Evaluating housing price predictability of alternative hedonic model formulations

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Abstract

We first use alternative hedonic model formulations to compare predicted and observed prices of property transactions in alternative locations. The estimation of model parameters is based on data from Western Norway, and the model formulations differ with respect to the representation of spatial structure. We discuss how measures like the distance to the cbd, a gravity based accessibility measure of labor market accessibility, and some local characteristics of the geography, contribute to predict spatial variations in housing prices. We also discuss how appropriate alternative models are to predict possible consequences on housing prices of changes in the spatial distribution of employment, and in the road transportation network. Finally, we recommend that a relative measure of labor market accessibility is introduced, to capture effects of spatial competition in the housing market.

JEL-classification: R21, R31

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1 Introduction

This paper addresses problems related to predicting prices resulting from housing market transactions. For this purpose we consider several alternative model formulations. The alternative models reflect different demands for data and different ways to account for characteristics of

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the spatial structure. We do not experiment by varying the set of non-spatial attributes of the residences, our focus is on how the modeling of spatial structure affects the predictability.

As a first step our models are used to predict housing prices at alternative locations. The predicted prices are compared to observed prices. Based on this exercise we discuss the relationship between goodness-of-fit and predictability in evaluating the alternative model formulations. Goodness-of-fit abilities of the model formulations considered are discussed in three previous papers (see Osland et al. (2005) and Osland and Thorsen (2005, 2006)). As formulated by Christ (1951), however, "The ultimate test of an econometric model . . . comes with checking its predictions". We also focus on the possibility that a model systematically produces serious prediction errors for houses in specific locations, while it is appropriate as a device to predict housing prices at other locations. Hence, the models are evaluated also from the perspective of predictability in a wide range of location alternatives.

We are not only concerned with predicting prices that are achieved in observed property transactions. In addition the alternative model formulations are evaluated from their ability to predict how changes in spatial structure characteristics affect housing prices. We consider both the effects of employment growth in specific locations and the effects of changes in the road transportation network. In those experiments model performance is evaluated from theoretical considerations, as well as from a comparison between predicted and observed house prices.

As mentioned above the models that we consider differ only with respect to the representation of spatial structure. In each section the presentation is organized according to an evaluation of the following model formulations:

MF1: a model formulation with only non-spatial attributes, estimated by data from the urban area

MF2: a model formulation where spatial separation (traveling time from the cbd) is represented by a power function specification, supplemented by a quadratic term

MF3: a model formulation where spatial structure is accounted for though a gravity based measure of labor market accessibility

MF4: a model formulation incorporating a power function specification of the traveling time from the cbd, supplemented by a quadratic term, and a gravity based measure of labor market accessibility

MF5: a model formulation where the regional measures of spatial separation and spatial structure are supplemented by the presence of two subcenters

Assume that local employment growth and/or an innovation in the transportation network cause a positive shift in housing demand in a specific zone. None of the modeling approaches listed above capture the possibility that increased demand and willingness-to-pay for houses in this area might reduce the demand for houses in other parts of the geography. We introduce the hypothesis that such elements of spatial competition in the housing market are captured by a gravity based measure of relative labor market accessibility.

The region and the data are presented in Section 2, while the alternative model formulations and estimation results are briefly reviewed in Section 3. Section 4 starts by defining a standard house, before predicted and observed prices are compared at alternative locations. In this section we also predictability from a comparison between zonal average observed and zonal average predicted prices for all houses that were traded, and the prediction accuracy is illustrated by 95% prediction intervals. We also consider the predictability of MF2 in a case where data on the spatial distribution of job opportunities. Section 5 deals with predicting effects on house prices of hypothetical changes in the spatial distribution of employment. We are concerned both with the performance of alternative model formulations and with forecasting the redistribution of assets through capitalization of property values. This also applies for Section 6, which focuses on predicting how house prices are affected by changes in the road transportation network. We introduce the hypothesis that a relative measure of labor market accessibility is appropriate for studying the impact of changes in the road transportation network. Finally, we offer some concluding remarks in Section 7.

2 The region and the data

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. 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. For further details on the region, see Osland and Thorsen (2005).

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

The estimation results underlying the predictions presented in this paper are based on housing market data for transactions of privately owned single-family houses in the period from 1997 through the first half of 2001. Our sample consists of 2788 transactions of privately owned single-family houses in the region during the relevant period. The transactions data on the freeholder dwellings have been provided from two sources: the national land register in Norway and Statistics Norway.

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 relevant information is provided for us by Statistics Norway. 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. For more details on those data, and descriptive housing market statistics for separate parts of the region, see Osland et al. (2005).

3 Estimation results based on alternative hedonic model formulations

In this section we summarize some estimation results based on model formulations in Osland et al. (2005), Osland and Thorsen (2005a), and Osland and Thorsen (2005b). All those papers apply for the same region and the same data set that is considered in this paper. The results in Osland et al. (2005) are relevant especially in cases where the only information on spatial characteristics is the distance from the cbd. Osland et al. (2005) start out by considering non-spatial model specifications, accounting only for the impact of dwelling-specific attributes. Such an approach is found to contribute with a reasonable explanation to variation in house prices only if a rather small part of the region is considered. General information on distances contributes less to an explanation if the study is for instance restricted to the most urbanized part of the region, rather than an extended labor market area. Results based on a non-spatial model formulation (MF1) and data from the municipality of Stavanger are included in Table 2. By comparing to the results based on the remaining model specifications, however, it follows that information on location adds significantly to explanatory power, and reduces spatial autocorrelation. See Osland et al. (2005) for details.

The variables corresponding to MF1 are defined as follows:

It is intuitively very reasonable that information on the distance from the central business district (cbd) contributes to more reliable explanations of house prices, especially in cases where the complete labor market area is accounted for. Osland et al. (2005) evaluate alternative functional representations of traveling time from the cbd in the model formulation. An one-parameter approach based on a negative exponential function ($e^{\beta_e d_{ij}}$) is found to perform better

Table 1: List of independent variables in MF1

Variable	Definition
LOTSIZE	lot-size measured in square meters
AGE	age of building
REBUILD	dummy variable indicating whether the building has been rebuilt/renovated
GARAGE	dummy variable indicating presence of garage
LIVAREA	living area measured in square meters
NUMBTOIL	number of toilets in the building
YEARDUMt_i	a yeardummy corresponding to year t_i (1998 is the base year)

than an approach where distance is represented through a power function. In evaluating alternative flexible functional specifications of traveling time from the cbd Osland et al. (2005) consider results on explanatory power in combination with pragmatic, theoretical, and interpretational arguments. An approach incorporating a quadratic term is found to be particularly appealing. Table 2 includes results based on an approach where a power function is supplemented by a quadratic term, represented by the function $h(d_{ij}) = d_{ij}^{\beta} \cdot ((d_{ij})^2)^{\beta_q}$; MF2. The variable RURLOT is the product of a dummy variable representing the most rural areas of the region and the variable LOTSIZE. For a more detailed explanation and discussion of the operative model formulation, see Osland et al. (2005).

The Alonso model (Alonso 1964) is the standard theoretical reference for the relationship between housing prices and labor market accessibility. 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 cbd. In more recent literature many examples can be found that account for the fact that workplaces are not solely located in the city center and that trips to work encompasses a declining share of overall household traveling. Relevant discussions can for instance be found in Dubin and Sung (1987), Heikkila et al. (1989), Waddell et al. (1993), Henneberry (1996), Adair et al. (2000), and McMillen (2003).

If detailed information is available on the spatial distribution of employment opportunities, labor market accessibility can be represented by more refined alternatives than one-dimensional measures of spatial separation. Osland and Thorsen (2005a) account for polycentric tendencies in the distribution of job opportunities through the introduction of gravity based accessibility measure. Compared to a non-spatial approach the introduction of such a measure improves the explanatory power of house prices considerably. Still, this measure is not found to represent an adequate alternative to distance from the cbd; it leads to poorer goodness-of-fit, and it does not reduce problems related to spatial autocorrelation to the same degree as traveling time from the cbd. Estimation results based on this model (MF3) are reported in Table 2. The accessibility measure underlying the estimation is defined by $S_j^e = \sum_{k=1}^{w} D_k^{\gamma_e} \exp(\sigma_e d_{jk})$, while the table also reports the estimated value corresponding to the ACCESSIBILITY measure in the model formulation.

It is more important, however, that the accessibility measure is found to contribute significantly to the explanatory power also in a model which tests for the simultaneous impact of labor market accessibility and the traveling time from the cbd. Based on this result Osland and Thorsen (2005a) distinguish between a labor market accessibility effect and an urban attraction effect. The trade-off between commuting costs and housing prices is claimed to be represented by the accessibility measure, while the urban attraction effect is captured by the traveling time from the cbd. Quantitatively, the two effects on house prices are predicted to be of the same order of magnitude. Estimation results (MF4) are reported in Table 2, and the corresponding hedonic regression formulation is given by:

$$\begin{aligned} \log P_{it} &= \beta_0 + \beta_1 \log \mathrm{LOTSIZE}_i + \beta_2 (\mathrm{RUR} \log \mathrm{LOT})_i + \beta_3 \log \mathrm{AGE}_i + \beta_4 (REBUILD \log \mathrm{AGE})_i + \\ &+ \beta_5 \mathrm{GARAGE}_i + \beta_6 \log LIVAREA_i + \beta_7 \log \mathrm{NUMBTOIL}_i + \beta \log \mathrm{TIMECBD}_i + \\ &+ \beta_q (\log \mathrm{TIMECBD}_i)^2 + \beta_8 \log \mathrm{ACCESSIBILITY}_i + \sum_{t=97}^{01} \beta_t \mathrm{YEARDUM} t_i + \epsilon_{it} \end{aligned} \tag{1}$$

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

Osland and Thorsen (2005b) test for the possible impact of local characteristics which are not represented by the traveling time from the cbd or the labor market accessibility measure. Several measures are tested; some are based on the presence of employment subcenters and administrative centers, others incorporate within-zone number of job opportunities and population densities. We also tested for local variations in house prices through the introduction of a measure where the value of labor market accessibility in a zone is compared to the corresponding value in the neighboring zones, with a common boundary to the zone. This measure contributes to explain spatial variations in house prices only in the case where it is defined separately for urban, semi-urban, and rural areas. Also some of the other proposed measures of local spatial structure contribute significantly to explain house prices, but the effects are found to be relatively marginal. The main conclusion is that the two globally defined measures of spatial structure (traveling time from the cbd and labor market accessibility) explain the major part of systematic spatial variations in house prices. The explanatory power improves significantly in an approach that tests for the simultaneous effect of local measures of spatial structure. In this case, however, standard errors are inflated, probably by the presence of multicollinearity. Consequently, the estimated impact of individual variables is not reliable, and we will not consider the predictability of this model formulation. As an alternative, the specification M6 in Table 2 refers to an approach that accounts for the presence of two subcenters (Bryne and Egersund), and traveling times within a cutoff value of 20 minutes from those subcenters. This is the local variable approach that contributes most to the explanatory power, and we want to test how the incorporation of local characteristics influences predictions of house prices in alternative scenarios. Notice from Table 2 that the estimated coefficient related to the partial effect of location in Egersund (SUB2) is significantly negative. In interpreting this results, remember that the effects of job concentrations are accounted for through the labor market accessibility measure. It also follows that the position of Egersund as a center in the southern parts of the region is reflected in the parameter estimate corresponding to the variable SUB2DIST. For further details on the impact of local spatial characteristics, see Osland and Thorsen (2005b).

4 Comparing predicted and observed prices of property transactions at alternative locations

In this section we test how the alternative model specifications succeed in predicting prices from observed property transactions in specific locations. We start by evaluating the ability to predict spatial variation in the price of a house with specific attributes, before we study predictions of average prices in alternative zones, and predictions of house prices at a specific location.

4.1 Predicting spatial variation of a standard house

For the purpose of evaluating predictability we start by defining a standard house. The standard house is defined as not being rebuilt, it has a garage, and the price refers to the year 2000. Lotsize,

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

	MF1	MF2	MF3	MF4	MF5
Constant	11,2651	11,9236	11,0212	11,2437	11,1779
	(0,1364)	(0,0892)	(0,0873)	(0,1630)	(0,1775)
LOTSIZE	0,0952	0,1259	0,1057	0,1298	0,1290
	(0,0159)	(0,0101)	(0,0098)	(0,0099)	(0,0100)
RURLOT	-	-0,0299	-0,0315	-0,0268	-0,0301
	(-)	(0,0032)	(0,0032)	(0,0031)	(0,0031)
AGE	-0,0461	-0,0828	-0,0717	-0,0846	-0,0836
	(0,0080)	(0,0066)	(0,0064)	(0,0066)	(0,0065)
AGE·REBUILD	0,0154	0,0106	0,0119	0,0105	0,0105
	(0,0043)	(0,0029)	(0,0030)	(0,0029)	(0,0029)
GARAGE	0,0436	0,0677	0,0549	0,0643	0,0640
	(0,0169)	(0,0110)	(0,0113)	(0,0108)	(0,0108)
LIVAREA	0,4665	0,3583	0,3643	0,3546	0,3546
	(0,0341)	(0,0177)	(0,0179)	(0,0177)	(0,0175)
NUMBTOIL	0,1226	0,1516	0,1454	0,1477	0,1476
	(0,0241)	(0,0147)	(0,0151)	(0,0146)	(0,0145)
β (quadratic)	-	-0,0679	-	-0,1031	-0,1308
	(-)	(0,0213)	(-)	(0,0215)	(0,0264)
β_q (quadratic)	-	-0,0298	-	-0,0141	-0,0049
	(-)	(0,0041)	(-)	(0,0049)	(0,0073)
ACCESSIBILITY	-	-	0,2352	0,0625	0,0700
	(-)	(-)	(0,0067)	(0,0132)	(0,0154)
σ_e	-	-	-0,1442	-0,1088	-0,1088
	(-)	(-)	(0,0108)	(0,0403)	(0,0403)
γ_e	-	-	0,0637	1,0963	1,0963
	(-)	(-)	(0,0534)	(0,2452)	(0,2452)
SUB1	-	-			0,0412
	(-)	(-)	()	()	(0,0233)
SUB1DIST	-	-			-0,1345
	(-)	(-)	()	()	(0,0057)
SUB2	-	-			-0,0685
	(-)	(-)	()	()	(0,0335)
SUB2DIST	-	-			-0,1367
	(-)	(-)	()	()	(0,0452)
YEARDUM97	-0,1524	-0,1333	-0,1343	-0,1357	-0,1361
	(0,0242)	(0,0135)	(0,0138)	(0,0134)	(0,0135)
YEARDUM99	0,1305	0,1294	0,1308	0,1300	0,1330
	(0,0232)	(0,0137)	(0,0142)	(0,0136)	(0,0134)
YEARDUM00	0,2582	0,2686	0,2698	0,2698	0,2715
	(0,0218)	(0,0135)	(0,0138)	(0,0135)	(0,0136)
YEARDUM01	0,2834	0,3029	0,3016	0,3031	0,3033
	(0,0234)	(0,0136)	(0,0140)	(0,0136)	(0,0136)
n	1188	2788	2788	2788	2788
R^2	0,6606	0,7381	0,7217	0,7407	0,7440
R^2-adj.	0,6578	0,7368	0,7205	0,7394	0,7424
L	56,73	281,62	197,39	295,78	313,78
APE	274597	216941	229429	215678	214651
SRMSE	0,2193	0,2045	0,2146	0,2035	0,2027
White test statistic	110	265	260	284	329
Moran's I	0,0718	0,0014	0,0219	0,0019	0,0014
Standard normal deviate (z_I)	26	1,2359	11,8773	1,563	1,4909
Ramsey reset test (p-value)	0,4705	0,8287	0,4673	0,8730	0,8809
VIF, average value	1,64	4,22	1,48	5,29	7,01

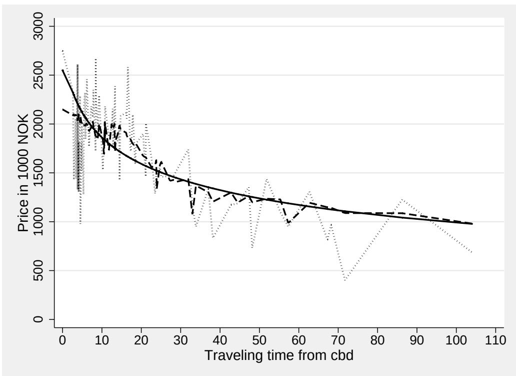
Note: Results based on observations from the period 1997-2001, robust standard errors in parentheses. For model MF4 the values of the parameters σ_e and γ_e in the measure of local labor market accessibility are assumed to be given, equal to the values resulting from the estimation of model MF3 ($\sigma_e = -0,1088$ and $\gamma_e = 1,0963$). 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).

age, living area, and the number of toilets are given by their average values. The solid line in the two parts of Figure 2 represents predictions based on estimation of MF2, where traveling time from the cbd is incorporated through a power function is supplemented by a quadratic term. Since this is the only information of the spatial structure this model predicts a continuously and monotonously falling housing price gradient.

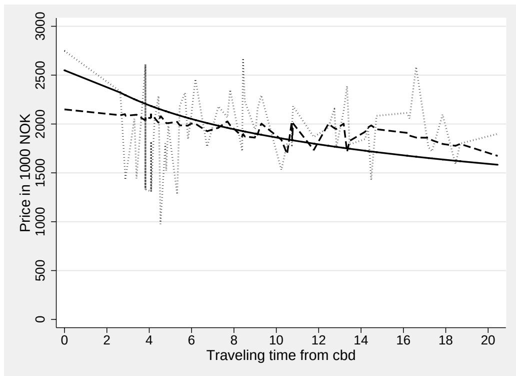
The dependent variable in all the models is the logarithm of real housing price. Used for prediction purposes, the logarithm of price has to be transformed. According to Wooldridge (2003) there are several ways this can be done, but none of them are unbiased. We have used the following transformation, which is consistent and relies on normality of the errors (Wooldridge 2003):

$$\hat{P} = \exp(\ln \hat{P}) \exp \frac{\hat{\sigma}^2}{2}$$

where $\hat{\sigma}^2$ is an unbiased estimator of the residual variance. The dependent variable in the models has also been transformed by using an estimator which is robust to non-normal errors (Wooldridge 2003). This yielded the same result for $\hat{P}$ as the method described above.



a) The entire region



b) The area within 20 minutes from the cbd

Figure 2: The dotted lines represent the observed zonal average house prices. The solid lines represent predicted prices of a standard house, based on a model (MF2) where only traveling time from the cbd is accounted for, while the dashed lines represent predictions based on a model (MF3) where only labor market accessibility is accounted for.

The dotted line in the two parts of Figure 2 is based on observations of house prices in the year 2000, and it reflects observed average house prices in each zone. As an alternative we could report observed median values in each zone. The median is in general less sensitive to extreme values than the mean. According to our experiments, however, the mean and the median results in a very similar spatial pattern of values, and the choice has no practical consequence for the discussion to follow.

The dashed line in Figure 2 reflects predictions related to a standard house, in a case where the labor market accessibility measure is the only information of spatial structure incorporated (MF3). Compared to the gradient resulting from MF2, the dashed line to some degree reflects apparent irregularities in the observed spatial pattern of house prices. This indicates that the labor market accessibility measure captures a basic feature of the housing market.

In part b) of Figure 2 we focus on observed and predicted house prices within 20 minutes from the cbd. According to the dotted line observed average prices tend to fall close to the cbd, followed by an interval where house prices develop more like a random walk. This observed pattern contributes to explain why a modeling approach with no information of spatial attributes results in a satisfying goodness-of-fit if the study area is restricted to the Stavanger municipality (MF1). In this case the predicted price of a standard house is 1730550 NOK. This is a reasonable prediction for houses located in Stavanger, but not for houses in more peripheral locations within the labor market area.

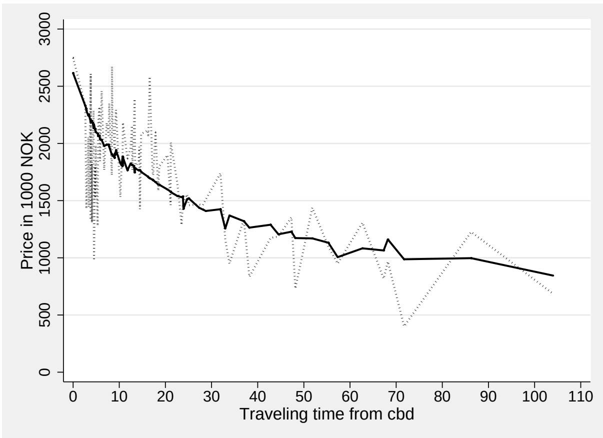


Figure 3: The solid line represents predicted prices of a standard house, based on a model (MF4) where both traveling time from the cbd and labor market accessibility are accounted for. The dotted line represent the observed zonal average house prices.

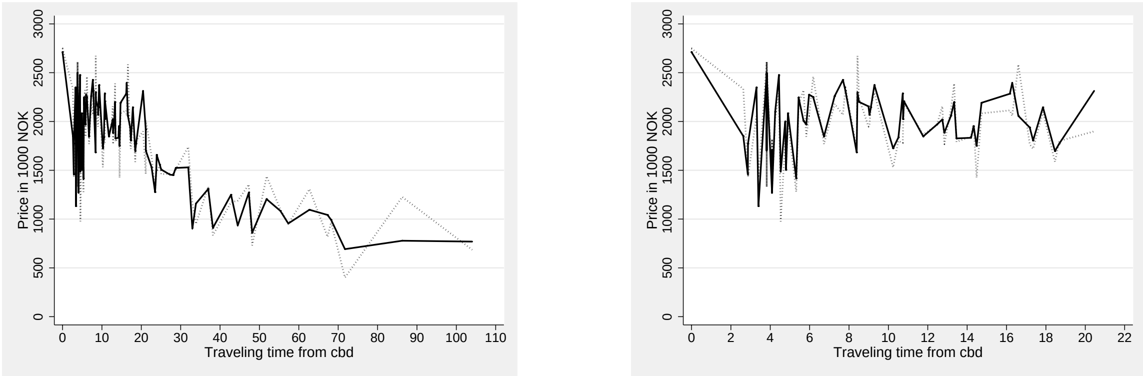
The solid line in Figure 3 corresponds to predictions resulting from MF4, which accounts both for the distance from the cbd and labor market accessibility. This model predicts a more regular spatial pattern in house prices, with smaller local variations than the predictions following from a model where only labor market accessibility is accounted for (MF3). The urban attraction effect, represented by the traveling time from the cbd, contributes to smooth out the local variations caused by a heterogeneous spatial pattern of job opportunities. Note also that the variable RURLOT is not accounted for in the predictions presented in this subsection. Without reporting the details, our experiments clearly demonstrate that this variable contributes to explain the spatial variation in house prices in peripheral areas of the region.

4.2 Predicting zonal variation in average house prices

So far we have compared observed zonal average prices to predicted prices of a standard house. Predictions referring to a standard house do not, however, necessarily reflect zonal average values of dwelling-specific attributes. This especially applies for houses within 20 minutes from the cbd, and indicates that attributes of houses traded in this area deviate systematically from average values fo the whole area. Some zones have a high density of large, high-standard houses, while the opposite applies for other zones. This is of course not reflected by predictions of a standard house. Hence, predictions referring to the standard house are not necessarily an adequate measure for evaluating the predictability of alternative models.

Alternatively, the evaluation can be based on a comparison between average observed and average predicted prices for all houses that were traded in a zone. The solid line in the two parts of Figure 4 represents predicted zonal average values, based on information of estimated coefficients (from MF4) and observed attributes for all houses that were traded this year. Compare next the predictions of zonal average prices to the predictions of the price of a so called standard house. It is obvious from studying Figures 2 and 4 that predicted zonal average prices covariate closer to observed average values. The correlation coefficient is 0,6494 for the relationship illustrated in Figure 2, and 0,9083 for the relationship between zonal average observed and zonal average predicted values.

It follows from Table 2 that the average prediction error (APE) related to all individual observations in our data is 215144 for MF4. The corresponding prediction error for zonal averages is 154578. This reduction in prediction error is according to the law of large numbers, and is especially applying to zones located in the most urbanized area of the region, indicating that attributes of many houses traded in this area deviates considerably from the average regional standard. Observed house prices reflect the heterogeneity of dwelling-specific attributes and location-specific amenities. In addition they reflect random incidents in the bid process. Such

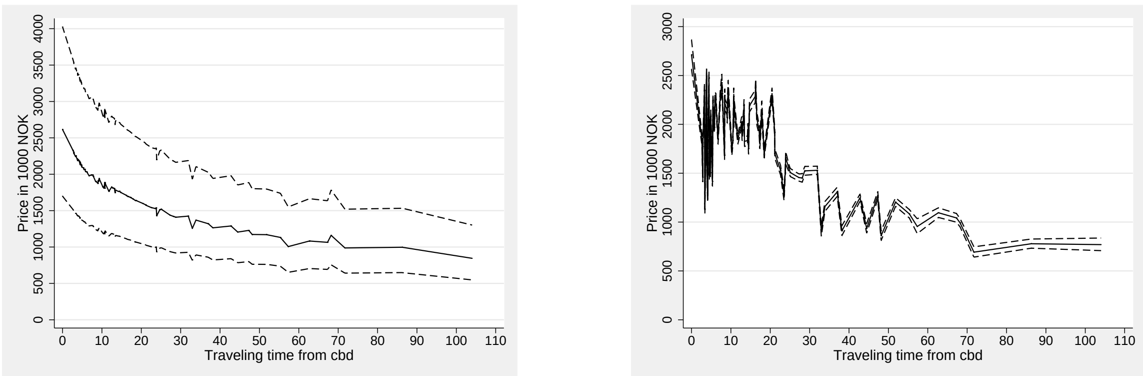


a) The entire region b) The area within 20 minutes from the cbd

Figure 4: The solid lines represent the predicted zonal average prices for all houses that were traded in 2000. The predictions area based on estimated coefficients from a model formulation (MF4) incorporating both the urban attraction and the labor market accessibility effect. The dotted lines represent the observed zonal average house prices.

irregularities are of course not captured in the predicted prices of a standard house, while predicted average prices at least capture the effect of systematic zonal variation in attributes accounted for in the model formulation.

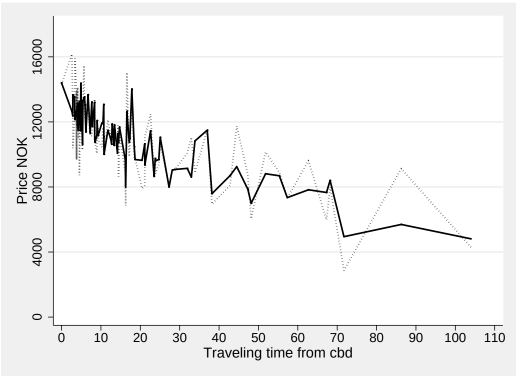
Prediction errors are considerably lower for zonal averages of traded houses than for an individual standard house. The law of large numbers and the difference in prediction accuracy are also reflected in Figure 5. Part a) of the figure illustrates a forecast interval for a standard house. The upper and lower symmetric 95% prediction interval is computed by using robust standard errors of the fitted values, which include both prediction and residual errors. The narrow prediction interval in part b) of the figure corresponds to the predicted zonal average values, which are based on observed attributes for all houses that were traded in 2000.



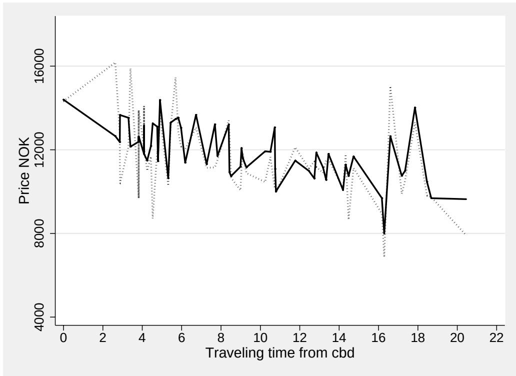
a) A standard house b) Zonal average

Figure 5: Predicted house price gradients, including prediction intervals.

The higher prediction accuracy does not mean, however, that predicted zonal averages offer more reliable information on the spatial variation in house prices than the predicted price gradient of the standard house. Neither predicted nor observed zonal averages adjust for the impact of other attributes than the location relative to the cbd and to labor market opportunities. One influential dwelling-specific attribute is the living area measured in square meters. Figure 6 illustrates the average predicted house price per square meter in each zone. The corresponding correlation coefficient is ... . Notice that the predicted house prices in this case tend to fall with increasing traveling time also within distances of 20 minutes from the cbd, while we have seen that both observed and predicted averages develop more like a random walk in this interval (see Figure 4b)). This reflects a tendency that the amount of housing space is negatively related to land prices, and illustrates the importance of adjusting for non-spatial attributes in studies of spatial variation in house prices.



a) The entire region



b) The area within 20 minutes from the cbd

Figure 6: The solid lines represent the average predicted house price per square meter, based on a model formulation (MF4) where both traveling time from the cbd and labor market accessibility are accounted for. The dotted lines represent the observed zonal average house prices.

Figure 4 and Figure 6 were based on a model formulation (MF4) incorporating both the urban attraction and the labor market accessibility effect. The figures would not differ perceptibly if the predictions were based on a model formulation which accounts for either traveling time from the cbd (MF2) or labor market accessibility (MF3). This is also reflected by measures of the prediction error. The Standardized Root Mean Square Error (SRMSE) between predicted and observed average zonal values of house prices is 0,1222 if the predictions are based on the model formulation where both measures of spatial structure are incorporated, 0,1221 if spatial structure is represented only by traveling time from the cbd, and 0,1458 if only labor market accessibility is explicitly accounted for.

4.3 Predicting house prices at a specific location

In evaluating the predictability of alternative models a natural next step is to distinguish between different locations. Without entering into tedious details on several kinds of locations, we briefly consider the subcenter Bryne, to focus on the effect of including a measure of labor market accessibility in the model. Bryne is the administrative center of the municipality Time, in a traveling time by car of about 32 minutes from the regional center (cbd). Both the spatial distribution of jobs and workers have a marked local peak in this subcenter. Based on the model (MF2), where the traveling time from the cbd is the only measure of spatial structure, the predicted price of a standard house at this location is 1409542 NOK. The corresponding predictions are 1437170 NOK if spatial structure is only represented by the labor market accessibility measure (MF3), and 1424853 NOK if both measures are accounted for (MF4). The observed average price of all houses traded at Bryne in 2000 was 1739695 NOK. This figure is not directly comparable to our predictions, however, since observations do not necessarily correspond to average values of different attributes. Our results indicate that houses traded at this location in 2000 tend to be somewhat larger and newer than the regional average. An alternative and/or supplementary explanation is that the mentioned models underpredict house prices at this subcenter. This hypothesis is confirmed by estimation results based on MF5, where the subcenter Bryne is explicitly accounted for through the introduction of a dummy variable. This modeling approach results in a prediction of a standard house at Bryne of 1512827.

It follows from the estimation results presented in Table 2 that a model formulation including both globally defined measures of spatial structure is superior to MF2 and MF3 in offering an adequate explanation of housing prices. Still, this model formulation is not unambiguously the preferred approach for making reliable predictions of house prices at specific locations. In cases where the concentrations of jobs deviates considerably from the regional average a model where spatial structure is accounted for only through the labor market accessibility measure might perform better as a device for predicting house prices. MF3 is biased, but the parameter estimates put more weight to the impact of job concentrations than estimates resulting from a model where the labor market accessibility effect and the urban attraction effect are accounted for by separate measures. We will see in the next section, however, that the biased model formulation is inappropriate for making predictions in other kinds of scenarios.

The labor market accessibility measure and location-specific dummy variables to some degree capture the effects of local irregularities in the spatial distributions of jobs. Still, we find that there are no considerable differences between the model formulations MF2, MF3, MF4, and MF5 in predicting house prices at specific locations in this relatively monocentric geography. This means that a model where the distance from the cbd is the only variable representing spatial structure offers a reasonable prediction of a housing price gradient in a case where adequate information of job opportunities is missing.

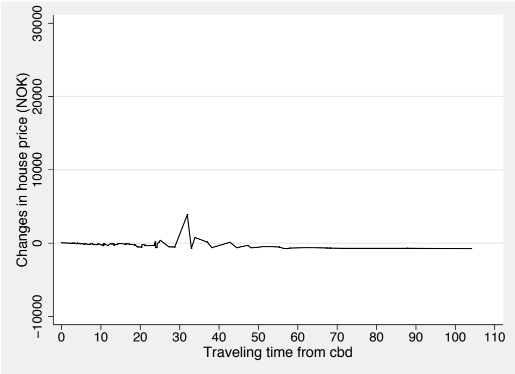
5 Predicting the impact of changes in the spatial distribution of employment

According to the estimation results referred in Table 2, labor market accessibility has a significantly positive impact on house prices. This means that changes in the spatial distribution of jobs lead to a redistribution of assets through capitalization of property values. The ambitions in this subsection are twofold:

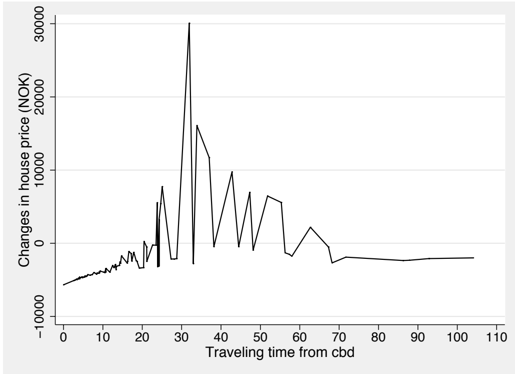
- test the appropriateness of alternative model formulations to predict the impact of a spatial redistribution of job opportunities on house prices
- discuss and quantify how alternative scenarios of job redistributions affect the spatial pattern of house prices

We consider scenarios with increased employment at a specific location, for a constant number of job opportunities in the region. One possible explanation is that a firm is relocated within the region. Another possibility is that the recruitment of workers to a new firm results from competitive forces in the labor market, resulting in reduced employment in other firms. Due to the effects of commuting costs and moving costs it can be argued that the recruitment of workers tend to be negatively related to the distance from the location of the new firm. The recruitment pattern also reflects the spatial distribution in the demand and supply for workers of specific qualifications and professions. As a simplification, however, we proceed by assuming that the increased employment in a zone is countervailed by proportional reductions in all the zones.

A model where spatial structure is represented only by traveling time from the cbd (MF2) is totally incapable of predicting potential consequences on house prices of changes in the spatial distribution of job opportunities. Models incorporating a measure of labor market accessibility are more appropriate for this purpose. Figure 7 illustrates how house prices in the 98 zones are predicted to be affected by an increase of 4000 jobs at Bryne. Total employment in the region is held constant, through a proportional reduction of jobs in all the other zones of the region. The factor of proportionality is the fraction of jobs in the region that is located in the specific zone.



a) Predictions based on MF3



b) Predictions based on MF4

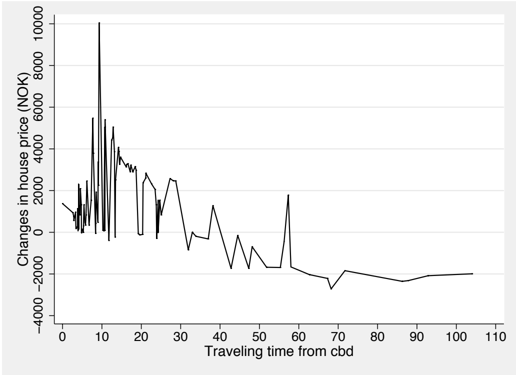
Figure 7: Predicted changes in the price of a standard house in a case where 4000 new jobs located at Bryne correspond to reduced employment in all the other zones. The reductions are proportional to the fraction of jobs located in the specific zones.

The plot in the left part of Figure 7 is based on estimates resulting from a model formulation where spatial structure is represented only by the labor market accessibility measure (MF3). The predicted changes illustrated in the right part of the figure are based on a model where the labor market accessibility effect and the urban attraction effect are accounted for through separate measures (MF4). The changes in house prices refer to a so called standard house. It follows from the figure that the predicted changes in house prices are very sensitive to the choice of modeling framework. In the case where the predictions are based on the model involving both effects (MF4) the predicted increase in house prices at Bryne is about 30000 NOK, while the predicted increase is only 4000 NOK in the case where the traveling distance from the cbd is not explicitly accounted for (MF3). Those predictions represent 2% and 0,3% of the corresponding predicted price of a standard house at this location. Similar results follow from experiments increasing employment in all the zones of the region.

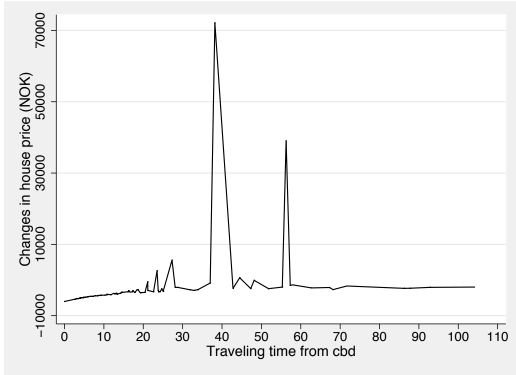
Remind that our model is based on the simplifying assumption of constant parameters. This means that we ignore possible interaction effects between the explanatory variables. Consequently, the predicted price increase resulting from improved labor market conditions is autonomous with respect to house-specific attributes. Hence, the predicted changes for a standard house apply for houses of any size (LIVAREA), and any combination of dwelling-specific attributes.

In the previous section we have seen that all the modeling alternatives contribute with reasonable predictions of house prices at alternative locations. The parameters in a biased model, like MF3, is adjusted to fit the data best possible. Even if such a model captures the effects of the basic mechanisms, however, it does not offer a satisfying explanation of the spatial variation in house prices. It follows from Table 2 that parameter estimates based on MF3 ($\hat{\gamma}_e = 0,0637$) puts considerably less weight on the impact of variations in employment than the corresponding estimates based on MF4 ($\hat{\gamma}_e = 1,0963$) in the measure of labor market accessibility. This is not adequately adjusted for by the remaining parameter estimates, and the biased model is not at all appropriate for the empirically based comparative statics performed in this section. Hence, our results illustrate the importance of using an unbiased model for the purpose of predicting the impact of exogenous shocks on the system. The model incorporating variables representing the presence of regional subcenters (MF5) contributes significantly to the explanatory power of the model, but it has practically no impact on predicting house prices at other locations than the relevant subcenters. Hence, MF4 is an appropriate model formulation for the empirically based numerical experiments to follow in this paper.

In evaluating the housing market impact of the spatial redistribution of job opportunities it certainly matters where the growth in employment appears. In the discussion to follow we illustrate this by considering three typical locations. Bryne is a semi-urban location in the region we study. Figure 8 illustrates the impact on house prices if the employment growth appears in either the suburban area in the central parts of the region (Forus, zone 32 in Figure 1), or a peripheral location, at a traveling time of 38,19 minutes from the cbd (zone 80 in the municipality of Gjesdal, see the map in Figure 1). The predictions are based on a model formulation incorporating both the labor market accessibility effect and the urban attraction effect.



a) Increased employment at Forus (zone 32), an urban location

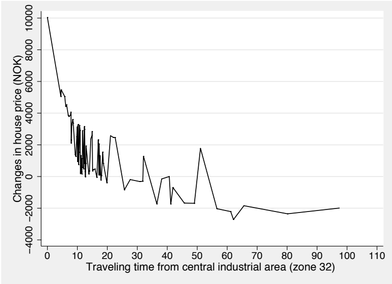


b) Increased employment at zone 80 in the municipality of Gjesdal, a peripheral location

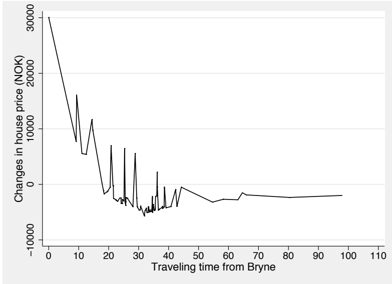
Figure 8: Predicted changes in the price of a standard house in a case where 4000 new jobs located at alternative locations correspond to reduced employment in all the other zones. The reductions are proportional to the fraction of jobs located in the specific zones.

Notice first that the scale on the vertical axis is not the same in the figures representing the effects on house prices in the urban, semi-urban and rural locations. By comparing Figure 7b and the two parts of Figure 8 it follows that the local impact on house prices of an employment expansion tends to be negatively related to the degree of urbanization in the relevant part of the region. An employment expansion leads to a considerably higher increase in local house prices if firms establish in rural, peripheral, areas, than in a case where the chosen location is within a reasonable commuting distance for the major part of the workers in the region. A decentralization in the demand for labor is predicted to lead to a considerable reduction of the spatial disparities in house prices. To the contrary, a corresponding centralization of job opportunities is predicted to exert a relatively marginal influence on the spatial distribution of house prices. This is an example of strongly asymmetric consequences of exogenous shocks at different locations.

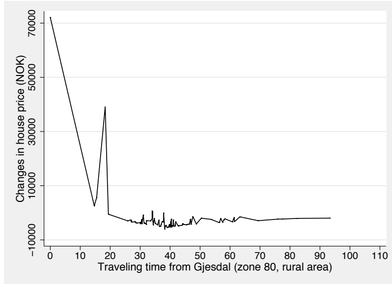
In Figures 7 and 8 the horizontal axis measures the traveling time from the cbd. Two zones which are located at about the same distance from the cbd are not necessarily neighbors in the transportation network, they might of course be located in different directions from the cbd. In Figure 9 the horizontal axis represents the traveling time from the zone that hypothetically attracts new employment. The vertical axis still reflects the impact on house prices of 4000 new jobs at the specific locations, for proportional reductions in job opportunities in all the other zones.



a) Stavanger/Sandnes (urban)



b) Bryne (semi-urban)



c) Gjesdal (rural)

Figure 9: Predicted changes in the price of a standard house in a case where 4000 new jobs located at alternative locations correspond to reduced employment in all the other zones. The reductions are proportional to the fraction of jobs located in the specific zones. Traveling time is measured from the zone attracting the new jobs.

The zones in the region can be subdivided into an urban, a semi-urban, and a rural category. According to our experiments the figures above illustrate results for three representative alternatives for each category. Adjusting for the marked differences in the level of predicted change in house prices, a similar pattern appears in the three parts of Figure 9. The positive impact on house prices tends to extend over an equally large area for all kinds of zones; only marginal effects appear for zones located in traveling distances beyond 20 minutes from the place of employment growth.

An alternative scenario is that a spatial redistribution of employment results from an intraregional relocation of a firm. As a hypothetical experiment we consider a relocation of a firm with 4000 employees between a zone in the cbd-area and the more peripheral southern parts of the region (Eigersund). The result of this experiment is illustrated in Figure 10, and confirm the spatially asymmetric consequences of an exogenous labor market shock. The dashed curve in the figure reflects the effects on house prices of relocating the firm from a zone in the central parts of the region to the more peripheral zone, while the solid line reflects the effects of a corresponding relocation in the opposite direction. One kind of asymmetry has been focused above: a specific change in the number of local job opportunities in a peripheral location has a substantially larger impact on the housing market than a corresponding change in the central parts of the region.

Another kind of asymmetry is also illustrated in Figure 10: a negative labor market shock in the peripheral location has a substantially larger impact on house prices than a corresponding positive labor market shock.

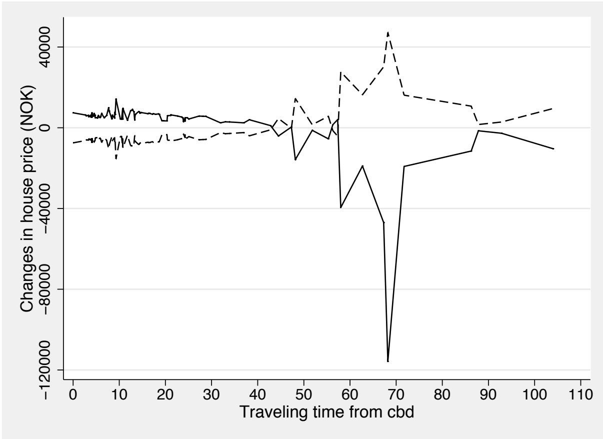


Figure 10: The solid line represents changes in the spatial distribution of house prices resulting from a hypothetical relocation of a firm with 4000 employees from Eigersund in the southern part of the region to zone 92 in the cbd area. The dotted line reflects the impact of a corresponding relocation in the opposite direction.

The predictions and illustrations presented in this section should be interpreted with care. They are based on a partially defined modeling framework, assuming that the spatial distribution of workers and residents is unaffected by the exogenous changes in the system. This does not mean that the results are without interest. They indicate how the housing market effects contribute to reduce labor market mobility and stabilize the spatial system. In a study of long term effects a possible next step is to integrate the housing market model into a more comprehensive general spatial equilibrium modeling framework. One fundamental relationship accounted for in such a framework is the economic base mechanism, representing the interdependence between population growth and local sector activities (see for instance Treyz 1993).

6 Predicting the impact on house prices of changes in the road transportation network

Changes in the road transportation network affect house prices both though the labor market accessibility effect and the urban attraction effect. In this section we predict the impact on house prices of hypothetical changes in the road infrastructure. We start by considering overall reductions in traveling times, before we study effects of investments on specific road links. For this purpose we introduce a modified measure of labor market accessibility, to capture spatial housing market competition effects.

6.1 Effects of investments in transportation infrastructure leading to overall reductions in traveling times of journeys-to-work

IN PREPARATION

6.2 Effects of investments leading to reductions in traveling times on specific road links

In this subsection we consider improvements on specific links of the road transportation network. We assume that five zones in the northern part of the region benefit from the relevant improvements, while (shortest route) traveling times remain unchanged for journeys-to-work between all other zones in the region. Four of the five zones belong to the municipality of Rennesøy (zones 1,2,3, and 4), while one is belonging to the municipality of Stavanger (zone 43). Once again, our analysis primarily refer to hypothetical simulation experiments rather than possible real world scenarios. The results reflect the hypothetical consequences on house prices of a more compact geography in this part of the region rather than realistic changes in the transportation network. Technically, we consider three scenarios, corresponding to reductions in traveling time of 20%, 50%, and 80% from the five zones to neighboring mainland zone in the transportation network.

In such kind of scenarios a single equation forecast model where the spatial structure is only represented by distance from the cbd results in the predictions that housing prices are reduced in the relevant zones in the north of the region, while housing prices in other parts of the region are unaffected by the specific changes in the transportation network. According to the results in Table 3 the price of a standard house is predicted to increase by 72375 NOK in the municipality center of Rennesøy (zone 1) if traveling time to the nearest mainland zone is reduced by 20%. This corresponds to an increase of about 4,8% in the price of a standard house. A reduction in traveling time of 80% means that the relevant zones in effect are assumed to be a part of the Stavanger urban area. Based on MF2 such a location is predicted to explain increases in the price of a standard house within the interval of 25%-30%, compared to the predicted price at the present transportation network.

An important difference appears when spatial structure is measured by labour market accessibility rather than the traveling time from the cbd. The point is that changes in terms of transportation on any link in the road transportation network affect the value of the labor

Table 3: Predicted changes in the price (in NOK) of a standard house corresponding to reductions in traveling time on links between 5 zones in the northern part and the remaining zones of the region

	20% reduction			**50% reduction**			**80% reduction**		
	MF2	**MF3**	**MF4**	**MF2**	**MF3**	**MF4**	**MF2**	**MF3**	**MF4**
zone 1	72375	116645	88475	214410	349416	256475	434236	602237	503391
zone 2	70718	115419	85783	207611	325881	245335	413538	538428	473680
zone 3	71232	116520	86536	209086	335904	247529	419114	557361	480731
zone 4	69320	114135	83896	202659	329399	239162	400528	536492	458657
zone 43	73751	116839	93101	219431	354192	268089	448253	612773	525020

market accessibility measure in all the zones of the region. Any reduction in traveling time at a specific road link induces higher values of the accessibility measure for all the zones. Since the estimate related to the accessibility measure is estimated to be significantly positive this means that house prices are predicted to increase all over the spatial system. At locations peripheral to the specific road link, the predicted increase will be very marginal, however.

It follows from Table 3 that a model (MF3) where spatial structure is accounted for through the labor market accessibility measure predicts a considerably higher increase in house prices than a model where traveling distance to the cbd is the only spatially related variable incorporated. Both models are biased. MF4 is a more reliable model formulation, comprising both the labor market accessibility effect and the urban attraction. The results in Table 3 indicate that the impact on house prices of changes in the road transportation network is underpredicted by MF2 and overpredicted by MF3. The predictions based on MF4 imply that a standard house in zone 1 will experience a price increase of 6,2% if traveling time on the relevant road links is reduced by 20%. If this zone were located in a more suburban position, 80% closer to the border of the Stavanger municipality, the price of a standard house is predicted to be 35,2% higher than at the present location.

6.3 Predictions based on a measure of relative labor market accessibility

As mentioned at the end of Section 5 the effects of changes in transportation infrastructure ideally should be studied within a spatial equilibrium framework rather than a partial single equation approach. In the lack of an operational spatial general equilibrium model, however, we think that an approach based on an accessibility measure is superior to an approach based on one-dimensional measures of spatial separation. This is based on the idea that gravity based accessibility measures capture fundamental effects in a growth process towards a new spatial equilibrium, see for instance Rietveld (1989). A changed road transportation network leads to changes in the zonal accessibility pattern, which influence the attractiveness of a location for residential purposes. Still, a partial approach ignores expected interdependence effects between the housing market and spatial relocations of population and employment. An interrelation can be expected between housing prices and residential location decisions, and this interrelation tends to reduce the initial effect of changes in transportation investments on housing prices. Such interdependencies are taken into account in some simultaneous equilibrium large scale models which combine transport and locations aspects, see for instance Wegener (1998). In the lack of such a comprehensive, data-intensive, modeling framework for the specific region, however, we think that an approach where labour market accessibility is included in the non-linear regression model represents a satisfying quantitative approximation of how the spatial variation in housing prices is affected by changes in the transportation network. We do not, however, think that models based on a one-dimensional separation measure are appropriate for making reliable predictions.

As mentioned in the previous subsection a model incorporating S_j predicts that a reduction of traveling time at any road link leads to increased house prices all over the spatial system. This is not necessarily a reasonable outcome of such investments. S_j is an absolute measure of labor market accessibility. It can be argued that a relative measure of accessibility is more appropriate in applied housing market analyses.

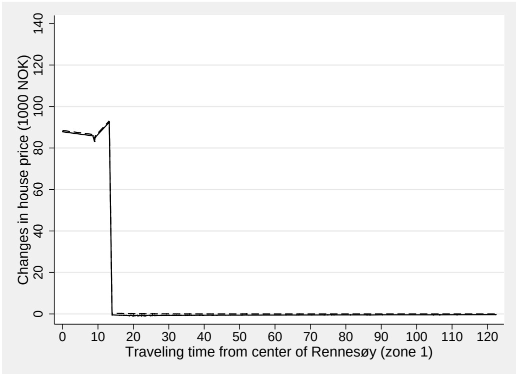
Consider the case with an improved road connection from a zone to the cbd of the region. According to the labor market accessibility effect and the urban attraction effect the relevant zone will then be more attractive for residential purposes, resulting in higher demand and higher bids for houses offered for sale in this zone. Correspondingly, demand might be reduced for houses offered for sale in other zones. The idea is that market prices to some degree reflect the *relative* labour market accessibility. The willingness-to-pay for a house reflects how attractive the location is relative to the locations of alternative houses offered for sale. Without entering into details a changed pattern of accessibility might influence both the reservation prices and the search process of potential buyers. Our hypothesis is that the effects of such mechanisms is better represented by the following relative measure of accessibility than by S_j:

$$\bar{S}_j = \frac{\sum_{k=1}^{w} D_k \exp(\sigma d_{jk})}{\sum_{k,j=1}^{w} D_k \exp(\sigma d_{jk})} \tag{2}$$

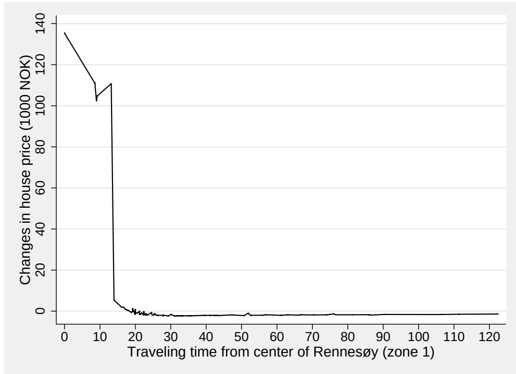
Notice that the numerator of this expression is the Hansen measure. Through the expression in the denominator, however, any change in the road transportation network will affect the accessibility pattern in the entire system. The numerator captures the direct effect of improvements in the road transportation network on the position relative to attractive job opportunities. In addition, however, the denominator captures the possibility that other zones might benefit more from the improvements in terms of commuting. The introduction of the denominator in expression 2 does not affect estimates of implicit prices or the explanatory power of the model. For a specific state of the system the denominator is a constant. The substantial difference between the two modeling alternatives appears when they are used for predictive purposes, for instance related to specific changes in the road transportation network.

It is straightforward to see that the measure of relative accessibility, $\bar{S}_j$, can be interpreted in terms of random utility maximization. Consider S_j as the relevant attribute of location j, and assume that the natural logarithm of this attribute represents the systematic component in a linearly specified random utility function. Assume next that the random disturbances are independent and identically distributed according to a type 1 extreme value distribution. It then follows that the probability of choosing location j is represented by $\bar{S}_j$, which corresponds to the well known multinomial logit model. This result was first derived by McFadden (1974).

Part a) in Figure 11 illustrates the predicted effects on house prices of reducing traveling time by 20% between the border of the municipality of Stavanger and the five zones located furthest to the north in the region. Those five island zones are connected to the mainland though tunnels and bridges. The dashed line in the figure follows from the use of the absolute measure of labor market accessibility, S_j, while the predictions represented by the solid line are based on a model formulation involving the relative accessibility measure $\bar{S}_j$. The figure indicates that house prices are predicted to fall in zones experiencing a reduced relative labor market accessibility. The predicted reductions in house prices are very marginal, however, ranging from 359 NOK to about 1000 NOK, almost invisible in the figure. The main effect of the changes in the transportation network is to increase house prices in the zones most directly involved, and the predictions are more or less totally insensitive to the choice of accessibility measure. The area benefitting from reduced commuting costs has few job opportunities, and the labor market attraction originating from the area is not strong enough that improvements in the local transportation network generate significant housing market competition effects.



a) A 20% reduction in traveling time



b) A 20% reduction in traveling time, accompanied by a relocation of 5000 jobs from the mainland to the five island zones in the north

Figure 11: Predicted changes in house prices of a 20% reduction in traveling distance between the border of the municipality of Stavanger and the five zones located furthest to the north in the region. The dashed line is based on an absolute measure of labor market accessibility, the solid lines refer to the use of a relative measure of labor market accessibility.

Consider next as another hypothetical experiment that employment is distributed to the relevant northern part of the region. The curve in part b) of Figure 11 represents predicted effects on house prices in a case where the number of jobs increases by 5000 in the relevant five zones. Those jobs are assumed to be relocated from the remaining zones of the region. Both the distribution of the new jobs between the five zones in the north and the reduction of jobs in the remaining zones are according to an assumption of proportionality with respect to the initial fractions of jobs in the respective areas. The relationship between investments in road transportation infrastructure and employment growth has been thoroughly addressed in the regional science literature, but it is beyond the scope of this paper to review this discussion. Our ambition in this paper is not to discuss the possible impact of improved transportation network on local employment. The hypothetical experiment is motivated to study how spatial housing market diffusion effects depend on the spatial distribution of job opportunities.

According to Figure 11 the relevant spatial redistribution of the 5000 jobs leads to an increase of housing prices in the interval between 20000 NOK and 50000 NOK for the five zones in the north. In comparing the two parts of the figure it also follows that the 20% reduction in traveling time has a marginally stronger impact on the neighboring mainland zones in this case where more jobs are distributed to the northern island zones. Basically, however, the dominating housing market benefits of both the employment growth and the improved terms of traveling are concentrated to the zones most directly involved. The predicted reductions in the price of houses located outside the northern area are partly due to the redistribution of jobs, and partly to the fact that part b) of the figure is based on the relative measure of labor market accessibility. None of those effects are strong, however, and a graphically based decomposition results in curves very similar to the one in part b) of Figure 11. Without entering into details we have experimented by more extreme variations in both traveling times and the distribution of job opportunities. A general conclusion is that predictions of house prices are relatively insensitive to the choice between an absolute and a relative measure of labor market accessibility.

7 Concluding remarks

Our main ambition has been to compare the predictability of alternative model formulations. What can be said about the prediction error in a situation where data on the spatial distribution of employment and population is missing? Is the distance from the cbd an adequate measure of spatial structure in such a situation? Is a labor market accessibility measure a satisfying substitute for the distance from the cbd, or is it important that predictions are based on the estimated impact of both measures simultaneously? In addition to the evaluation of alternative models we have been concerned with studying the impact of changes in the road transportation network and the spatial employment pattern on house prices.

In general, the modeling alternatives considered in this paper offer very different explanations of the spatial variation in house prices. The model (MF4) where both the labor market accessibility measure and the traveling time from the cbd are incorporated explains variation in house prices as a result of a labor market accessibility effect and an urban attraction effect. Still, the values of the goodness-of-fit indices is not very different. This is also reflected in the predicted prices of a (standard) house at a specific location, and in the predicted average house prices in alternative zones. The predicted values are of course not totally insensitive to the choice of model formulation, but the predictions are less sensitive to this choice than might be expected from theoretical considerations even in this relatively monocentric geography. Hence, a model where traveling time to the cbd is the only measure of spatial structure offers a reasonable prediction of a housing price gradient in a case where adequate information of job opportunities is missing. We also find that the labor market accessibility measure to some degree accounts for local irregularities in the housing market. This applies for instance for variations within the urban area. In fact, a model where this is the only measure of spatial structure (MF3) might outperform the theoretically more satisfying model (MF4) in predicting house prices where the concentrations of jobs deviates considerably from the regional average. The urban attraction effect contributes to smooth out potential irregularities in predicted house price gradients.

The prediction of zonal average house prices is based on information of estimated coefficients and observed attributes for all houses that were traded. It is reasonable that predicting average values is considerably more accurate than predicting the price of a specific house at a specific location. It is in general important to account for non-spatial attributes in studies of spatial variation in house prices. If, for instance, living area is explicitly accounted for in predicting the house price per square meter, the house price gradient is predicted to be a falling function of the distance from the cbd also within the urban area, reflecting the tendency that the amount of housing space is negatively related to land prices. For the most urbanized area of the region no distinct spatial trend appears in the case where living area is not explicitly accounted for.

As a next step the models are evaluated from their ability to forecast the impact of exogenous shocks on house prices. One kind of exogenous shock is a spatial intraregional redistribution of job opportunities. A model ignoring the labor market accessibility effect (MF2) is of course totally incapable of predicting the effects of such a shock. The forecasts are very sensitive with respect to the choice of modeling framework. In general, our experiments illustrate the importance of using an unbiased model for the purpose of forecasting the impact of exogenous shocks on house prices.

According to our experiments the local impact on house prices of an employment expansion tends to be negatively related to the degree of urbanization in the area. The increase in house prices are predicted to be considerably higher if firms establish in rural, peripheral, areas, than in a case where the chosen location is within a reasonable commuting distance for the major part of the workers in the region. Correspondingly, apparent asymmetric tendencies are predicted: a centralization of job opportunities has a relatively marginal influence on the spatial pattern of house prices, while the reverse is not true for a decentralization of job opportunities. Ignoring the differences in the level of the predicted changes, however, we find that the positive impact of local employment growth on house prices tends to extend over an equally large are for both urban, semi-urban, and rural areas. Only marginal effects appear for zones located in traveling distances beyond 20 minutes from the place of employment growth.

Another kind of asymmetry relates to negative versus positive labor market shocks. We find that a negative labor market shock at a peripheral location has a substantially larger impact on house prices than a corresponding positive labor market shock.

We also find that the predicted impact on house prices of changes in the transportation network is very sensitive to the model specification. If data on the spatial distribution of employment and population is missing, a model where spatial structure is represented by the traveling time from the cbd is a natural choice. Our results indicate that such an approach underpredicts considerably the impact on house prices of investments leading to reduced traveling time from a specific location to the cbd. A model formulation where the labor market accessibility measure is the only variable representing spatial structure tends to overpredict the housing market impact of such investments. Reliable predictions of how changes in the road infrastructure affect property values call for a model where both the urban attraction effect and the labor market accessibility effect are explicitly accounted for. Experiments based on such a model (MF4) demonstrate that property values are relatively sensitive to changes in the road transportation network.

A model incorporating a labor market accessibility measure predicts that house prices increase all over the system if traveling time is reduced at a specific link in the road transportation network. The increase will be very marginal at locations peripheral to the predicted increase, however. Still, we argue that such results are not reasonable, and introduce the hypothesis that housing market spatial competition effects are better represented by a relative measure of labor market accessibility. Theoretical arguments are in favor of such a relative measure, but our experiments demonstrate that results are quantitatively rather insensitive to the choice between an absolute and a relative measure of labor market accessibility.

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