Bid Rents of Spatial Interaction Model With Land Use in the Munich Region

Bid Rents dos Modelos de Interação Espacial com Uso do Solo na Região de Munique

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Abstract/Resumo

The calibrated of bid rents of spatial interaction models can be very useful spatial economic indicators. The paper shows that the bid rents of the spatial interaction model calibrated for the Munich Region are strongly related to the prices of land. Being so, it is possible to evaluate the impacts of changes in exogenous variables such as the basic employment, the accessibility and the available urban area, not only on the commuting and shopping movements between the zones of the spatial interaction model, on population and on employment but also changes in land values.

Keywords: bid rents, land prices, land use model, spatial interaction model, Munich, Germany

*JEL Codes:*R15 R31, R52

A calibração das bid rents dos modelos de interação espacial podem ser indicadores importantes da economia regional. Este artigo mostra que as bid rents calibradas para um modelo de interação espacial aplicado à Região de Munique está fortemente relacionado com os preços da terra. Sendo assim é possível avaliar os impactos das alterações no emprego básico, na acessibilidade e na disponibilidade de solo não só nos movimentos residência emprego e residência serviços entre as zonas do modelo de interação espacial, a população e o emprego mas também as alterações nos preços do solo.

Palavras Chave: bid rentes, preços do solo, modelo de uso do solo, modelo de interação espacial, Munique, Alemanha.

Códigos JEL: R15 R31, R52

1. INTRODUCTION

Spatial interaction models explain commuting and shopping movements based on the accessibility between places, the location of basic employment and the attractiveness of the different zones. They are a combination of geographical and economic modelling (Wegener, 2001) and a decision support tool for spatial policies (Veldkamp and Lambin, 2001; Agarwal et al., 2002; Veldkamp and Verburg, 2004; Silveira and Dentinho, 2009; Borba et al., 2015). Bid rents are implicit to the attractiveness indicators of the gravity expressions of Spatial Interaction Models (Wilson, 2000). The data required to calibrate these models are available space, accessibility, population and employment distinguished between basic employment that moves the economy through the multiplier effects of exports and external transferences, and non-basic employment, targeted to local markets providing goods and services for local citizens.

The concept of bid-rents was initially proposed by Alonso (1964) that said that real estate markets are comparable with auction markets. Prices for land are defined through best bids which is the basic idea of the bid-approach (Martinez, 1992; Hurtubia et al., 2011; Buurman et al., 2001; Martinez, 1992). Choice approach assumes that consumers choose the location with the greatest benefits dependent on their individual references (Martinez, 1992; Hurtubia et al., 2011).

The aim of this paper is show the importance of the calibration of the bid rents of spatial interaction models because they reveal the changes in land values associated with changes in accessibility, in land availability and in basic employment. To achieve such aim a spatial interaction model for the area of Munich is formulated and calibrated for the attrition parameters and for the bid rents using the technique developed by (Borba and Dentinho, 2016); contrary to other methods that technique secures that demand for land does not overcomes the land available while guaranteeing that the estimated average costs work-residence and residence-shopping are equal to the real costs. A second model, estimated with Ordinary Least Squares (OLS) relates the calibrated bid-rents to land prices which results show that, on the one hand, land prices can be used as spatial interaction indicators and, on the other hand, that bid rents can reflect the impact of land value associated with external shocks in the model.

The second section introduces the research area around Munich in the south-east of Germany. The third section presents the methodology and the data required to calibrate the spatial interaction model. Results are presented in section four that present the calibrated bid rents and relates them with land prices. Conclusions are presented in section 5.

2. STUDY AREA

Bavaria is the largest state of Germany and Central Europe. It is located in the south-east of Germany (figure 1) and has a population of more than 12,6 million (German Federal Statistical Office, 2013). To examine the different economic and geographical factors the research area is divided into ten zones. These zones are selected in order to include two major cities in South Bavaria with their surroundings and the area around Lake Ammersee. The study area consists of Munich Metropolis (containing city Munich and district Munich), Augsburg Metropolis (containing city Augsburg, district Augsburg and district Aichach-Friedberg), Dachau, Ebersberg, Erding, Freising and around Lake Ammersee there are Landsberg am Lech, Starnberg, Weilheim-Schongau and Fuerstenfeldbruck. Around those ten zones Bavaria is selected as an external zone to compare the main zones to the outside due to the assumption of interaction between the zones and the surrounding area (Borba et al., 2015; Wilson, 2010). The outer region Bavaria is calculated as data of total Bavaria except the ten zones.

Due to its central location Munich is known as a metropolitan region in Europe and in Bavaria (Thierstein and Reiss-Schmidt, 2008). Therefore a concept for the Munich land development is written in “Munich Perspective” considering the combination of sustainability, urbanity, economy, employment, sociality and community development. (Thierstein and Reiss-Schmidt, 2008 ; Landeshauptstadt München, 2013; Wiese et al., 2014).

Table 1 presents the official numbers (German Federal Statistical Office, 2013) of people living in each zone, the area in square km and the total number of employees subject to social insurance contributions. It is clear that there are two major cities in the Region, Munich and Augsburg, which surrounding regions are commonly shared.

Figure 1: Research area in Bavaria in south-east of Germany

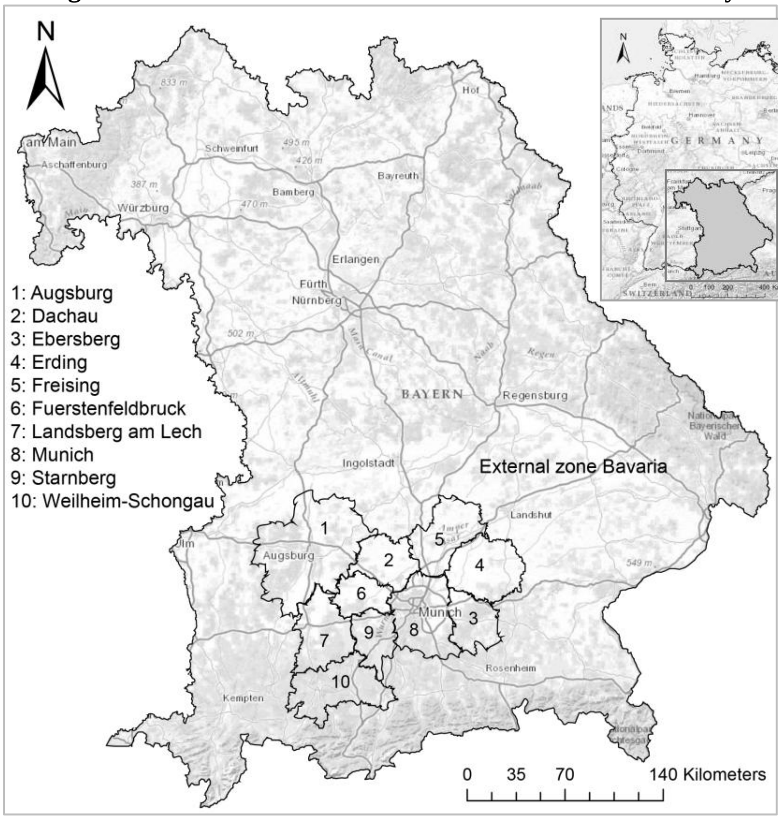


Table 1: Official numbers of total population, employment and area (German Federal Statistical Office, 2013)

Zones	Total Population	Total Employment	Area in km^2
External Zone Bavaria	9,059,481	3,390,873	62,084.56
Munich Metropolis	1,737,817	949,763	974.99
Dachau	144,407	35,308	579.18
Ebersberg	133,007	33,754	549.37
Erding	130,238	34,343	870.72
Freising	169,010	75,575	799.82
Fuerstenfeldbruck	208,272	43,561	434.79
Landsberg am Lech	114,926	32,331	804.38
Starnberg	130,811	43,199	487.71
Weilheim-Schongau	130,387	42,238	966.38
Augsburg Metropolis	645,888	229,391	1,998.29

3. METHODOLOGY AND DATA

To create the model different parameters and indexes are required for assessing the occurring interactions and the dynamics of land use (Agarwal et al., 2002; Veldkamp and Verburg, 2004). The statistical input data that are used for the model are collected from the German Federal Statistical Office. The explanations how to calculate those different data show the complexity of gaining an appropriate index that allows to evaluate the economic status of the examined area.

3.1 Demand Driven Regional Model with Employment

The model is a demand driven model and assumes that supply responds to demand.

$$Y = C + I + G + E - M \qquad (1)$$

Where, Y represents the income, C is the consumption, I is the investment, G is government expenditure, E represents the exports and M the imports. The equilibrium equation can be transformed into non basic activities $(C+I+G-M)$ and basic activities (E).

$$Y = (C + I + G - M) + E \quad (2)$$

Because it is difficult to get regional economic activities in monetary terms it is possible to assume equal productivity and replace equation (2) by an equation based on employment that states that total employment E_t equals the sum of non-tradable non-basic employment E_{nb} and tradable basic employment E_b as

$$E_t = E_{nb} + E_b \quad (3)$$

Non-basic employment works to satisfy the needs of local population and basic employ ment is the fundamental factor for exports and external businesses. To estimate these different kinds of employment first it was necessary to collect the number of employees in different sectors for each zone and its percentage to the total employment. Then the minimum of this percentage for each sector is multiplied with the total employment E_t of a zone to get the non-basic employment E_{nb} for each sector in the zone. The sum of all employments per sector for each zone is the non-basic employment E_{nb} for each zone. Table 2 shows this subdivision of employment for the different zones.

Table 2: Total employment (German Federal Statistical Office, 2013), non-basic employment and basic employment

Zones	Total Employment	Non-Basic Employment	Basic Employment
External Zone Bavaria	3,390,873	2,003,301	1,387,572
Munich Metropolis	949,763	561,112	388,651
Dachau	35,308	20,860	14,448
Ebersberg	33,754	19,942	13,812
Erding	34,343	20,290	14,053
Freising	75,575	44,649	30,926
Fuerstenfeldbruck	43,561	25,735	17,826
Landsberg am Lech	32,331	19,101	13,230
Starnberg	43,199	25,522	17,677
Weilheim-Schongau	42,238	24,954	17,284
Augsburg Metropolis	229,391	135,522	93,869

3.2 Distance matrix

The average distance between the zones was calculated both in kilometers and minutes (EntfernungBerechnen.com, 2015). For the model the distances in minutes were used (table 3).

The distance between zone i and zone j is d_{ij}. To achieve the time distance within a zone d_{ij}, the square root of the total area of this region j (in km^2) divided by π is halved. For the external zone this internal distance is calculated as the median value of the other ten considered zones. To calculate the distances to the

Table 3: Distance matrix in minutes (EntfernungBerechnen.com, 2015)

Zones	External zone Bavaria	Munich Metropolis	Dachau	Ebersberg	Erding	Freising	Fuerstenfeldbruck	Landsberg am Lech	Starnberg	Weilheim-Schongau	Augsburg Metropolis
External zone Bavaria	8	106	103	115	106	92	113	134	120	155	115
Munich Metropolis	106	9	36	36	40	39	39	54	31	68	68
Dachau	103	36	7	45	42	34	21	49	39	74	38
Ebersberg	115	36	45	7	30	48	52	72	57	64	67
Erding	106	40	42	30	8	25	53	74	60	87	69
Freising	92	39	34	48	25	8	46	66	53	87	61
Fuerstenfeldbruck	113	39	21	52	53	46	6	34	32	59	41
Landsberg am Lech	134	54	49	72	74	66	34	8	40	38	36
Starnberg	120	31	39	57	60	53	32	40	6	39	56
Weilheim-Schongau	155	68	74	94	87	87	59	38	39	9	67
Augsburg Metropolis	115	68	38	67	69	61	41	36	56	67	8

external zone Bavaria the second biggest city in Bavaria Nuernberg is chosen as center of the outer region and then adjusted to secure that the external zone, bigger than the others, does not attract all the flows.

3.3 Inverse of the Activity Rate and Service Coefficient

Value s illustrates the non-basic activity rate in relation to population and is calculated as

$$s = \frac{E_{nb}}{P_t} \tag{4}$$

The coefficient r represents the inverse of the rate for activity,

$$r = \frac{P_t}{E_t} \tag{5}$$

Where, E_t and P_t are based on statistical data.

The multiplier effect of the Basic Employment on Population is:

$$P = \frac{r}{1 - r \cdot s} \cdot E_b \tag{6}$$

And the multiplier effect of the Basic Employment on Total Employment is

$$E_t = \frac{1}{1 - r \cdot s} \cdot E_b \tag{7}$$

Where, s is the service rate; r is the inverse of the activity rate; and E_b is the basic employment.

3.4 Spatial Interaction Model with Land Use

To calibrate the model some input data are required, such as distance matric d_{ij} and footprints for employment and population. The available statistical data for land use for living and the rest of the building area are used for calculating footprints for residence and work. Therefore the areas for these two kinds of land use are divided by the number of population, respectively the number of employees. The footprints for population and employment are determined for each zone (table 4). The total area of urban use consequently is the sum of living and employment land use. The footprint is lower for regions close to cities unlike remote districts with higher footprints. In order to calculate the bid rents as well the calculation of average footprints are required for each study region. This value is established for each zone by multiplying the employment footprint with an average factor of 50% summed with multiplying the population footprint with 50%.

Table 4: Footprints for employment and population for each zone (German Federal Statistical Office, 2013)

Footprints	External zone Bavaria	Munich Metropolis	Dachau	Ebersberg	Erding	Freising	Fuerstenfeldbruck	Landsberg am Lech	Starnberg	Weilheim-Schongau	Augsburg Metropolis
Employment	0.0549	0.0106	0.0632	0.0517	0.0812	0.0378	0.0375	0.0738	0.0340	0.0608	0.0405
Population	0.0178	0.0068	0.0135	0.0130	0.0146	0.0135	0.0131	0.0184	0.0202	0.0177	0.0135
Average	0.036	0.009	0.038	0.032	0.048	0.026	0.025	0.046	0.027	0.039	0.027

To assess the economy factors in the zones, first the proportional value of residential attraction W_{ij} and service attraction Q_{ij} from zone i to j with the urban area A_j in zone j need to be determined as

$$W_{ij} = \frac{A_j \cdot e^{(-bid\,rent_j - \alpha \cdot d_{ij})}}{\sum_j A_j \cdot e^{(-bid\,rent_j - \alpha \cdot d_{ij})}} \quad \text{for all } i \tag{8}$$

$$Q_{ij} = \frac{A_j \cdot e^{(-bid\,rent_j - \beta \cdot d_{ij})}}{\sum_j A_j \cdot e^{(-bid\,rent_j - \beta \cdot d_{ij})}} \quad \text{for all } i \tag{9}$$

Where, W_{ij} represents the percentage of workers from region (i) that live in region (j) for commuting and Q_{ij} for shopping, representing the percentage of population in region (i) that shopps in region (j); d_{ij} is the distance in minutes between zone i and j; parameter α is the friction for commuting distances whereas β reflects the distance friction for shopping trips (Goncalves and Dentinho, 2007); bid rent are the parameters that are calibrated o secure that the demand for land in region (j) do not exceed the supply of land Aj (Borba and Dentinho, 2016).

The matrixes *[A]* and *[B]* are

$$[A] = W_{ij} \cdot r_i \tag{10}$$

$$[B] = Q_{ij} \cdot s_i \tag{11}$$

Where, s_i is the ratio of non-basic on population in region I, and r_i is the inverse of the activity rate in region *i*.

By now the employment and population can be calculated.

$$[E] = ([I] - [AB])^{-1} \cdot [E_b] \quad (12)$$

As well as the number of population as

$$[P] = ([I] - [AB])^{-1} \cdot [E_b][A] \quad (13)$$

Not only for land use these models can be used but also for transport and traffic planning (Hurturbia and Bierlaire, 2012) which are also considered in this model. Citizens living in the surrounding of Munich generated traffic due to commuting to work and movements to shopping of goods and services (shopping movements) which challenges the Munich land development especially due to expected increasing numbers of commuters by car (Thierstein and Reiss-Schmidt, 2008). The numbers of commuter T_{ij} who work in zone *i* and commute home into zone *j* are

$$[T_{ij}] = \frac{W_{ij} \cdot P_j}{r_i} \quad (14)$$

Where, P_j is population in zone *j*; *r* is the inverse activity rate of zone *i*. According to the calculation of *r* and *E* this equals to

$$[T_{ij}] = r_i W_{ij} E_j \quad (15)$$

In contrast, S_{ij} indicates the activities generated by zone *j* to serve the population living in zone *i* as

$$[S_{ij}] = s_i Q_{ij} \cdot P_j \quad (16)$$

Where E_j is the employment and P_j is the population in zone *j*.

For the results, the differences between the statistical values about population are compared to the calculated values. Therefore, assuming that every person requires some kind of services, the total population P_j for zone *j* equals to the sum of S_{ij}.

$$P_j = \sum_i S_{ij} \quad (17)$$

The real costs for commuting and shopping are calculated as

$$Average\ Commuting\ Distance\ (min) = \sum_{ij} \frac{[d_{ij}][T_{ij}]}{[T_{ij}]} \quad (18)$$

$$Average\ Shopping\ Distance\ (min) = \sum_{ij} \frac{[d_{ij}][S_{ij}]}{[S_{ij}]} \quad (19)$$

Where, d_{ij} is the distance between zone *i* and *j*; T_{ij} is the number of commuters that work in zone *i* and live in zone *j*; S_{ij} are the number of people that live in zone *i* and use services in zone *j*. Despite several attempts of adaptation, the calculated *average distance time* for *commuting = 10 [min]* and *shopping = 9 (min)* are lower than some indicators but they are the closest numbers that could lead to a good functioning of the model where distances internal to each zone are defined exogenously (see point 3.2). The estimation of the basic employment was done using the minimum requiremnte method (Ullman and Dacey, 1960) to secure that the basic employment is positive to all areas including the external area.

3.5 Calculation of parameter α and β

Parameters α (for commuting) and β (for shopping) that interact with bid rents, are generated through the solver function in Excel to secure that the real average commuting and shopping costs are equal to the calculated costs in the model. Results show that α is lower than β, as $\alpha = 0.07219$ and $\beta = 0.09298$.

3.6 Calculation of bid rents

Bid rents are important factors that influence the attraction of each specific area. High attraction areas are associated to high bid rents and high purchase value for built space. The employment footprint in zone *j* is multiplied with the total employment E_j to get to know the *employment land use*. For *population land use* the same calculations are realized with the total population per area P_j. The sum A'_j of employment land use and population land use is supposed to be less or equal to the actual urban area for each zone A_j.

The proportional value $quotient_j$ shows the relation between calculated urban area A'_j divided by the actual urban area A_j. For all the zones the mean value of this error index *quotient* is supposed to be close to 1.0 (External zone Bavaria 1.01; Munich Metropolis 0.99; Dachau 1.00; Ebersberg 0.92; Erding 1.02; Freising 0.98; Fuerstenfeldbruck 1.00; Landsberg am Lech 0.99; Starnberg 1.00; Weilheim-Schongau 0.94; Augsburg Metropolis 1.03; Mean value 0.99). To improve the *quotient*, the external distances are corrected with the adapted factor 1.04 because of different scales and the adapted gravity center of the surrounding external zone.

New bid rents are calculated as multiplication of the *former bid rent*$_j$ and the *quotient*$_j$ if the quotient is higher than 1.0. If not, no changes are conducted at the former bid rents. At the beginning all former bid rents are set as -1.0 and then are replaced by the new bid rents until the difference between them is as low as possible. After several approaches, it turned out that the final bid rents that ultimately are related to the level of land prices.

The relation between land prices and calibrated bid rents is done using a linear regression model with the expression:

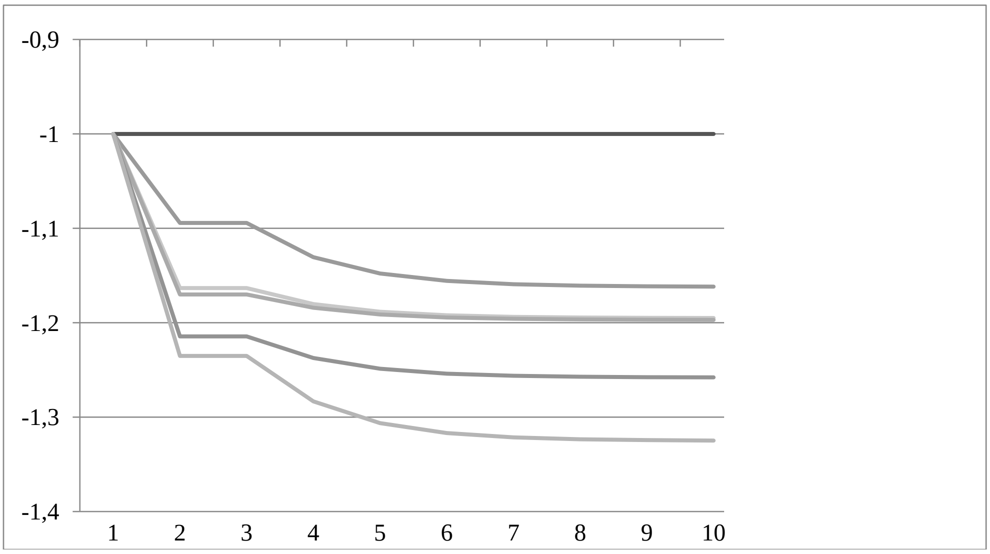
$$Land\ \ price_j = a + b * bid\ rents_j + \ \varepsilon_j \qquad (20)$$

Where, a is the intercept, b is the coefficient of the bid rents and ε_j is the error term.

4 RESULTS

Figure 2 shows the process of the calibration of the bid-rents of model 1. Bid-rents are adjusted in each iteration that the profile of interaction changes whenever the attrition parameters are adjusted through solver. The process stops when former bid rents stabilizes and demand for land does not overcome available land.

Figure 2: Development of former bid rents



Bid rents appear in the formulas as (8) and (9) negative terms because they avoid that everybody is located in the more central places, with higher attraction and higher demand. So it makes sense that the bide-rents calibrated for Munich are higher than in other areas (Figure 3).

Table 5 show the results of commuting behavior (T_{ij}) from the place of work to place of residence estimated in model 1.

Figure 3: Bid rents for each zone

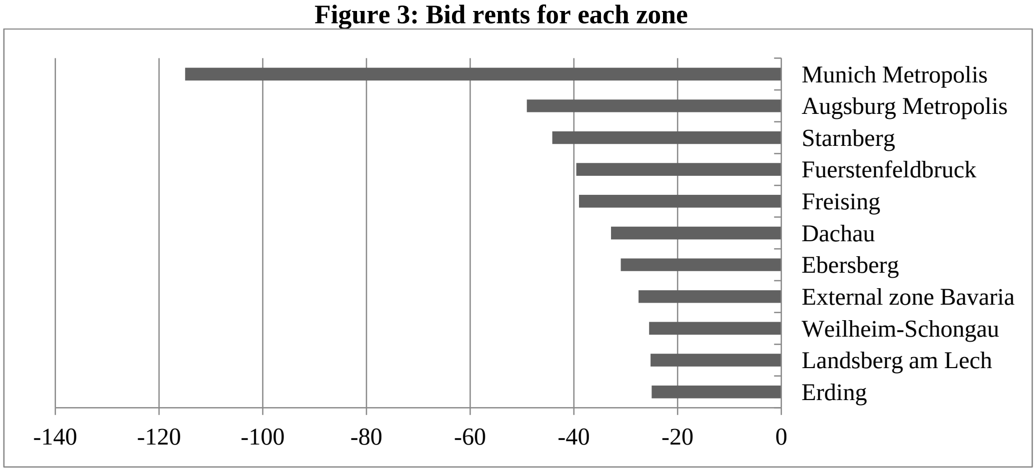


Table 5: Commuting matrix of model 1

Model 1 Commuting T_{ij}	Exter-nal zone Bavaria	Munich Metropo-lis	Da-chau	Ebers-berg	Er-ding	Frei-sing	Fuersten-feldbru-ck	Lands-berg am Lech	Starn-berg	Wei-lheim-Schon-gau	Augs-burg Metro-polis
External zone Bavaria	3,431,544	133	25	11	23	89	16	3	7	1	40
Munich Metropolis	8,499	811,816	16,810	18,068	15,020	21,541	18,274	5,443	25,249	2,520	6,731
Dachau	765	8,188	9,948	678	934	2,220	4,814	561	1,018	117	4,216
Ebersberg	363	9,567	737	12,652	2,594	944	600	125	324	282	607
Erding	778	7,818	998	2,551	13,534	5,418	609	118	285	59	573
Freising	4,391	16,579	3,507	1,372	8,010	36,526	1,991	413	931	115	2,015
Fuerstenfeldbruck	444	8,116	4,389	503	519	1,149	17,648	2,039	2,077	427	4,179
Landsberg am Lech	103	3,072	650	133	128	303	2,591	14,891	1,303	2,172	6,702
Starnberg	297	16,374	1,355	397	355	785	3,032	1,497	15,113	2,047	1,602
Weilheim-Schongau	35	1,862	178	45	83	111	710	2,843	2,332	29,841	1,191
Augsburg Metropolis	1,683	4,404	5,664	750	721	1,713	6,157	7,770	1,617	1,054	206,614

Table 7 show the results of the regressions performed with data of Table 6. The first regression relates land prices with calibrated bid-rents. The second regression introduces a dummy to the more expensive areas. And the third regression forces the intercept to be zero. Figure 4 illustrates the graph of the regression of Model 2 – first regression.

Table 6: Parameter for regression of model 1

Zones	Bid rents (positive)	Dummy	Soil Price
External zone Bavaria	27.531	0	143 €
Munich Metropolis	114.947	1	1,000 €
Dachau	32.816	0	235 €
Ebersberg	30.942	1	341 €
Erding	24.992	0	153 €
Freising	39.001	0	187 €
Fuerstenfeldbruck	39.523	0	334 €
Landsberg am Lech	25.195	0	141 €
Starnberg	44.147	1	478 €
Weilheim-Schongau	25.480	0	164 €
Augsburg Metropolis	49.050	0	208 €

When comparing official data with estimated data about population and employment, deviations occur. The sum of total employment and total population for all the zones are slightly higher in the model compared to the official numbers due to different *ri* values for each zone.

In order to compare the official numbers with the calculated numbers for employment, respectively population, an error is established.

Table 7: Regressions of model 1

Regressions of model 1	**Regression 1:** Y = soil prices X = bid rents (positive)			**Regression 2:** Y = soil prices X = bid rents (positive) + dummy			Regression 3: Y = soil prices X = bid rents (positive) + dummy with constant as zero		
R^2	87%			96%			98%		
F	0.000023789			0.000002679			0.0000000759		
	Coefficient	t-Statistic	P-Value	Coefficient	t-Statistic	P-Value	Coefficient	t-Statistic	P-Value
Intersect	-70.5656	-1.2701	0.2359039	-44.3368	-1.3002	0.2297236	0	-	-
Correct bid rent	9.1753	7.9281	0.0000238	7.2901	8.7217	0.0000233	6.4123	12.5382	0.00000053
Dummy	-	-	-	188.886	4.0948	0.0034625	200.1527	4.2574	0.00211935

Figure 2: Diagram and trend line of regression 1

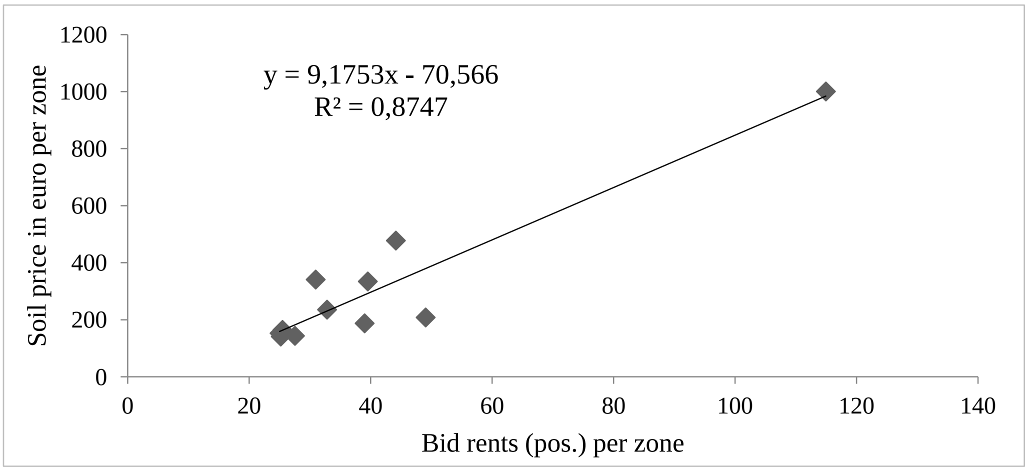


Table 8: Employment and population compared between statistical data (German Federal Statistical Office, 2013) and estimated values of the model

	Employment		Population	
	Model	**Reality**	**Model**	**Official**
External zone Bavaria	3,431,891	3,390,873	9,169,070	9,059,481
Munich Metropolis	949,971	949,763	1,738,197	1,737,817
Dachau	33,458	35,308	136,842	144,407
Ebersberg	28,795	33,754	113,467	133,007
Erding	32,739	34,343	124,156	130,238
Freising	75,851	75,575	169,628	169,010
Fuerstenfeldbruck	41,491	43,561	198,377	208,272
Landsberg am Lech	32,047	32,331	113,916	114,926
Starnberg	42,855	43,199	129,768	130,811
Weilheim-Schongau	39,232	42,238	121,107	130,387
Augsburg Metropolis	238,146	229,391	670,540	645,888
Total of Bavaria	4,946,477	4,910,336	12,685,068	12,604,244

When comparing official data with estimated data about population and employment, deviations occur. The sum of total employment and total population for all the zones are slightly higher in the model compared to the official numbers due to different *ri* values for each zone.

In order to compare the official numbers with the calculated numbers for employment, respectively population, an error is established.

5 DISCUSSION AND CONCLUSION

Effects of varying numbers of population and employment can be measured and may influence decisions in land use management (Veldkamp and Lambin, 2001). The model has demonstrated that bid rents are highly correlated land prices and indicate effects on regional dynamics (Borba et al., 2015). The economic meaning of bid rents is avoiding more people to go to areas with high attraction rates e.g. metropolises such as Munich. Furthermore, the model points out that a competition exists for the same space for residence and employment. It is shown that choice for places of residence depends among on travel distances to work as well as on the land value (Wegener, 2001). The exercise has shown that it is important to consider an external zone apart of the examined area to include the interaction between the study area and the outside world (Borba et al., 2015; Wilson, 2010).

Future work of the model will involve dividing large zones into smaller ones so that economic effects can be measured in more detailed. As well having two major cities included in the model makes it more difficult to analyze flows of employees. It is shown that models of land use planning they could be in use as even more helpful supporting tools (Couclelis, 2005) and that land use, directly affected by places of residence and places of work, depends very much on human interaction in space (Veldkamp and Lambin, 2001, Agarwal et al., 2002; Leibowitz et al., 2000).

Such a model can also help public participation in public decisions (Thierstein and Reiss-Schmidt, 2008) and there is a strong demand for that interaction as it is shown in the project "Munich Perspective" where the city Munich land development involve citizens and planning teams (Landeshauptstadt München, 2013). Land use models for planning urbanization and modelling correlations are important to design future scenarios and assess possible impacts on the environment (Haase and Schwarz, 2009; Veldkamp and Lambin, 2001) and on land value since these models are able to deliver possible consequences of political interventions on e.g. urban development or real estate (Hurturbia and Bierlaire, 2012).

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