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EFFECTS ON HOUSING PRICES OF URBAN ATTRACTION AND LABOR MARKET ACCESSIBILITY

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Effects on housing prices of urban attraction and labor market accessibility*

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Abstract

Through a hedonic approach this study primarily focuses on how house prices vary systematically with respect to some general spatial structure characteristics in a Norwegian region. The introduction of a gravity based labor market accessibility measure contributes significantly to explain variation in housing prices, also in a model formulation where the distance from the city center is accounted for. Based on these results we suggest a distinction between an urban attraction effect and a labor market accessibility effect. Quantitatively, the two distinct effects are found to contribute about equally to intraregional variation in housing prices.

Keywords: house prices, urban attraction, labor market accessibility, hedonic approach, price and accessibility gradients

JEL-classification: R21, R31

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1 Introduction

It is well known in the literature that house prices vary systematically with respect to some general characteristics of the spatial structure in a region. One such characteristic is the location of jobs. The relationship between labour market accessibility and housing prices has for a long time been given a lot of attention in the housing market literature, and it is often a basic part of spatial equilibrium models in regional science and urban economics. The standard theoretical reference for the relationship is the "access-space-trade-off "model of Alonso (1964). This model is based on the assumption that all jobs are located in the city center, and labor market accessibility is represented by the distance to this central business district (cbd). Though the modeling framework has been extended in several directions and adapted for regions with multiple centers (see for instance Richardson 1988), many theoretical and empirical studies are pivoted on the central idea of the "access-space-trade-off "model, which gives rise to house prices falling with increased distance from the city center.

The analysis in this paper is based on data from the southern parts of Rogaland County in the southwest of Norway. This region represents a relatively self-contained labor market, with a dominating city (Stavanger) that influences the economic situation and labor market decisions in all other parts of the region. Since our analysis is focussing on the interaction between the labor market and the housing market, it is reasonable to consider a regional rather than an urban perspective. Our study area is very appropriate also because topographical barriers deter disturbing interaction with adjacent areas.

Job opportunities are definitely not totally concentrated to the cbd even in this rather monocentric geography. Motivated from this fact we introduce a gravity based labor market accessibility measure, as an attempt to deal explicitly with polycentric tendencies in the spatial structure. Our basic hypothesis is that this measure is a better representation of the trade-off between commuting costs and housing consumption than the distance from the cbd.

It is intuitively reasonable that labour market accessibility and potential commuting distances are important determinants for how readily saleable a house is, and what price that is achieved. It is also obvious that households value high accessibility to other activities than their job. Our data do not allow us to enter into details on non-work activities, but we proceed through the hypothesis that the dominating city center has a particularly high density of relevant attractions. We attempt to find how this is reflected in house prices, when labor market accessibility is accounted for by a separate measure. Are both the labor market accessibility measure and the distance to the cbd relevant spatial characteristics in an explanation of housing prices? Do housing prices tend to be negatively related to the distance from the cbd also in such an approach? If so, how does this comply with the standard interpretation that falling housing price gradients from the cbd reflect the trade-off between housing consumption and commuting costs? By addressing such questions our main ambition is to contribute to an improved understanding of systematic spatial variation in housing prices.

In addition it is of course also our ambition to offer quantitative estimates of how general spatial structure characteristics affect housing prices. The market evaluation of accessibility represents important input in urban and regional planning, like for instance the development of decentralized employment centers. Research based on the hedonic framework in general offers useful information on the valuation of goods which are not directly bought and sold in markets.

In Section 2 we review some relevant contributions in the literature. The region and our data are described in Section 3, while the basic modeling setup is presented in Section 4. The results are presented in Section 5 and Section 6 offers some concluding remarks.

2 Relevant contributions in the literature

The Alonso model has increasingly been criticized by researchers who claim that workplaces are not solely located in the city center and that trips to work encompass a declining share of the overall household traveling. Experience has also proved that it is not straightforward to carry through reliable empirical studies of the relevant relationship. The polycentric nature of many housing market areas represents one kind of complexity, affecting in particular the use of one-dimensional separation measures, like physical distance and travelling time from a distinctly defined center. The presence of multiple-worker households and multiple workplaces motivate the use of alternative separation measures. As stated by Heikkila et al. (1989) "... with multiple-worker households, multiple workplaces are common; given a high degree of residential mobility, sites offering accessibility to many employment nodes are more valuable because it is not very likely that successive owners will work in the same workplace" (page 222). With a spatially very dispersed distribution of employment opportunities it might even prove difficult to find a significantly falling housing price gradient within an area. As opposed to the case for ten other locational nodes in the LA-area, Heikkila et al. (1989) for instance found that the distance to cbd had a very low t-value and unexpected sign. Based on such results Heikkila et al. (1989) claimed that the impact of workplace accessibility has been overemphasized. Richardson et al. (1990) found a significantly negative value of the coefficient related to distance from the LA cbd in 1970, while this variable were not found to influence house prices in 1980. Waddell et al. (1993) emphasized the importance of including the distance to secondary employment centers, and they found both a strong and significant asymmetric cbd-gradient, and strong effects from the non-cbd employment centers. More recently McMillen (2003) has discussed the steady decline in the importance of the cbd in American cities in the 1980's. McMillen (2003) found that data on repeated sales in Chicago suggest that the unit price of housing falls with distance from the cbd.

The utility-maximizing framework underlying the trade-off between housing consumption and commuting costs implies that the individual price-distance function is income-dependent. A general result in this theory is that higher income classes live farther from the cbd, see for instance Yinger (1979). Yinger (1979) combines this result with the observation that employment is in general not entirely concentrated to the cbd. He defines rings of employment around the cbd, measures the distance to place of employment within each ring, and assumes that households within each ring represents the same income class. Based on data from two US metropolitan areas Yinger (1979) finds that, except for the inner ring, the price-distance function is flatter than expected, and is actually upward sloping in some rings. The modeling challenge is that distance to the city center is not adequate as a measure of spatial separation between job opportunities and residents. Dubin and Sung (1987) find that both cbd and suburban employment and amenity centers exert the expected influence on housing prices. They highlight that it is a complex problem to ascertain the effect of employment location on housing prices, and advocate the use of alternative measures of employment accessibility than one-dimensional measures of distance.

An appealing hypothesis is that model performance improves substantially if a gravity based accessibility measure is introduced to account for the possibility that the relevant kind of spatial pull originates from several destinations. A hedonic approach offers an estimate of the implicit prices for a location with a marginally improved labour market accessibility. Adair et al. (2000) introduce a sophisticated gravity based measure of transport accessibility in a hedonic model explaining house prices in the Belfast urban area. The measure distinguishes between two person types (according to car availability) and three trip purposes (work, non-home based, and others). The authors proceed through a stepwise estimation approach, where mean values of the transport accessibility measure are calculated for 182 traffic zones in the Belfast urban area. Those values are based on estimates from a separate transport gravity model, incorporating trip generation, distribution, modal split and assignment.

Adair et al. (2000) find that transport accessibility has a minimal effect upon house prices in the Belfast urban area. In a logarithmic model specification the accessibility index appears to be significant, but accounts for a very small percent of the variation in housing prices. Specific physical housing attributes and socioeconomic variables appears to be a lot more influential. Still, Adair et al. (2000) find that transport accessibility has a considerable impact on housing prices within some submarkets. According to their results transport accessibility explains 14% of the variation in prices of terraced houses in areas of the city with relatively low income and low car accessibility. Within such a submarket the implicit price of transport accessibility is estimated to be positive.

In emphasizing the importance of taking the polycentric nature of geographies into account, Heikkila et al. (1989) distinguish between macro-and microlocational effects. Some centers mainly offer complementary services, and affect housing prices in a wide area, while other centres primarily provide local, substitutable, services, and affect housing prices in a small area. The distinction between macro- and microlocational effects implicitly introduces the impact related to the multilevel nature of services demanded by a household. A polycentric spatial structure is not the only reason why many empirical studies conclude that distance from the cbd has little effect on housing prices. Another explanation is the multipurpose nature of household spatial interaction. Residential site decisions and housing demand are not solely determined by distances to job opportunities, households also value access to other activities. Following Li and Brown (1980) these activities can be related to three categories of attributes: aesthetic attributes, pollution sources and service activities. The consequence of ignoring such attributes might result in biased estimates of how labour market accessibility affects housing prices.

As stated in Chesire and Sheppard (1997) data applied for hedonic studies often lack information on location characteristics. In studies where such characteristics are accounted for, the conclusion frequently is that accessibility to different services and amenities only marginally affects housing prices, see for instance Henneberry (1996) and Adair et al. (2000). They conclude that potential buyers do not put much weight on characteristics of the road transportation network, implying that investments in road infrastructure only marginally capitalise in property values. According to Laakso (1997) the majority of studies come from cities and urban areas of the USA. Laakso (1997) offers a summary of 18 empirical studies on housing prices, rents and land prices in the literature of urban economics since 1979. All studies use hedonic models. According to Laakso (1997) and Sandberg (2004) the number of published empirical studies on European cities is small. Combined with the fact that approaches and results vary considerably this explains need for further research in this area.

3 The region and the data

3.1 The region

The southern parts of Rogaland represents an integrated region with a connected road transportation network. There are 13 municipalities in the region, and each municipality is divided into postal delivery zones. Altogether the region is divided into 98 (postal delivery) zones, as indicated in Figure 1. The Appendix provides a list of municipalities and postal delivery zones, with corresponding figures of population and employment in 2001. As an indicator of (commuting) distances, there are 79 km from the centre of Stavanger to the center of Eigersund in the south.

The region is delimited by the North Sea in the west, fjords in the north and the east, while the southern delimitation is an administrative county border in a sparsely populated, mountainous area. Hence, the demarcation of the region is mainly determined by natural boundaries. This is advantageous, since it will then be reasonable to ignore effects from observations outside the region (see for instance Upton and Fingleton (1985)). The region is well suited for our purposes also since it involves areas heavily interrelated through significant commuting flows, appropriate for studies focusing on the relationship between labour and housing markets. The region is also relatively monocentric, in the sense that the city center of Stavanger has a dominating position concerning the supply of specific urban facilities, represented for instance by leisure and cultural services, and by shopping opportunities. The area has not developed into the characteristic multi-nodal structure observed in many metropolitan areas. As indicated by the figures in the Appendix, however, the spatial distribution of jobs does not correspond to the assumption of concentration underlying the basic version of the “access-space-trade-off ”model. For more details on this prosperous region, see Osland et al. (2005).

3.2 Data

The housing market data consist of transactions of privately owned single-family houses in the period from 1997 through the first half of 2001. Our sample of 2788 property transactions represents approximately 50% of the total number of transactions of privately owned single-family houses in the region during the relevant period, we have ignored transactions where information is missing for some variable(s). The transactions data on the freeholder dwellings have been provided from two sources: the national land register in Norway and Statistics Norway. For more details on those data, and descriptive housing market statistics for separate parts of the region, see Osland et al. (2005).

The division of the region into zones corresponds to the most detailed level of information which is officially available on residential and work location of each individual worker within the region. The information is based on the Employer-Employee register, and provided for us by Statistics Norway. Our analysis also requires data on total population in the (postal delivery) zones. We gained access to this information through the Central Population Register in Statistics Norway. Data restrictions represent the main reason why we consider a relatively macroscopical description of the geography. Still, we doubt that the additional insight and explanatory power resulting from a more disaggregated representation of the geography would be reasonably related to the massive effort and resources required on data collection.

The matrices of Euclidean distances and traveling times were prepared for us by the Norwegian Mapping Authority, who have at their disposal all the required information on the road network and the spatial residential pattern.

The calculations were based on the specification of the road network into separate links, with known distances and speed limits, and it is accounted for the fact that actual speed depends

Figure 1: The division of the region into municipalities and zones

on road category. Information of speed limits and road categories is converted into travelling times through instructions (adjustment factors for specific road categories) worked out by the Institute of Transport Economics. The center of each (postal delivery) zone is found through detailed information on residential densities and the road network. Finally, both the matrix of distances and the matrix of traveling times is constructed from a shortest route algorithm.

4 The modeling framework

In this section we start by presenting the list of structural non-spatial attributes that are incorporated in the alternative model formulations. As a next step the specific functional representation of distance from the cbd is explained, before we suggest alternative measures of labor market accessibility for the empirical analysis.

4.1 The basic set-up

In this paper we focus on the impact of the location relative to the cbd and to labor market opportunities rather than on specific non-spatial attributes of a residence. We do not attempt to account for accessibility to recreational facilities and shopping opportunities, and we ignore environmental conditions, location-specific amenities, and aesthetic attributes. This practice is partly explained from the fact that we consider interzonal rather than intrazonal variations in housing prices. If variations in housing prices within a (postal delivery) zone were considered, it would be relevant to account for the position relative to shopping and recreational facilities, schools, main roads (environmental conditions), the view etc. Our approach is implicitly based on the assumption that such housing and location specific (microlocational) attributes are not varying systematically across the zones, they are reasonably equally present in most of the (postal delivery) zones that we consider. In other words we implicitly assume that the regional variation in such attributes can also be found within a zone, and that there is insignificant spatial variation in zonal average values. Hence, we ignore the impact of intrazonal location-specific amenities and services in a macroscopical approach to our problem. Similarly, we ignore the possible impact on housing prices of systematic variation in zonal socioeconomic characteristics. Centrality and labour market accessibility, on the other hand, are location-specific characteristics with considerable interarea variation that is accounted for in our explanation of housing prices.

We distinguish between two categories of attributes. One category is the physical or structural attributes of the specific dwelling, the other is related to the location relative to the cbd and to labour market opportunities. In a corresponding general form the hedonic price equation can be written as follows:

$$P_{it} = f(z_{sit}, z_{lit}) \tag{1}$$

Here

P_{it} = the price of house i in year t

z_{sit} = value of dwelling-specific structural attribute s for house i in year t; $s = 1, ...S$, $i = 1, ...n$

z_{lit} = value of location-specific attribute l for house i in year t; $l = 1, ...L$, $i = 1, ...n$

The rest of this section is organised according to this distinction between the two categories of attributes. For a separate discussion of non-spatial modeling alternatives, see Osland et al. (2005). In this paper the challenge is how to represent characteristics of the geography in spatial modeling alternatives. Osland et al. (2005) also considered model performance for different spatial delimitations of the housing market, and they experimented with different mathematical representations of the relationship between dependent and independent variables, as well as different measures of spatial separation (physical distance and traveling time). In this paper we take as our starting point a model specification where spatial separation is measured by traveling time. The dependent variable and all non-spatial independent variables, except the dummy variables, are represented by their logarithms in the hedonic regression model. Table 1 offers a list of non-spatial dwelling-specific attributes incorporated in our modeling framework.

Table 1: List of non-spatial dwelling-specific variables

Variable	**Operational definition**
PRICE	selling price of property
REALPRICE	selling price deflated by the consumer price index, base year is 1998
AGE	age of building
LIVAREA	living area measured in square meters
LOTSIZE	lot-size measured in square meters
GARAGE	dummy variable indicating presence of garage
NUMBTOIL	number of toilets in the building
REBUILD	dummy variable indicating whether the building has been rebuilt/renovated

In addition to the dwelling-specific attributes we introduce the variable RURLOT into our regression model specifications. This variable is based on a stratification of the geography into rural and urban areas. The rural areas include four municipalities; Gjesdal, Bjerkreim, Lund, and Sokndal, see Osland et al. (2005) for details and criteria. RURLOT is defined to be the product of the dummy variable representing rural areas and the variable LOTSIZE, defined in Table 1. Osland et al. (2005) found that this variable, reflecting characteristics of the spatial structure, increased the explanatory power of the model significantly. Testing the joint significance of the two variables LOTSIZE and RURLOT by a Wald test, indicates significant differences in the elasticities of LOTSIZE in the rural and non-rural areas.

4.2 A model incorporating the traveling time from the cbd

The journey-to-work is an important kind of spatial interaction that is explicitly accounted for in this paper. Despite the tendency that workplace traveling represents a relatively smaller part of total traveling (see Statistics Norway 2005), such trips are more tied up than other trips in the time and money budgets of households. Osland et al. (2005) offer results of an empirical housing market study based on a hedonic function where the spatial separation between jobs and houses are represented by the distance from the cbd. Distances are measured relative to the core of the Stavanger cbd. The region has to a large degree developed from employment growth in and close to the dominating city center (Stavanger). It is probably hard to find geographies that come considerably closer to the construction in the "access-space-trade-off "model, with a monocentric city in a featureless plain landscape. This means that even an approach based on a one-dimensional representation of spatial separation potentially offers reliable parameter estimates reflecting the "access-space-trade-off "rather than local characteristics of the central place system.

Osland et al. (2005) found that the use of more complex and flexible functional specifications of traveling time contributes significantly to the explanatory power compared to a one-parameter approach. In addition the more flexible forms are found to represent a more reliable basis for predicting housing price gradients. The results presented in Osland et al. (2005) do not distinguish clearly between the alternative flexible function approaches. Based on explanatory power in combination with pragmatic, theoretical, econometric, and interpretational arguments, however, they recommended a power function specification supplemented by a quadratic term. According to this approach traveling time appears in the regression equation through the following expression:

$$h(d_{ij}) = d_{ij}^{\beta} \cdot ((d_{ij})^2)^{\beta_q}$$

The results achieved from such a model specification is included in Table 2, as a benchmark for evaluating models incorporating other characteristics of spatial structure than traveling time to the cbd. Hence, model M1 in the table is defined as follows:

M1: traveling time to the cbd is represented by a power function that is supplemented by a quadratic term

4.3 Models incorporating a measure of regional labor market accessibility

Our main ambition is to reveal and explain systematic spatial variation of housing prices. According to the idea of a trade-off between housing prices and commuting costs, this ambition calls for a measure representing the spatial separation between residents and job opportunities. As made clear in the introduction many authors have focused on the fact that not all workers commute to the cbd. One approach is to define employment rings around the cbd, combined with information of systematic spatial variation in individual incomes (see Yinger 1979). We have not attempted to account for socioeconomic characteristics in specific location alternatives, but we doubt that strongly regular and systematic spatial patterns can be found in this economy with a rather uniform distribution.

Though the geography that is considered is appropriate for empirical studies of the "access-space-trade-off "model, here are some multicentric and multinodal tendencies. Rather than introducing employment rings around the city center, we attempt to capture the impact of such characteristics through a gravity based accessibility measure. The relevant basic hypothesis is that workers prefer a location with favorable job opportunities within a reasonable distance from their residential site. Hence, labor market accessibility influences the number of households bidding for a house that is for sale, explaining spatial variation in housing prices. The standard type of accessibility measure refers to Hansen (1959). Assume that distance appears through a negative exponential function in the definition of the accessibility measure, and let σ_e be the weight attached to distance; $\sigma_e < 0$. The Hansen type of accessibility measure, S_j is then defined as follows:

$$S_j = \sum_{k=1}^{w} D_k \exp(\sigma_e d_{jk}) \tag{2}$$

Here, D_k represents the number of jobs (employment opportunities) in destination (zone) k. The measure S_j is based on the principle that the accessibility of a destination is a decreasing function of relative distance to other potential destinations, where each destination is weighted by its size, or in other words the number of opportunities available at the specific location. Hence, it can be interpreted as an opportunity density function, introduced to account for the possibility that the relevant kind of spatial pull originates from several destination opportunities. The Appendix offers estimates of the relative labor market accessibility of all the zones in our study, defined by $\frac{S_j}{\frac{1}{98}\sum_{j=1}^{98} S_j}$.

Accessibility measures are widely used in the literature on spatial interaction problems. It was first explicitly introduced by Fotheringham (1983), defining the so called competing destinations model of spatial interaction. Several parametric and functional formulations of accessibility measures can be found in the literature. Based on commuting flow data from Western Norway Thorsen and Gitlesen (1998) demonstrated that the evaluation of a spatial interaction model depends on the formulation of the accessibility measure. They argued, for instance, that a parameter should be attached also to the number of job opportunities, D_k, and the introduction of this parameter was found to add significantly to the explanation of the commuting flow pattern. With an interpretation in terms of the "access-space-trade-off "theory this also represents a natural alternative in an explanation of spatial variation in housing prices, corresponding to the accessibility measure $S_j^e = \sum_{k=1}^{w} D_k^{\gamma_e} \exp(\sigma_e d_{jk})$.

Another class of accessibility measures is the cumulative opportunities measures. As formulated in Handy and Niemeier (1997) such a measure is defined by the number of opportunities reached within a given travel time (or distance). Given our rather aggregate subdivision of the geography, with some zones covering large areas, this very simple definition of accessibility is not appropriate for an accurate specification of regional accessibility. An alternative gravity based specification is to introduce the weighted average distance to job opportunities as a measure of labor market accessibility. Let each zone be weighted by the fraction between the number of jobs located here and the total number of jobs in the region (D). The average distance to job opportunities is then defined by $\bar{d}_i = \sum_k \frac{D_k}{D} d_{ik}$, and this intuitively appealing measure can be introduced as an independent variable in the model formulation.

The average distance to job opportunities, $\bar{d}_i$, can be used as a starting point for defining other labor market accessibility measures. A parameter can be attached to distance, reflecting the possibility that nearby and more distant potential labor market destinations are not given the same weight in the definition of accessibility. This leads to a measure of labor market accessibility that is numerically equivalent to S_j in Equation 2, except from the fact that the distance term is now represented by a power function specification. In our empirical experiments we also add a parameter to the number of job opportunities in this power function approach, defining the accessibility measure $S_j^p = \sum_k^w D_{k=1}^{\gamma_p} d_{jk}^{\sigma_p}$.

Corresponding to the alternative measures of labor market accessibility proposed above we test the following model alternatives:

M2: labor market accessibility is represented by a traditional Hansen accessibility measure; S_j.

M3: labor market accessibility is represented by S_j^e

M4: labor market accessibility is represented by the weighted average distance to job opportunities, $\bar{d}_i$

M5: labor market accessibility is represented by S_j^p

M6: model M1 extended by the labor market accessibility measure S_j^e

M7: model M1 extended by the labor market accessibility measure S_j^p

The alternative accessibility measures are introduced log-linearly in the corresponding hedonic regression models. Referring to model M6 as an example this means that the hedonic regression formulation is given by:

$$\begin{aligned}\log P_{it} \;=\; & \beta_0 + \beta_1 \log \mathrm{LOTSIZE}_i + \beta_2 (\mathrm{RUR} \log \mathrm{LOT})_i + \beta_3 \log \mathrm{AGE}_i + \beta_4 (REBUILD \log \mathrm{AGE})_i + \\ & + \beta_5 \mathrm{GARAGE}_i + \beta_6 \log LIVAREA_i + \beta_7 \log \mathrm{NUMBTOIL}_i + \beta \log \mathrm{TIMECBD}_i + \\ & + \beta_q (\log \mathrm{TIMECBD}_i)^2 + \beta_8 \log \mathrm{ACCESSIBILITY}_i + \sum_{t=97}^{01} \beta_t \mathrm{YEARDUM}t_i + \epsilon_{it} \end{aligned} \quad (3)$$

where log(·) denotes the natural logarithm, and ϵ_{ij} is the error of disturbance for a specific observation.

Except for the models M1 and M4, which are estimated by ordinary least squares estimation, the models are estimated by the method of maximum likelihood. The reported statistics corresponding to those models are computed by the way of ordinary least squares estimation, on the basis of imputed values of the estimated parameter(s) inside the different accessibility indicators.

The results are presented in Table 2. Contrary to for instance Adair et al. (2000) and Handy and Niemeier (1997) all parameters are estimated simultaneously rather than through a stepwise procedure, where values of the accessibility measure are estimated from commuting flow data before they enter into the hedonic housing model.

5 Results

5.1 An evaluation of the alternative model formulations

Our estimation results are presented in Table 2. For the model evaluation we have reported the values of alternative goodness-of-fit statistics. Besides R^2 (and the adjusted R^2) we have included the log-likelihood value (L), the Average Prediction Error (APE $= \frac{\sum_i(|\hat{P}_i - P_i|)}{n}$, where $\hat{P}_i$ is the predicted price of house i, and n is the observed number of houses), and the Standardized Root Mean Square Error (SRMSE). We obtain positive values of log-likelihood, reflecting a case where the density function has a very small variance, allowing for density values exceeding 1,0. Such cases are typically met in problems where dependent variables are defined for a relatively small range of high values. The logarithm of housing prices defines a function that is very flat for the relevant range of values, with correspondingly small variance.

The analysis to follow is based on the use of pooled cross section data. This explains the introduction of the time-dummies in our models. The advantage of this procedure is that it enables an increase in sample size, and greater variations in the independent variables.

Consider first the modeling alternatives M1-M5. According to those results approaches based on an accessibility measure lead to poorer goodness-to-fit than the approach based on the one-dimensional measure of spatial separation underlying model M1. In addition, the accessibility measure does not reduce problems related to spatial autocorrelation to the same degree as traveling time from the cbd. Hence, labor market accessibility is not a satisfying alternative to traveling time from the cbd to explain variation in housing prices in our data. An accessibility measure probably adds more to the explanatory power in a more multicentric geography than the one we consider.

Besides this general conclusion we will also comment on some specific results in Table 2. Notice first that the estimated impact of other attributes than those related to spatial separation and accessibility appears to be relatively invariant with respect to how spatial characteristics are introduced into the model. The differences are in particular small when we compare the models that performs best with respect to explanatory power; models M1 and M6 do, for instance, only result in minor differences in non-spatial parameter estimates. The differences are larger when M6-estimates are compared to the less satisfactory model M4, see for example the parameter estimate reflecting the partial impact of LOTSIZE on housing prices. It is in general reasonable that any parameter estimate is more reliable the better the model captures relevant determinants of the dependent variable. Since LOTSIZE is positively correlated to the distance from the cbd (see Osland et al. 2005), it is also reasonable that the estimated parameter attached to LOTSIZE is negatively biased especially in approaches where the distance from the cbd is omitted from the model.

The additional parameter related to the number of employment opportunities in the Hansen measure of labor market accessibility is found to add significantly to the goodness-of-fit. All the measures of explanatory power have more satisfying values in model M3 than in model M2. According to our results the choice between a power function and an exponential function specification of distance in the accessibility measure is essentially a pragmatic one. Still, the approach based on the exponential function specification (model M6) performs marginally better in all the goodness-of-fit indices. Hence, in the rest of this paper we use model M6 rather than model M7 to discuss the impact of labor market accessibility on housing prices.

White's general test (see for instance Greene 2003) is performed to test for heteroskedasticity. Since $\chi^2_{0,05} = 16,919$ it follows from Table 2 that the hypothesis of homoskedasticity is rejected in all model specifications. In order to make reliable inferences on the least square estimates when heteroskedasticity is present, the reported standard errors in all models are estimated by a robust estimator of variance. In our data, however, this robust estimator of variance does not produce results that deviate much from estimates based on the ordinary least squares estimator.

The Moran's I statistic is used to test for spatial effects in the residuals (Anselin 1988). Positive values of Moran's I indicate positive autocorrelation. The Moran's I is calculated from a binary row standardized weight matrix, see for instance Anselin (2002), where zones are defined as neighbors if they have a common border. The standard normal deviate z_I is constructed from values of the mean and the variance of the Moran statistic (Anselin (1988). The null hypothesis of no spatial autocorrelation in the residuals is rejected at the 5% significance level if $z_I > 1,645$. According to the results in Table 2 this hypothesis is rejected for the models M2-M5, while it cannot be rejected for models M1, M6, and M7. Depending on the reasons for spatial autocorrelation this problem may lead to both biased and inefficient estimates. Our results, however, indicate that the introduction of an appropriate measure of spatial separation removes potential problems related to spatial autocorrelation.

We also report the p-values of the Ramsey reset test (see for instance Davidson and MacKinnon (1993)). This is usually referred to as an omitted variable test, and is also used to detect incorrect functional form (see for instance Wooldridge 2002). The null is that the model is correctly specified. At the 5% level of significance we find that the null is rejected only for model M2.

Table 2 offers information of the average VIF-values for the alternative model formulations. It can be shown that VIF-values indicate how much the variances of the estimated coefficients are inflated by multicollinarity (Greene 2003). A value of 1 indicates no multicollinearity. According to Studenmund (2001) multicollinearity is often characterized as severe if VIF > 5, while Kennedy (2003) suggests that VIF > 10 indicates harmful collinearity. In our study VIF-values naturally are highest in models M1, M6, and M7, due to the high correlation between the variables distance from the cbd and its square. On all other variables the VIF-values are far below 10. Given our relatively large number of observations, the values in the correlation matrix do not indicate serious multicollinearity problems.

Osland et al. (2005) demonstrated that the explanatory power increased considerably when the distance from the cbd was represented in the regression equation by a more flexible mathematical function than the simple exponential or power function. We have also experimented with the mathematical specification of the accessibility measure in the regression equation, for example by supplementing a power function representation by a quadratic term. Such attempts, however, only resulted in very marginal changes in explanatory power and estimated coefficients.

As mentioned above our results do not recommend a labor market accessibility measure as an appropriate alternative to the distance from the cbd in the regression model. This does not mean, however, that such a measure is not relevant in a model explaining spatial variation in housing prices. Compared to a non-spatial approach, a model with labor market accessibility as the only measure of spatial structure contributes considerably to explain variations in housing prices (results based on non-spatial approaches are presented in Osland et al. (2005)). R^2 increases from around 0,52 in a non-spatial model formulation to around 0,72 when labor market accessibility is included (model M3). This increase in goodness-of-fit might of course to some degree be explained by a tendency that labor market accessibility captures effects of omitted variables, like the distance from the cbd. Labor market accessibility is obviously covariant to the distance from the cbd. In our data this is represented by a correlation coefficient of -0,8589.

In comparing model M6 to M1 it follows that labor market accessibility contributes significantly to the explanatory power also in a model which tests for the simultaneous impact of labor market accessibility and the relevant one-dimensional measure of spatial separation. The value of the likelihood ratio test statistic is 26,74, which clearly exceeds the critical value of a chi square distribution with three degrees of freedom. It also follows from Table 2 that labor market accessibility is statistically significant. Both the two coefficients in the accessibility measure are also estimated to be statistically significant, with values of the t-statistic of 2,7 (t_{σ_e}) and 4,5 (t_{γ_e}). Hence, our results indicate that a measure of labor market accessibility captures relevant characteristics of the geography which are not captured by the distance from the cbd. As mentioned in the introduction the study by Adair et al. (2000) for instance concluded that transport accessibility has a minimal effect upon house prices in the Belfast urban area. This conclusion is reached despite the fact that location is not taken into account through other variables, like for instance the distance from the city center. Hence, those results are strongly contradicted in our study, which is based on observations from a regional labor and housing market area. In our opinion it is important to specify a connected labor market area in a study focusing on the trade-off between commuting costs and housing prices, and we find our study area to be very appropriate for this purpose.

Table 2: Results based on alternative specifications of spatial separation and spatial structure characteristics

	M1	M2	M3	M4	M5	M6	M7
Constant	11,9275	9,1921	11,0357	13,1233	31,6401	11,2081	30,8516
	(0,0892)	(0,1135)	(0,0874)	(0,1064)	(0,6268)	(0,1700)	(4,6076)
LOTSIZE	0,1262	0,0960	0,1100	0,0819	0,0991	0,1310	0,1305
	(0,0101)	(0,0099)	(0,0098)	(0,0097)	(0,0097)	(0,0099)	(0,0099)
RURLOT	-0,0270	-0,0270	-0,0316	-0,0391	-0,0273	-0,0270	-0,0299
	(0,0032)	(0,0033)	(0,0032)	(0,0032)	(0,0031)	(0,0031)	(0,0031)
AGE	- 0,0828	-0,0677	-0,0717	-0,0632	-0,0701	-0,0849	-0,0852
	(0,0066)	(0,0064)	(0,0064)	(0,0064)	(0,0064)	(0,0066)	(0,0066)
AGE·REBUILD	0,0116	0,0116	0,0118	0,0131	0,0124	0,0104	0,0106
	(0,0029)	(0,0031)	(0,0030)	(0,0031)	(0,0031)	(0,0029)	(0,0029)
GARAGE	0,0543	0,0521	0,0541	0,0546	0,0554	0,0639	0,0658
	(0,0110)	(0,0115)	(0,0113)	(0,0116)	(0,0114)	(0,0109)	(0,0109)
LIVAREA	0,3747	0,3747	0,3634	0,3724	0,3688	0,3543	0,3562
	(0,0178)	(0,0182)	(0,0179)	(0,0183)	(0,0180)	(0,0177)	(0,0176)
NUMBTOIL	0,1482	0,1468	0,1461	0,1538	0,1506	0,1482	0,1501
	(0,0147)	(0,0153)	(0,0151)	(0,0155)	(0,0152)	(0,0146)	(0,0146)
β (quadratic)	- 0,0689	-	-	-	-	-0,1093	-0,0947
	(0,0213)	(-)	(-)	(-)	(-)	(0,0215)	(0,0218)
β_q (quadratic)	- 0,0295	-	-	-	-	-0,0102	-0,0184
	(0,0041)	(-)	(-)	(-)	(-)	(0,0053)	(0,0047)
ACCESSIBILITY	-	0,2402	0,2346	-0,4531	2,6010	0,0754	2,6854
	(-)	(0,0066)	(0,0067)	(0,0145)	(0,0792)	(0,0160)	(0,6528)
σ_e	-	-0,0862	-0,1442	-	-	-0.1088	-
	(-)	(0,0051)	(0,0108)	(-)	(-)	(0,0403)	(-)
γ_e	-	-	0,0637	-	-	1,0963	-
	(-)	(-)	(0,0534)	(-)	(-)	(0,2452)	(-)
σ_p	-	-	-	-	-0,1685	-	-0,0320
	(-)	(-)	(-)	(-)	(0,0202)	(-)	(0,0133)
γ_p	-	-	-	-	0,3997	-	0,3683
	(-)	(-)	(-)	(-)	(0,1004)	(-)	(0,1050)
YEARDUM97	- 0,1333	-0,1369	-0,1343	-0,1337	-0,1340	-0,1361	-0,1342
	(0,0135)	(0,0140)	(0,0138)	(0,0141)	(0,0139)	(0,0135)	(0,0134)
YEARDUM99	0,1295	0,1298	0,1308	0,1325	0,1329	0,1297	0,1303
	(0,0137)	(0,0144)	(0,0142)	(0,0145)	(0,0143)	(0,0136)	(0,0136)
YEARDUM00	0,2686	0,2721	0,2693	0,2701	0,2714	0,2700	0,2700
	(0,0135)	(0,0142)	(0,0138)	(0,0143)	(0,0140)	(0,0135)	(0,0135)
YEARDUM01	0,3041	0,2996	0,3028	0,3015	0,3015	0,3042	0,3051
	(0,0136)	(0,0144)	(0,0140)	(0,0145)	(0,0142)	(0,0136)	(0,0136)
n	2788	2788	2788	2788	2788	2788	2788
R^2	0,7376	0,7115	0,7212	0,7056	0,7151	0,7403	0,7395
R^2-adj.	0,7364	0,7102	0,7200	0,7043	0,7139	0,7390	0,7382
L	279,68	147,24	195,19	119,31	165,14	293,96	289,96
APE	216736,08	232882	228011	240314	234171	215343	216082
SRMSE	0,2058	0,2203	0,2161	0,2250	0,2200	0,2047	0,2052
White test statistic	264	268,87	259,45	259,30	258,60	282,05	293,37
Moran's I	-0,0015	0,0258	0,0146	0,0311	0,0231	0,0017	0,0013
Standard normal deviate (z_I)	1,3068	15,2145	8,9450	18,3090	13,7327	1,4268	1,3056
Ramsey reset test (p-value)	0,8274	0,0005	0,4542	0,1965	0,3681	0,8601	0,8945
VIF, average value	4,22	1,49	1,48	1,47	1,48	5,29	4,86

Note: Results based on observations from the period 1997-2001, robust standard errors in parentheses.

5.2 A decomposition of the spatial variation in housing prices

The measure of labor market accessibility naturally covariates with the distance from the cbd, but our sample size is large enough to allow us to distinguish between the impact of those two spatially defined variables. As mentioned in the preceding subsection multicollinearity does not represent a serious problem in our study.

Despite the fact that the region is relatively monocentric, the spatial distribution of jobs is considerably more evenly scattered across space than specific urban services and facilities, like cinemas, restaurants etc. The trade-off theory is basically motivated by labor market considerations. Hence, a reasonable hypothesis is that the estimated impact of labor market accessibility reflects the trade-off between housing prices and commuting time. The estimated partial impact of distance from the cbd then reflects a general urban attraction effect, the proximity to specific urban facilities and urban services represent an attribute that increases the willingness-to-pay for a house, ceteris paribus.

Our point is illustrated in Figure 2. Both lines in the figure refer to a standard house. The standard house is defined as not being rebuilt, it has a garage, it is not located in the rural areas, and the price refers to the year 2000. Lotsize, age, living area and the number of toilets are given by their average values. The solid line in this figure represents a prediction of how the price of the standard house depends on the distance from the cbd in a case where no explicit measure of labor market accessibility is taken into account. In other words this predicted housing price gradient is based on parameter estimates from model M1.

The dashed line in Figure 2 is based on parameter estimates from model M6. This line is not an ordinary housing price gradient, however, and should be interpreted with care. It refers to the same standard house that was described above, but the corresponding low values of housing prices reflect the fact that the accessibility index is given the value of zero. Hence, attention should be paid to the predicted changes in housing prices rather than to the price level. The changes in housing prices predicted by the dashed line in Figure 2 correspond to the urban attraction effect rather than the effect of variation in labor market accessibility. According to our results the urban attraction effect explains housing price variations within a range of about 700000 NOK (with 1998 as the base year). This means that a standard house at the price of 2.5 million NOK in the center of Stavanger would cost about 1.8 million NOK at a traveling distance of 100 minutes from the cbd, if labor market accessibility was the same in the two locations.

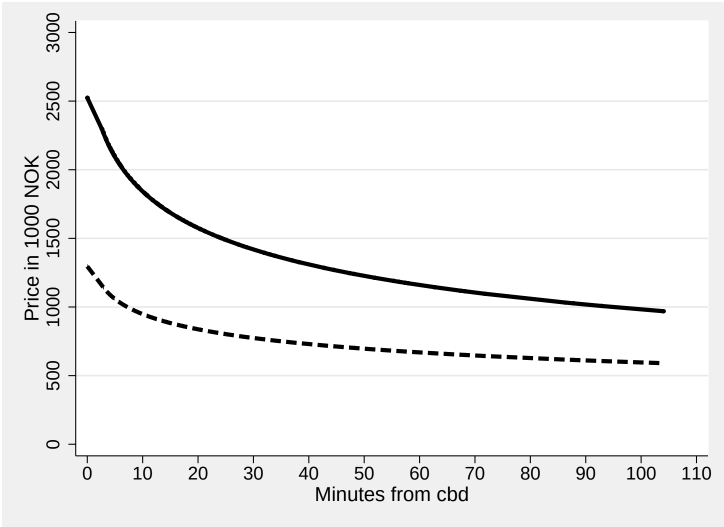


Figure 2: The solid line represents a predicted housing price gradient in an approach where spatial separation is measured only by the distance to the cbd (model M1). The dashed line reflects the urban attraction effect, that is the effect of variations in the distance from the cbd when the value of the labor market accessibility index is given the value of zero in model M6.

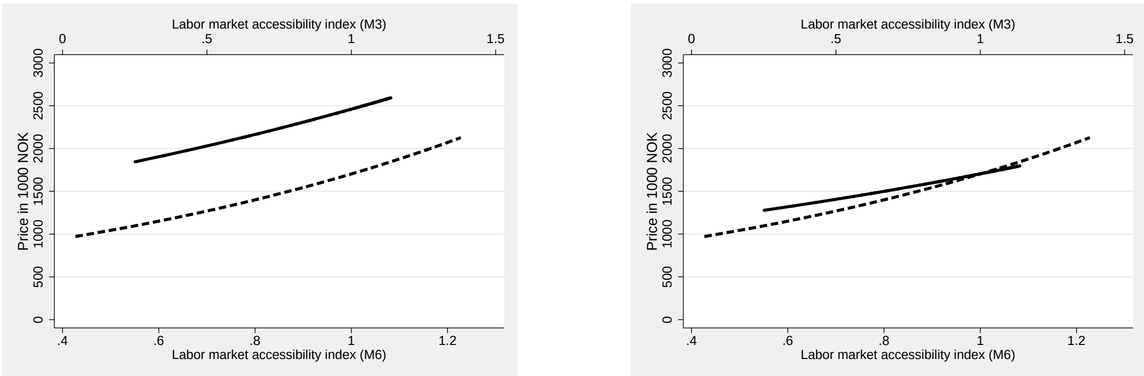
It now seems natural to interpret the distance between the two lines in Figure 2 as a prediction of the impact of variations in labor market accessibility. Based on such an interpretation the figure can be claimed to decompose spatial variation in housing prices into a:

- labor market accessibility effect
- urban attraction effect

The solid line is, however, based on a misspecified model formulation, with biased parameter estimates, and we cannot be sure that this line adequately captures the aggregated effect of urban attraction and labor market accessibility.

The dashed line in the two parts of Figure 3 represents a predicted accessibility gradient based on model M3, while the solid lines are based on model M6. The variables on the horizontal axis represent the labor market accessibility index. A value of 1.2, for instance, represents a location with a 20% higher labor market accessibility than the average location in the region. According to the dashed line the price of a standard house is predicted to fall from 2.15 million NOK in the most accessible location to just below 1 million NOK in the location with the lowest observed value of the accessibility index.

Since the dashed line is based on a misspecified model formulation, however, it does not represent a reliable prediction of a labor market accessibility gradient. The line also captures an urban attraction effect. The solid lines, on the contrary, are based on model M6, that explicitly adjusts for the urban attraction effect. The solid line in part a) of the figure refers to a standard house located in the center of Stavanger (the distance from the cbd is set equal to zero), with (hypothetical) variations in the labor market accessibility index. The solid line in part b) of the figure is also based on model M6, but traveling time from the cbd is now set equal to the average value. This offers a more transparent indication of the relative size of the urban attraction effect. As seen from the figure the gradient based on model M6 is defining a more narrow interval of accessibility index values than model M3.



a) b)

Figure 3: Accessibility gradients for a standard house. The dashed line is based on model M3, while the solid lines are based on model M6. The solid line in part a) of the figure is based on the assumption that the standard house is located in the center of Stavanger, while the solid line in part b) of the figure is based on the assumption that the standard house is located in the observed average distance from the cbd.

According to Figure 3 the labor market accessibility effect explains housing price variations within the range of 800000 NOK for a standard house. For such a house located in the cbd variations in labor market accessibility (hypothetically) could explain variations in housing prices from about 1.8 million NOK to about 2.6 million NOK.

Our results challenge the standard interpretation that housing price gradients from the cbd reflect the trade-off between commuting costs and housing consumption. We find it more reasonable to distinguish between an urban attraction effect and a labor market accessibility effect reflecting the mentioned trade-off. Graphically, the two effects are represented by the dashed line in Figure 2 and the solid lines in Figure 3, respectively. Quantitatively, we predict the two effects to be of the same order of magnitude. According to our predictions a standard house at the price of 2,5 million NOK in the center of Stavanger would cost about 1,8 million NOK at a traveling distance of 100 minutes from the cbd, if labor market accessibility was the same in the two locations. If labor market accessibility is at its maximum value in the cbd and minimum at the most distant intraregional location, the predicted housing price is reduced by 1.5 million NOK, to a level of 1 million NOK.

This tends to be approximately the same range for spatial variation in housing prices that is predicted by the misspecified model M1. This does not mean, however, that this model is in general appropriate for prediction purposes, and the model is of course inadequate as a device to explain housing price variations as a result of different characteristics of the spatial structure. In general our discussion has demonstrated how a misspecified model formulation might result in a false prediction of how a specific attribute affects the dependent variable.

A potential bias in our approach is related to the calculations of traveling times. We use off-peak, uncongested, estimates. It is not straightforward to predict how congestion problems might affect housing prices in alternative locations. This is a complex problem that involves both the willingness-to-pay for residential locations close to the cbd and effects through the location pattern of firms. Still, we doubt that the rather modest congestion tendencies in the region we consider represent a significant determinant of housing prices.

6 Concluding remarks

One empirical finding in this paper is that housing prices fall with increasing distance from the cbd even when labor market accessibility is accounted for. This is interpreted to represent an urban attraction effect, reflecting households evaluation of urban amenities in general. The effect of labor market accessibility is captured through the introduction of a gravity based accessibility measure, that accounts for the fact that jobs by no means are entirely concentrated to the cbd even in the relatively monocentric geography that we consider. In other words we find it appropriate to distinguish between labor market accessibility and centrality relative to urban activities in our model formulation. Our results indicate that the urban attraction effect and the labor market accessibility effect quantitatively contribute about equally to intraregional variation in house prices.

It is intuitively reasonable that the urban attraction effect is represented by an isotropic and ring-like cbd-gradient; it is traveling distance rather than direction that matters. The situation is not analogous for the spatial distribution of employment; the non-cbd employment cannot in general be expected to be evenly spread in rings of employment around the cbd. Some (local sector) employment tends to be spatially distributed according to population densities, see for instance Gjestland et al. (2006) for a theoretical discussion, while some employment is more concentrated to activity centers, due to agglomeration economies (see for instance Guiliano and Small 1991). Our study indicate that such irregular tendencies are adequately represented by the gravity based accessibility measure.

Housing price gradients are often estimated from models where spatial separation is represented only by the distance from the cbd, see for instance Osland et al. (2005). In a relatively monocentric kind of region like the one we consider, this might be a recommendable approach if for instance data are not available on the spatial distribution of employment and population. The results presented in the preceding section indicate that such gradients might offer reliable predictions of housing prices in specific locations. Since labor market accessibility covariates strongly with the distance from the cbd the gradients capture the aggregated effect of the urban attraction and the labor market accessibility forces. It is important, however, that the gradients are interpreted with care, especially in causal terms. The results presented in this paper challenge the standard interpretation that falling housing price gradients from the cbd reflect the trade-off between housing consumption and commuting costs.

Our estimation resulted in satisfying values of the goodness-of-fit indices, for instance with values of adjusted R^2 about 0,74. Still, the explanatory power of our model is lower than for instance the values reported in Adair et al. (2000), who find an adjusted R^2 of 0,79. In such a comparison it is important to notice, however, that Adair et al. (2000) have information on more variables on physical attributes of the properties, they incorporate information on socioeconomic characteristics, and their study applies for a very disaggregated zonal subdivision of an urban area (Belfast).

As mentioned in the introduction Adair et al. (2000) also study the impact of transport accessibility within submarkets and subareas of the urban area. Our study refers to a regional rather than an urban context, with zones covering a considerably larger area, and we have no other spatial information of the zones than the (average) position relative to the cbd and an accessibility measure reflecting the position relative to job opportunities in the regional labor market. Through this approach we have primarily focused on the impact of general spatial characteristics rather than explaining housing prices in this specific region. Contrary to Adair et al. (2000) we also find that the accessibility measure contributes considerably to explain variation in housing price. An estimation of the urban attraction effect and the labor market accessibility effect probably requires that data refer to a connected labor and housing market rather than just an urban area. Studies restricted to specific urban areas cannot be expected to provide unbiased estimates of the mentioned effects. In general labor market accessibility is relatively invariant across zones within an urban area, and studies ignoring this spatial structure characteristic might still explain a very large proportion of intraurban variation in housing prices. In a regional setting we find that the labor market accessibility measure is no adequate alternative to the distance from the cbd, but it appears to be a very useful supplement in the hedonic model equation.

Appendix

Table 3: Zonal data

Zone	Working population	Jobs	Observations	Relative access.
Rennesøy				
1	725	552	16	0,8946
2	98	24	4	0,9346
3	354	145	5	0,9267
4	127	23	4	0,9388
Randaberg				
5	3748	2195	89	1,0403
Stavanger				
6	328	4961	12	1,1390
7	95	4058	1	1,1331
8	769	1736	11	1,1140
9	688	1586	36	1,1322
10	1021	328	47	1,1343
11	1177	1630	41	1,1292
12	863	3905	23	1,1245
13	1125	1398	21	1,1277
14	555	2339	34	1,1319
15	1274	2864	41	1,1214
16	1382	396	26	1,1138
17	1518	4695	8	1,1262
18	1151	2141	29	1,1032
19	1750	407	47	1,0856
20	1637	392	16	1,1254
21	1777	1751	102	1,1029
22	2367	1627	40	1,1029
23	1340	627	45	1,1057
24	959	226	33	1,1018
25	846	271	16	1,1202
26	1042	341	27	1,1028
27	1001	132	23	1,1021
28	997	254	46	1,0930
29	1662	239	42	1,0777
30	945	1746	29	1,0707
31	1212	630	28	1,1118
32	2436	11309	10	1,1154
33	1719	529	44	1,0937
34	760	930	24	1,1147
35	240	583	4	1,0925
36	999	101	35	1,0677
37	919	147	28	1,0703
38	284	14	14	1,0622
39	1106	338	16	1,0550
40	1169	110	22	1,0506
41	4674	968	135	1,0642
42	237	37	13	0,7849
43	92	11	1	0,8779
Sola				
44	893	83	34	1,0961
45	2925	6178	70	1,0825
46	945	115	34	1,0902
47	497	63	22	0,9935
48	514	131	11	1,0236
49	2681	5423	74	1,0519
Sandnes				
50	1215	4870	22	1,1073
51	1338	1506	43	1,0900
52	1090	218	16	0,9432
53	371	147	8	1,0458
54	1383	240	57	0,9348
55	1150	302	40	0,9308
56	543	214	4	1,0501
57	788	6151	25	1,1017
58	1592	570	55	1,1014
59	651	1515	10	1,0871
60	678	207	19	1,1012
61	1280	175	10	1,0795
62	1911	307	53	1,0795
63	966	1355	23	1,1012
64	824	537	21	1,0830
65	737	276	6	1,0627
66	1010	787	22	1,0684
67	979	380	21	1,0670
68	914	49	10	1,0746
69	960	574	25	1,0791
70	1198	477	23	1,0474
71	942	253	13	1,0180
72	668	240	24	1,0245
73	21	3	3	0,5834
Klepp				
74	429	158	5	0,9335
75	3034	2043	72	1,0093
76	1047	1502	16	1,0111
77	340	208	2	0,9911
78	1457	457	10	1,0015
Gjesdal				
79	3354	1760	129	1,0046
80	336	184	16	0,8392
81	362	353	1	0,6896
Time				
82	5148	4343	93	0,9792
83	383	123	5	0,9036
84	1457	457	27	1,0015
Hå				
85	1493	1106	35	0,8704
86	1021	525	12	0,8149
87	348	81	6	0,7830
88	376	289	10	0,7491
89	2795	2511	62	0,9074
Bjerkreim				
90	395	213	8	0,7926
91	540	511	8	0,8143
Eigersund				
92	4612	4830	148	0,8825
93	367	97	7	0,7448
94	342	106	1	0,7472
Lund				
95	742	920	10	0,7219
96	235	45	2	0,5864
97	152	53	1	0,6349
Sokndal				
98	1125	916	21	0,7294
99	17	1	3	0,5308

Note: The relative accessibility is found by dividing S_j (see Equation 2) by the mean value of this measure for all the zones.

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