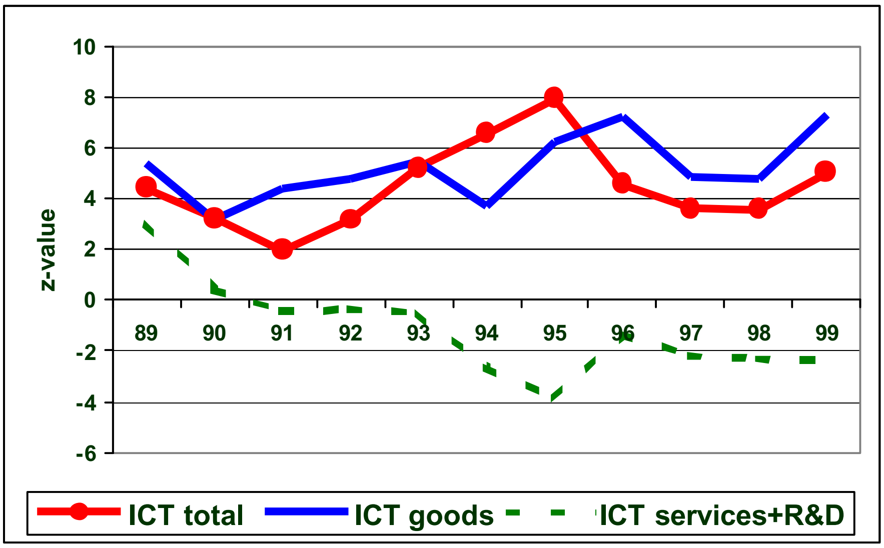
ICT goods and services

The ICT sector of MUTEIS includes several industries and industry groups, which probably have different effects on efficiency. It is natural to divide ICT industries into goods production, services and research and development activity. Here we unfortunately had to group services and R&D together because of data and confidentiality reasons. Development of the effects through 1988-1999 is presented in figure 5.7, which bases on two-year panels.

The results are surprising, as services and R&D seem to have no positive effect on efficiency in the regions, but rather the connection is statistically insignificant and negative. With both ICT goods production and total ICT volume, the positive connection is very clear and significant during the whole period.

One explanation for this result could be that R&D and ICT services are directly not very productive, what comes to creating value added, whereas the their indirect benefits (which may be large) may leak out from the regions. This sounds plausible, as the study regions are mostly small. Goods production on the other hand is likely to be quite productive even directly, with high value added for a resource unit used.

Figure 5.7. Increasing effects on efficiency from production shares of ICT and its parts



What is the effect on the relative ranking of regions?

Regions may assess their prospects by comparing themselves with other domestic regions. Then, would ICT's effect on regional performance be large enough to move a region's position with respect to other regions? The results are in figures 5.8 and 5.9. Again, two types of ICT increase are considered, as in figures 5.3 and 5.4. Two-year Tobit panels are applied.

Figure 5.8: Improvement in efficiency ranking (83 regions) for a typical region, caused by a 5 % increase in ICT shares

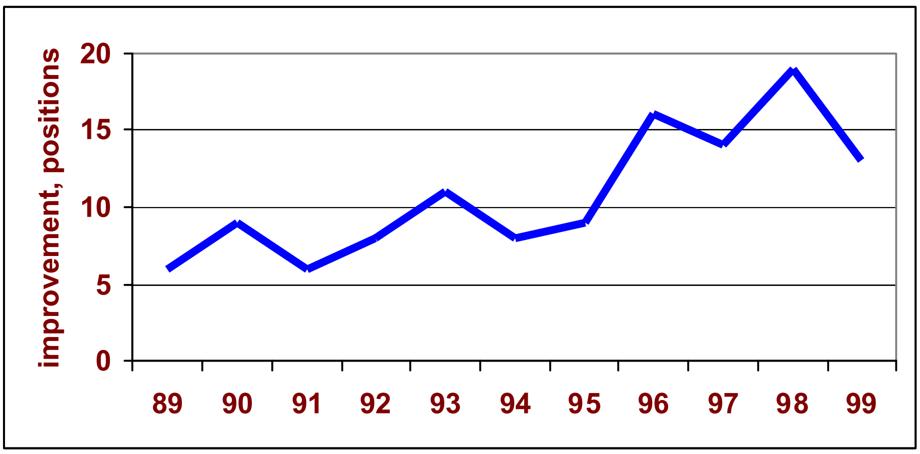
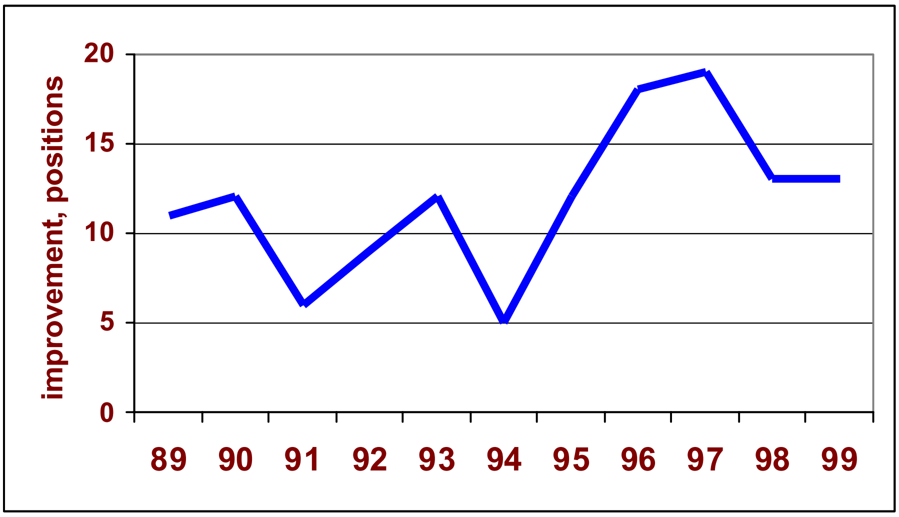


Figure 5.9: Improvement in efficiency ranking (83 regions) for a typical region, caused by an increase in ICT share from median to 5th best



An increase in the effect has taken place in the 1990's according to both figures. The effect of a 5 % ICT increase (fig. 5.8) has grown steadily and more or less doubled. The effect of an increase in ICT with respect to other regions (fig. 5.9) took a leap in the mid-90's. The results depend among other things on the efficiency distribution of the 83 regions each year. We saw in figure 5.2 that the efficiency density of regions is fairly dense between 75 to 87 per cent of full economic efficiency. In this range a shift of just a few per cent may alter the position of a region considerably.

An increase in ICT can have a significant effect on the relative performance ranking of a region in the range where many regions are close to one another in performance. This relative effect has grown in Finland during the 1990's.

How do different regions react?

An interesting question with policy relevance is whether all regions have equal opportunity to benefit from ICT. In particular, does ICT favour only large regional economies or do also smaller ones benefit? We now briefly test this by estimating quarters of the whole data by choosing each time 21 of the 83 NUTS 4 regions: the largest ones, the smallest ones etc. The estimations were done with the basic model for the whole period 1988-1999 and the most recent sub-period 1996-99.

Inefficiency (not efficiency) is the variable explained here. For this reason we now expect negative z-values, not positive. This is because a decrease in inefficiency (a minus sign) means an increase in efficiency, or a positive effect on the economy. For this reason, the z-values should be clearly negative (less than minus 2) for the expected beneficial effect to be present.

Table 5.1. Parameter estimates for an ICT effect in explaining regional inefficiency. Six region groups, inefficiency scaled to 0-100.

Region group	1988-1999			1996-1999		
	coeff.	z-value	increase in eff. /5 % increase in ICT share	coeff.	z-value	incr. in eff. /5 % increase in ICT share
Largest regions	-0.64	-7.97	3.2	-0.57	-3.95	2.8
Smallest regions	-0.22	-0.48	…	0.96	1.64	…
Most efficient regions	-0.39	-5.65	2.0	-0.53	-4.68	2.7
Least efficient regions	-0.24	-0.76	…	0.05	0.11	…
Most accessible regions	-0.28	-2.08	1.4	-0.45	-1.59	…
Peripheral regions	-0.43	-3.05	2.2	-0.42	-2.32	2.1

The results are interesting, for the benefits of ICT seem to concentrate into certain types of regions. The largest regions and those with already a competitive private sector clearly further benefit from ICT. A 5 percent increase in the ICT share of whole regional private sector (for example an increase in regional ICT activity from 20 per cent of the whole private sector to 25 per cent) would tend to increase the efficiency of large regions by some 3 percent. For the regions that are already most efficient, the corresponding increase would be at least 2 per cent. On the contrary, no statistically significant benefit can be found for the smallest and most inefficient regions. This can be seen from the low z-values, which tell that the estimates obtained may very well be incidental.

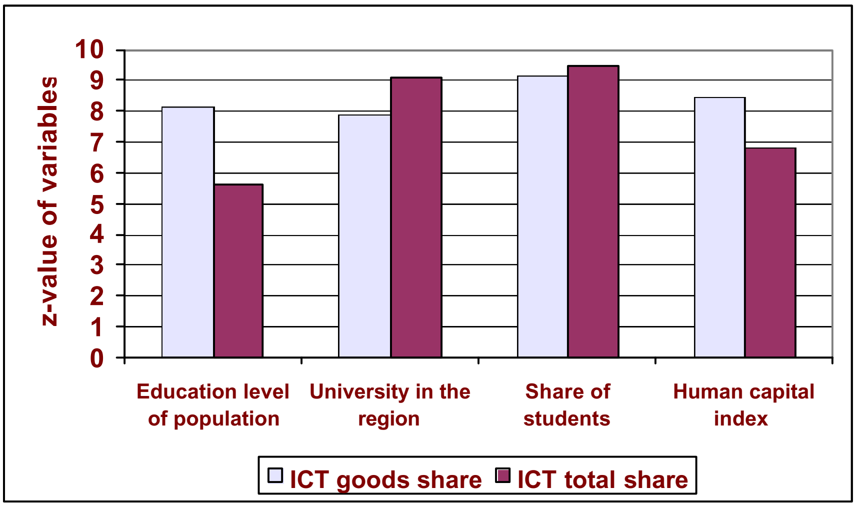
However, accessibility of a region does not seem to affect much the efficiency benefit of ICT. Being peripherally situated would not prevent a region from taking advantage of ICT. The possible benefit may even be slightly bigger for peripheral regions than for regions close to economic centres. But we are not denying the negative effect of remoteness itself to economic performance, as figure 5.6 indicates that this is the case.

Conclusion: the beneficial effects of growing ICT tend to concentrate to larger regions and those that already possess a competitive private sector. Small and inefficient regions do not derive a notable benefit, according to our results. In this sense ICT tends to increase economic *concentration into larger centres. But surprisingly, poor accessibility does not in itself prevent a region from taking advantage of ICT, even though it tends to decrease the level of efficiency.*

Alternative measures of regional knowledge

Of all the explanatory phenomena used, the amount of knowledge in the region is the most difficult one to measure. Its importance to the performance level of a regional economy may come from many sources. Different types of education of the population are important, as well as the experience and maybe even the age structure of the work force, and so on. How much then does the choice of the knowledge variable affect the results of the estimations? This question is first examined in figure 5.10, which again shows the statistical significance (negatives of z-values) of the effects. Tobit random effect panels are once more applied for 1988-1999. Positive columns indicate a positive effect on economic performance.

Figure 5.10. Increasing effects on efficiency from total ICT and ICT goods, when different knowledge variables are used, 1988-1999



The height of the columns in figure 5.10 tells the z-value of the effect, when the explanation uses the variable stated below the columns. The effect is statistically highly significant in all cases (z-values are always far above 2). The z-values mostly do not differ too much, nor are they very different for total ICT or ICT goods. Actually, the lowest value (5.62) is observed for our basic model for total ICT, using the education level of the population as the variable for regional knowledge. This is the basic model of all the calculations, unless stated otherwise.

In table 5.2 below the period 1988-1999 was broken into three sub-periods: 1988-1990, 1991-1995 and 1996-1999, corresponding to the three very different periods in the Finnish economy.

For each sub-period we chose the knowledge level variable (university in the area, number of university students, human capital index or average years of education) having the best explanatory power. The other variables remain unchanged.

Like in table 5.1, inefficiency is explained. A negative figure indicates increasing efficiency (decreasing inefficiency) and vice versa.

Table 5.2. Explaining regional inefficiency, when educational variables are chosen according to explanatory power. Three sub-periods and 1988-1999, inefficiency scaled to 0-100.

	Before depression 1988-90		Depression and early recovery 1991-95		Growth continues 1996-99		All 88-99	
	coeff.	z-ratio	coeff.	z-ratio	coeff.	z-ratio	coeff.	z-ratio
Population (logarithmic)	-1,05	-1,25	-1,802	-2,59	-0,908	-0,51	-,221	-5,82
Distance (100 km)	1,085	3,62	2,124	10,10	2,807	10,03	2,728	14,89
Specialisation index	-0,379	-5,07	-0,628	-13,86	-0,763	-8,53	-,592	-16,64
Proportion of students, %					-0,078	-0,25		
Human capital index	-0,129	-3,11	-0,093	-2,65				
Education level (years)							-,040	-2,06
ICT total share, %	*-0,523*	*-4,68*	*-0,274*	*-4,19*	*-0,520*	*-4,71*	*-0,31*	*-5,62*
Constant	28,623	11,16	29,075	13,63	25,071	4,35	32,13	9,27

In the sub-periods either the proportion of students in regional population or a general human capital index (constant in 1988-99) performs best. However, average years of education is the variable chosen for the basic model for the whole period, because it uses the whole regional population and also develops during the decade, reflecting changes in the regions' educational resources. The z-values for ICT shares do not differ much between the sub-periods in table 5.2, but the strength of the ICT effect is again lowest in 1991-1995. Moreover, no single education variable performed satisfactorily for 1996-99.

Conclusion: The effect of ICT on regional economic performance is not very sensitive to the choice of a regional knowledge variable. This holds for both ICT goods and total ICT. In the three sub-periods different knowledge measures perform best.

5.3. The direction of causality: ICT to performance or vice versa?

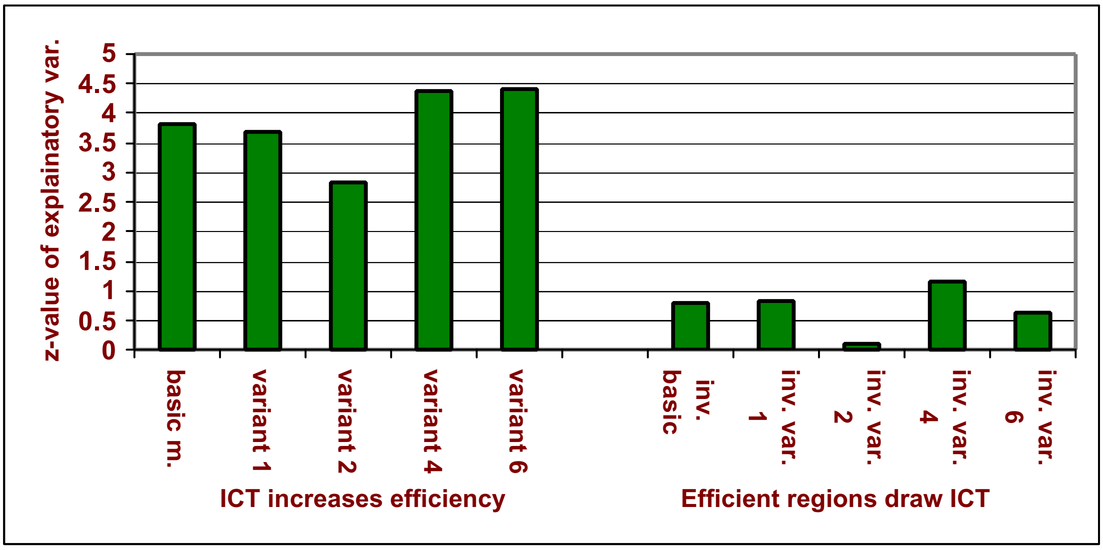
All the above models assumed that causality goes from the size of ICT to regional economic performance. But could the reverse rather be true: regional economies with high efficiency or performance would draw ICT, as ICT actors become aware of the good prospects of such regions? Looking at this question, it makes sense to assume a time lag in both possible effects.

Four-year Tobit random effects panels were applied in assessing the direction of causality. We do not perform a full testing on the direction of causality, so the results are only tentative. Because the data is incomplete considering the direction of causality question, we had to use the same basic structural variables in all tests. This meant that we "inverted" the original models: we explained ICT shares with lagged efficiency, size and distance of the regions etc. We again used our basic modeland moreover four of the six variants of figure 5.5 (1, 2, 4 and 6), now first in their original form (assuming that ICT increases efficiency) and then in an "inverted" form (assuming that efficient regions draw ICT). The remaining model variants (3 and 5) produced insensible results and were dropped.

Basically identical lags were used for both causality directions. The explanatory variable (ICT share when explaining efficiency and vice versa) was calculated as a moving four-year average for the beginning of the period (also three and five-year averages were tried, with only unimportant changes in results). For example, when explaining 1996 regional efficiency the ICT variable was the average share of 1988-1991. For 1997, averages for 1989-1992 were taken and so on.

In figure 5.11 the z-values (statistical significance) of the coefficients are again presented. Figures above +2 indicate a significant relationship in the explanations. All models assuming that ICT increases the performance level of regions have a highly significant and expected coefficient. Assuming in reverse that efficient regions draw ICT, all coefficients were again positive, but never close to being statistically significant.

Figure 5.11. Direction of causality: explaining efficiency with ICT and ICT with efficiency. Basic model and four variants, 1996-1999



We may also assume lags shorter than the 5 to 8 years above. The lag might be shorter if a high regional performance level draws ICT into the region. To look at this possibility, some calculations were made with 2 to 4 year lags. Then efficiency averages in early 90's would then explain annual ICT levels in late 1990's. The results were similar to figure 5.11: the effects were again positive but never statistically significant (z-values well below 2). The significance of different explanatory variables and the overall fit were considerably lower with the reverse assumption (efficiency draws ICT).

Conclusion: our data suggests that the causation is from ICT to efficiency, not from efficiency to increasing ICT. However the testing was incomplete and accordingly the result is tentative.

6. EFFICIENCY AND ICT IN SWEDISH REGIONS 1996-2000

For Sweden, data for DEA estimation was available for the years 1996 and 1998-2000. The list of available variables is somewhat different and more limited for Sweden than for Finland:

-regional private sector wage sums were used as the output measure for DEA

-DEA inputs were:

-number of employed in the private sector by five main education classes
-value of private capital stock in the region, dwellings excluded.

Altogether four DEA models were used for the efficiency estimation, and the regional efficiency scores were obtained as averages of the four models. This approach was similar to the Finnish case. The four models differed from each other as to the construction of the labour input variables by education level. The results of the DEA phase are described in chapter 6.1.

After this, the efficiency scores were statistically explained by four model specifications. The following variables were used in the analysis:

-logarithm of total regional population

-an index of accessibility, obtained from by Jöngköping International Business School

-Herfindahl index of regional specialisation in production, constructed from wage sums and at the detailed level of over 450 industries

-existence of a university in the region (yes / no)

-share of the ICT sector in total regional wages

Preliminary specification tests were again first performed to find an appropriate model type. In particular Hausman and Breusch-Pagan tests were applied, and as for Finland earlier, a random effects Tobit model was chosen. The results of the calculations are briefly presented in chapter 6.2.

6.1. DEA results

For Sweden, the efficiency distribution of the 81 regions is quite smooth in 1996-2000 (figure 6.1). However, the seven weakest regions (scoring below 80) seem to have fallen more clearly below the others. Interestingly, a similar result was also observed for the Finnish regions. Unfortunately it is impossible to compare generally the width of the Finnish and Swedish efficiency distributions, because the estimated models were different.

No direct connection between ICT share in wages and regional economic efficiency can be observed for Sweden (figure 6.2). This preliminary observation suggests that ICT might not have much explanatory power in statistical models either. We will see below that this really is the case for Sweden. What comes to size of the region it seems that the largest six or seven regions are among the more efficient ones, but that otherwise there is no connection between size and efficiency (figure 6.3).

Figure 6.1. Swedish NUTS 4 regions in decreasing order of efficiency 1996-2000

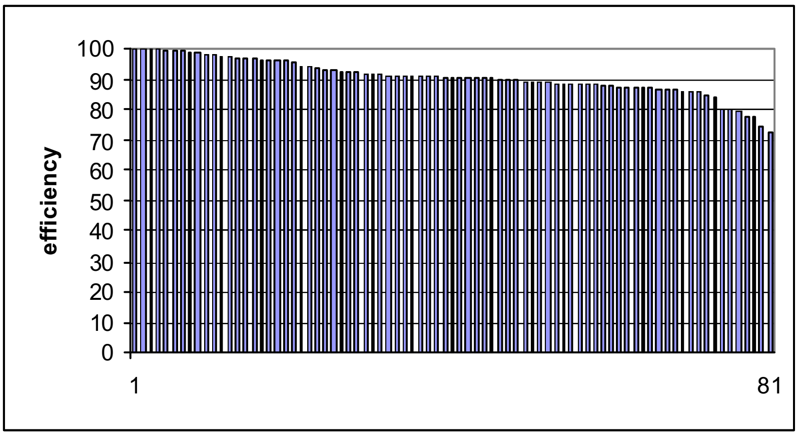


Figure 6.2. Share of ICT in wages and efficiency, Swedish regions 1996-2000

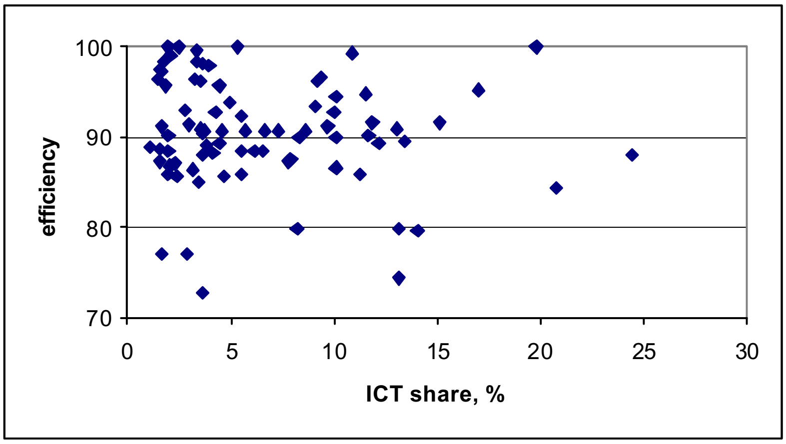


Figure 6.3. Population (logarithmic) and efficiency, Swedish regions 1996-2000

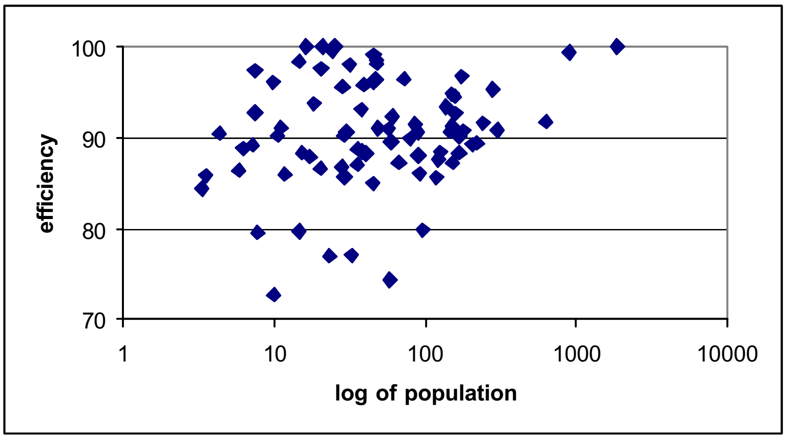


Figure 6.4. Stability of regional performance: efficiency scores 1996 and 2000

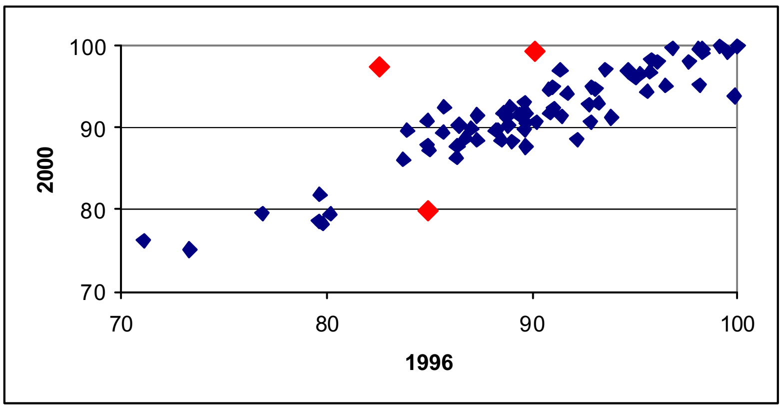


Table 6.1. Statistics of the results of DEA estimation for Swedish regions, 1996-2000

Average number of efficient regions	11
Average efficiency of regions, %	90,6
Average efficiency of weakest region, %	70,4
Average correlation of results between:	
- all the four years	+0,862
- successive years	+0,861
- the four DEA models	+0,896

The average number of efficient regions ranged in the four experiments between 6 and 20, largely depending on the number of explanatory variables. These regions received the efficiency score 100 per cent for the years in which they were fully efficient. The lowest relative efficiency for any region in any model was 67.2 percent, 70.4 being the average of the four models. The results were quite stable both what comes to time or estimated models (see also figure 6.4).

As a detail on temporal changes, it may be noted that particularly the position of three regions has changed markedly. The Storuman region has improved its position from 82.55 to 96.7 per cent as well as Årgäng region (99 to 99.3), whereas a clear deterioration has taken place in Sorsele, from 84.9 to 79.8. All these are small regions with a population under 10 000 people. It is of course possible that for such small regions statistical data problems may become especially large. But on the other hand fast changes are also more likely to occur in small regions, where the number of actors is smaller and the region may be heavily dependent on one or a few firms.

6.2. Results from panel estimation

The main result from the panel models can be very briefly stated: ICT had no expected effect on efficiency. Rather the result was opposite, or increasing ICT is connected with weaker regional performance. This seems of course implausible.

Table 6.2. Explaining regional inefficiency with ICT share and other variables: Sweden 1996-2000. Four random effects Tobit models, z-values

	Model 1: without ICT, without university	Model 2: with ICT, without university	Model 3: with university, without ICT	Model 4: with ICT and university
Population (log)	-4.01	-6.61	-4.14	-5.94
Accessibility index	-3.64	-5.19	-3.79	-4.50
Specialization index	-11.67	-8.34	-12.07	-12.12
ICT share in wages		*+6.12*		*+4.84*
University in region			+4.63	+1.41

Table 6.2 shows the main results by z-values of the coefficients. So, the question is again about the statistical certainty with which we can say that there is an effect, not the size of the effect itself.

And because we are again explaining inefficiency, a negative coefficient means that the factor in question increases efficiency, and a positive coefficient means that it decreases efficiency. Differently with the Finnish case, an accessibility index is here used to measure distance. So we expect here that the coefficients for accessibility would be negative: the closer you are to economic centres (more accessibility), the better performance you would have (less inefficiency).

What comes to the agglomeration effect (population), accessibility and rate of general specialisation (Herfindahl index), the results are similar to those of Finland (table 6.2, model 1). *Larger population, better accessibility and more general specialisation all mean better economic performance for a region* (or less inefficiency). These results were as expected and they also are insensitive to model specification, as is observed by comparing models 1 to 4 in table 6.2.

However there are two other variables, which proved to be problematic: ICT share in wages and the existence of a university in the region (table 6.2, models 2-4. Both ICT and university seem to be detrimental to regional economic performance! Certainly this should not be the case.

What causes such results? Instead of believing that regional development factors would differ so drastically between Finland and Sweden, we think it more plausible that data problems lie behind the results. Lacking regional value added data by industry, efficiency had to be measured by wage sums. Accordingly also the volume of ICT was measured by wages. But this may not be a good measure, as ICT may be characterised by high profits and by other GDP contributions.

Considering the nature of the results and the data limitations, the analysis was not carried further for Sweden. However if possible, it would be very interesting later to extend the work to Sweden and also to conduct a more extensive European comparative research. This is quite possible methodologically, provided that the data problems can be solved.

7. CONCLUSIONS

The aim of this sub-study of the MUTEIS project was to find out whether the ICT sector has an effect on regional economic performance levels. The study had a quantitative econometric orientation, and economic efficiency was chosen as the performance measure to be explained statistically. The main focus was on Finland 1988-1999, in addition to which a limited analysis of Swedish regions 1996-2000 was conducted. The regional level was NUTS 4, giving 83 regions for Finland and 81 for Sweden. No sufficient data could be found for Ireland or the Netherlands, and these countries were left outside the study.

Several interesting results were obtained. Increasing the volume of ICT in a Finnish region has a clear effect on efficiency, according to the estimation results. If the share of ICT in the whole regional economy grows by 5 per cent units (i.e. from 10 per cent of the whole region's production to 15 per cent), average efficiency increases 1 – 2.5 percent for the regions. This means that after such an ICT increase, a region can produce 1-2,5 per cent more goods and services than before, using the same resources as before. This means that the region's competitive position is enhanced, relative to other regions. Even a significant improvement in the relative position of a region can result, if many regions are close to one another, what comes to their performance levels.

The effect of ICT on efficiency was equally clear in the late 1980's and in the second half of 1990's in Finland, which were economically normal times. In the early 1990's when Finland was in economic crisis the effect was less clear. This efficiency effect includes both the efficiency of ICT sector itself and its indirect effects on other sectors.

However, ICT does not seem to treat regions equally, for the beneficial effects of increasing ICT tend to concentrate to larger regions and those that already possess a competitive private sector. Small and inefficient regions do not derive a notable benefit, according to our estimations. By time this would increase economic concentration into larger centres. But poor accessibility does not in itself prevent a region from taking advantage of ICT, even though it tends to decrease the level of efficiency.

The direction of causation was tentatively investigated for Finland. It was our assumption at the start of the study that increasing ICT would increase the economic performance of the region. But also the reverse could be possible: if a region is originally efficient, it would gradually draw ICT activity into the region, as ICT firms and other economic actors learn about the region's strength and prospects. To solve this problem, the direction of the effect was tentatively tested. The results suggested that the causation runs from increasing ICT to higher efficiency, not from higher efficiency to ICT growth.

Surprisingly, the efficiency increase seems to be limited to total ICT and ICT goods production, but no effect was found for services or R&D. One explanation for this may be that the indirect benefits of ICT services and R&D may leak out from the small regions. On the other hand R&D and ICT services may immediately not be very productive, while ICT goods production is likely to be highly productive even directly with their high contribution to GRP. A more refined method is needed to catch the remaining effects.

As to the other background factors of efficiency, economic distance is important as well as the rate of regional specialisation, and the effects of these factors have become clearer in Finland during the 1990's. The more accessible and the more specialised a region is, the higher efficiency tends to be, while for example peripheral regions tend to be economically inefficient. Amount of population of the region (agglomeration) also has an effect, education level (knowledge) to a limited extent. On the other hand it does not seem in itself to be important for efficiency whether a region has a university or not.

For Sweden the main result can be briefly stated: ICT had no expected effect on efficiency. Rather the result was opposite, or increasing ICT is connected with weaker regional performance. This seems of course implausible. What comes to the population effect, accessibility and rate of general specialisation, the results were similar to Finland. Larger population, better accessibility and more specialisation all mean better economic performance for a region. While it is likely that the missing ICT effect for Sweden is due to data problems and not real differences between Finland and Sweden, the analysis was not carried further for Sweden.

The study was conducted in two stages. First, efficiency scores were estimated for the NUTS 4 level regions by using Data Envelopment Analysis (DEA), a well known optimisation method. These efficiency scores were then statistically explained by applying Tobit random effect panel models. Regional volume of ICT activity was used as an explanatory factor, together with several other regional variables.

REFERENCES

Baltagi, B. (1995): Econometric Analysis of Panel Data, Wiley

Banker, R.D. - Charnes, A. - Cooper, W.W. (1984): Some models of estimating technical and scale inefficiencies in data envelopment analysis. Management Science, Vol. 9, No. 9, 1078-1092.

Bernard, J. - Cantner, U. (1997): French Regional Performance and Variety. A Non-Parametric Frontier Approach. Paper Presented at the 37th Congress of the European Regional Science Association, Rome.

Chang, P. - Hwang, S. - Cheng, W. (1995): Using Data Envelopment Analysis to Measure the Achievement and Change of Regional Development in Taiwan. Journal of Environmental Management, Vol. 43, 49-66.

Charnes, A., Cooper, W.W. and Rhodes, E. (1978): Measuring the efficiency of decision making units. European Journal of Operational Research, Vol. 2, 429-444.

Charnes, A. - Cooper, W. - Li, S. (1989): Using Data Envelopment Analysis to Evaluate Efficiency in the Economic Performance of Chinese Cities. Socio-Economic Planning Sciences, Vol. 23, No. 6, 325-344.

Farrell, M.J. (1957): Measurement of Productive Efficiency. Journal of the Royal Statistical Society, Series A, 253-281.

Huovari, J. - Kangasharju, A. - Alanen, A. (2001): Alueiden kilpailukyky. Pellervon taloudellisen tutkimuslaitoksen raportteja n:o 176, Helsinki (in Finnish, an abridged English version available).

Kirjavainen, T. – Loikkanen, H. (1998): Efficiency Differences of Finnish Senior Secondary Schools: An Application of DEA and Tobit Analysis. Economics of Education Review, 377-394.

Mao, W. - Koo, W. (1997): Productivity Growth, Technological Progress, and Efficiency Change in Chinese Agriculture after Rural Economic Reforms: A DEA Approach. China Economic Review, Vol. 8. No. 2, 157-174.

Maudos, J. – Pastor, J. – Serrano, L. (2000): Efficiency and Productive Specialisation: An Application to the Spanish Regions. Regional Studies vol. 34, 9, 829-842.

Matyas, L. – Sevestre, P. (1996): The Econometrics of Panel Data, a Handbook of the Theory with Applications. Kluwer Academic Publishers, Dordrecht.

Millan, J. - Aldaz, N. (1998): Agricultural Productivity of the Spanish Regions: A Non-Parametric Malmquist Analysis. Applied Economics, Vol. 30, 875-884.

Susiluoto, I. - Loikkanen H. (2001 a): The Economic Efficiency of Finnish Regions 1988-1999, an Application of the DEA Method. Paper presented at the 41st Congress of the European Regional Science Association, Zagreb, Croatia, 29.8. - 1.9.2001

Susiluoto, I. - Loikkanen H. (2001 b): Seutukuntien taloudellinen tehokkuus (Economic Efficiency of Regions). Helsingin kaupungin tietokeskuksen tutkimuksia 9/2001, Helsinki (in Finnish, English summary).

Susiluoto, I. - Loikkanen H. (2002): An Evaluation of Economic Efficiency of Finnish Regions by DEA and Tobit models. Paper presented at the 42st Congress of the European Regional Science Association, Dortmund, Germany, 27-31.8.2002

Tong, C. (1996): Industrial Production Efficiency and its Spatial Disparity among the TVEs of China: A DEA Analysis. Singapore Economic Review, Vol. 41, No. 1, 85-101.

Tong, C. (1997): China's Spatial Disparity within the Context of Industrial Production Efficiency: A Macro Study By the Data Envelopment Analysis (DEA) System. Asian Economic Journal, Vol. 11, No. 21, 207-217.

Weaver, R. (1984): Multiple Input, Multiple Output Production Choices and Technology in the U.S. Wheat Region. American Journal of Agricultural Economics, Vol 65, 45-56.