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ORIGINAL PAPER

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The identification of functional regions: theory, methods, and applications

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Abstract A functional region is characterised by a high frequency of intra-regional interaction. The text analyses how functional regions can be identified by using labour market data. Three approaches are applied in this task, named the local labour market, commuting zone, and accessibility approach, respectively. The text includes an application using the Fyrstad region. The situation is also studied at two points in time. The outcomes using the different approaches are compared, and the results combined have a richer flavour.

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1 Introduction

In Sweden, the daily average mobility of persons has increased from half a kilometre in the year 1900 to 45 km in the year 1999 (Andersson and Strömquist 1988; SIKA 2000). Moreover, the average daily mobility for men and women in the age group 25–44 is 77 and 59 km, respectively (SIKA 2000). Although the daily commuting region has expanded, economic activities are spatially concentrated. In particular, this is true for production activities. According to Krugman (1991), geographical concentration is the most striking feature of economic reality. Consumers' daily activities, including work, tend to be performed close to their residence. Firms hire workers living relatively close to the firm, buy services from firms located nearby and often sell their products in close proximity.

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This means that short-distance spatial interaction dominates for most households and firms. For each centre of economic activities, there exists a hinterland dominated by interactions with the centre. In the subsequent analysis, an economic functional region consists of one or more centres and the appurtenant hinterland (Karlsson 1994). A functional region is characterised by a high frequency of intra-regional economic interaction (Johansson 1998), such as intra-regional trade in goods and services, labour commuting and household shopping. Hence, the essence of a functional region is a system of highly connected smaller and larger places.

Given the rather general definition the question arises, how do we delimit functional regions in geographical space? The answer to this question is of considerable interest, since it has important analytical and planning implications. Functional regions often contain several administrative regions. This creates tensions and causes planning problems, since in the generic case several local governments are responsible for the planning of the functional region as a whole. The administrative regions need to co-operate in order to support the functional region. For labour market analysis and infrastructure planning, the functional region is the relevant geographic concept.

The purpose of this paper is to analyse various methods for identifying functional regions and to apply them on the Fyrstad region in western Sweden. In forming functional regions, the aim is to aggregate areas with high economic interaction. There are many types of interaction that one may consider, such as population flows (migration and commuting), trade in goods and services, communication, traffic flows, goods flows, service connections, newspaper circulation and financial flows (Vanhove and Klaassen 1987). In this paper, we make use of commuting data, since the pattern of daily interaction in the labour market can be assumed to be a good proxy for the functional region. The interest in economic regions started with Christaller (1933) and (Lösch 1938). Moreover, a restrictive list of related publications are Micklander (1971); Brown and Holmes (1971); Hay and Hall (1978); Hemmasi (1980); SCB (1992); Killian and Tolbert (1993); Johnston (1995); Johansson (1998) and Florkemeier.

The major contribution of this paper is the comparison of methods to delineate functional regions. The text discusses what is the core part of the Fyrstad region. Moreover, the peripheral Fyrstad is identified. The text argues that the larger Fyrstad region consists of ten municipalities: Färgelanda, Grästorp, Lilla Edet, Lysekil, Mellerud, Munkedal, Sotenäs, Trollhättan, Uddevalla and Vänersborg. The text offers discussions of relevant policy issues, and provides information that is important to decision making and model building.

Theoretical and practical methods for identifying functional regions using labour market data are presented in Section 2. In Section 3, alternative methods are applied to the Fyrstad region for the years 1986 and 1996. Conclusions and suggestions for future research are presented in Section 4.

2 Methods for identifying functional regions based upon labour market data

The purpose of this section is to present and discuss alternative methods for identifying functional regions using labour market data. In this paper, three delineation alternatives will be applied; these are (1) the local labour market, (2) the commuting zone and (3) the accessibility approach. The local labour market

approach uses one-way commuter flows. In the commuting zone approach we calculate the connection among municipalities, using commuter flows in both ways. With the accessibility approach we form a region based on the potential interaction between locations. Moreover, in this section the ways these methods are applied will be explained. These differences in how to define regions have consequences for the outcome, which will be seen in the Section 3.

2.1 A theoretical model delineating commuting regions

This first section analyses factors that determine where persons with a fixed place of residence choose to work. These ideas can be found in Beckmann (1996). This is a reasonable framework for the short term. In the medium term, people may move and then the framework should be modified. In a short-run analysis, the following simplified assumptions can be made. All workers have perfect information about jobs, wages and travel costs. All jobs are concentrated in two centres, i and j. All wages are the same in i and the same applies to j, but wages in j are assumed to be higher than in i, i.e. $w_j > w_i$.

Wages can be higher in j due to higher productivity in j. All jobs are equal in terms of the skills they demand and all workers have the same skills. All workers are assumed to live on a linear strip between i and j. Travelling from any point between i and j is associated with travel costs, c_i and c_j, that increase with the distance to i and j, respectively.

Given this we now assume that the objective of the workers is to maximise the real wage (w) net of the generalised travel cost (c). This net wage we refer to as ω. The net wage at any location between the two centres is max $\{\omega_i, \omega_j\}$. The two functional regions consist of the locations (x), which satisfy either $\mathbf{FR}_i\{x{:}\omega_i(x) > \omega_j(x)\}$ or $\mathbf{FR}_j\{x{:}\omega_j(x) > \omega_i(x)\}$.

In the sequel, we will analyse what happens to the functional regions when the basic conditions change. First, we analyse what happens when there is a change in the commuting costs. Assume that travel costs to centre j decrease due to investments in infrastructure or improvements in the public transport system. This will lead to a shift upward in the function ω_j. Hence, functional region j will be extended and functional region i will become smaller. Moreover, there will be an increase in the net wages and thus an improvement in economic welfare, given that the tax cost of the improvements is lower than the wage increase. There will also be an increase in the supply of workers, since fewer people will have reservation wages that are higher than the net wage.

In a second step we analyse what happens if the real wage in j, w_j, increases compared to the real wage in i, w_i. The driving force behind such an increase can be productivity improvements in j due to e.g. capital investments and/or an increase of agglomeration economies in j. The effects of a comparative real-wage increase are the same as those of a reduction of the generalised travel costs. The reach of the functional region j will be extended.

An alternative approach when delineating functional regions is to use commuting frequencies. Even if the real wages are not the only things valued by workers, they have a strong influence on behaviour. Hence, one can assume that commuting is attracted by the places with the highest net wage. Rouwendal (1998) defines the optimal area from which a person would accept the first job-offer, as **A***. The job-acceptance area is defined based on an assumption that each worker

maximises the net present value of income. In Rouwendal's model job-search takes time, because of incomplete information about vacant jobs. The probability for a job offer from centre i is γ_i. The place of residence and the place of work are by definition in the job-acceptance area. Therefore, the (conditional) probability of working in centre i is $P_i = \gamma_i \Big/ \sum_{j \in A^*} \gamma_j, i \in A^*$.

This probability can explain the empirical regularity (Bradford and Kent 1981) that commuting frequencies to a centre decline with increasing distance to the centre in question (Fig. 1). Assume that the household choice of location reveals the job-acceptance area in consideration. Assume that a household is located in a centre, since the members prefer to live and work in the same centre. A choice of living outside the large centre reveals that if the household members have to work in the centre they will do so, but they will not live there. The household located outside the centre has already accepted longer commuting (on average). The size of the job-acceptance area therefore increases with the distance from the centre in question. Outside the centre, there are small towns, with some job offers, which the household automatically takes into consideration. This enlarged job-acceptance area increases the sum of job-offer probabilities and causes the commuting probability (to centre i) to decline.

2.2 Taking the models closer to empirical observations

The distance interval that is observed in everyday commuting for a majority of the working population in Sweden is 15–60 min. When the distance gets too long other solutions than everyday commuting are usually preferred, such as weekly commuting, moving or teleworking (some or all of the time).

Johansson (1998) uses a distance-dependent cost function to explain that the interaction frequency declines with the distance (Fig. 1). The sum of all costs that depend on geography (distance) is called Geographical Interaction Costs. The

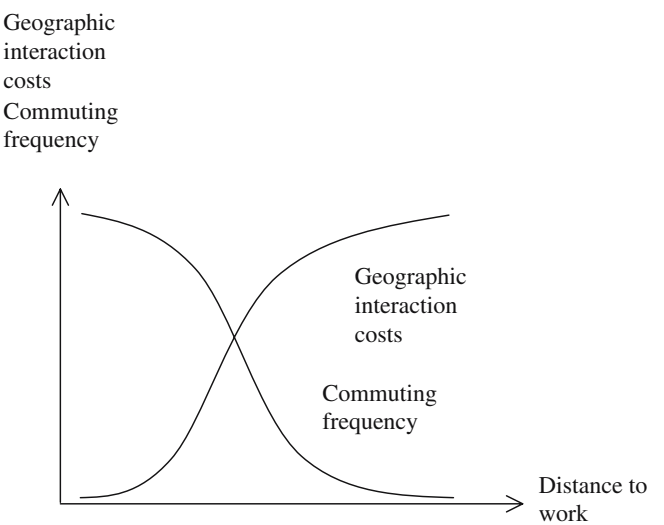

Fig. 1 The geographical interaction cost and the commuting frequency (Johansson 1998)

geographical interaction costs include costs for transportation, communication and transactions.

Products differ in their distance-sensitivity. Non-standardised production such as service production is of a local nature and the cost curve is very distance-sensitive. Standardised products have very flat cost curves. According to Johansson, it is possible to identify the border of the functional region when a large share of all distance-sensitive products has approximately the same distance barrier (approximately the distance where the interaction frequency is significantly reduced). One may argue that for a product it is interaction costs per unit value of the product that matter. A similar argument may be made with regard to type of labour and the pertinent wage level associated with each commuting link.

In the labour market, such barriers exist because of frictions in the transport system. The infrastructure and the functioning of the transport system give rise to discontinuous travel costs (including the value of time). The tariff system, when crossing an administrative border, often causes the costs to take a leap. During commuting, a change of means of transport induces waiting time. The reliability of the transport system is important and a change of transport mode may lower reliability. The infrastructure may cause traffic congestion and the unpredictability of commuting time is costly.

In reality, the border between two functional regions is always fuzzy. Workers do not have perfect information about job offerings in different centres. Not all jobs are concentrated in the centre. Different jobs demand different skills and offer different wages. Different workers have different skills. A further complication arises from the fact that many households contain two or more persons that are working. As the persons have different skills, it can be expected that even if they live in a given functional region not all of them work in the region. The following three methods may be applied to disaggregate data. For illustration, it may be interesting to analyse categories defined using occupation, industry, education, age et cetera per se. Different categories are likely to have different number and hence geographical extension of their functional regions. In the next section, aggregate data is used. Hence, the presented regional delimitation in a sense is an average.

The local labour market approach There are three different levels of interaction that may be used in estimating the extension of a functional region. Assume two centres indexed i and j connected by a line. The left endpoint is signified by i and the right by j. Moreover, x denotes an intermediate point between i and j. At a location (x) the commuting frequency to centre i is $f_i(x)$. The functional region consists of all geographic locations that satisfy one of the following three conditions.

The first condition would be to include all locations with any commuting to the centre i. The extension of the functional region i, $\mathbf{FR}_i$, is defined by $\mathbf{FR}_i = \{x : f_i(x) > 0\}$.

A second alternative condition would be to use a cut-off frequency (larger than zero) for inclusion, $\mathbf{FR}_i = \left\{x : f_i(x) \geq \bar{f} > 0\right\}$. The cut-off frequency gets rid of the very few long distance commuters. This rule does not allow extremely low interaction. With the second condition one obtains a smaller functional region than when using the first condition.

The third criterion for defining a functional region is to consider neighbouring central places and to calculate the breakpoint between the different central places.

The border is found where the attraction is equal to both of the closest cores. This is formally described by $\mathbf{FR}_i = \{x : f_i(x) \geq f_j(x)\}$. Moreover, combinations are possible and a combination of the second and third alternatives is applied in the application. Hence, $\mathbf{FR}_i = \{x : f_i(x) \geq f_j(x) \text{ and } f_i(x) \geq \bar{f}\}$.

In theory, the borders are exactly defined and the theoretical borders will not necessarily follow administrative borders. In practice, the functional region will consist of smaller areas that have been aggregated. This means that the smallest geographical area for which there exist commuting data (usually municipalities[1]) influences how close the estimated functional region will be to the theoretical functional region.

Several attempts have been made to delineate functional regions with the help of commuting data. One method to create the official local labour markets can be found in SCB (1992). As a first step of this method, municipalities that are strongly self-sufficient are identified. A municipality is considered strongly self-sufficient if less than 20% of the working population commute (from the municipality) and if no more than 7.5% of the working population commute to any specific municipality. SCB has examined different breakpoint values and found these values to be acceptable approximations. During the 1990s the above-presented values have been used in a number of studies (CERUM 1993; Kullenberg and Persson 1997; NUTEK 1997). The second step in this method is to add municipalities to the strongly self-sufficient ones. The municipalities that are not strongly self-sufficient are added in a chain to the municipality to which most commuters direct themselves. The chain is allowed to have three links (NUTEK 1997). If more links exist, the link is broken at the weakest point. The cut-off municipality is added to the municipality which receives the second largest flow of commuters. In SCB (1992) one more rule is presented, but not used. If two municipalities are not strongly self-sufficient, but the largest commuter flow in each municipality goes to the other, they themselves form a local labour market.

The above description is the traditional one and has the focus on the workers situation. A complement is to take the industrial life perspective. Hence, the self-sufficiency may be defined as the share of jobs in a municipality that is filled with workers residing in the same municipality. This kind of analysis is not taken further within this approach. However, both perspectives are applied in the accessibility approach (below).

Florkemeier presents intensity indices as a way to relate (here) commuting frequencies. The intensity index is defined as $I_{ij} = \left(C_{ij}/C_i\right) \Big/ \left(\sum_s C_{sj} \Big/ \sum_s C_s\right)$, where $C_i = \sum_r C_{ir}$. Relatively large (small) commuting frequencies correspond to intensity indices above (below) one. However, intensity indices have not been applied in this paper.

The commuting zone approach Killian and Tolbert (1993) estimate commuting zones. This second approach is less focused on urban cores than the methods mentioned above. The commuting zones are built from the existing mutual dependency of municipalities, rather than from one-way dependency. The number of commuters

[1] A municipality is the smallest civil jurisdiction in Sweden. Counties consist of several municipalities, which include both urban and non-urban areas.

from municipality i (j) to municipality j (i) is measured by C_{ij} (C_{ij}), and P_i (P_i) measures the working population in municipality i (j). A measure of the strength of the two-way commuting ties is calculated by $\left(C_{ij} + C_{ji}\right)/\min\left\{P_i, P_j\right\}$. With such a measure, two municipalities with a large one-way commuter-flow do not necessarily qualify as a region. Also in this approach, it is perfectly fine to alter the perspective, by replacing the denominator by the corresponding numbers for the industrial life. However, this line of inquiry is not further pursued within this approach. Moreover, observe the potential to make the intensity indices (above) two directional.

The accessibility approach The third delineation approach makes use of the accessibility concept, and two versions will be used here. The first investigates the employers' access to workers and the second investigates the workers' access to jobs. Moreover, the importance of these accessibility measures comes from the implications for the commuting patterns.

We want to find out which municipalities are the most important regarding potential labour supply for the employers in a municipality labelled i. To calculate the accessibility measure we use the number of workers that live in a municipality (identified by j), O_j, the commuting time between the two municipalities, t_{ij}, together with the distance friction, λ. The employers' worker-accessibility can be calculated by $A_i^w = \sum_j O_j e^{-\lambda t_{ij}}$. The contribution to the accessibility by a single municipality k is $O_k e^{-\lambda t_{ik}}$. The process starts by ranking these accessibility increments from large to small. In the following step, municipalities are added in that order, until a cut-off point is reached. When the n most influential municipalities are included, the accessibility is $A_{i(n)}^w = \sum_{j=1}^{n} O_j e^{-\lambda t_{ij}}$. The nth municipality is included if the accessibility increment is sufficiently large, $\Delta A_i^w / A_{i(n-1)}^w > x\%$ where $\Delta A_i^w = A_{i(n)}^w - A_{i(n-1)}^w$ and x is the chosen limit. This procedure results in a list of the most important municipalities from an employer perspective. The accessibility approach puts more focus on the needs of the core municipalities than the other approaches do.

Moreover, the same approach will be applied to the workers' accessibility to jobs, $A_i^j = \sum_j D_j e^{-\lambda t_{ij}}$, where the number of jobs in a municipality is measured by D_j. This procedure results in a list of the most important municipalities from a worker perspective.

3 The Fyrstad region as a functional region

Statistics Sweden collects commuting data (ÅRSSYS), and in this application, data from 1986 and 1996 are used. The number of functional regions in Sweden decreased between 1986 and 1996. An implication of the smaller number of regions is that several functional regions have grown in geographical space. Johansson et al. (2003) analyse the commuting pattern in Sweden.

The size of a functional region is an important indicator of local market size, which is an important variable in the decision whether to start a firm or not. The threshold market size is different between industries, and the bigger the local market, the more industries there are in the region. The size of the functional region

also has implications for worker flexibility. A worker in a larger functional region has more to choose from, regarding both workplace and type of occupation. For a thorough description of these ideas and many references see Nilsson (2001).

The purpose of this section is to use the tools from Section 2 to analyse the Fyrstad region in Western Sweden. The Fyrstad region is used as the name for the region formed by four neighbouring municipalities: Uddevalla, Trollhättan, Vänersborg and Lysekil. The location of the Fyrstad region is shown in a map of the county of Västra Götaland (Fig. 2). However, if we look upon the region as a functional region it also contains a number of neighbouring municipalities, i.e. the peripheral Fyrstad surrounding the core. We refer to this enlarged region as the larger Fyrstad region. The text argues that the larger Fyrstad region consists of ten municipalities: Färgelanda, Grästorp, Lilla Edet, Lysekil, Mellerud, Munkedal, Sotenäs, Trollhättan, Uddevalla and Vänersborg.

In Table 1 we list municipalities potentially in the larger Fyrstad region and illustrate the situation in 1986 and 1996 in terms of self-sufficiency. Self-sufficiency is defined as the share of persons employed who work in the municipality where they live. The self-sufficiency values are lower in 1996 than in 1986, for all municipalities. This is a sign of increasing regional integration. The change is largest for Vänersborg. Moreover, the changes in Lysekil, Trollhättan and Uddevalla are relatively small. However, the self-sufficiency has only been marginally reduced for Sotenäs.

Fig. 2 The position of the Fyrstad region in the county Västra Götaland. Source: The county administration of Västra Götaland

Table 1 Self-sufficiency in 1986 and 1996 for municipalities potentially in the larger Fyrstad region

Municipality	1986	1996	Change
Vänersborg	0.77	0.61	−0.16
Grästorp	0.59	0.51	−0.08
Lilla Edet	0.56	0.50	−0.06
Munkedal	0.67	0.62	−0.05
Mellerud	0.78	0.73	−0.05
Orust	0.60	0.56	−0.04
Essunga	0.64	0.60	−0.04
Uddevalla	0.83	0.79	−0.04
Lysekil	0.84	0.81	−0.03
Trollhättan	0.87	0.84	−0.03
Färgelanda	0.69	0.67	−0.02
Sotenäs	0.79	0.79	0

The local labour market approach Trollhättan is the only self-sufficient municipality at a self-sufficiency level higher than 81% in 1996. Non-self-sufficient municipalities with commuter flows greater than 5% to Trollhättan are added to Trollhättan to form the functional region (with the self-sufficient municipality as the core). According to this definition, the municipalities of Uddevalla, Mellerud, Vänersborg, Lilla Edet, Grästorp and Essunga belong to the functional region. If the self-sufficiency criterion is set at 80% Lysekil becomes self-sufficient. Sotenäs is added to the functional region as a non-self-sufficient municipality with a commuter flow to Lysekil larger than 5%. The larger Fyrstad region now consists of two functional regions (Table 2).

Trollhättan, Lysekil, Sotenäs and Uddevalla are self-sufficient municipalities when the limit is set at 79%. Hence, Sotenäs no longer belongs to the larger Fyrstad region. Munkedal, Färgelanda and Orust have more than 5% of the workers commuting to Uddevalla and are therefore included in the larger Fyrstad region. When the limit for self-sufficiency is lowered to 73% Mellerud is classified as self-sufficient municipalities. At this level Mellerud no longer belongs to the larger Fyrstad region. The larger Fyrstad region now consists of the three functional regions (Table 2).

If the self-sufficiency criterion is set to 65% Färgelanda becomes self-sufficient. When the limit is 60% Vänersborg, Munkedal and Essunga are classified as self-sufficient. Färgelanda, Munkedal and Essunga are self-sufficient and do not at this level belong to the larger Fyrstad region. The larger Fyrstad region then consists of four functional regions.

If the requirement for self-sufficiency is lowered to 50% then Orust, Grästorp and Lilla Edet become self-sufficient. This is seen in Table 2, and the larger Fyrstad region then consists of the four municipalities Uddevalla, Trollhättan, Vänersborg and Lysekil.

The definition of the official local labour markets (SCB 1992) can be used to classify the municipalities in the Fyrstad region. The self-sufficient municipalities (close to the Fyrstad region) are Lysekil, Strömstad, Bengtsfors, Trollhättan, Lidköping and Skövde. The result of using the local labour market criterion is that

Table 2 The larger Fyrstad region in 1996

Self-sufficiency (*S*)	Core	Periphery
0.81	Trollhättan	Essunga, Grästorp, Lilla Edet, Mellerud, Uddevalla and Vänersborg
	Lysekil	Sotenäs
0.79	Trollhättan	Essunga, Grästorp, Lilla Edet, Mellerud and Vänersborg
	Lysekil	–
	Uddevalla	Färgelanda, Munkedal and Orust
0.73	Trollhättan	Essunga, Grästorp, Lilla Edet and Vänersborg
	Lysekil	–
	Uddevalla	Färgelanda, Munkedal and Orust
0.65	Trollhättan	Essunga, Grästorp, Lilla Edet and Vänersborg
	Lysekil	–
	Uddevalla	Munkedal and Orust
0.60	Trollhättan	Grästorp and Lilla Edet
	Lysekil	–
	Uddevalla	Orust
	Vänersborg	–
0.50	Trollhättan	–
	Lysekil	–
	Uddevalla	–
	Vänersborg	–

the Fyrstad region consists of two local labour markets. The municipalities included in these local labour markets are 1) Lysekil (Core) and Sotenäs, and 2) Färgelanda, Grästorp, Mellerud, Munkedal, Trollhättan (Core), Uddevalla and Vänersborg. The other surrounding municipalities, not included in the Fyrstad region are: Orust (largest commuter flow to Göteborg [G]), Tjörn (G), Stenungsund (G), Lilla Edet (G), Ale (G), Alingsås (G), Vårgårda (Alingsås), Herrljunga (Borås), Essunga (Vara), Vara (Lidköping), Falköping (Skövde), Skara (Skövde), Åmål (Bengtsfors), Dals-Ed (Bengtsfors), Tanum (Strömstad).

The commuting zone approach A two-way commuter-flow measure (Section 2.2) has also been calculated for the municipalities in the larger Fyrstad region. The larger Fyrstad region would then consist of two areas with strong mutual commuter flows (Table 3). The municipalities in these regions are 1) Färgelanda, Lysekil, Munkedal, Sotenäs and Uddevalla, and 2) Grästorp, Lilla Edet, Mellerud, Trollhättan and Vänersborg. Lilla Edet is a municipality with interesting characteristics. Lilla Edet sends most of its commuters to Göteborg so Lilla Edet does not belong to the larger Fyrstad region using a one-way flow measure. Very few people commute from Göteborg to Lilla Edet. Lilla Edet sends almost as many commuters to Trollhättan as to Göteborg but more people commute from Trollhättan than from Göteborg to Lilla Edet. Using a two-way flow measure Lilla Edet would be included in the larger Fyrstad region (through Trollhättan), because the two-way flow measure between

Lilla Edet and Trollhättan was 0.21 which is larger than 0.19 that was the two-way flow measure between Lilla Edet and Göteborg.

We now continue by analysing how the situation has changed between 1986 and 1996 in the larger Fyrstad region.

The local labour market approach If the self-sufficiency limit is between 87 and 84%, only Trollhättan was self-sufficient in 1986 (Table 4). In 1986, four municipalities (Grästorp, Essunga, Vänersborg and Lilla Edet) had more than 5% commuting into Trollhättan. The functional region in 1986 did not contain Mellerud and Uddevalla, which was the case in 1996 (Table 2). Lysekil becomes self-sufficient at 84% and Uddevalla at 83%. Sotenäs is added to Lysekil and Orust, Munkedal and Färgelanda to Uddevalla (Table 4). The larger Fyrstad region at this self-sufficiency level consists of three functional regions.

Lowering the limit to 79% makes Sotenäs self-sufficient. Because of that, Sotenäs does not belong to the larger Fyrstad region. Vänersborg turns self-sufficient at 77%. No municipality is added to Vänersborg. The main difference compared to 1996 is that in 1986 Vänersborg is much less connected to the neighbouring municipalities. The larger Fyrstad region then consists of four functional regions (Table 4).

As the requirement for self-sufficiency gets lower, more municipalities become self-sufficient and are excluded from the larger Fyrstad region. Färgelanda is lost at 69%, Munkedal at 67% and Essunga at 64%. Orust becomes self-sufficient at 60%, Grästorp at 59% and Lilla Edet at 56%. The larger Fyrstad region at this self-sufficiency level consists of the core municipalities.

In 1996, the larger Fyrstad region consisted of two local labour markets. Repeating the procedure for 1986 shows that in 1986, the larger Fyrstad region contained three local labour markets. From 1986 to 1996, the larger Fyrstad region did not change, but the labour markets became more interwoven. The local labour markets are 1) Lysekil (Core) and Sotenäs, 2) Färgelanda, Munkedal and Uddevalla (Core), and 3) Grästorp, Mellerud and Trollhättan (Core). The second and third local labour markets were 1996 joined into one.

The commuting zone approach If the two-way commuter-flow measure used for 1996 is used for 1986 it can be shown that the larger Fyrstad region has not changed over these 10 years. However, during these ten years, there has been an increase in the connectivity between the municipalities (Table 3), but the larger

Table 3 Two-way flow measures in 1986 and 1996

Municipality	Municipality	1986	1996	Change
Vänersborg	Trollhättan	0.26	0.37	0.11
Munkedal	Uddevalla	0.19	0.22	0.03
Grästorp	Trollhättan	0.15	0.18	0.03
Mellerud	Vänersborg	0.11	0.14	0.03
Lysekil	Uddevalla	0.08	0.10	0.02
Färgelanda	Uddevalla	0.17	0.18	0.01
Sotenäs	Lysekil	0.07	0.08	0.01
Lilla Edet	Trollhättan	0.21	0.21	0.00

Table 4 The larger Fyrstad region in 1986

Self-sufficiency (S)	Core	Periphery
0.83	Trollhättan	Essunga, Grästorp, Lilla Edet and Vänersborg
	Lysekil	Sotenäs
	Uddevalla	Färgelanda, Munkedal and Orust
0.79	Trollhättan	Essunga, Grästorp, Lilla Edet and Vänersborg
	Lysekil	–
	Uddevalla	Färgelanda, Munkedal and Orust
0.77	Trollhättan	Essunga, Grästorp and Lilla Edet
	Lysekil	–
	Uddevalla	Färgelanda, Munkedal and Orust
	Vänersborg	–
0.69	Trollhättan	Essunga, Grästorp and Lilla Edet
	Lysekil	–
	Uddevalla	Munkedal and Orust
	Vänersborg	–
0.60	Trollhättan	Grästorp and Lilla Edet
	Lysekil	–
	Uddevalla	–
	Vänersborg	–
0.56	Trollhättan	–
	Lysekil	–
	Uddevalla	–
	Vänersborg	–

Fyrstad region has not expanded to include other municipalities. The largest observed increase in connectivity is between Trollhättan and Vänersborg.

The accessibility approach The accessibility procedure is repeated for each municipality in the Fyrstad region, i.e. Lysekil, Trollhättan, Uddevalla and Vänersborg. The distance friction used in all calculations is 0.11. This distance

Table 5 Worker-accessibility and job-accessibility measures for Lysekil in 1996

n	Municipality	$A^w_{i(n)}$	$\Delta A^w_i / A^w_{i(n-1)}$	n	Municipality	$A^j_{i(n)}$	$\Delta A^j_i / A^j_{i(n-1)}$
1	Lysekil	2,004		1	Lysekil	1,936	
2	Uddevalla	2,983	0.489	2	Uddevalla	2,952	0.525
3	Munkedal	3,188	0.069	3	Munkedal	3,115	0.055
4	Orust	3,347	0.050	4	Trollhättan	3,232	0.038
5	Sotenäs	3,466	0.036	5	Sotenäs	3,347	0.036
6	Trollhättan	3,558	0.027	6	Orust	3,453	0.032
7	Vänersborg	3,624	0.019	7	Göteborg	3,514	0.018
8	Stenungsund	3,684	0.017	8	Stenungsund	3,574	0.017
9	Tanum	3,742	0.016	9	Vänersborg	3,628	0.015
10	Göteborg	3,792	0.013	10	Tanum	3,682	0.015

friction originates from estimation of a gravity model. Moreover, the distance friction serves as a discounting factor and the results would principally be the same for other values too. The results for year 1996 are summarised in Tables 5, 6, 7 and 8.

The Fyrstad region is a concept, but is it really a region? The analysis using the local labour market and commuting zone approaches indicates that the larger Fyrstad region is divided into (two) parts. Trollhättan, Uddevalla and Vänersborg all are important suppliers of jobs and workers to each other. Moreover, this is especially true for Trollhättan and Vänersborg, which really are highly mutually dependent. Uddevalla has no neighbour municipality that is very important either as a supplier of workers or of workplaces. Figure 3 shows that the neighbour municipalities contribute to Uddevalla, but the importance of the most accessible neighbours are lower than is observed in, for example, Vänersborg.

Even with this approach, Lysekil is a loner, and hence a questionable core member. Lysekil's contribution to the other core members is very limited. Lysekil is neither an influential source of potential labour supply nor an important source of potential labour demand. Uddevalla is important for Lyskeil as a supplier of jobs and workers. In this respect, it is also worth noting that infrastructure investments shortening commuting times from Uddevalla (or Lysekil) to Trollhättan and Vänersborg would increase the mutual accessibility significantly, connecting the municipalities into a real core of the larger Fyrstad region. Observe that with a narrow cluster definition we get a region that consists of Trollhättan, Uddevalla and Vänersborg. These three municipalities are included in each others set of the most accessible municipalities (Table 9). Hemmasi (1980) group city-centered counties into functional regions using factor analytic techniques. Moreover, some functional regions are more connected than others. Hence, he forms macro functional regions by grouping functional regions. In our context, it is very likely that the two functional regions making the larger Fyrstad region both belong to the same macro functional region.

In the next step, we create a region for these four municipalities considered together. To begin with, we include municipalities until the added accessibility is less than 4%, x=4%. In essence, such a region consists of all municipalities that are (that) important to at least one of the core municipalities. Using the employers' accessibility to workers, the larger Fyrstad region is presented in Table 9. The larger Fyrstad region that is constructed using the workers' accessibility to jobs is

Table 6 Worker-accessibility and job-accessibility measures for Trollhättan in 1996

n	Municipality	$A^w_{i(n)}$	$\Delta A^w_i / A^w_{i(n-1)}$	n	Municipality	$A^j_{i(n)}$	$\Delta A^j_i / A^j_{i(n-1)}$
1	Trollhättan	7,084		1	Trollhättan	9,004	
2	Vänersborg	8,826	0.246	2	Vänersborg	10,414	0.157
3	Lilla Edet	9,600	0.088	3	Uddevalla	11,076	0.064
4	Uddevalla	10,238	0.066	4	Göteborg	11,592	0.047
5	Göteborg	10,662	0.041	5	Lilla Edet	12,097	0.044
6	Grästorp	10,891	0.021	6	Alingsås	12,293	0.016
7	Alingsås	11,117	0.021	7	Stenungsund	12,464	0.014
8	Ale	11,327	0.019	8	Grästorp	12,619	0.012
9	Stenungsund	11,498	0.015	9	Lidköping	12,766	0.012
10	Lidköping	11,648	0.013	10	Ale	12,883	0.009

Table 7 Worker-accessibility and job-accessibility measures for Uddevalla in 1996

n	Municipality	$A^w_{i(n)}$	$\Delta A^w_i / A^w_{i(n-1)}$	n	Municipality	$A^j_{i(n)}$	$\Delta A^j_i / A^j_{i(n-1)}$
1	Uddevalla	6,441		1	Uddevalla	6,687	
2	Trollhättan	7,143	0.109	2	Trollhättan	7,579	0.133
3	Vänersborg	7,656	0.072	3	Göteborg	8,065	0.064
4	Stenungsund	8,117	0.060	4	Stenungsund	8,525	0.057
5	Göteborg	8,516	0.049	5	Vänersborg	8,941	0.049
6	Lysekil	8,820	0.036	6	Lysekil	9,235	0.033
7	Orust	9,024	0.023	7	Munkedal	9,383	0.016
8	Munkedal	9,210	0.021	8	Orust	9,519	0.014
9	Lilla Edet	9,366	0.017	9	Kungälv	9,634	0.012
10	Kungälv	9,519	0.016	10	Lilla Edet	9,735	0.010

presented in Table 10. Since the results are very much the same, only the results in Table 9 are commented upon.

Now we can compare the results from using the accessibility measures to the results from the other approaches used. In Table 11, the results from the commuting zone and accessibility approaches are compared. When the accessibility approach is used Färgelanda, Grästorp, Mellerud and Sotenäs are excluded from the region. Sotenäs has a low accessibility but lack of options force workers in this municipality to commute to Uddevalla and Lysekil—in spite of the time distance. Moreover, Orust, Stenungsund and Göteborg are added to the region. In other words, Stenungsund is accessible but has Göteborg as a better option.

Using the accessibility approach we obtain a region that is located to the south of the region that we obtain when using the commuting zone approach. Because, the accessibility approach puts more emphasis on the situation in the core municipalities, the shift southward is not surprising, since Göteborg (the second largest city in Sweden) acts like a magnet. Stenungsund, for example, is included in the larger Fyrstad region using the accessibility approach. This is the case, since Stenungsund is sufficiently large as a potential source of both workers and jobs. Nevertheless, the interaction between the Fyrstad region and Stenungsund is not large enough to include Stenungsund in the larger Fyrstad region, when the

Table 8 Worker-accessibility and job-accessibility measures for Vänersborg in 1996

n	Municipality	$A^w_{i(n)}$	$\Delta A^w_i / A^w_{i(n-1)}$	n	Municipality	$A^j_{i(n)}$	$\Delta A^j_i / A^j_{i(n-1)}$
1	Vänersborg	5,162		1	Vänersborg	4,178	
2	Trollhättan	7,553	0.463	2	Trollhättan	7,217	0.727
3	Uddevalla	8,194	0.085	3	Uddevalla	7,882	0.092
4	Lilla Edet	8,365	0.021	4	Mellerud	8,015	0.017
5	Mellerud	8,525	0.019	5	Göteborg	8,129	0.014
6	Grästorp	8,664	0.016	6	Lilla Edet	8,240	0.014
7	Färgelanda	8,780	0.013	7	Grästorp	8,334	0.011
8	Göteborg	8,874	0.011	8	Färgelanda	8,426	0.011
9	Lidköping	8,965	0.010	9	Lidköping	8,515	0.011
10	Alingsås	9,042	0.009	10	Alingsås	8,582	0.008

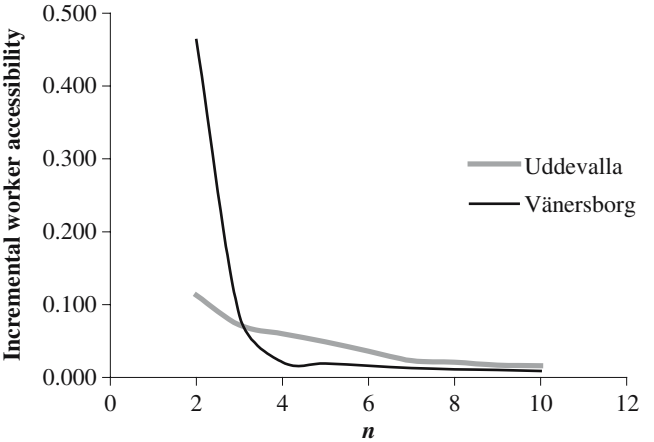

Fig. 3 Incremental worker accessibility for Uddevalla and Vänersborg

commuting zone approach is used. In other words, when actual commuting rather than potential is used to delineate a region, the flows to and from Stenungsund are not large enough. The accessibility approach ignores the intervening opportunities available for workers living and firms located in Stenungsund. Göteborg has a very strong attracting effect pulling Stenungsund away from the larger Fyrstad region. Moreover, the same analysis is relevant for Lilla Edet, which in spite of being accessible to the Fyrstad region gradually has developed more and more interaction with Göteborg.

This idea can of course also be used in a reversed way for a municipality such as Sotenäs, which due to a lack of large-city attraction is rather pushed to the larger Fyrstad region. In other words, Sotenäs has a high enough interaction with the core municipalities to be included into the region when the local labour market and commuting zone approaches are applied, even though the accessibility would suggest the opposite. Moreover, one evident drawback of the accessibility approach is that the region can consist of parts, which are geographically disconnected.

This analysis suggests an option to use the accessibility approach in a different way. If accessibility measures were calculated for all municipalities, not just for the municipalities in the Fyrstad region, there is a possibility to divide Sweden into regions using cluster analysis based on the accessibility figures. Florkemeier applies cluster analysis and other multivariate techniques on the intensity indices to form international functional trade regions.

Raising the inclusion limit to 7% (x=7%) reduces the larger Fyrstad region to Lilla Edet, Lysekil, Trollhättan, Uddevalla and Vänersborg. If the inclusion level is

Table 9 The larger Fyrstad region using employers' accessibility to workers in 1996 (x=4%)

Core member	Most accessible municipalities
Lysekil	Uddevalla, Munkedal and Orust
Trollhättan	Vänersborg, Lilla Edet, Uddevalla and Göteborg
Uddevalla	Trollhättan, Vänersborg, Stenungsund and Göteborg
Vänersborg	Trollhättan and Uddevalla

Table 10 The larger Fyrstad region using workers' accessibility to jobs in 1996 (x=4%)

Core member	Most accessible municipalities
Lysekil	Uddevalla and Munkedal
Trollhättan	Vänersborg, Uddevalla, Göteborg and Lilla Edet
Uddevalla	Trollhättan, Göteborg, Stenungsund and Vänersborg
Vänersborg	Trollhättan and Uddevalla

set to 9% or higher ($x \geq 9\%$) the Fyrstad region consists of the core municipalities only.

We argue that the functional region should be formed from actual commuting patterns, rather than potential commuting. However, discrepancies between commuting patterns and accessibility patterns indicate a potential for change processes in the future.

The larger Fyrstad region in 1996 consisted of municipalities from three counties (now joined into the county of Västra Götaland).

In the larger Fyrstad region defined by using the commuting zone approach, the borders of the functional regions tend to follow the former county borders (Fig. 4). Municipalities are relatively more connected inside counties than across counties. The exceptional municipalities are Grästorp and Färgelanda. Färgelanda belonged to the county of Älvsborg but to the functional region with Lysekil, Munkedal, Sotenäs and Uddevalla. Grästorp belonged to the county of Skaraborg but to the functional region with Lilla Edet, Mellerud, Trollhättan and Vänersborg. These cross-county functional regions created planning problems and might have been the main reason for the relative stability of the larger Fyrstad region between 1986 and 1996. This also suggests that barriers to crossing county borders may exist. Note the possibility that the low interaction may be due to the relatively long commuting time alone, without any extra barrier effects. Olsson (2002) analyse barriers per se as well as investigate the effects of improved infrastructure in the region. Using local labour markets instead, in principle, leads to the same conclusions, except that Lilla Edet is not included in the larger Fyrstad region. The larger Fyrstad region consists of ten municipalities: Färgelanda, Grästorp, Lilla Edet, Lysekil, Mellerud, Munkedal, Sotenäs, Trollhättan, Uddevalla and Vänersborg. We include Lilla Edet, even though the larger Fyrstad region seems to gradually lose Lilla Edet to Göteborg. The two-way flow measure between Lilla Edet and Göteborg increased from 0.14 in 1986 to 0.19 in 1996 while the two-way flow measure between Lilla Edet and Trollhättan was unchanged at 0.21, and hence still larger than the 1996 Göteborg index measure (Table 3).

Table 11 A comparison of the commuting zone and the accessibility approaches in 1996

Approach	Municipalities included in the functional region
Commuting zone	Färgelanda, Grästorp, Lilla Edet, Lysekil, Mellerud, Munkedal, Sotenäs, Trollhättan, Uddevalla and Vänersborg
Accessibility	Göteborg, Lilla Edet, Lysekil, Munkedal, Orust, Stenungsund, Trollhättan, Uddevalla and Vänersborg

Fig. 4 The larger Fyrstad region (commuting zone approach) had parts in three counties. Source: The county administration of Västra Götaland

4 Conclusions and suggestions for future research

Between 1986 and 1996 the self-sufficiency of Swedish municipalities decreases. At the national level, there are fewer functional regions 1996.

A general reflection regarding the municipalities in the larger Fyrstad region is that their mutual connectivity has increased over the study period. It is noteworthy that this has had limited effects on which municipalities are members of the constructed region. This is in contrast to what has happened in the rest of Sweden. For the larger Fyrstad region, the commuter flows have become more intertwined among the municipalities, but the geographical extension of the region has not grown. Based upon our analysis we consider the larger Fyrstad region to consist of Färgelanda, Grästorp, Lilla Edet, Lysekil, Mellerud, Munkedal, Sotenäs, Trollhättan, Uddevalla and Vänersborg.

This study of functional regions and labour markets suggests a need for further research. This paper was based on total commuter flows. The commuting distances for men are on average longer than the commuting distances for women, and the distance commuted tends to increase with the commuters' level of education. Hence, the functional regions for males are larger (in geographical space) than the functional regions for females, and people with a high education have a larger functional region than people with a lower education. Since the main motivation for this study is labour market integration and infrastructure planning, it is not enough to have knowledge of the functional regions based only on total flows. It would be of value to perform an analysis of gender differences and to study the connection between commuting behaviour and educational level.

We also found that the functional regions in the larger Fyrstad region behaved as if they were prevented from growing geographically, because of the prevailing county borders. This matter is serious. To measure the sizes of these apparent barriers to commuting is important, since such barriers contribute to welfare losses. Another issue for future research is to examine how the relative wage levels change in municipalities as these become more connected and form an integrated labour market.

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