Gabriel M. Ahlfeldt and Nicolai Wendland

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Gabriel M. Ahlfeldt* & Nicolai Wendland**

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Abstract: We show that an employment potential capitalisation model produces estimates of the spatial decay in employment impact on land prices that are very close to the decay observed in commuting data.

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1 Introduction

The standard urban economics framework predicts that *ceteris paribus* the price of land will mirror the cost of commuting. In classic stylized models, the price of land must decline as a compensation for the increase in commuting costs to the central business district (CBD), the destination of all commuting trips, in order to maintain a spatial equilibrium with no relocation incentives (Alonso, 1964; Mills, 1967; Muth, 1969). In reality, employment is dispersed and there is a remarkable degree of cross-commuting within most metropolitan areas. Recent models that rationalise these empirical observations feature agglomeration economies and idiosyncratic worker preferences for location (Ahlfeldt et al., 2015) or probabilistic household and firm location choice (Wrede, 2015). A central theoretical implication of such models is that the price of residential land at a given location depends on the proximity to employment at all locations in a labour market area, not just proximity to the CBD.

Recent empirical literature uses employment potentials to capture the labour market accessibility effects on the price of real estate in cities with a polycentric or dispersed employment distribution (Ahlfeldt, 2011, 2013; McArthur et al., 2012; Osland & Thorsen, 2008). Borrowing from Harris'

C* *Corresponding author*. London School of Economics (LSE) and Centre for Economic Policy Research (CEPR), Houghton St, WC2A 2AE London, UK, g.ahlfeldt@lse.ac.uk.

** Touro College Berlin.

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(1954) market potential concept, an employment potential capitalisation model establishes a spatial relationship between the price of land at a given location and employment at all locations in the city. Briefly summarised, the employment potential at a given location is the sum of employment across all potential commuting destinations, weighted by the bilateral transport costs. Crucially, employment at closer locations receives a higher weight in the employment potential, with the exact rate of spatial decay being subject to estimation. Although the evidence base is fairly limited, it is notable that the existing studies tend to find a similar spatial decay (Ahlfeldt, 2013).

Employment potentials tend to be successful in empirically establishing a relationship between land prices and the spatial distribution of employment (Ahlfeldt, 2011). It is less clear, however, to which extent the estimated spatial decays in employment potential capitalisation models reflect the declining commuting probability between two locations as travel costs increase. Theoretically, an employment potential may also capture the benefits from access to the amenities that often correlate with the distribution of employment in space, such as retail services or gastronomic establishments. Locational fundamentals – such as access to parks or water spaces – that simultaneously determine the distribution of population at residence and employment at workplace could also affect the estimated spatial decay in an employment potential capitalisation model. This raises the question of how to interpret the capitalisation effect captured by an employment potential.[1]

In this short paper we seek to shed light on this question by comparing estimates of the decay parameter in an employment capitalisation model to the actual decay in bilateral commuting probabilities observed in commuting data. To benchmark the estimates from the employment potential capitalization model we draw on a separate literature that has estimated the decay in the commuting probability between two localities as a function of effective distance (e.g. travel time) using commuting gravity equations (e.g. Ahlfeldt et al., 2015; McArthur et al., 2011).[2] This approach provides credible estimates of the rate at which the bilateral commuting probability declines in travel cost as it is directly estimated from commuting data. Commuting gravity models share many similarities with

[1] One approach to dealing with this endogeneity problem would be to use an instrumental variable strategy. We refrain from such a strategy due to space constraints and because every instrumental variable model produces a local estimate while we are interested in a general comparison across the whole range of the distribution of travel times.

[2] For a recent review on the reduced form literature on commuting gravity estimates see McDonald and McMillen (2010).

gravity models of trade (e.g. Camarero et al., 2014) or immigration (e.g. Lewer & Van den Berg, 2008), but micro-geography data on commuting flows is usually more difficult to find. If the employment potential captures the cost of commuting in a polycentric environment, the estimated decay parameters in the employment potential capitalisation model and the commuting gravity model will be of similar magnitude.

Our contribution to the literatures is twofold. First, we estimate an employment potential capitalization model using a large polycentric metropolitan region, which has never been analysed using these methods before. Thus, we add to the growing, but still small evidence base in this literature. Second, we compare the estimated spatial decay from the employment potential capitalisation model to the spatial decay in commuting probabilities estimated from a commuting gravity model using actual commuting data from the same region. Our results substantiate the claim in the literature that the estimated spatial decay in employment potential capitalisation models is reflective of the cost of commuting in polycentric regions. As collateral we find that commuting decays can be inferred from the spatial distribution of land prices and employment where suitable data for the estimation of a commuting gravity model are not available.

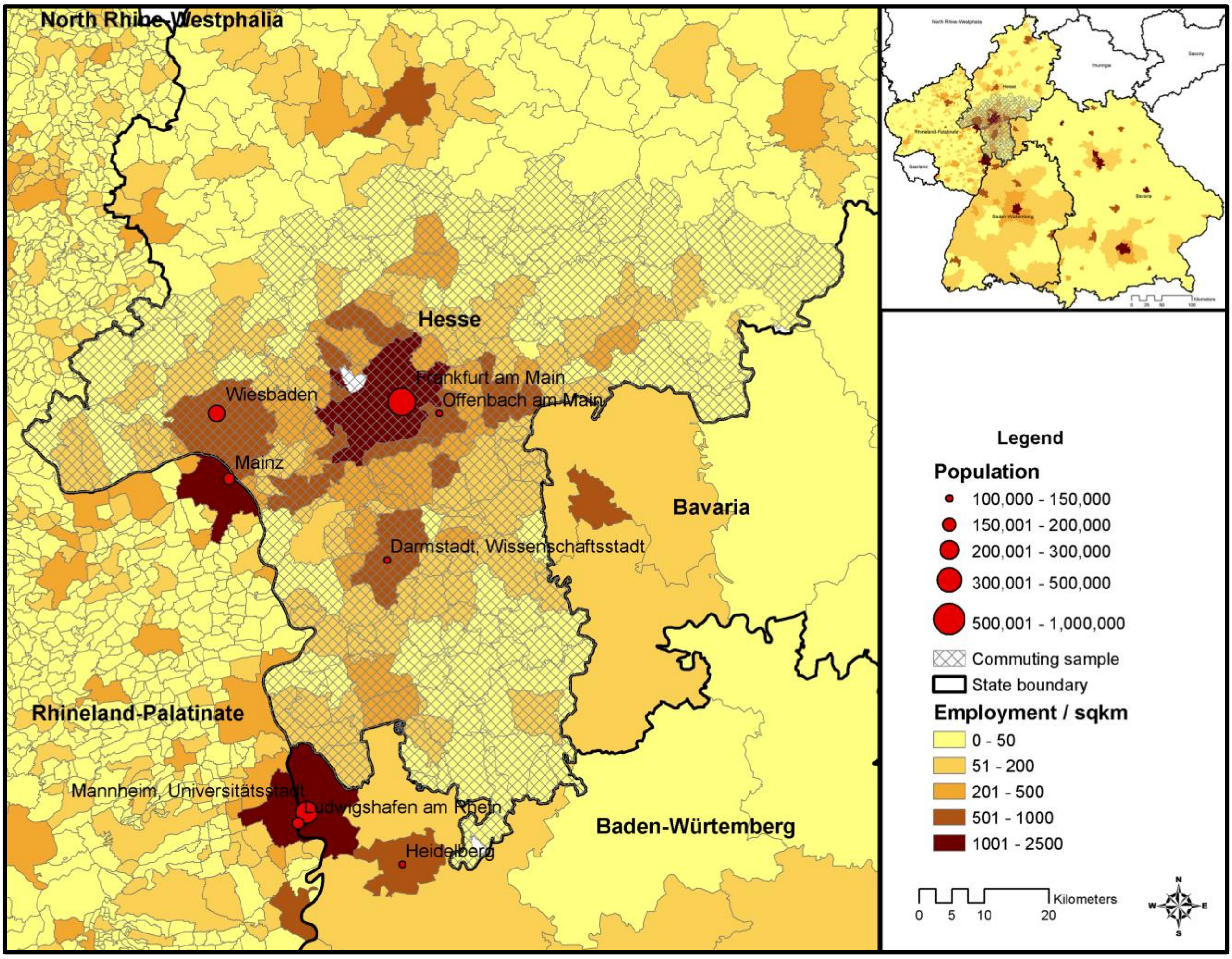
2 Data

Our core study area is the planning region South-Hesse (Planungsregion Südhessen), which roughly corresponds to the wider Frankfurt (Main) metropolitan area. comprises of 185 municipalities (Gemeinden) within the hatched area in Figure 1. With a 2009 population of slightly less than 3.8m and a 2009 GDP of slightly more than €150bn this region belongs to the economically more prosperous regions in Germany. From the Federal Employment Agency we obtained bilateral commuting data for all combinations of municipalities within this region with at least 10 commuters on the reporting day (30/6/2011).

For the same set of municipalities we collected standard land values (Bodenrichtwerte) of residential land from the respective local Committees of Valuation Experts (Gutachterausschüsse).Land values assessed by such committees, which exist throughout Germany, capture the fair market value of a square metre of land if it was undeveloped. The assessment by these committees is based on recent market transactions and is generally considered reliable (Weiss, 2004). Ahlfeldt et al. (2015), who use similar data, show that the standard land values tend to closely follow market prices. We further use data on the resident population 2009 and employment at workplace form the German Federal

Statistical Office. To avoid border effects in the employment potential we collect employment at workplace for a much larger region, namely 2,872 administrative units in Hesse and Rhineland Palatinate (both at municipality level), Baden-Württemberg and Bavaria (both at county level) illustrated in the small map in the upper-right corner of Figure 1. Shares of the 2009 population with completed A-levels, apprenticeship, polytechnic degree, and university degree were also available from the Federal Statistical Office at the county level (Kreise und kreisfreie Städte).

Fig. 1 Study area



Notes: Own illustration using electronic maps from the Federal Agency for Cartography and Geodesy and data from the Federal Statistical Office. Hatched area is the sample of municipalities for which commuting data is available. The small map in the upper right corner shows the coverage of employment data in the potential (the states of Baden-Würtemberg, Bavaria, Hesse, and Rhineland-Palatinate).

3 Empirical strategy

The empirical specifications we use are reduced-form versions of equilibrium conditions of the Ahlfeldt et al. (2015) model.[3] Our employment potential capitalisation model takes the following form:

$$\ln(P_i) = \alpha + \beta \ln\left(\sum_j E_j e^{\tau^P t_{ij}}\right) + X_i b + \varepsilon_i \qquad (1)$$

, where P_i is the residential land price at location i, E_j is employment at workplace j, X_i is a vector of locational control variables, and t_{ij} is the travel time in minutes between the geographic centroids of i and j.[4] The vector of corresponding implicit hedonic prices (Rosen, 1974) b, α, and τ^P are the parameters to be estimated and ε_i is a random error term. The capitalisation effect of the employment potential is jointly determined by β, the elasticity of land price with respect to employment potential, and τ^P, the spatial decay parameter, the latter being the parameter of primary interest in this research. Economically sensible combinations of parameter values satisfy $\beta > 0$ and $\tau^P < 0$. Following the standard in the literature we estimate this non-linear model using a non-linear least squares estimator.

To obtain a reliable approximation of the true spatial decay in the bilateral commuting probabilities we estimate the following commuting gravity equation:

$$\ln(c_{ij}) = \tau^C t_{ij} + o_i + d_j + \epsilon_{ij} \qquad (2)$$

, where c_{ij} is the probability that a commuter commutes from locality i to locality j, which we empirically approximate as the share of commuters in i commuting to j (C_{ij}) at all commuters in i $(C_{ij}/\sum_j C_{ij})$. o_i and d_j are origin and destination fixed effects which capture all push and pull factors specific to individual locations in a flexible manner, t_{ij} is defined as above, and ϵ_{ij} is an error term. $\tau^C < 0$ is the parameter of interest capturing the spatial decay in commuting probabilities, which is directly comparable to τ^P in equation (1). We estimate the specification using OLS and the Poisson PML estimator used by Silva and Tenreyro (2006; 2010).

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3 Actually, the model predicts that residential land prices are a function of the wage potential rather than the employment potential. However, the model also predicts that productivity and wages increase in local employment due to spillovers.

4 Travel times are computed using MS MapPoint 2010. We approximate the internal travel time (minutes) for *i=j* using the following formula: $t_{ii} = 2/3\sqrt{A\pi}/30 \times 60$, where A is the geographic area of a spatial unit in km, 30 (km/h) is the assumed average speed within *i=j*, and the multiplication by 60 converts hours to minutes.

We note that while the exponential cost functions in (1) and (2) have received empirical support in the literature (Ahlfeldt, 2013; Ahlfeldt et al., 2015), we also use a log-log specifications in complementary models.[5]

4 Empirical results

We report the results of the estimation of equation (1) in Table 1. We begin with a model excluding controls in column (1), then add a number of exogenous geographic controls in column (2) and some additional endogenous controls capturing the density and education of the resident population in column (3). While in theory the last model could be subject to a "bad control problem" (Angrist & Pischke, 2009) it turns out that the estimates are highly consistent across specifications. The estimated decay parameters are also within the range of previous estimates of employment potential capitalisation models (Ahlfeldt, 2011, 2013; Osland & Thorsen, 2008). According to model (1), the effect of any employment at one location on the price of land at another location declines by 11.2% per minute of travel time.[6] At the population-weighted mean of the distribution of bilateral travel times of close to 20 minutes the implied travel time elasticity is 2.3, which is within the range of the decay estimates in the log-log models (4-6).

[5] According to Fortheringham and O'Kelly (1989) the semi-log specification has emerged as a consensus in the related literature. See for another recent application McArthur et al. (2011).

[6] We use the standard transformation that applies to semi-log models $(\exp(-0.119) - 1) \times 100 = -11.2\%$.

Tab. 1 Employment potential capitalisation model estimates

	(1) Ln land price	(2) Ln land price	(3) Ln land price	(4) Ln land price	(5) Ln land price	(6) Ln land price
Ln employment	0.566***	0.529***	0.558***	1.037***	0.645***	0.741***
potential	(0.028)	(0.035)	(0.079)	(0.056)	(0.048)	(0.145)
Spatial decay estimate	0.119***	0.137***	0.097***	2.032***	2.792***	2.516***
	(0.013)	(0.014)	(0.018)	(0.209)	(0.178)	(0.217)
Decay functional form	Semi-log	Semi-log	Semi-log	Log-log	Log-log	Log-log
Estimation	NLS	NLS	NLS	NLS	NLS	NLS
Exogenous controls	-	Yes	Yes	-	Yes	Yes
Endogenous controls	-	-	Yes	-	-	Yes
Observations	185	185	185	185	185	185
R^2	0.684	0.729	0.766	0.654	0.718	0.743

Notes: Exogenous controls are geographic surface area of the municipality, the latitude and the longitude of the geographic centroid, the elevation, and the distance from the nearest river. Endogenous controls are population density as well as shares of the population with completed A-levels, apprenticeship, polytechnic degree, and university degree (county level). Standard errors for ln employment potential are NLS in (1) and (4), heteroscedasticity robust (homoscedasticity rejected by White tests) in (2) and (5) and clustered on counties (due to county-level controls) in (3) and (6). * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

The elasticity of land price with respect to the employment potential at 0.53-1.0 is large and within the range of the elasticity of land prices with respect to population estimated by Combes et al. (2013). To facilitate a comparison with the existing employment potential capitalisation literature we translate our estimated land price capitalisation elasticity into a house price capitalisation elasticity by multiplying the former by 0.25 following Ahlfeldt at al. (2015) and Combes et al. (2013). This transformation follows from assuming a competitive construction sector with a Cobb-Douglas housing production function, with 0.25 being the land share. The implied elasticity of house prices with respect to employment potential of about 0.14-0.25 reasonably close to previous estimates (Ahlfeldt, 2011, 2013; Osland & Thorsen, 2008).

We report the results of the estimation of equation (2) in Table 2. Our preferred model is the Poisson PML model using all available data reported in column (4). The estimated decay is almost identical to the result in Table 1, column (1) and within the range of recent estimates in the literature (Ahlfeldt et al., 2015; McArthur et al., 2011). The estimated parameter is not particularly sensitive to changes in sample size as shown by the estimates in column (5) which use less than one fourth of all available observations. The estimates are also reasonably close to OLS estimates (reported in columns 1 and 2). Finally, the elasticity estimates in columns (3) and (6) are within close range of the respective estimates in Table 1 (columns 4-6), suggesting that our results generalise to other functional forms of the spatial decay (see Figure A1 for a graphical comparison).

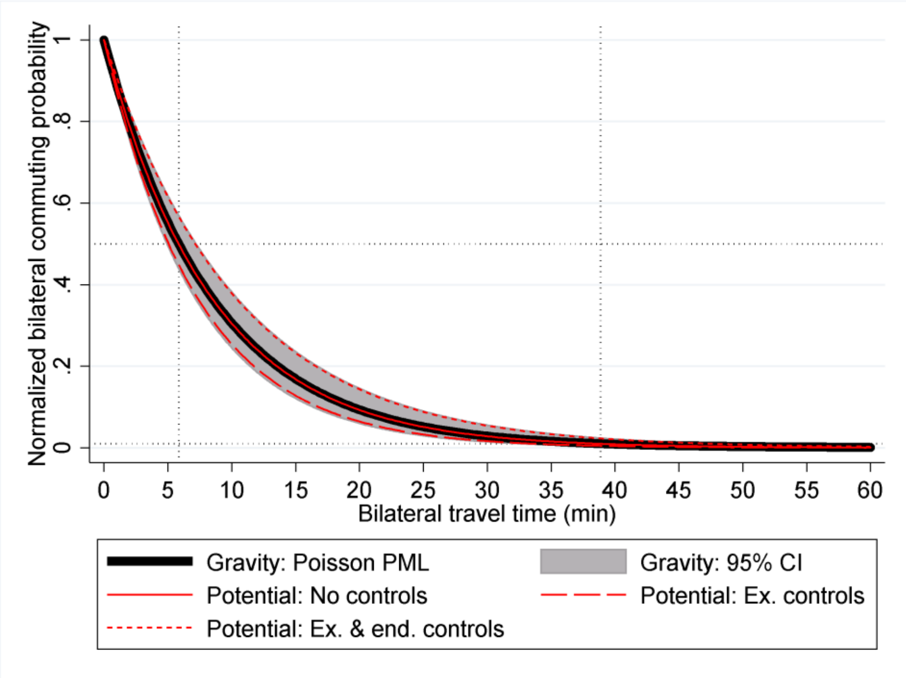
Tab. 2 Commuting gravity model estimates

	(1) Ln bilateral commuting probability	(2) Ln bilateral commuting probability	(3) Ln bilateral commuting probability	(4) Ln Bilateral commuting probability	(5) Ln Bilateral commuting probability	(6) Ln Bilateral commuting probability
(Log) Travel time from *i* to *j* in minutes	-0.074*** (0.002)	-0.088*** (0.003)	-2.326*** (0.022)	-0.119*** (0.011)	-0.105*** (0.011)	-2.160*** (0.052)
Decay functional form	Semi-log	Semi-log	Log-log	Semi-log	Semi-log	Log-log
Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Model	OLS	OLS	OLS	Poisson PML	Poisson PML	Poisson PML
Flows	>=10	>=100	>=10	>=10	>=100	>=10
Observations	6918	1507	6918	6918	1507	6918
R^2	0.790	0.872	0.866	0.791	0.803	0.792

Notes: Observations are bilateral pairs of 185 workplace and residence localities. Only pairs with more than 10 commuters are included. Travel time is measured in minutes. Fixed effects are workplace locality fixed effects and residence locality fixed effects. The specifications labelled ≥10 (≥100) commuters restrict attention to bilateral pairs with 10 (100) or more commuters. Poisson PML is Poisson Pseudo Maximum Likelihood estimator. Standard errors in parentheses are heteroscedasticity robust (homoscedasticity rejected by White tests). * p<0.1, ** p<0.05, *** p<0.01.

Figure 2 illustrates the estimated decay parameters reported in Table 1, columns (1-3) and the benchmark estimate from Table 2, column (4). Consistently, the estimated parameters point to a half-live distance of slightly more than five minutes. After slightly less than 40 minutes the commuting probability is reduced to 1% of its value at a hypothetical travel time of zero. Notably, all estimates of the employment potential capitalisation models fall within the 95% confidence interval of our benchmark gravity estimate. In two-sided t-tests none of the estimates from the semi-log potential models is rejected to be the same as the baseline gravity estimate (p-values > 0.3).

Fig. 2 Decay parameters: Employment potential vs. commuting gravity



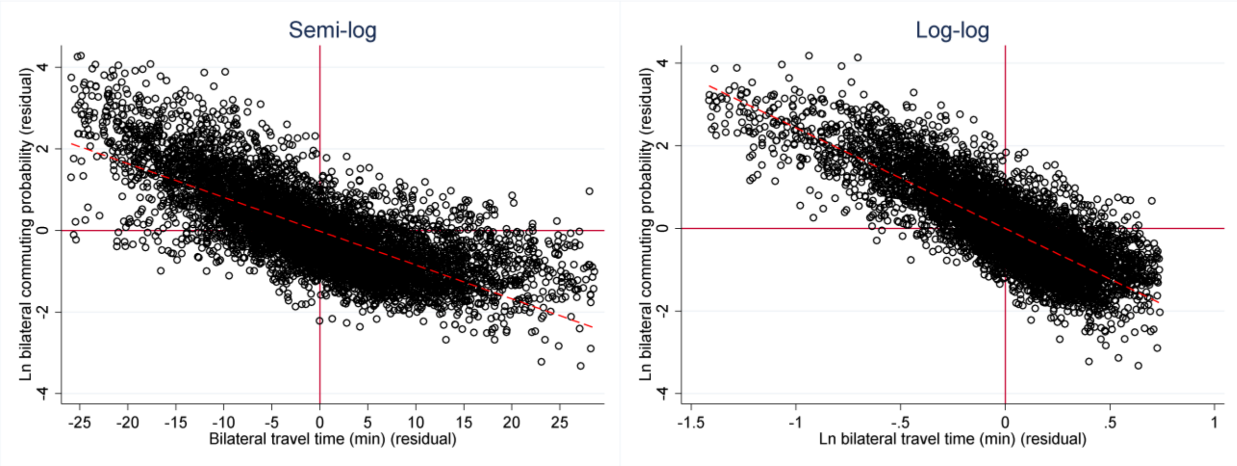
Notes: Figure plots the function $f(d) = e^{\tau^A d_{ij}}, A = (C, P)$ using the decay parameter estimates from Table 1, column (3) and Table 2, columns (1–3). The intersections of the dotted lines define where the commuting probability declines to 50% and 1% of its value at a travel time of zero.

5 Conclusion

Using a combination of spatial data sets for the polycentric Rhein-Main-Neckar region in Germany we show that the estimated spatial decay in an employment potential capitalisation model is very close to the spatial decay in observable commuting data. These results suggest that the estimated spatial decay in employment potential capitalization models is reflective of the cost of commuting in polycentric regions as typically assumed in the literature. A collateral finding is that with the help of such a model the decay in commuting probabilities can indirectly be inferred from the spatial distribution of land prices and employment if bilateral commuting data are not available. More generally, our findings support the use of employment potentials as a means to capture labour market accessibility effects in polycentric regions.

Appendix

Fig. A1: Partial correlation between bilateral commuting probabilities and travel time



Notes: Figure illustrates the residuals from separate regressions of ln bilateral commuting probabilities and travel time (left) or ln travel time (right) against origin fixed effects and destination fixed effects.

Literature

Ahlfeldt, G. M. (2011). If Alonso was right: Modeling Accessibility and Explaining the Residential Land Gradient. *Journal of Regional Science, 51*(2), 318-338.

Ahlfeldt, G. M. (2013). If we build it, will they pay? Predicting property price effects of transport innovations. *Environment and Planning A, 45*(8), 1977 – 1994.

Ahlfeldt, G. M., Redding, S. J., Sturm, D. M., & Wolf, N. (2015). The Economics of Density: Evidence from the Berlin Wall. *Econometrica, 83*(6), 2127–2189.

Alonso, W. (1964). *Location and Land Use: Toward a general Theory of Land Rent*. Cambridge, Massachusetts: Harvard University Press.

Angrist, J. D., & Pischke, J.-S. (2009). *Mostly Harmless Econometrics: An Empiricist's Companion*. Princeton, New Jersey: Princton University Press.

Camarero, M., Gómez, E., & Tamarit, C. (2014). Is the 'euro effect' on trade so small after all? New evidence using gravity equations with panel cointegration techniques. *Economics Letters, 124*(1), 140-142. doi: http://dx.doi.org/10.1016/j.econlet.2014.04.033

Combes, P.-P., Duranton, G., & Gobillon, L. (2013). The Costs of Agglomeration: Land Prices in French Cities. *Paris School of Economics Working Paper No 2013 - 28*.

Fortheringham, S., & O'Kelly, M. (1989). *Spatial Interaction Models: Formulations and Applications*. Dordrecht: Kluwer.

Harris, C. D. (1954). The Market as a Factor in the Localization of Industry in the United States. *Annals of the Association of American Geographers, 44*(4), 315-348.

Lewer, J. J., & Van den Berg, H. (2008). A gravity model of immigration. *Economics Letters, 99*(1), 164-167. doi: http://dx.doi.org/10.1016/j.econlet.2007.06.019

McArthur, D. P., Kleppe, G., Thorsen, I., & Ubøe, J. (2011). The spatial transferability of parameters in a gravity model of commuting flows. *Journal of Transport Geography, 19*(4), 596-605. doi: http://dx.doi.org/10.1016/j.jtrangeo.2010.06.014

McArthur, D. P., Osland, L., & Thorsen, I. (2012). Spatial Transferability of Hedonic House Price Functions. *Regional Studies, 46*(5), 597-610. doi: 10.1080/00343404.2010.521147

McDonald, J. F., & McMillen, D. P. (2010). *Urban Economics and Real Estate: Theory and Policy*. Hoboken, NJ: John Wiley & Sons.

Mills, E. S. (1967). An Aggregative Model of Resource Allocation in a Metropolitan Area. *The American Economic Review, 57*(2), 197-210.

Muth, R. F. (1969). *Cities and Housing: The Spatial Pattern of Urban Residential Land Use*. Chicago: University of Chicago Press.

Osland, L., & Thorsen, I. (2008). Effects on housing prices of urban attraction and labor-market accessibility. *Environment and Planning A, 40*, 2490-2509.

Rosen, S. (1974). Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition. *Journal of Political Economy, 82*(1), 34-55.

Silva, J. M. C. S., & Tenreyro, S. (2006). The Log of Gravity. *The Review of Economics and Statistics, 88*(4), 641-658. doi: Doi:

Silva, J. M. C. S., & Tenreyro, S. (2010). On the existence of the maximum likelihood estimates in Poisson regression. *Economics Letters, 107*(2), 310-312. doi: 10.1016/j.econlet.2010.02.020

Statistisches Bundesamt. (2015). Wohnkosten betragen mehr als ein Drittel des privaten Konsums. *Press release*.

Weiss, E. (2004). Replacing a 'Combined Tax on Land and Buildings' with a simplified 'Land Value Tax' in the Federal Republic of Germany. *International Journal of Strategic Property Management, 8*(4), 241-245.

Wrede, M. (2015). A continuous spatial choice logit model of a polycentric city. *Regional Science and Urban Economics, 53*, 68-73. doi: http://dx.doi.org/10.1016/j.regsciurbeco.2015.05.001