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PREDICTING HOUSING PRICES AT ALTERNATIVE LOCATIONS AND IN ALTERNATIVE SCENARIOS OF THE SPATIAL JOB DISTRIBUTION

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Predicting housing prices at alternative locations and in alternative scenarios of the spatial job distribution

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Abstract

Alternative hedonic model formulations are used 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 alternative model formulations primarily differ with respect to how spatial structure is represented. In addition to evaluating the predicability of alternative model formulations we also study how housing prices in different areas are affected by changes in the spatial distribution of employment. Alternative scenarios of job relocations are considered. We find, for instance, that the local impact of labor market shocks is negatively related to the degree of urbanization in the relevant region.

JEL-classification: R21, R31

1 Introduction

This paper addresses problems related to predicting prices resulting from housing market transactions. For this purpose we consider alternative hedonic model formulations. The alternative models reflect different demands for data and different ways to account for characteristics of 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 several model formulations are used to predict housing prices at alternative locations within a housing and labor market area. We are not concerned with predicting the price of

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a specific house; local variations in socioeconomic conditions, the view, the provision of public services etc. are ignored, and we concentrate on systematic, macroscopical, spatial variation across the geography. Predictions of average housing prices are produced through a traditional econometric approach, and the predicted prices are compared to observed average prices. Based on this exercise we discuss the relationship between goodness-of-fit and predictability in evaluating the alternative model formulations.

We are not only concerned with predicting (average) prices that are achieved in property transactions at specific locations. In addition the alternative model formulations are evaluated from their ability to predict how changes in spatial structure characteristics affect housing prices. We both consider the effects of local employment growth and the effects of a redistribution of jobs between alternative locations.

The selection of model formulations is based on results reported in three previous papers (Osland et al. (2007) and Osland and Thorsen (2006, 2008)). As mentioned above they differ primarily with respect to the representation of spatial structure. The standard theoretical justification for incorporating measures of spatial structure is represented by the access-space tradeoff model of residential location. This model was introduced by Alonso (1964), for a monocentric framework. Due to the presence of commuting costs workers find residential locations close to the cbd to be attractive. Hence, equilibrium prices per unit of housing tend to be negatively related to the distance from the cbd. This modeling framework has been extended in several directions, for example by introducing the possibility of decentralized employment (Brueckner 1979). The idea that the polycentric character of the labor market matters in explanation of housing prices is of course reflected in empirical studies, see for instance Dubin and Sung (1987), Heikkila et al. (1989), Richardson et al. (1990), Waddell et al. (1993). Those contributions emphasize the importance of including the distance to secondary employment centers, while for instance Adair et al. (2000) introduced a gravity based measure of transport accessibility in a study of the Belfast urban area. As pointed out by McMillen (2004) empirical studies are not unambiguously consistent with standard urban theory, suggesting that both the price of a unit of housing and the population density should be relatively high in and near subcenters. Heikkila et al. (1989) and Richardson et al. (1990) are examples of studies confirming these standard theoretical hypotheses, while McMillen (2003) and McMillen (2004) present evidence that proximity to Chicago's subcenters is not valued highly in the residential market. Similar results are presented in Clapp et al. (2001), also rejecting standard polycentric urban economics.

Osland and Thorsen (2008) introduced both a gravity based accessibility measure and the distance from the cbd into the modeling framework. The accessibility measure represents a generalization of the basic idea underlying the trade-off hypothesis, while the distance to the cbd is interpreted to represent the effect of accessibility to urban-specific amenities. In such an approach changes in the spatial distribution of job opportunities affect house prices through the impact on the labor market accessibility measure.

As stated above the ambitions of this paper are twofold: we evaluate alternative modeling approaches, in addition to focusing on substantial aspects of how housing prices are influenced by changes in the spatial distribution of labor demand. Belonging to the first category of ambitions we consider 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? Reliable predictions of housing prices at alternative locations represent important information both for local housing developers and for planning authorities. As an example of a substantial housing market problem we study how housing prices are influenced by employment growth at a specific location, and we also study the impact of an intraregional relocation of a firm. In addition we study how the impact on housing prices depends on where the employment growth appears in the geography. Is the impact of employment growth in the city center on housing prices quantitatively different from the impact of suburban or rural employment growth? Is the impact on housing prices primarily concentrated to the location where the employment growth appears, or more evenly spread out over a larger geographical area? The answers to such questions represent important input in a study evaluating how changes in the spatial distribution of employment opportunities lead to a redistribution of assets through capitalization of property values.

The region and the data are presented in Section 2, while alternative model formulations and estimation results are briefly reviewed in Section 3. Section 4 offers a comparison of predicted and observed prices at alternative locations, and section 5 addresses housing market effects of hypothetical changes in the spatial distribution of employment. Finally, we offer some concluding remarks in Section 6.

2 The region and the data

Our study area is the southern parts of the Rogaland county in Western Norway. This represents an integrated region with a connected road transportation network. As indicated in Figure 1 there are 13 municipalities in the region. Each municipality is divided into postal delivery zones, and altogether the region is divided into 98 zones. The locations of the zonal centers are represented by the numbers 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 some more details on the region, see Osland et al. (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

The alternative model formulations considered in this paper differ only with respect to the representation of spatial structure, and the most general model is given by the following hedonic regression formulation:

$$\begin{aligned}\log P_{it} \;=\;& \beta_0 + \beta_1 \log \mathrm{LOTSIZE}_i + \beta_2(\mathrm{RUR} \log \mathrm{LOT})_i + \beta_3 \log \mathrm{AGE}_i + \beta_4(\mathrm{REBUILD} \log \mathrm{AGE})_i + \\ &+ \beta_5 \mathrm{GARAGE}_i + \beta_6 \log LIVAREA_i + \beta_7 \log \mathrm{NUMBTOIL}_i + \beta \log \mathrm{TIMECBD}_i + \\ &+ \beta_q (\log \mathrm{TIMECBD}_i)^2 + \beta_8 \log \mathrm{ACCESSIBILITY}_i + \beta_9 \mathrm{SUB1} + \beta_{10} \log \mathrm{SUB1DIST} + \\ &+ \beta_{11} \mathrm{SUB2} + \beta_{12} \log \mathrm{SUB2DIST} + \sum_{t=97}^{01} \beta_t \mathrm{YEARDUM} t_i + \epsilon_{it} \qquad (1)\end{aligned}$$

where $\log(\cdot)$ denotes the natural logarithm, and ϵ_{ij} is the error of disturbance for a specific observation. P_{it} represents the price of a house in zone i at time t. According to Wooldridge (2003) there are several ways that the logarithm of real housing price can be transformed to house prices, but none of them are unbiased. We have used the transformation $\hat{P} = \exp(\ln \hat{P}) \exp \frac{\hat{\sigma}^2}{2}$, where $\hat{\sigma}^2$ is an unbiased estimator of the residual variance. This transformation is consistent and relies on normality of the errors (Wooldridge 2003). The independent variables of the model are defined in Table 1. The variable RURLOT combines information of location with a dwelling-specific attribute, and will be incorporated in all the model formulations to be considered in this paper. The six variables at the end of the list in Table 1 measure spatial structure characteristics. As stated in the introduction Osland and Thorsen (2008) account for polycentric tendencies in the distribution of job opportunities

Table 1: List of independent variables

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)
RURLOT	the product of a dummy variable representing the most rural areas of the region and the variable LOTSIZE
TIMECBD$_i$	the traveling time from zone i to the cbd
ACCESSIBILITY$_i$	measures the labor market accessibility of zone i
SUB1	a dummy variable representing subcenter 1 (Bryne)
SUB1DIST	the traveling time within a cutoff value of 20 minutes from subcenter 1
SUB2	a dummy variable representing subcenter 2 (Egersund)
SUB2DIST	the traveling time within a cutoff value of 20 minutes from subcenter 2

through the introduction of a gravity based accessibility measure, defined by ACCESSIBILITY$_i$ = $\sum_{k=1}^{w} D_k^{\gamma} \exp(\sigma_e d_{ik})$. Here, d_{ik} represents the traveling time from zone i to zone j, while D_k is the number of job opportunities in zone k. The parameters γ and σ measure the effect of variations in, respectively, job opportunities and distances on labor market accessibility. For more details on the use of such an accessibility measure in studying spatial labor market interaction, see for instance Thorsen and Gitlesen (1998).

The remaining spatial structure variables are adequately specified in Table 1. In the section to follow we study how important it is to incorporate the alternative measures of spatial structure in predicting housing prices at specific locations. For this purpose we consider five alternative model formulations. The first four model formulations listed below (MF1-MF4) are all nested reductions of the general model that is represented by Equation 1 (MF5):

MF1: incorporates only dwelling-specific attributes, estimated by data from the urban area

MF2: accounts for spatial separation; traveling time from the cbd is represented by a power function specification, supplemented by a quadratic term

MF3: accounts for spatial structure through the specification of a gravity based labor market accessibility measure

MF4: accounts for both spatial separation and spatial structure, by combining MF2 and MF3

MF5: accounts for the presence of two subcenters, in addition to the regional measures of spatial separation and spatial structure; this model formulation is represented by Equation 1

Osland et al. (2007) discuss estimation results based on model formulations including MF1 and MF2, while Osland and Thorsen (2008) offer a discussion of estimation results based on MF3 and MF4. Osland and Thorsen (2006) test for the impact on housing prices of local spatial structure characteristics, like the variables representing the presence of subcenters in MF5. All those papers are based on the data set that was described in Section 2. In the current paper the estimation results are presented in Table 2, and briefly commented upon in this section.

According to the findings in Osland et al. (2007) an approach accounting only for dwelling-specific attributes is found to contribute with a reasonable explanation to variation in housing 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. This is the reason why results based on MF1 are restricted to the case where only data from the municipality of Stavanger are used in the estimation. By comparing to the results based on the other model specifications it follows, however, that information on spatial separation and spatial structure add significantly to explanatory power, and reduce spatial autocorrelation in the residuals.

It follows from Equation 1 that the impact of the traveling distance from the cbd on the spatial variation in housing prices is represented by a power function supplemented by a quadratic term. This specification is recommended in Osland et al. (2007), based on results on explanatory power in combination with pragmatic, theoretical, and interpretational arguments from evaluating alternative flexible functional specifications. The estimates of β and β_q in Table 2 correspond to a significantly strong impact of the traveling time from the cbd on housing prices. Compared to a model formulation where traveling time from the cbd is not accounted for, the estimation results based on MF2 further corresponds to a considerably improved explanatory power, measured by any of the goodness-of-fit indices in Table 2.

The labor market accessibility measure is the only spatial structure characteristic accounted for in MF3. By comparing to results based on the non-spatial MF1 it follows from Table 2 that the introduction of such a measure improves the explanatory power of house prices considerably. Still, the introduction of this measure is not found to represent an adequate alternative to the distance from the cbd. MF3 corresponds to poorer goodness-of-fit than MF2, and the accessibility measure does not

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

	MF1	MF2	MF3	MF4	MF5
Constant	11,2651	11,9236	11,0212	11,1835	11,1318
	(0,1364)	(0,0892)	(0,0873)	(0,1687)	(0,1819)
LOTSIZE	0,0952	0,1259	0,1057	0,1308	0,1302
	(0,0159)	(0,0101)	(0,0098)	(0,0099)	(0,0100)
RURLOT	-	-0,0299	-0,0315	-0,0271	-0,0304
	(-)	(0,0032)	(0,0032)	(0,0031)	(0,0031)
AGE	-0,0461	-0,0828	-0,0717	-0,0849	-0,0839
	(0,0080)	(0,0066)	(0,0064)	(0,0066)	(0,0065)
AGE·REBUILD	0,0154	0,0106	0,0119	0,0104	0,0104
	(0,0043)	(0,0029)	(0,0030)	(0,0029)	(0,0029)
GARAGE	0,0436	0,0677	0,0549	0,0645	0,0644
	(0,0169)	(0,0110)	(0,0113)	(0,0108)	(0,0108)
LIVAREA	0,4665	0,3583	0,3643	0,3552	0,3554
	(0,0341)	(0,0177)	(0,0179)	(0,0177)	(0,0175)
NUMBTOIL	0,1226	0,1516	0,1454	0,1477	0,1473
	(0,0241)	(0,0147)	(0,0151)	(0,0146)	(0,0145)
β	-	-0,0679	-	-0,1095	-0,1352
	(-)	(0,0213)	(-)	(0,0218)	(0,0268)
β_q	-	-0,0298	-	-0,0104	-0,0017
	(-)	(0,0041)	(-)	(0,0053)	(0,0077)
ACCESSIBILITY	-	-	0,2352	0,0776	0,0844
	(-)	(-)	(0,0067)	(0,0159)	(0,0181)
σ	-	-	-0,1442	-0,1088	-0,1088
	(-)	(-)	(0,0108)	(0,0403)	(0,0403)
γ	-	-	0,0637	1,0963	1,0963
	(-)	(-)	(0,0534)	(0,2452)	(0,2452)
SUB1	-	-			0,0386
	(-)	(-)	()	()	(0,0233)
SUB1DIST	-	-			-0,014
	(-)	(-)	()	()	(0,0057)
SUB2	-	-			-0,0645
	(-)	(-)	()	()	(0,0329)
SUB2DIST	-	-			-0,1351
	(-)	(-)	()	()	(0,0452)
YEARDUM97	-0,1524	-0,1333	-0,1343	-0,1362	-0,1366
	(0,0242)	(0,0135)	(0,0138)	(0,0135)	(0,0135)
YEARDUM99	0,1305	0,1294	0,1308	0,1297	0,1326
	(0,0232)	(0,0137)	(0,0142)	(0,0136)	(0,0134)
YEARDUM00	0,2582	0,2686	0,2698	0,2700	0,2717
	(0,0218)	(0,0135)	(0,0138)	(0,0135)	(0,0134)
YEARDUM01	0,2834	0,3029	0,3016	0,3030	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	0,7441
R^2-adj.	0,6578	0,7368	0,7205	0,7396	0,7424
L	56,73	281,62	197,39	296,79	314,21
APE	274597	216941	229429	215690	214551
SRMSE	0,2193	0,2045	0,2147	0,2035	0,2027
White test statistic	110	265	260	281	324
Moran's I	0,0718	0,0189	0,0551	0,0080	0,0063
Standard normal deviate (z_I)	26,39	7,13	29,86	5,28	4,8868
Ramsey reset test (p-value)	0,4705	0,8287	0,4673	0,8572	0,8554
VIF, average value	1,64	4,22	1,48	5,83	7,66

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 ($\sigma = -0,1088$ and $\gamma = 1,0963$). 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).

reduce problems related to spatial autocorrelation in the residuals to the same degree as introducing traveling time from the cbd. Regarding spatial effects we have performed tests proving that spatial autocorrelation in the dependent variable is not a dominating feature in our data.

It is more important, however, that the accessibility measure is found to contribute significantly to the explanatory power also in a model (MF4) which tests for the simultaneous impact of labor market accessibility and the traveling time from the cbd. Based on this result Osland and Thorsen (2008) 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. As stated in Osland and Thorsen (2008) the last mentioned effect reflects the tendency that the proximity to specific urban facilities and urban services represent an attribute that increases the willingness-to-pay for a house, ceteris paribus. Osland and Thorsen (2008) further demonstrate that the estimation results based on MF4 mean that the two effects quantitatively contribute about equally to intraregional variation in house prices.

Osland and Thorsen (2006) 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. Some of the 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. MF5 represents the local variable approach that was found to contribute most to the explanatory power in Osland and Thorsen (2006). We now want to test how the incorporation of those 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 result, 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 (2006).

Our data do not allow us to account explicitly for possible systematic spatial variation in the provision of public services, the crime rate, and in the neighborhood composition. No strong variation is expected in socioeconomic conditions in the relatively egalitarian society we consider. To some degree the socioeconomic composition of the population probably depends systematically on the distance from the cbd. This means that such variables may be implicitly accounted for through the endogenous variables in the reduced form of the model.

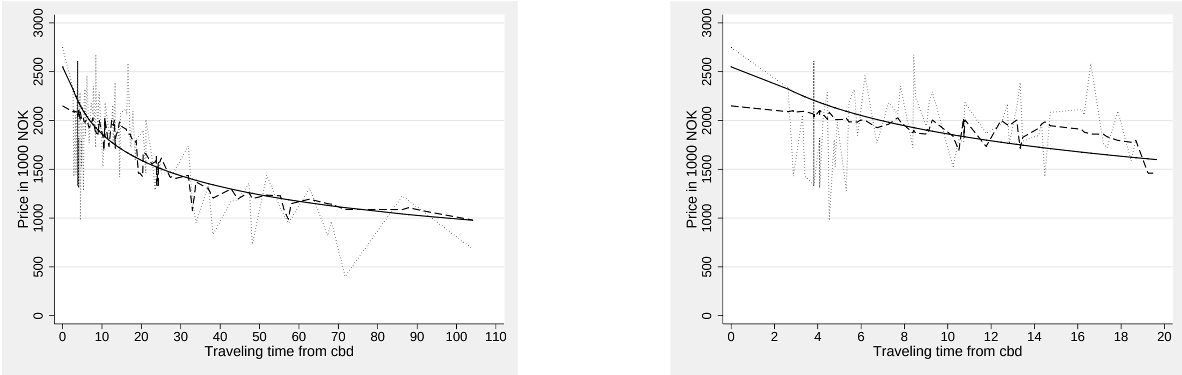
4 Comparing predicted and observed prices of property transactions at alternative locations

In this section we test how the alternative model formulations succeed in predicting prices from observed property transactions in specific locations. We start in Section 4.1 by evaluating the ability to predict spatial variation in the price of a house with average, standard, values of the non-spatial attributes. In Section 4.2 we study predictions of average prices for all houses that were traded in a zone, accounting for variation in dwelling-specific attributes. Finally, in Section 4.3 we test the ability of alternative model formulations to predict the prices of a standard house at a specific subcenter.

4.1 Predicting spatial variation in the price of a standard house

A standard house is defined as not being rebuilt, it has a garage, and the price refers to the year 2000. Lotsize, age, living area, and the number of toilets are given by their average values. The variable RURLOT is not accounted for in the predictions presented in this subsection. The solid and dashed lines in the two parts of Figure 2 represent predictions of the price of a standard house at alternative distances from the cbd. The solid lines are based on MF2 while the dashed lines are based on MF3. The dotted lines represent observed average house prices in each zone, based on data from 2000. Notice in particular that the gradients based on MF3 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.

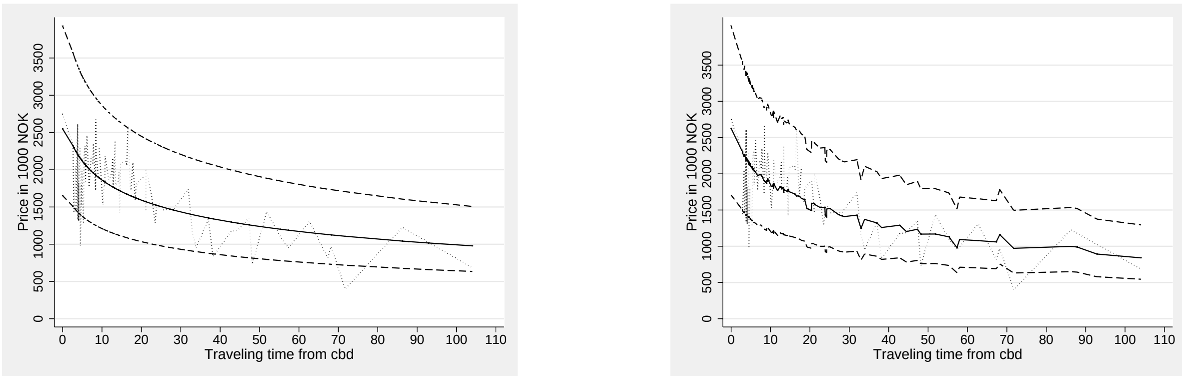
In part b of Figure 2 we focus on observed and predicted house prices within 20 minutes from the cbd. According to the dotted line observed average prices tend to fall close to the cbd, followed by an interval where house prices apparently develop more like a random walk with no trend. This observed 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). Our data refer to a relatively short period of time, representing what Clapp et al. (2001) denote as a snapshot of a dynamic process. One possible dynamic mechanism is that the suburbanization of



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 MF2, while the dashed lines represent predictions based on MF3.

jobs in combination with transportation innovations have resulted in a flattening of the housing price gradient.



a) M2 b) M4

Figure 3: The solid line in the two parts of the figure represents predicted prices of a standard house. The dotted lines represent the observed zonal average house prices, while the bands of the prediction intervals are represented by the dashed lines.

The solid line in part b of Figure 3 corresponds to predictions resulting from MF4. This model predicts a more regular spatial pattern in house prices, with smaller local variations than the predictions following from MF3 in Figure 2. 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.

Our results demonstrates how the incorporation of a labor market accessibility measure opens for a more irregularly shaped estimated gradient. For given values of the parameters attached to TIMECBD_i and ACCESSIBILITY_i the magnitude of the irregularities is positively related to the spatial dispersion of job opportunities, depending on polycentric tendencies. The fact that the gradients estimated by

MF3 and MF4 are relatively smooth in principle reflects a fairly monocentric region and/or low estimates of the parameter attached to ACCESSIBILITY_i. Since the labor market accessibility effect is estimated to be substantial in our study, the estimated gradient clearly indicates a region with a dominating cbd.

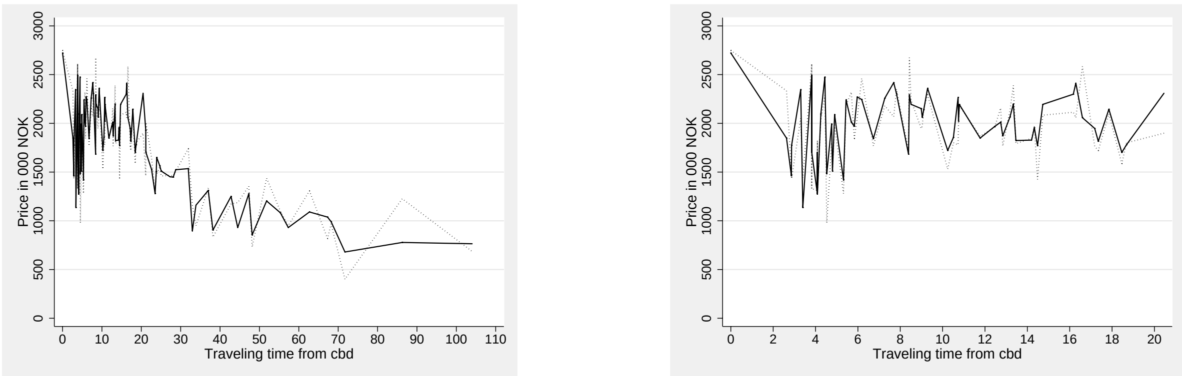
In Figure 3 the estimated gradients are supplemented by 95% prediction intervals. The intervals are computed by using robust standard errors of fitted values, and include both prediction and residual errors. The figure illustrates that there is a considerable uncertainty in predicting the price of a standard house at a specific location. In this perspective the choice of model might seem somewhat subordinate, suggesting the conclusion that the model choice is primarily important for explanatory purposes. If the main purpose is to provide predictions, our results suggest that there is not much to gain from an approach where data have to be collected on the spatial distribution of job opportunities. The estimated prediction intervals of the price of a standard house incorporate the observed average prices in almost all the zones. These conclusions might be reversed if the study area was more polycentric, resulting in a more irregular MF4-gradient.

Notice also from Figure 3 the tendency that prediction uncertainty is negatively related to the distance from the cbd. A reasonable hypothesis is that this reflects that values of omitted attributes tend to be more homogeneous in peripheral than in urban locations. Despite the fact that the local economy is in general relatively egalitarian, many zones within the urban area have both particularly attractive neighborhoods, and less exclusive locations attracting households with below average regional income. This heterogeneity might for instance reflect the view, the proximity to a recreation area, pollution, noise, or result from planning decisions concerning social housing projects. Accurate price predictions on specific houses at specific locations call for more information on for instance neighborhood characteristics. Still, the macroscopical model formulations discussed above might be adequate as a device to predict average housing prices within an area.

4.2 Predicting zonal variation in average house prices

Predictions referring to a standard house do not necessarily reflect zonal average values of dwelling-specific attributes. Attributes of houses traded in a zone might deviate systematically from average values for the entire area. Some zones have a high density of large, high-standard houses, while the opposite applies for other zones. This especially applies for houses within 20 minutes from the cbd, and it is of course not reflected by predictions of a standard house.

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 in year 2000. It is obvious from studying Figures 2 and 4 that predicted zonal average prices covariate closer to observed average values than the predictions of a standard house. The correlation coefficient is 0,6727 for the relationship between observations and predictions based on MF2, and 0,9374 for the relationship between observed and predicted zonal average values that is illustrated in Figure 4.



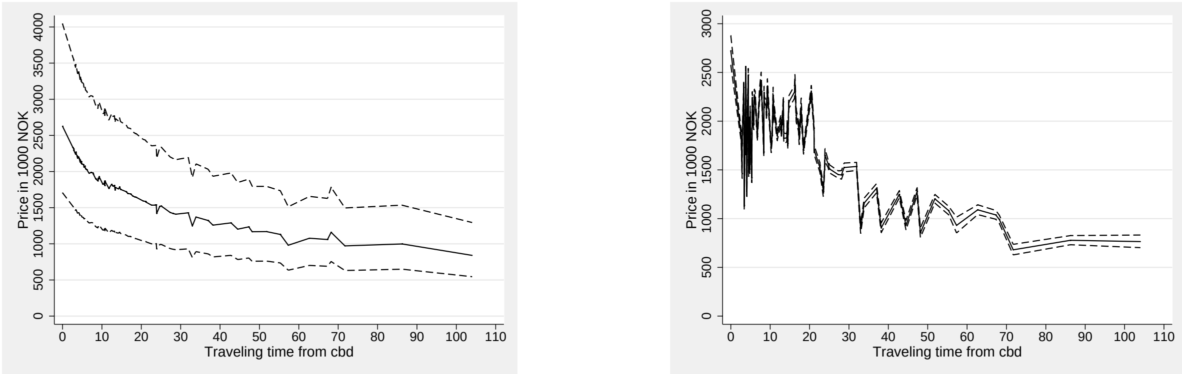
a) The entire region

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 are based on estimated coefficients from MF4. The dotted lines represent the observed zonal average house prices.

It follows from Table 2 that the average prediction error (APE) related to all individual observations in our data is 215690 for MF4. The corresponding prediction error for zonal averages is 154511. This reduction in prediction error is according to the law of large numbers. 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 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. The law of large numbers and the difference in prediction accuracy are reflected in Figure 5; 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.

The figures illustrating spatial variation in average zonal housing prices do not reflect the possibility that some attributes vary systematically across space. One such 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 0,8427. In this case both predicted and observed prices fall with increasing traveling time also within distances of 20 minutes from the cbd, apparently according to a random walk with drift. Since such a drift was not present in 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.



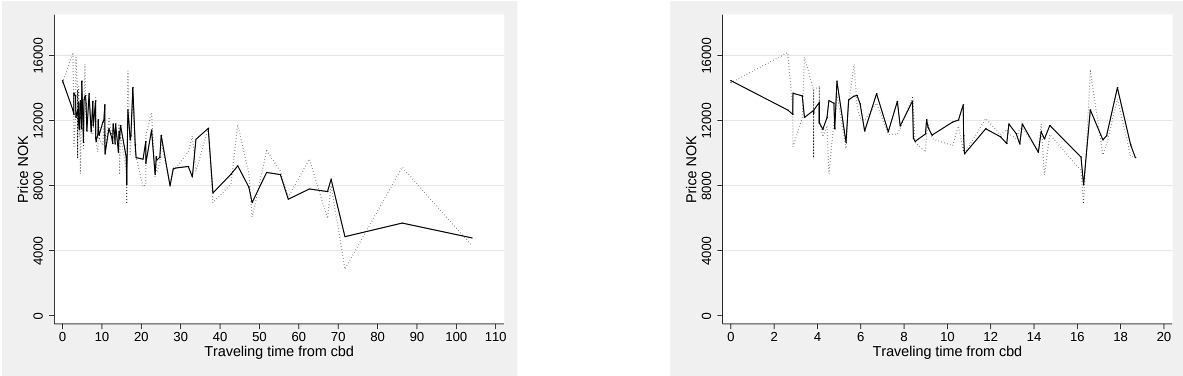
a) A standard house b) Zonal average

Figure 5: Predicted house price gradients, including prediction intervals, based on MF4.

The predictions of average zonal house prices are relatively insensitive to the choice of model. The Standardized Root Mean Square Error (SRMSE) between predicted and observed average zonal values of house prices is 0,1221 if the predictions are based on the model formulation where both measures of spatial structure are incorporated (MF4), 0,1458 if spatial structure is represented only by traveling time from the cbd (MF2), and 0,1221 if only labor market accessibility is explicitly accounted for (MF3). This means that there is not much to gain from collecting data on the spatial distribution of job opportunities if the ambition is to predict zonal average house prices. In this perspective the less data-demanding MF2 is the recommended choice for such studies.

4.3 Predicting house prices at a specific subcenter

We will now evaluate the ability of alternative models to predict house prices at a specific location. As an example we consider the subcenter Bryne, which is zone 82 in Figure 1, where both the spatial distribution of jobs and workers have a marked local peak. Bryne is the administrative center of the municipality Time, in a traveling time by car of about 32 minutes from the regional cbd. Based on MF2 the predicted price of a standard house at this location is 1409541 NOK. The corresponding predictions are 1437170 NOK if spatial structure is only represented by the labor market accessibility



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 MF4. The dotted lines represent the observed zonal average house prices.

measure (MF3), and 1424853 NOK if both measures are accounted for (MF4). The observed average price of all privately owned single-family 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. Bryne is an expanding town, where houses traded on average are 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 to some degree confirmed by estimation results based on MF5. Explicitly accounting for the subcenter Bryne in the model formulation results in a prediction of a standard house at this location of 1512827.

According to our results MF4 is not necessarily superior to MF2 and MF3 in offering reliable predictions of house prices at specific locations. This reflects the results reported in Table 2 that the explanatory power, measured for instance by R^2, is relatively similar for other approaches than MF1. Especially in cases where the concentration of jobs deviates considerably from the regional average MF3 might even perform better as a device for predicting house prices. According to the estimates attached to ACCESSIBILITY in Table 2, MF3 puts more weight to job concentrations than MF4. It is also interesting to notice that a model where the distance from the cbd is the only variable representing spatial structure offers reasonable predictions of house prices at specific locations in a case where adequate information of job opportunities is missing. We will see in the next section, however, that the somewhat more parsimonious model formulations are less appropriate than MF4 for making predictions in other kinds of scenarios.

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

According to our estimation results labor market accessibility has a significantly positive impact on house prices. This means that changes in the spatial distribution of jobs induce a redistribution of assets through capitalization of property values. We start in Section 5.1 by discussing the potential for redistributions in job opportunities, and the rationale for ignoring possible effects on the residential location pattern. In Section 5.2 we evaluate how appropriate alternative model formulations are in studying the relationship between the house prices and the spatial distribution of jobs. Finally, in Section 5.3 we discuss and quantify how alternative scenarios of job redistributions affect the spatial pattern of house prices.

5.1 A basic interpretation of the scenarios

The approach underlying the predictions to be reported is to calculate how a change in the spatial distribution of employment affects the value of labor market accessibility in each zone, and then plug these values into our estimated model. We have no a priori reasons to believe that the functional model specification is not valid for new values of the independent variables. For the non-spatial attributes our predictions refer to the standard house.

It is not essential in this paper to discuss in detail the underlying determinants of employment relocations. A firm may for instance relocate to attract more customers, as a result of capacity constraints at the existing site, as a result of spatial competition and land prices, to achieve agglomeration and/or location economies, to improve the potential of recruiting qualified labor at favorable costs, and/or to benefit from lower transport costs through an improved location relative to the transportation network. From a theoretical point of view specific combinations of these factors can be used to explain almost any relocation pattern of job opportunities.

As mentioned in Section 3 Osland and Thorsen (2006) tested for the possible impact of several local characteristics of spatial structure. Some of the variables introduced were related to the residential location pattern and the prospects of receiving job offers in the neighborhood. The results, however, gave no support for the hypothesis that house prices are reflected by the intrazonal balance between workers and jobs, and house prices were found to be only marginally influenced by variations in population densities. By far the dominating variation in house prices is explained by the traveling distance to the cbd and the labor market accessibility measure. Those results contribute to justify prediction approaches ignoring measures related to the residential location pattern.

This is not, however, equivalent to the hypothesis that relocations of job opportunities typically find place without corresponding changes in the residential location pattern. Changes in the spatial employment pattern in general initiate a process involving moves and housing construction. Such a process can be elaborated in terms of an economic base multiplier mechanism, where a new location pattern emerges as a result of interdependent location decisions of households and local sector firms (see for instance Thorsen (1998) for a study employing economic base theory to explain regional development). A zone experiencing improved labor market accessibility becomes more attractive for residential location, and consequently for local sector firms. The resulting increase in house prices contributes to reduce the local population and employment growth in the process towards a new equilibrium state. The house price predictions to follow in this paper implicitly assume that the outcome of this process is adequately captured through the changes in labor market accessibility. This corresponds to the hypothesis that spatial variation in house prices basically reflect accessibility to job opportunities and urban-specific amenities. In other words, the predictions resulting from this approach can be interpreted to represent long-term effects on house prices, incorporating the impact of the process towards a new equilibrium state.

In the scenarios to be considered in this paper employment is assumed to be increased at a specific location, for a constant total 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 in the region. 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 in general 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 remaining zones.

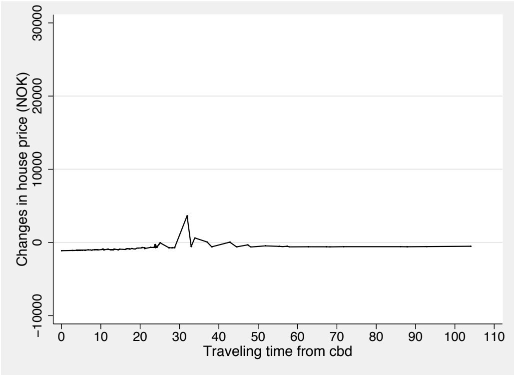
It is not obvious that the assumption of constant parameters in the hedonic price function is reasonable for out-of-sample predictions. We consider non-marginal changes in characteristics of the spatial structure. According to Bartik and Smith (1987) an estimated hedonic function could be empirically representative for the new situation if the changes "take place in a geographic area that is small relative to the market" (page 1222). Non-marginal changes in only one or two of the zones in the region that we consider fall into this category. In most cases the changes in the number of jobs are certainly large compared to the employment in the zones. Such changes will induce adjustments in for instance residential location decisions, but as stated by Freeman (1994), this will not change the hedonic price function if "the number of people wishing to do this is quite small, relatively to the market" (page 395). In other words, the number of houses affected by the change should be relatively small compared to the total number of houses in the area if the assumption of a constant hedonic price function is to hold. Since we restrict our experiments to such scenarios, we do not enter into a discussion of potential errors in cases with large changes in spatial structure. See for instance Freeman (1994) for such a discussion.

From another, supplementing, point of view our approach can be considered as a comparative static experiment, where some exogenous shocks are introduced to an initial equilibrium state. The estimated model contributes with equilibrium house price predictions before and after the exogenous shock. This corresponds to the interpretation that our predictions reflect a new long-term equilibrium state of a spatial residential and employment pattern. According to our estimation results spatial variation in house prices is in general determined only by labor market accessibility and commuting time to the cbd. Our experiment can be interpreted as a comparison between two geographies that differ only with respect to the pattern of labor market accessibility. The corresponding reasonable hypothesis is that the parameter estimate reflecting the marginal impact of variations in labor market accessibility is autonomous to the relevant relatively marginal changes in the spatial distribution of employment.

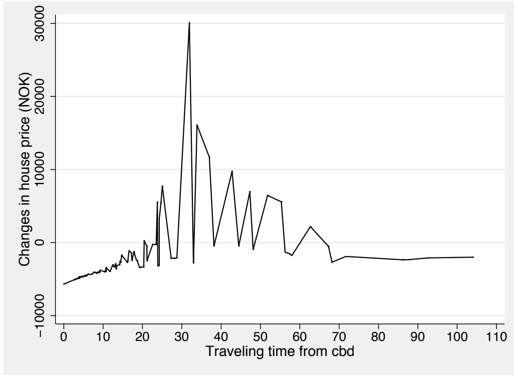
5.2 The appropriateness of alternative model formulations to predict the impact of a spatial redistribution of job opportunities on house prices

MF2 is totally incapable of predicting potential consequences on house prices of changes in the spatial distribution of job opportunities. Models incorporating labor market accessibility measure 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, balanced by corresponding reductions in the other zones, proportional to their fraction of the total regional employment.

It follows from Figure 7 that the predicted changes in house prices are very sensitive to the choice of modeling framework. Based on MF4 the predicted increase in house prices at Bryne is about



a) Predictions based on MF3



b) Predictions based on MF4

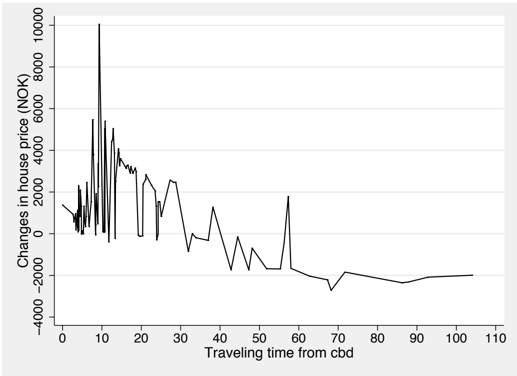
Figure 7: Predicted changes in the price of a standard house in a case where 4000 new jobs located at Bryne correspond to reduced employment in all the other zones, proportional to their fraction of total employment.

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 for all the other zones.

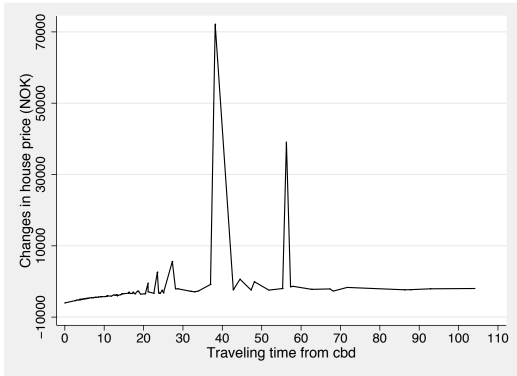
In the previous sections our conclusion was that MF3 performs reasonably well for prediction purposes. Even if such a model captures the effects of the basic mechanisms, however, it does not offer a satisfying explanation of the spatial variation in house prices. It follows from Table 2 that parameter estimates based on MF3 ($\hat{\gamma} = 0,0637$) puts considerably less weight on the impact of variations in employment than the corresponding estimates based on MF4 ($\hat{\gamma} = 1,0963$) in the measure of labor market accessibility. This is not adequately adjusted for by the remaining parameter estimates, and MF3 is not at all appropriate for the empirically based comparative statics performed in this section. Hence, our results illustrate the importance of using a correctly specified model to predict the impact of exogenous shocks on the system. MF5 contributes significantly to the explanatory power, 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.

5.3 Predicting how alternative scenarios of job redistributions affect the spatial pattern of house prices

The impact on house prices of a spatial redistribution of job opportunities is sensitive to where the growth in employment appears. 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 central part of the region (Forus, zone 32 in Figure 1), or a peripheral location (zone 80 in the municipality of Gjesdal, see the map in Figure 1).



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



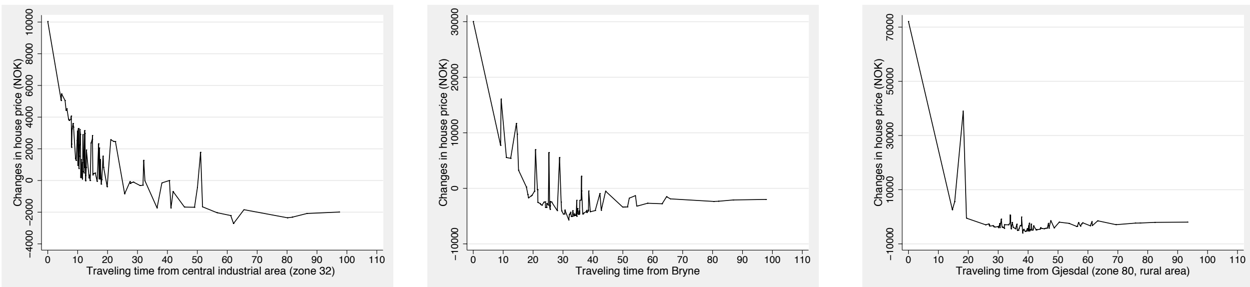
b) Increased employment at zone 80 in the municipality of Gjesdal, a peripheral location

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, proportional to their fraction of total regional employment. The predictions are based on MF4.

Notice first that the scale on the vertical axis is not the same in Figure 7b and the two parts of Figure 8. By comparing those figures 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 reduce 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.

As an intuitive explanation increased labor demand in a central, highly accessible location, will to a large degree be met through commuting flows from adjacent locations. This contributes to reduce the impact on the spatial pattern of housing demand. The adjustment can be argued to be different in a case where the job growth appears in a more peripheral location. Some of the employees will not be comfortable with long-distance commuting, and choose to move into the geographical proximity of the expanding firm(s). Hence, the relevant area gets more attractive for residential purposes, and house prices can be expected to rise. In a central location the impact of job growth on house prices will be dispersed over a large area, while the effect will be more concentrated in one spot if the shock appear at a more isolated location. Stated in other terms, people tend to follow jobs in rural areas, while this is not the case if the job growth appears in central parts of the region.

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. Figure 9 refers to the same numerical experiment, but the horizontal axis represents the traveling time from the zone that hypothetically attracts new employment. 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.



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 at alternative locations correspond to reduced employment in all the other zones, proportional to their fraction of total regional employment. Traveling time is measured from the zone attracting the new jobs. The predictions are based on MF4.

Not many empirical studies can be found on the relationship between house prices and changes in the spatial distribution of jobs. Based on data from Fairfax, Virginia, over the period 1975-1992, Clapp et al. (2001) found that decentralization of jobs had no significant influence on land values. Another example based on US data is provided by Voith (1999), who studied the effect of job growth on house prices and house construction rates. This study was based on data from more than 88000 sales of single-family detached houses over the period 1972-1995 from the Philadelphia metropolitan area. Voith (1999) found a large positive effect on house prices of city employment growth for close-in communities, while the effects of suburban employment growth are found to be negligible. Voith (1999) argues that the results conform to a theoretical equilibrium analysis assuming an inelastic housing supply in a city center, and a flatter supply curve in communities on the urban fringe. In such a situation a demand shift caused by local job growth results in higher prices in the city center, while an increased construction rate is the dominating effect at suburban locations.

The results presented by Voith (1999) appear to be qualitatively and quantitatively very different from the results in our study. One reason why the results differ substantially may be that the study areas are very different. We consider a relatively large region, representing a coherent labor and housing market area, rather than a metropolitan area. As mentioned in Section 5.1 it also follows from estimation results reported in Osland and Thorsen (2006) that variables reflecting the availability of open land and intrazonal balance between jobs and residents do not contribute to explain spatial variation in house prices. We also restrict our study to transactions of single-family houses sold on second-hand markets. The approaches also differ in other respects. Voith (1999) for instance defines the city center to be the city of Philadelphia, including areas within 20 minutes of commuting time from the cbd. In our study the city center is extending over a considerably smaller area, and a delimitation of 20 minutes would involve both urban and suburban locations. In addition, our approach is more disaggregate in the sense that the urban area is subdivided into many zones. Through our accessibility measure approach we find that the housing market effects of a local employment expansion to a relatively large degree spread to adjacent zones within the urban area. This corresponds to a scenario of small demand shifts in many zones rather than a large shift concentrated to the zone hosting the expanding firms. According to the discussion above the basic behavioral explanation is represented by the reasonable hypothesis that the spatial labor market interaction response to job growth will be different in central and peripheral locations. Increased labor demand in the central areas typically induce commuting flows, resulting in a relatively small local impact on the housing market. A peripheral job expansion to a larger degree calls for workers to move, resulting in stronger local housing market effects.

In the experiments reported above we have assumed that expanding firms recruit workers from all the remaining zones of the region. 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.

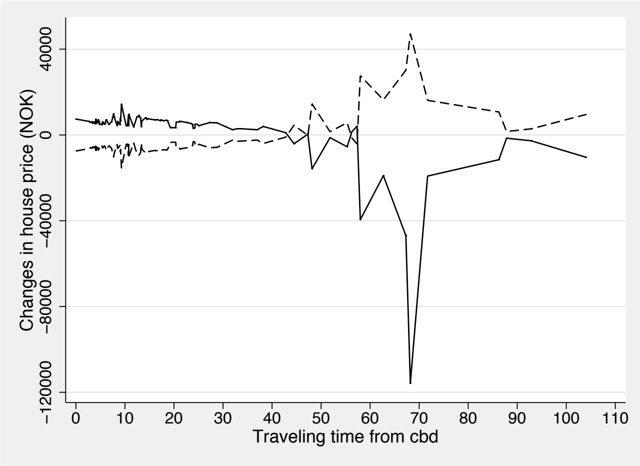


Figure 10: The solid line represents changes in the spatial distribution of house prices resulting from a hypothetical relocation of a firm with 4000 employees from Eigersund in the southern part of the region to zone 32 (Forus) in the cbd area. The dotted line reflects the impact of a corresponding relocation in the opposite direction. Predictions are based on MF4.

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.

6 Concluding remarks

In general, the modeling alternatives considered in this paper offer very different explanations of the spatial variation in house prices. 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 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 models are also 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 a correctly specified model formulation 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 area for both urban, semi-urban, and rural areas. Only marginal effects appear for zones located in traveling distances beyond about 20 minutes from the place of employment growth.

Our results on the effects of job relocations contradict empirical results based on time series data from US metropolitan areas (Voith 1999, Clapp et al. 2001). One possible explanation why empirical results differ substantially is that different approaches are employed. We had no sufficient time series data at our disposal, but we think that the introduction of an accessibility measure is an important element in explanations of spatial variation in housing markets. Our results also illustrate the importance of disaggregating the geography into a relatively large number of zones. A very aggregate specification of the central areas of the geography might for instance lead to false conclusions on the housing market effects of labor market shocks. Another possible explanation of the diverging results is represented by the substantial differences between the housing market in US metropolitan areas and a Norwegian urban area, both with respect to spatial structure and with respect to relevant socioeconomic conditions. In general, housing market effects of changes in the spatial pattern of job opportunities are important both from an efficiency perspective and for evaluations of the distribution of wealth. Taking the sparse and diverging empirical results into account, both theoretical and empirically based studies are required on the relevant relationship. The experience in existing literature calls for empirical studies from different geographical settings on different continents.

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