The Economics of Density: Evidence from the Berlin Wall*

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Abstract

In explaining the uneven distribution of economic activity, a key empirical challenge is separating agglomeration and dispersion forces from natural advantages and amenities. This paper uses the division and reunification of Berlin as a natural experiment to provide new evidence on the strength of agglomeration and dispersion forces. We develop a quantitative model of city structure that allows for variation in natural advantages, amenities and transport infrastructure. We use disaggregated data on land rents, workplace employment and residence employment to determine the model's parameters and show that it can account both qualitatively and quantitatively for the observed changes in city structure.

Keywords: agglomeration, dispersion, density, cities

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1 Introduction

Cities are one of the starkest examples of the uneven distribution of economic activity across geographical space. Equally striking is the concentration of economic activity in specific locations within cities, such as Manhattan in New York and the Square Mile in London. Understanding the strength of the agglomeration and dispersion forces that underlie these concentrations of economic activity is central to range of economic and policy questions. For example, both the spatial concentration of economic growth and the evolution of regional inequalities depend crucially on the strength of these two sets of forces. Changes in the balance between them affect the size and internal structure of cities, with implications for the incomes of immobile factors, the resource costs of congestion and the productivity of economic activity. Similarly, the relative magnitude of agglomeration and dispersion forces plays a central role in influencing the impact of public policy interventions, such as transport infrastructure investments, regional policies and local government taxation.

Although there is a long literature on economic geography dating back to at least Marshall (1920), determining the strength of agglomeration and dispersion forces remains a challenging problem. While high commercial and residential rents in a location are consistent with strong agglomeration forces, they are also consistent with amenities that make a residential area an attractive place to live (e.g. leafy suburbs and scenic views) or natural advantages that make a commercial area attractive for production (e.g. access to mineral resources or navigable waterways). This identification problem is an example of the broader problem of distinguishing spillovers from correlated individual effects in the social sciences. But the problem is particularly challenging for location choices, because amenities and natural advantages of purely historical significance can have long-lived effects in the presence of sunk costs, durable structures or co-ordination problems (e.g. the ports of London and New York). To convincingly distinguish spillovers from correlated individual effects, one requires a source of exogenous variation in the surrounding concentration of economic activity, which is typically difficult to find.

In this paper, we develop a quantitative model of city structure that features agglomeration and dispersion forces, while also capturing empirically-relevant differences across locations in residential consumption amenities, natural advantages for production and transport infrastructure. We combine the model with a rich source of disaggregated data on land rents, workplace employment, residence employment and the transport network for thousands of city blocks in Berlin for the years 1936, 1986 and 2006. We use the structure of the model and the exogenous variation in the surrounding concentration of economic activity provided by Berlin's division and reunification to determine the strength of agglomeration and dispersion forces. Prior to division, we find that Berlin's rent gradient was approximately monocentric, centred on the district ("Bezirk") of Mitte in East Berlin. Surrounding this rent peak was a concentric ring of lower rent values, which included the area around the Kudamm ("Kurfürstendamm") in West Berlin. In the aftermath of division, West Berlin's rent gradient re-orientated away from the pre-war center and towards a new Central Business District in the area around the Kudamm. Following reunification, there is a re-emergence of the pre-war rent gradient towards the district Mitte in East Berlin. We show that the model can account qualitatively and quantitatively for the observed changes in the structure of economic activity for a plausible set of parameter values.

Map 1 illustrates how the Berlin Wall ran through the heart of the pre-war city and severed West Berlin from the pre-war city's commercial center in Mitte. The drawing of the border between East and West Berlin was motivated by the military considerations of allocating areas of approximately equal population to the American, British and Soviet armies. Following the establishment of East and West Germany, restrictions on political freedom and economic stagnation in East Germany led to an outflow of civilians to West Germany via West Berlin. To stem this outflow, the East German authorities built the Berlin Wall in 1961, which closed West Berlin's boundaries with East Berlin and the surrounding East German hinterland. While the division of Berlin appeared to be permanent, Soviet policies of "Glasnost" and "Perestroika" in the late 1980s started a process of opening up in Eastern Europe. This opening-up in turn stimulated large-scale demonstrations in East Germany, which culminated in the fall of the Berlin Wall on 9 November 1989. Only eleven months later East and West Germany were formally reunified on 3 October 1990 and the two halves of Berlin became again part of the same city.

The key idea behind our empirical approach is that areas within West Berlin were differentially affected by the city's division. In the model, both production externalities and commuting costs vary with the economic distance between agents, which we measure using information on Berlin's transportation network. Firms located in areas of West Berlin close to employment and residential concentrations East of the Berlin Wall experienced the largest reductions in productivity from diminished production externalities and the largest increases in wages required to attract commuters. Similarly, residents located in areas of West Berlin close to employment concentrations East of the Berlin Wall experienced the largest reductions in income from lost commuting possibilities. In contrast, the effect on areas of West Berlin further away from employment and residential concentrations East of the Berlin Wall was more muted.

Our empirical approach has a number of advantages. First, as the division of Berlin was driven by military considerations that are unlikely to be correlated with pre-war characteristics of localities, it provides a plausible source of exogenous variation in the surrounding concentration of economic activity. Second, we combine this exogenous variation with a structural model of the spatial distribution of economic activity, which can be used to determine agglomeration and dispersion forces. Third, we make use of disaggregated data for thousands of city blocks on land rents, workplace employment and residence employment, which are the three variables required to separate agglomeration forces from congestion forces in the model. While we focus on Berlin's division and reunification, the model provides a quantitative framework for evaluating other interventions and public policies, such as the construction of transport infrastructure and local government taxation and spending policies. Fourth, reunification provides a separate source of variation from division, which can be used as an additional check on the model's predictions, and to examine the extent to which the strength of agglomeration and dispersion forces has changed over time. Fifth, division and reunification both interact with the pre-existing transport network, including suburban ("S-Bahn") and underground ("U-Bahn") railway lines, to provide a rich source of variation in the extent to which areas of West Berlin were affected by the change in the surrounding concentration of economic activity.

Our paper is related to a number of literatures. The model builds on the theory of equilibrium city structure of Lucas and Rossi-Hansberg (2002), henceforth LRH, which has the key advantages of modelling location in two spatial dimensions and allowing for a non-monocentric city structure.[1] Both of these features are relevant for our empirical analysis, since cities are in reality arranged in latitude and longitude space and need not be monocentric. While LRH consider a perfectly symmetric city, in which the radius summarizes the spatial organization of economic activity, we allow for asymmetries in residential consumption amenities, natural production advantages and transport infrastructure across locations. In contrast to the concentric rings of economic activity found in a symmetric city, we allow rents to be higher in certain neighborhoods than others (e.g. West versus East) and for uneven clusters of economic activity to form throughout the city. Despite these rich sources of asymmetries across locations, the model remains tractable as a result of heterogeneity in workers' commuting decisions, which is modelled following Eaton and Kortum (2002). Worker income net of commuting costs depends on the wage at the place of employment, the labor time lost in commuting and an idiosyncratic productivity draw. Heterogeneity in idiosyncratic productivity draws ensures that the supply of commuters to each production location is continuous in the wage paid and generates a gravity equation for bilateral commuting flows, as observed empirically.

Second, our findings relate to the large empirical literature on the nature and sources of agglomeration economies, as reviewed in Rosenthal and Strange (2004). A key insight underlying this literature is that population mobility requires the higher land rents of urban areas to be offset by higher wages, which in turn requires higher productivity in urban areas. Therefore a long line of research has used wage data to estimate the relationship between productivity and population density, including Glaeser

[1] The classic urban agglomeration models of Alonso (1964), Mills (1967) and Muth (1969) impose a monocentric city structure. While Fujita and Ogawa (1982) and Fujita and Krugman (1995) allow for non-monocentricity, they model one-dimensional cities on the real line.

and Mare (2001), Rauch (1993) and Sveikauskas (1975) among many others.[2] A somewhat smaller literature has used rent data to estimate this relationship, including in particular Deckle and Eaton (1999) and Roback (1982). While there is a strong empirical relationship between these endogenous variables and population density, determining how much of this relationship is causal is more challenging. One approach to is to use instruments for population density, but finding variables that plausibly satisfy the exclusion restriction of only affecting productivity through population density is difficult.[3] Furthermore, while this line of research has generated reduced-form estimates of the relationship between productivity and population density, there have been few attempts to estimate agglomeration forces structurally or to separately identify them from dispersion forces, consumption amenities and natural production advantages.[4]

Third, another empirical literature has examined the impact of changes in transport infrastructure on employment, land rents, population, productivity and wages. For example, Donaldson (2008) examines the development of the railway network in Colonial India; Baum-Snow (2007), Duranton and Turner (2008), Faber (2009) and Michaels (2008) investigate the construction of highway networks; Gibbons and Machin (2005) examine the Jubilee Underground Line extension in London; and McDonald and Osuji (1995) consider the Chicago Midway Rapid Transit Line. Since the construction of transport infrastructure typically responds to economic incentives, a key concern in this literature is the development of instruments for transport infrastructure. While a number of reduced-form estimates of the impact of transport infrastructure improvements exist, less progress has been made in developing quantitative theoretical frameworks for analyzing their general equilibrium effects. We develop such a quantitative theoretical framework and use the exogenous variation provided by Berlin's division and reunification as a check on its predictions.

Fourth, our paper is related to an empirical literature in economic geography, which has examined the impact of natural experiments on the location of economic activity, including Bleakley and Lin (2010), Brakman et al. (2004), Davis and Weinstein (2002, 2008), Hanson (1996, 1997), Redding and Sturm (2008), and Redding et al. (2010).[5] A key concern of this literature has been the extent to which temporary shocks have permanent effects on the location of economic activity. In contrast, our

[2] Other related approaches use data on employment density (as in Ciccone and Hall 1996) or employment growth (as in Glaeser et al. 1992 and Henderson, Kuncoro and Turner 1995).

[3] For example, lagged population density is often used as an instrument for current population density, but as natural advantages are strongly persistent over time, it is unlikely that lagged population density only affects productivity through current population density. To address such concerns, Rosenthal and Strange (2008) and Combes et al. (2009) use geology as an instrument, making use of the limitations imposed on building heights by geological sub-structure. While an ingenious source of variation, geology is not always a constraint on city formation, and is often most relevant for comparing the high densities in urban areas to the low densities in rural areas, rather than for analysing the internal organization of economic activity at small spatial scales within cities.

[4] For structural estimates of the city-size wage gap using a search model, see Baum-Snow and Pavan (2010).

[5] For surveys of the empirical economic geography literature, see Head and Mayer (2004), Overman et al. (2003) and Redding (2009).

focus is on developing a quantitative model of city structure to determine agglomeration and dispersion forces, while controlling for consumption amenities and natural production advantages. Although the empirical economic geography literature has typically exploited variation across cities or regions, our analysis makes use of data on a much finer spatial scale (thousands of blocks within a city) and for a wider range of economic outcomes than usually available (rents, workplace employment and residence employment).[6]

The remainder of the paper is structured as follows. Section 2 discusses the historical background. Section 3 outlines the model. Section 4 reports some reduced-form empirical results on the impact of Berlin's division and reunification. Section 5 undertakes a quantitative analysis of the model's predictions. Section 6 concludes.

2 Historical Background

The political process that ultimately led to the construction of the Berlin Wall had its origins in the Second World War. While a number of proposals to divide Germany after its eventual defeat were discussed during the early phase of the Second World War, the United States and the Soviet Union backed off such plans towards the end of the war (see for example Franklin 1963 and Kettenacker 1989). Instead it was decided to allocate separate "occupation *zones*" in Germany to the American, British and Soviet armies. Although Berlin was located around 200 kilometers East of the Western border of the Soviet occupation zone, it was decided that the capital of pre-war Germany should be jointly occupied. For this purpose, Berlin was itself divided into separate "occupation *sectors*." The planning process for these zones and sectors began in Spring 1943, negotiations continued during 1944, and the protocol formalizing their boundaries was signed in London in September 1944. The protocol was modified in 1945 to create a small French occupation zone and sector by reducing the size of the British and American zones and sectors.

The key principles underlying the drawing of the boundaries of the occupation sectors in Berlin were that the sectors should be geographically-orientated to correspond with the occupation zones (with the Soviets in the East and the Western Allies in the West); the boundaries between them should respect the boundaries of the existing administrative districts ("Bezirke") of Greater Berlin; and the American, British and Soviet sectors should be approximately equal in population (prior to the creation of the French sector from part of the British sector). The final agreement in July 1945 allocated six districts to the American sector (31 percent of the 1939 population and 24 percent of the area), four districts to the British sector (21 percent of the 1939 population and 19 percent of the area), two districts to the French sector (12 percent of the 1939 population and 12 percent of the

[6] In other recent research using within-city data, Arzaghi and Henderson (2008) consider the location of advertising agencies in Manhattan, and Rossi-Hansberg et al. (2010) examine urban revitalization policies in Richmond, Virginia.

area), and eight districts to the Soviet sector (37 percent of the 1939 population and 46 percent of the area).[7]

The protocol envisioned an Allied Control Council to co-ordinate the joint administration of the occupation zones of Germany and a Kommandatura to fulfil the same function for the occupation sectors of Berlin. Despite Berlin's location around 200 kilometers within the Soviet zone, the protocol made no separate provision for access to Berlin from the Western zones. Instead access by road, rail and air to Berlin was negotiated between the military commanders of the Allied armies to coincide with the Western armies' withdrawal in July 1945 to the boundaries of the occupation zones within Germany agreed in the protocol. With the onset of the Cold War, the relationship between the Western allies and the Soviet Union began to deteriorate. Amidst these growing tensions, plans for closer economic integration in the Western zones and sectors precipitated the collapse of the Allied Control Council and Kommandatura, and led to the associated creation of separate city governments for the Western and Soviet sectors of Berlin. Following a currency reform initiated by the Western allies in June 1948, the Soviet Union blockaded road and rail access to Berlin. As a result, for nearly a year the Western sectors of the city were supplied by air until the restrictions on road and rail access were lifted in May 1949.[8]

As part of this wider change in relations, West Germany was founded in 1949 on the American, British and French occupation zones, and East Germany was founded in the same year on the Soviet occupation zone. While Berlin remained formally occupied by the war-time allies until 1990, West and East Berlin functioned as *de facto* parts of East and West Germany respectively. From 1952 onwards, the border between East and West Germany was closed, but travel between East and West Berlin remained possible, which gave rise to a continuous stream of refugees from East Germany passing through West Berlin on route to West Germany. To stem this flow of refugees, the East German authorities constructed the Berlin Wall in August 1961, which separated West Berlin from East Berlin and the surrounding economic hinterland in East Germany.[9]

The Berlin Wall ran along the Western boundary of the district Mitte, which contained all of

[7] In delineating the occupation sectors, the boundaries of Berlin as a whole were based on the 1920 definition of Greater Berlin ("Gross Berlin"), while the boundaries of the individual districts were based on the amendments to the 1920 district boundaries that came into effect in March 1938. While the districts of Berlin implemented some local administration functions, the boundaries between them had no special significance in the pre-war, division and post-reunification periods, apart from where they defined the boundaries of the occupation sectors during the period of division. For further discussion of the various proposals for sector boundaries, see Sharp (1973).

[8] A formal agreement on access routes from West Germany to West Berlin was only reached in 1971, with the signing of the Four Power Agreement of September 1971 and the subsequent Transit Agreement ("Transitabkommen") of December 1971. This Transit Agreement designated a small number of road, rail and air corridors from West Germany to West Berlin.

[9] The Statistical Yearbook of West Germany reports that 257,308 East German refugees left West Berlin by plane in 1953 following the violent uprisings in June of that year. During 1954-60 this stream of East German refugees departing from West Berlin by plane continued at a rate of approximately 95,000 people per year and ceased with the construction of the Berlin Wall in 1961.

Berlin's main administrative, cultural and educational institutions, most of its commercial services, such as banks and insurance, and a central retail area located around Leipziger Strasse. The Berlin Wall thus separated the Western sectors of Berlin from the pre-war CBD in the Soviet sector. Underground and suburban rail lines, which in the initial post-war years had carried traffic across the sector boundaries, were severed and closed off at the boundary between the Western and Soviet sectors.[10] On the Eastern side of this boundary, the East German authorities constructed a sophisticated system of border fences and other barriers to prevent civilians escaping from East Germany. As a result, all local economic interaction between areas of East and West Berlin on either side of the sector boundary was brought to a close.[11]

While the division of Germany and Berlin appeared to be permanent, the Soviet policies of "Glasnost" and "Perestroika" introduced by Mikhail Gorbachev in 1985 started a process of opening up of Eastern Europe.[12] As part of this wider transformation, large-scale demonstrations in East Germany in 1989 led to the fall of the Berlin Wall on 9 November 1989. In the aftermath of these events, the East German system rapidly began to disintegrate. Only eleven months later East and West Germany were formally reunified on 3 October 1990. In June 1991 the German parliament voted to relocate the seat of the parliament and the majority of the federal ministries back to Berlin. As East and West Berlin again became part of the same city, suburban and underground rail lines and utility networks were rapidly reconnected.

3 Theoretical Model

To guide our empirical analysis, we develop a model in which the internal structure of the city is driven by a tension between production externalities (which favor the concentration of economic activity) and commuting costs and an inelastic supply of land (which favor the dispersion of economic activity).[13] We focus on the canonical approach to modelling urban production externalities, based on knowledge

[10] In a few cases, trains briefly passed through East Berlin territory en route from one part of West Berlin to another. These cases gave rise to ghost stations ("Geisterbahnhöfe") in East Berlin, where trains ran straight through stations patrolled by East German guards without stopping. The underground and suburban rail station "Friedrichstrasse" functioned as one of a limited number of border checkpoints between East and West Berlin.

[11] In the immediate post-war years, around 400,000 people were estimated to cross the boundaries between the Western and Eastern sectors each day (Robinson 1953), but this traffic ceased with the construction of the Berlin Wall. Military personnel from the four occupying powers remained in principle free to travel between the four sectors of Berlin and citizens of West Germany were typically granted visas to travel to East Berlin and East Germany. However, following the construction of the Berlin Wall, the East German authorities refused to allow residents of either West Berlin or East Berlin to travel across the Berlin Wall. As time progressed, a small number of exemptions were introduced by the East German authorities, such as for elderly people of above-working age. Nonetheless, there remained no local economic interaction between areas of East and West Berlin either side of the Berlin Wall.

[12] After the signing of the Basic Treaty ("Grundlagenvertrag ") in December 1972, which recognized "two German states in one German Nation", East and West Germany were accepted as full members of the United Nations. West German opinion polls in the 1980s show that less than 10 percent of the respondents expected a re-unification to occur during their lifetime (Herdegen and Schultz 1993).

[13] A more detailed exposition of the model is contained in a web appendix.

spillovers, and extend LRH to develop a quantitative framework that can be used for empirical analysis. While LRH consider a perfectly symmetric city, we introduce empirically-relevant differences across locations in consumption amenities, natural production advantages and the transport network. The model remains tractable despite this rich pattern of asymmetries, because of heterogeneity in workers' idiosyncratic productivity draws, which are modelled following Eaton and Kortum (2002).

3.1 Preferences and Endowments

We consider a city embedded within a larger economy: pre-war Germany before division, West Germany after division, and modern-day Germany after reunification. The city consists of a set of discrete blocks indexed by $i = 1, ..., S$. The effective supply of land for each block ($L_i = \varphi_i K_i$) depends on geographical land area (K_i) and effective land services per unit of area (φ_i). Geographical land area is held constant, as in our empirical application, since the boundaries of the occupation sectors were defined based on the pre-war boundaries of Greater Berlin. The parameter for effective land services (φ_i) captures, for example, the fraction of geographical land area that is developed and building density on developed land. Both can in principle change over time, and effective land services are determined separately in each year in the quantitative analysis of the model below. Land use is determined endogenously and we denote the fractions of the effective supply of land (L_i) within each block allocated to commercial and residential use by θ_i and $1 - \theta_i$, respectively. The land market is perfectly competitive and rent is accrued by absentee landlords and not spent within the city.[14]

The city produces a single final good, which is sold to (or purchased from) the larger economy at a competitive price.[15] The city is populated by an endogenous measure of $\bar{H}$ agents, each of whom is endowed with one unit of labor that is supplied inelastically with zero disutility.[16] Workers are mobile across blocks within the city and between the city and the larger economy. City blocks are connected by a bilateral transport network, which workers can use to commute between their locations of residence and employment.

Workers are risk neutral, such that the utility of worker ω residing in block i and working in block j is linear in an aggregate consumption index: $U_{ij\omega} = C_{ij\omega}$. This aggregate consumption index is defined over consumption of the single final good ($c_{ij\omega}$) and residential land ($\ell_{ij\omega}$), and is assumed for

[14] While the assumption of absentee landlords follows LRH and is standard, we could alternatively assume that land rent is redistributed lump sum to workers.

[15] Even during division, there was substantial trade between West Berlin and West Germany. In 1963, the ratio of exports to GDP in West Berlin was around 70 percent, with West Germany the largest trade partner. Overall, industrial production accounted for around 50 percent of West Berlin's GDP in this year (American Embassy 1965).

[16] While for simplicity, we model agents and workers as being synonymous, it is straightforward to extend the analysis to introduce families, where each worker has a fixed number of dependents that consume but do not work, and where workers maximize family utility. Similarly, while we focus on labor income, the model can be extended to allow agents to have a constant amount of non-labor income.

simplicity to take the Cobb-Douglas form:[17]

$$C_i\left(c_{ij\omega}, \ell_{ij\omega}\right) = B_i c_{ij\omega}^{\beta} \ell_{ij\omega}^{1-\beta}, \qquad 0 < \beta < 1. \tag{1}$$

where the parameter B_i captures residential consumption amenities (such as green spaces and scenic views) that make the block a more or less pleasant place to live. The final good is traded at zero cost and is chosen as the numeraire, so that $p_i = 1$ for all i.

Income net of commuting costs ($v_{ij\omega}$) depends on the wage per effective unit of labor at the block of employment j (w_j) the loss of labor time in commuting between blocks i and j (d_{ij}) and a stochastic shock to the productivity of a worker ω residing in block i and employed in block j ($z_{ij\omega}$):

$$v_{ij\omega} = \frac{z_{ij\omega} w_j}{d_{ij}}, \qquad d_{ij} = e^{\kappa \tau_{ij}} \geq 1. \tag{2}$$

Commuting costs are modeled here as forgone labor earnings, where the labor time lost in commuting between blocks i and j depends on travel time (τ_{ij}), and where $\kappa > 0$ parameterizes the magnitude of commuting costs.

The stochastic shock $z_{ij\omega}$ is an idiosyncratic productivity draw that determines the worker's effective units of labor in a given employment location. This captures the idea that workers and employment locations may have heterogeneous characteristics that make the pairing of a worker and employment location more or less productive. For a given wage (w_j) and commuting cost (d_{ij}), workers with higher values of $z_{ij\omega}$ receive higher incomes net of commuting costs, because they have more effective units of labor. Workers choose their block of residence before observing their idiosyncratic productivity draws across alternative possible employment locations.[18] Idiosyncratic productivity is drawn from an independent Fréchet distribution with a common scale parameter T and shape parameter ϵ. The cumulative distribution function for worker productivity is therefore:

$$F_{ij}(z) = e^{-Tz^{-\epsilon}}, \qquad T > 0, \ \epsilon > 1, \tag{3}$$

where $\epsilon > 1$ is required for the distribution of worker productivity to have a finite mean.[19] The idiosyncratic productivity draw is independently distributed across both workers and employment locations. Therefore it varies for a given worker ω residing in a given block i across alternative possible blocks of employment j. Since workers with the same productivity draw and the same blocks

[17] For empirical evidence using US data in support of the constant housing expenditure share implied by the Cobb-Douglas functional form, see Davis and Ortalo-Magne (2008).

[18] While we interpret z as an idiosyncratic productivity draw that determines effective units of labor, an equivalent interpretation is as a stochastic shock to commuting costs. In the specification here workers choose their block of residence before their block of employment, but it is straightforward to consider an alternative specification where workers choose their block of employment first, as long as income net of commuting costs in each block of residence varies stochastically (e.g. because of stochastic commuting costs).

[19] While it is straightforward to allow the Fréchet scale parameter, T, to vary across blocks of residence i or blocks of employment j, such variation plays a similar role in the model to differences in consumption amenities or natural advantages in production. Hence we assume that T is common across blocks.

of employment and residence behave symmetrically, we suppress ω and index workers from now on by i, j and z alone, except where otherwise indicated.

Once a worker has chosen a block of residence and her realizations of idiosyncratic productivity for each block of employment have been observed, she chooses her block of employment, residential land use and goods consumption to maximize her utility. In general, workers residing within a given block experience different *ex post* realizations of idiosyncratic productivity, and hence choose different blocks of employment and receive different incomes net of commuting costs.

Population mobility implies that workers must have the same *ex ante* expected utility across all blocks of residence that are populated in equilibrium. Combining population mobility with the first-order conditions for utility maximization, we obtain the following expression for equilibrium residential rents:

$$Q_i^{1-\beta} = \bar{U}^{-1} \beta^{\beta} (1-\beta)^{1-\beta} B_i \bar{v}_i, \tag{4}$$

where $\bar{v}_i \equiv \mathbb{E}[v_i]$ is expected worker income net of commuting costs, where the expectation is over values for idiosyncratic productivity and hence employment locations, and $\bar{U}$ denotes workers' reservation level of expected utility in the larger economy. From this population mobility condition, differences in residential rents across blocks reflect differences in consumption amenities, B_i, and expected worker income, $\bar{v}_i$.

Using the Fréchet distribution for idiosyncratic productivity, expected worker income net of commuting costs can be evaluated as:

$$\bar{v}_i = \Phi_i^{1/\epsilon} \Gamma\left(\frac{\epsilon-1}{\epsilon}\right), \qquad \Phi_i \equiv \left[\sum_{s=1}^{S} T\left(w_s/d_{is}\right)^{\epsilon}\right], \tag{5}$$

where Γ is the Gamma function and recall $d_{ij} = e^{\kappa \tau_{ij}}$. Expected worker income depends on wages and travel times to all potential employment locations. Other things equal, blocks with low travel times (τ_{ij}) to high-wage employment locations have high expected worker income (5) and hence residential rents (4).

Another implication of the Fréchet distribution for worker productivity is that bilateral commuting flows satisfy a gravity equation, as observed empirically.[20] The probability that a worker residing in block i works in block j, π_{ij}, depends on wages at block j and bilateral transport connections between i and j ("bilateral resistance"), but also depends on wages and transport connections for all other possible blocks of employment ("multilateral resistance"). These commuting probabilities yield the following relationship between workplace employment (H_{Mj}) in each block j and residence employment

[20] An empirical literature finds that commuting flows are well described by such a gravity equation relationship, including for example Erlander and Stewart (1990) and Sen and Smith (1995). For empirical evidence for pre-war Berlin on the role of distance in dampening commuting flows, see Feder (1939).

in all blocks i (H_{Ri}):

$$H_{Mj} = \sum_{i=1}^{S} \pi_{ij} H_{Ri}, \qquad \pi_{ij} = \frac{(w_j/d_{ij})^{\epsilon}}{\sum_{s=1}^{S} (w_s/d_{is})^{\epsilon}}. \tag{6}$$

In contrast to LRH, the supply of commuters to a block is continuous in the wage paid as a result of heterogeneity in worker productivity across potential blocks of employment. Even when block j offers a higher wage net of commuting costs (w_j/d_{ij}) for residents of block i, not all of these residents commute to block j, because worker income net of commuting costs ($v_{ij\omega} = z_{ij\omega} w_j/d_{ij}$) also depends on the realized values of worker productivity.

Residential land market clearing requires that the total demand for residential land equals the supply of land allocated to residential use:

$$\mathbb{E}\left[\ell_{ijz}\right] H_{Ri} = \frac{H_{Ri} \bar{U}^{\frac{1}{1-\beta}}}{\beta^{\frac{\beta}{1-\beta}} B_i^{\frac{1}{1-\beta}} \bar{v}_i^{\frac{\beta}{1-\beta}}} = (1-\theta_i) L_i, \tag{7}$$

where $\mathbb{E}\left[\ell_{ijz}\right]$ denotes expected residential land use and the expectation is again over values for worker productivity and hence employment locations; the first equation uses population mobility and utility maximization.

3.2 Production

The final good is produced under conditions of perfect competition and according to a constant returns to scale technology. For simplicity, we assume that this production technology is Cobb-Douglas, and hence the aggregate amount of final goods output produced in block j is:

$$X_j = A_j \left(\widetilde{H_{Mj}}\right)^{\alpha} (\theta_j L_j)^{1-\alpha},$$

where A_j denotes final goods productivity; $\widetilde{H_{Mj}}$ is effective employment, which is adjusted for worker productivity and labor time lost in commuting.

The productivity of final goods production (A_j) depends on a parameter capturing natural advantages (a_j), such as the gradient of the land or the presence of a natural supply of water, and agglomeration forces (Υ_j). Following LRH and a long literature in economics, we assume that these agglomeration forces take the form of knowledge spillovers that are increasing in the surrounding density of economic activity:[21]

$$A_j = \Upsilon_j^{\gamma} a_j, \qquad 0 \le \gamma < 1 \tag{8}$$

$$\Upsilon_j \equiv \sum_{s=1}^{S} e^{-\delta \tau_{js}} \left(\frac{\widetilde{H_{Ms}}}{K_s}\right), \qquad \delta \ge 0. \tag{9}$$

[21] See also Alonso (1964), Fujita and Ogawa (1982), Lucas (2000), Muth (1969), Mills (1969) and Sveikauskas (1975). While we follow this long literature in modeling agglomeration forces as knowledge spillovers, other formalizations are possible, as discussed for example in Duranton and Puga (2004).

In this specification, knowledge spillovers depend on effective employment ($\widetilde{H_{Ms}}$) per unit of geographical land area (K_s). Effective employment densities in all blocks contribute towards knowledge spillovers, with weights depending on bilateral travel times (τ_{js}). The parameter γ determines the relative importance of knowledge spillovers for productivity, with $\gamma = 0$ corresponding to the special case of exogenous productivity. The parameter $\delta \geq 0$ determines the rate of decay of knowledge spillovers with travel time, where $0 \leq e^{-\delta\tau_{js}} \leq 1$.

Firms choose their block of production, effective employment and commercial land use to maximize their profits taking as given goods and factor prices, productivity and the location decisions of other firms and workers. From the first-order conditions for profit maximization and the requirement that zero profits are made if the final good is produced, equilibrium commercial rent for each block with positive employment is determined as:

$$q_j = (1-\alpha)\left(\frac{\alpha}{w_j}\right)^{\frac{\alpha}{1-\alpha}} A_j^{\frac{1}{1-\alpha}}. \tag{10}$$

Higher productivity, A_j, and lower wages, w_j, both make a block more attractive for production and imply higher commercial rent (10).

Commercial land market clearing requires that the demand for commercial land (ι_j) equals the supply of land allocated to commercial use. Using the first-order conditions for profit maximization, this commercial land market clearing condition can be written as:

$$\iota_j = \widetilde{H_{Mj}}\left(\frac{w_j}{\alpha A_j}\right)^{\frac{1}{1-\alpha}} = \theta_j L_j \tag{11}$$

3.3 Labor and Land Market Clearing

Equilibrium wages are determined by labor market clearing, which requires that payments for effective labor input equal income net of commuting costs:

$$w_j\widetilde{H_{Mj}} = \sum_{i=1}^{S} \pi_{ij}\bar{v}_i H_{Ri}, \qquad \pi_{ij} = \frac{(w_j/d_{ij})^{\epsilon}}{\sum_{s=1}^{S}(w_s/d_{is})^{\epsilon}}. \tag{12}$$

To determine the equilibrium allocation of land between residential and commercial use, we use no-arbitrage between residential and commercial rents. Land is allocated to whichever use offers the highest rent net of the tax equivalent of land use regulations. As only the relative tax equivalent of land use regulations matters for the allocation of land, we normalize the tax equivalent of land use regulations for residential land to equal one, and allow the tax equivalent of land use regulations for commercial land to vary across blocks ($\Delta_i = 1 + \kappa_i$). No-arbitrage between alternative uses of land implies:

$$\theta_i = \begin{cases} 1 & \text{if } q_i > \Delta_i Q_i \\ \widehat{\theta}_i & \text{if } q_i = \Delta_i Q_i \\ 0 & \text{if } q_i < \Delta_i Q_i \end{cases}. \tag{13}$$

Combining utility maximization, population mobility and residential land market clearing with profit maximization, zero profits and commercial land market clearing, $\widehat{\theta}_i$ for incompletely specialized blocks is implicitly defined by:

$$(1-\alpha)\left(\frac{\widetilde{H_{Mi}}}{\widehat{\theta}_i L_i}\right)^{\alpha} A_i = q_i = \Delta_i Q_i = \Delta_i \frac{1-\beta}{1-\widehat{\theta}_i} \bar{v}_i \frac{H_{Ri}}{L_i}.$$

Positive fractions of land are only allocated to both commercial and residential use within the same block if residential rents and commercial rents net of the tax equivalent of land use regulations are equalized within that block.

3.4 Berlin's Division and Reunification

We use the model to examine the impact of division and reunification on the distribution of economic activity within West Berlin. We focus on West Berlin, since it remained a market-based economy after division and we would therefore expect the mechanisms in the model to apply.[22] In the remainder of this section, we discuss the model's qualitative predictions for the impact of division. In the ensuing sections, we present non-parametric evidence on these qualitative predictions, before turning, in a later section, to a quantitative analysis of the model's predictions.

The model points to three key channels through which division affects the distribution of economic activity within West Berlin. First, firms in West Berlin cease to benefit from production externalities from employment centres in East Berlin. This reduction in production externalities reduces productivity, which in turn reduces rents and employment. The loss in production externalities is greatest for areas of West Berlin close to employment centres in East Berlin, reducing rents and employment in these parts of West Berlin relative to those elsewhere in West Berlin.

Second, firms in West Berlin lose access to flows of commuters from residential concentrations in East Berlin. This reduction in commuting flows increases the wage required to attract a given level of effective employment, which reduces rents and employment. The loss of commuting flows is greatest for areas of West Berlin close to residential concentrations in East Berlin, reducing rents and employment in these parts of West Berlin relative to those elsewhere in West Berlin.

Third, residents in West Berlin lose access to employment centres in East Berlin. This reduction in employment opportunities reduces expected worker income, which in turn reduces rents and residential population. The loss in employment opportunities is greatest for areas of West Berlin close to employment centres in East Berlin, reducing rents and residential population in these parts of West Berlin relative to those elsewhere in West Berlin.

[22] In contrast, the distribution of economic activity in East Berlin during division was heavily influenced by central planning, which is unlikely to mimic market forces.

Each of these three channels operates simultaneously and there are general equilibrium interactions between them. Thus the expected income of West Berlin residents falls not only because of the direct loss of Eastern employment opportunities, but also because the lost Eastern production externalities reduce the wages paid by firms located in West Berlin. The mechanisms that restore equilibrium in the model are changes in wages, commercial rents and residential rents. Employment and population reallocate across locations within West Berlin and to and from the larger West German economy until wages and rents have adjusted such that firms make zero profits in all locations with positive production, workers are indifferent across all populated locations, and there are no-arbitrage opportunities in reallocating land between commercial and residential use.

For each of the three channels above, the impact of division depends on proximity to economic activity in East Berlin. The pre-war CBD in the district Mitte contained by far the largest concentration of employment and one of the largest concentrations of residents in East Berlin. Furthermore, it is one of the parts of East Berlin closest to West Berlin. Therefore, taking all three channels together, a key qualitative prediction of the model is that division leads to a decline in rents, workplace employment and residence employment in areas of West Berlin close to the pre-war CBD relative to other parts of West Berlin.[23]

To the extent that reunification involves a re-integration of West Berlin with employment and residential concentrations in East Berlin, we would expect to observe the reverse pattern of results in response to reunification. Comparisons of division and reunification are, however, more subtle than this would suggest. If knowledge spillovers are sufficiently strong relative to the differences across locations in consumption amenities, natural production advantages and transport connections, the model can exhibit multiple equilibria. In this case, division could shift the distribution of economic activity in West Berlin between multiple equilibria, and reunification need not necessarily reverse the impact of division. More generally, the level and distribution of economic activity within East Berlin is likely to have changed between the pre-war and division periods, so that reunification is a different shock from division. Nevertheless, despite these caveats, reintegration with employment and residential concentrations in East Berlin would be expected to raise relative rents, workplace employment and residence employment in areas of West Berlin close to those concentrations.

In the model, the mobility of workers and immobility of land implies that rents are a summary statistic for the relative attractiveness of a location for production and residence. Therefore, in our analysis of the model's qualitative predictions, we focus on the impact of division and reunification

[23] As the Berlin Wall also separated West Berlin from its East German hinterland, similar effects could in principle operate for areas of West Berlin close to employment and residential concentrations in the East German hinterland. However, given the large geographical area encompassed by the boundaries of Greater Berlin (which includes extensive parks, forests and lakes), and given the relatively undeveloped nature of the East German hinterland, these effects are likely to be small relative to those for areas of West Berlin close to the pre-war CBD.

on West Berlin's rent gradient relative to the pre-war CBD. As the model imposes structure on the relationship between rents, workplace employment and residence employment, we return to examine the relationship between these three variables when we evaluate the model's quantitative predictions for the impact of division and reunification.

4 Data Description

Data are available for Berlin at a number of different levels of spatial disaggregation, including districts ("Bezirke"), statistical areas ("Gebiete") and statistical blocks ("blocke").[24] The occupation sectors of Berlin were defined based on 1938 district boundaries, and hence we use these district boundaries in our statistical analysis throughout the pre-war, division and reunification periods.[25] Blocks are a partition of the surface area of Greater Berlin, and aggregate to areas, which in turn aggregate to districts. West Berlin consists of twelve districts, around 90 areas and around 9,000 blocks. These blocks have an average area of around 200 metres squared and an average 2006 population of around 300, permitting a relatively fine characterization of the spatial distribution of economic activity.[26]

The quantitative analysis of the model requires three key sets of data: land rents, workplace employment and residence employment. Our land rent data for 1986 and 2006 are standard land values ("Bodenrichtwerte") per square metre of land area as measured by a German committee of valuation experts ("Gutachterausschuss für Grundstückswerte"). Data are reported for each block on the assessed land value of a representative undeveloped property or the fair market value of a developed property if it were not developed. The representative property is defined to be homogenous in terms of its physical attributes, such as the density of development, and the market values are based on a statistical analysis of market transactions during the relevant time period. Where insufficient market transactions are available, the market value is adjusted in line with the trend in a wider neighborhood and the judgment of the valuation committee. These standardized land values are highly regarded in the German real estate community and are used by government as an input in determining taxes related to property. Data are also reported for each block on the typical density of development, measured as the ratio of building floor space to geographical land area ("GFZ"), and on land use, which is classified in terms of commercial, residential and mixed.

Our main source of data on land rent for the pre-WWII period is Kalweit (1937). Kalweit was a

[24] For further discussion concerning the data definitions and sources, see the data appendix.

[25] A decree published in April 1938 specified minor revisions to the district boundaries, as originally specified in the 1920 law that defined Greater Berlin. During division, the East Berlin authorities created three new districts (Hellersdorf, Marzahn and Hohenschoenhausen), which were sub-divisions of Weissensee and Lichtenberg. Except for a few other minor changes, as discussed in Elkins and Hoffmeister (1988), the boundaries of the districts remained unchanged during the post-war period until an administrative reform of 2001, which reduced the overall number of districts.

[26] Outlying blocks typically have larger areas and lower populations than those that are more centrally located. Some of the larger blocks comprise forests and parks, which account for around twenty percent of the area of West Berlin, while another six percent is accounted for by lakes and rivers (Friedensburg 1967).

chartered building surveyor ("Gerichtlich Beeideter Bausachverständiger"), who received a government commission for the assessment of standard land values ("Baustellenwerte") for 1936. These land values were intended to provide official and representative guides for private and public investors in Berlin's real estate market. The land values are reported per square metre of land area in a street atlas, which contains representative land values for each street or segment of street in Greater Berlin. As with the more recent valuation committee data, the assessed land values are for a representative undeveloped property or the fair market value of a developed property if it were not developed. The representative property is again defined to be homogenous in terms of its physical attributes, such as the density of development. Data are also reported on the typical density of development, measured as the ratio of building floor space to geographical land area. Using Geographical Information Systems (GIS) software, we matched the streets or segments of streets in Kalweit (1937) to the blocks in which they fell, and aggregated the street-level rent data to the block-level.[27] As robustness checks, we use similar land values data for 1928 from Kalweit (1929) and data for 1938 compiled in Runge (1950) as part of an official commission for the post-war occupation authorities. Since our empirical analysis is based on relative variation in rents across locations within Berlin, and to ensure comparable units for rents over time, we normalize rents in each year by their mean, so that the resulting distribution of normalized rents has a mean of one in each year.

Our data on employment for 1987 are from the West Berlin population census, which reports both residence employment and workplace employment by block. Our data on residence employment for 2006 combine information from two sources. From the register of the Federal Agency of Labor, we obtained a tabulation of residence employment for all employees with social security liability by traffic cell ("Verkehrszellen"), of which there are 338 in Berlin. From the Berlin Register of Residents, we obtained a tabulation of population by block.[28] Taking these two data sources together, we construct residence employment for each block by assuming that labor force participation is the same across blocks within each traffic cell.[29] As the self-employed and some other categories of workers are not liable for social security, we scale residence employment in each block by the aggregate ratio of social security employment to total employment for Berlin as a whole. Our data on workplace employment for 2003 are from the Berlin Business Register, from which we obtained a tabulation by block of workplace employment for all employees with social security liability. To take account of the self-employed and other categories of workers, we again scale workplace employment in each block by the aggregate ratio of social security employment to total employment for Berlin as a whole.

[27] Street names and layout have in some cases changed since the pre-war period. To facilitate the matching of streets to blocks, we compared modern and historical maps, and consulted historical listings of changes in street names.

[28] As the West German population census of 1987 was the last population census undertaken in Germany, more recent census data on population are not available.

[29] Empirically, we find little variation in rates of labor force participation across traffic cells within Berlin in 2006, suggesting that the assumption of a constant rate of labor force participation is a reasonable approximation.

Our sources for pre-war employment data are the industry and population censuses of 1933, which report workplace employment, residence employment and population for each district of Berlin. The 1933 population census also reports population by street or segment of street in Berlin. Using a contemporary GIS template that matches streets to blocks, and taking account of changes in street names over time using historical sources, we constructed population for each block. To obtain residence employment, we combine these block-level population data with our district-level information on labor force participation, assuming a constant rate of labor force participation across blocks within each district.[30] From the 1933 industry census, we obtain detailed workplace employment data for several hundred disaggregated industries by district of Berlin. Combining these data with GIS information from historical maps on the location of establishments by industry and size classification within Berlin, we constructed workplace employment for each block.

Finally, we combine our data on rents, residence employment and workplace employment with GIS information on the geographical land area of blocks, the suburban ("S-Bahn") and underground ("U-Bahn") railway network in 1936, 1986 and 2006, and other block characteristics, such as proximity to parks, lakes, rivers, canals and schools, the location of government buildings, the extent of destruction during the Second World War, and eligibility for government subsidies.

5 Empirical Analysis

In this section, we examine the qualitative predictions of the model for the impact of division and reunification on West Berlin's rent gradient. We first display the evolution of Berlin's rent gradient over time. We next estimate a "difference-in-differences" econometric specification, which allows us to control for other potential determinants of rents, and enables us to compare the model's explanation to alternative possible explanations.

5.1 Evolution of the Rent Gradient over Time

A distinctive feature of the model is that it allows for a rich internal organization of economic activity within the city without imposing mono-centricity. To examine the rent gradient empirically without imposing a prior structure on the data, Map 1 displays the distribution of rents in Reichsmark in 1936 across five discrete classes, which are chosen to group together similar rent values within classes and maximize the differences in rent values between classes. Blank spaces correspond to roads, railways, parks, canals, lakes, rivers, and other areas of undeveloped land. As apparent from the map, Berlin's rent gradient in 1936 was in fact approximately mono-centric, with the highest rent values concentrated in the district Mitte just East of the Berlin Wall. Based on this rent gradient, we determine the central

[30] Empirically, we again find little variation in rates of labor force participation across districts of Berlin in 1933, suggesting that the assumption of a constant rate of labor force participation is a reasonable approximation.

point of the pre-war Central Business District (CBD) as the intersection of Friedrich Str. and Leipziger Str., which lies close to the U-Bahn station "Stadtmitte," and is approximately one kilometer East of where the Berlin Wall intersected Leipziger Str. at Potsdamer Platz.

Around this central point, there are concentric rings of progressively lower rents, which define an ellipse around the pre-war CBD in Map 1. From the path of the Berlin Wall shown in Map 1, it is clear that areas of West Berlin were differentially affected by division. For example, Kreuzburg, Tiergarten and Wedding are immediately adjacent to Mitte and lost access to a nearby dense concentration of economic activity. In contrast, the white area immediately West of Mitte is the Tiergarten park. As a result of this area of open space, Charlottenburg and Wilmersdorf were further away from the pre-war CBD, and hence were less adversely affected by the loss of access to it.[31] Just to the South-West of the Tiergarten in Wilmersdorf, the Kudamm ("Kurfürstendamm") had developed into a fashionable shopping area prior to the Second World War. As this area was both part of the ellipse of concentrated development surrounding the pre-war CBD and relatively centrally located within West Berlin, this area was a natural possible location for the emergence of West Berlin's CBD during division.

To provide another perspective, Figure 1 displays Berlin's 1936 rent gradient across blocks in three dimensions using a latitude and longitude grid.[32] In this figure and the remainder of our empirical analysis, rents are normalized to have a mean of one in each year in order to focus on changes in relative rents across locations. Again the pre-war CBD in Mitte is evident as the highest rent peak. Also evident are the concentric rings of progressively lower rents around the pre-war CBD, including the area around the Kudamm, as well as the area of open space in between the Kudamm and Mitte. To provide a point of comparison, Figure 2 displays the 1936 rent gradient only for blocks in West Berlin. As apparent from this panel, the two areas of West Berlin with the highest pre-war rents were parts of the concentric ring around the pre-war CBD: the area around the Kudamm and the area just West of Potsdamer Platz and the line of the Berlin Wall, which contained high-density office and retail development surrounding the "Anhalter Bahnhof" mainline and suburban rail station. Both areas were distinct from the main center of government administration, which was concentrated around Wilhelmstrasse in the district Mitte.

To illustrate the impact of division, Figure 3 displays the 1986 rent gradient across blocks within West Berlin. Comparing Figures 2 and 3, several striking features are apparent. First, one of the pre-war rent peaks in West Berlin – the area just West of Potsdamer Platz – is entirely eliminated following division, as this area ceased to be an important center of commercial and retail activity.

[31] West Berlin's East-West and North-South axes are approximately 30 kilometers long and the Westernmost edge of the Tiergarten is approximately 3 kilometers from the Berlin Wall.

[32] To construct the figure, blocks are first arrayed on a discrete grid of around 4,000 points of 0.0025 intervals of latitude and longitude. A surface is next constructed through the points in the discrete grid using linear (triangular) interpolation, such that the surface passes through the observations for each block. The same pattern is observed for the rent gradient for a wide range of intervals for the discrete grid.

Second, West Berlin's CBD during division coincided with the other pre-war rent peak in the area around the Kudamm, which was relatively centrally located within West Berlin. The period of division saw a westwards consolidation of the high land values in this area relative to the pre-war period. Both features are consistent with the role played by the surrounding concentration of economic activity in determining the rent gradient in the model. Further evidence on the geographical distribution of the change in rents following division is provided in Map 2. As evident from the map, the largest declines in rents are concentrated around those segments of the Berlin Wall surrounding the pre-war CBD, with relatively little evidence of declines in rents on sections of the Berlin Wall remote from the pre-war CBD. The only other area of the city with comparable declines in rents is found in Spandau, which was the site of Siemens's huge industrial and residential complex ("Siemensstadt"), which relocated to Munich following the Second World War.

To illustrate the impact of reunification, Figure 4 displays Berlin's rent gradient in 2006. Comparing this figure and the previous three figures, several features are again apparent. First, there is a re-emergence of the second rent peak in West Berlin in the area just West of Potsdamer Platz, which became the site of a large commercial development by Daimler-Benz, Sony and the German businessman Otto Beisheim. Again this area was distinct from the main center of government activity, which was concentrated around the parliament building ("Reichstag") around one kilometer North. Comparing Maps 2 and 3, it is quite striking how the areas of Kreuzberg, Tiergarten and Wedding surrounding the pre-war CBD, which experienced the largest declines in rents from 1936-86, exhibit the largest increases in rents from 1986-2006. Second, following reunification, the pre-war CBD in Mitte has again become a major center of economic activity. Third, while Mitte and the area just West of Potsdamer Platz had developed into major rent peaks by 2006, there remains a substantial rent peak in the area around the Kudamm.

Taken together, these findings suggest that division and reunification did indeed impact differentially on areas of West Berlin depending on their location relative to pre-war concentrations of economic activity. In the next section, we examine the robustness of these findings to controlling for other potential determinants of rents.

5.2 Difference-in-Difference Estimates

The model emphasizes two key sets of determinants of rents. First, there are exogenous differences across blocks in natural advantage and consumption amenities. Second, there are endogenous differences across blocks in accessibility to production externalities and commuting possibilities, which depend on the transport network and the spatial distribution of workplace and residence employment. To explore the role of these two key sets of determinants, we begin with the following reduced-form empirical specification:

$$\ln Q_{it} = \eta_i + f(a_{it}) + \ln X_i \mu_t + \nu_t + u_{it}, \tag{14}$$

where i denotes blocks and t corresponds to time; Q_{it} is the normalized land rent (i.e. the land rent divided by its mean in each year); η_i is an unobserved block fixed effect; $f(a_{it})$ is an arbitrary function of accessibility to concentrations of economic activity within the city, a_{it}; X_i are observable block characteristics and μ_t are time-varying coefficients on these observable block characteristics; ν_t is a time fixed effect; and u_{it} is a stochastic error.

To examine the impact of division or reunification, we take long differences in (14) to obtain the following cross-section regression specification:

$$\triangle \ln Q_i = \psi + g(a_{it}, a_{it-T}) + \ln X_i \zeta + \chi_i, \tag{15}$$

where $\triangle$ is the difference operator and T is the time interval for the differencing; $\psi = \nu_t - \nu_{t-T}$ is the regression constant; $g(a_{it}, a_{it-T})$ is a function of accessibility in the two time periods; $\zeta = \mu_t - \mu_{t-T}$; and $\chi_i = u_{it} - u_{it-T}$.

A key empirical challenge in estimating (15) is that changes in rents and accessibility are typically jointly and endogenously determined. To address this challenge, we exploit the exogenous source of variation in accessibility provided by Berlin's division and reunification. We model the change in accessibility of each block in West Berlin as a non-parametric function of distance from the pre-war CBD East of the Berlin Wall, which yields our baseline econometric specification:

$$\triangle \ln Q_i = \psi + \sum_{j=1}^{J} d_{ij} \xi_j + \ln X_i \zeta + \chi_i, \tag{16}$$

where d_{ij} is a $(0, 1)$ dummy variable which equals one if block i lies within distance grid cell j and zero otherwise; and ξ_j is a coefficient to be estimated for each distance grid cell j. We begin by considering distance grid cells of 500 meter intervals. As the minimum distance to the pre-war CBD in West Berlin is around 0.75 kilometers, our first distance grid cell is for blocks less than 1.25 kilometers from the pre-war centre, and we consider grid cells up to 3.25-3.75 kilometers from the pre-war centre, with the excluded category given by blocks more than 3.75 kilometers away.[33] We discuss the robustness of the results to alternative specifications below. We estimate this specification both for division (taking differences between 1936 and 1986) and for reunification (taking differences between 1986 and 2006). To allow the errors for neighboring blocks to be correlated, we cluster the standard errors by the 90 statistical areas ("Gebiete") in our sample.[34]

[33] There are 87 West Berlin blocks within 1.25 kilometers of the pre-war CBD and 1,749 West Berlin blocks within 3.75 kilometers of the pre-war CBD. The maximum distance to the pre-war CBD across West Berlin blocks is around 23 kilometers.

[34] Bertrand et al. (2004) examine several approaches to serial correlation and show that clustering the standard errors performs well in settings with at least 50 clusters as in our application.

This baseline econometric specification has a "difference-in-difference" interpretation, where the first difference is over time and the second difference is between areas of West Berlin at differing distances from the pre-war CBD East of the Berlin Wall. The key coefficients of interest on the distance grid cells, ξ_j, capture the treatment effects of division or reunification on blocks in West Berlin proximate to the pre-war CBD. Our specification allows for a flexible functional form for the relationship between changes in rents and distance from the pre-war CBD. We incorporate time-invariant unobserved determinants of the level of rents, η_i, which are differenced out when we take long differences. We also allow observable block characteristics to have time-varying effects on rents, μ_t. We consider a wide range of observable block characteristics as controls, X_i, including block geographical land area, the ratio of building floor space to geographical land area, distance to the nearest U-Bahn and S-Bahn station in 1936, 1986 and 2006, distance to the nearest park, distance to the nearest canal, lake or river, distance to the nearest school, the percentage of the block's area destroyed during the Second World War, and the district of Berlin in which the block is located. While we wish to demonstrate the robustness of our results to the inclusion of these controls, some of them could be affected by division or reunification, and hence we report results both with and without the controls.

Table 1 reports the results of estimating our baseline specification (16) for division. In Column (1), which includes only the distance grid cells, the estimated treatment effect of division is negative, statistically significant and declines monotonically with distance from the pre-war CBD. From the estimated coefficients, West Berlin blocks less than 1.25 kilometers from the pre-war CBD experienced a 300 percent reduction in rents between 1936 and 1986 relative to West Berlin blocks more than 3.75 kilometers away. Together the six distance grid cells alone explain around one fifth of the variation in rent changes following division ($R^2 = 0.21$), which suggests a powerful effect of proximity to the pre-war concentration of economic activity in East Berlin. In Column (2), we include district fixed effects, which control for potential variation in the implementation of city policies across districts and across the occupation sectors that were based on these districts. While districts differ substantially in terms of their centrality relative to the pre-war CBD, this specification abstracts from any variation across districts. Even focusing solely on variation in proximity to the pre-war CBD within districts, we continue to find strong and statistically significant effects.

In Column (3), we further augment the specification with our full set of controls for observable block characteristics. In this specification too, we find a strong and statistically significant division treatment. While the estimated coefficient falls somewhat in magnitude, a number of the controls, such as the ratio of building floor space to geographical land area in 1986, are likely to be influenced by division. After including these controls, the treatment effect of division is statistically significant up to 2.25 kilometers from the pre-war CBD. In Column (4), we include additional policy controls for blocks that qualified for government financial support in 2006 or that contained a federal government building in 2006. Since these controls are included in our specification for reunification below, we include them here for division to check whether blocks with these characteristics differed in terms of their rent growth even prior to reunification.

In Columns (5)-(6), we examine whether it is really proximity to the pre-war CBD that matters or whether other distance measures are also important. In Column (5), we include distance grid cells defined over the same 500 meter intervals for distance to the inner boundary where the Berlin Wall separated East and West Berlin and for distance to the outer boundary where the Berlin Wall separated West Berlin from East Germany. While distance to the pre-war CBD is measured relative to a fixed point in Mitte in East Berlin, distance to the inner boundary is measured relative to the closest point on the section of the Berlin Wall that separated East and West Berlin. Although we continue to find a strong and statistically significant negative effect of proximity to the pre-war CBD, we find a very different pattern of results for proximity to the inner and outer boundaries. Both sets of coefficients are positive and an order of magnitude smaller in size, with only some of the outer-boundary coefficients statistically significant at conventional critical values. This pattern of results is reassuring, because it suggests that the reorientation of West Berlin's rent gradient following division did indeed reflect a loss of access to the pre-war CBD rather than other considerations associated with being close to the Berlin Wall, such as its disamenity value.[35] In Column (6), we show that we find a similar pattern of results if we include distance grid cells for proximity to the CBD-West on the Kudamm, again confirming the importance of the loss of access to the pre-war CBD.

Table 2 reports the results of estimating our baseline specification (16) for reunification. We find a positive and statistically significant reunification treatment, which declines monotonically with distance from the pre-war CBD. The reunification effect treatment is somewhat smaller in magnitude than the division treatment, which is consistent with the lower relative levels of economic activity in East Berlin and East Germany at the time of reunification than prior to the Second World War and with the smaller time interval over which to observe the effects. In Column (1), which includes only the distance grid cells, we find that West Berlin blocks less than 1.25 kilometers from the pre-war CBD experienced a 143 percent increase in rents following reunification relative to West Berlin blocks more than 3.75 kilometers away. Together the six distance grid cells now explain around one tenth of the variation in observed rent changes ($R^2 = 0.08$).

[35] In principle, West Berlin's loss of access to its economic hinterland in East Germany could generate a negative treatment effect of proximity to the outer boundary. As discussed above, the absence of such an effect is unsurprising, because of the relative underdevelopment of the East German hinterland and the large geographical area of Greater Berlin, which together ensured small net commuting even prior to the Second World War. In 1933, total workplace and residence employment in Greater Berlin were 1,628,622 and 1,591,723, respectively, implying net inward commuting of 36,899.

When the specification in Column (1) is augmented with district fixed effects (Column 2) or with our controls for block characteristics (Column 3), we continue to find the same pattern of results. Further augmenting the specification with controls for whether a block qualified for government financial support in 2006 or contained a federal government building in 2006 (Column 4) has little effect on the estimated coefficients. After including both sets of controls, we find that the reunification treatment effect is statistically significant up to around 1.75 kilometers from the pre-war CBD. In Column (5), we show that the reunification treatment, like the division treatment, is driven by proximity to the pre-war CBD rather than proximity to the inner and outer boundaries of West Berlin. In Column (6), we show that we find a similar pattern of results if we control for proximity to the CBD-West on the Kudamm. Taken together, the results for re-unification provide further confirmation of the importance of proximity to the surrounding concentration of economic activity.

While not reported in the interests of brevity, we have also undertaken a number of further robustness checks. We find similar results if we include a quadratic in observable block characteristics to allow for a more flexible functional form for the controls or if we sequentially exclude districts from the sample. To check that the areas of West Berlin proximate to the pre-war CBD were not declining even prior to division, we undertake a placebo analysis using our 1928 rents data, and find no relationship between the log difference in normalized rents from 1928-36 and distance from the pre-war CBD. To check that the areas of West Berlin proximate to the pre-war CBD were not expanding even prior to reunification, we examine district ("Bezirke") data on employment by workplace and residence, and find no evidence of an increase in the employment shares of the districts closest to the pre-war CBD in the decades immediately preceding reunification. This absence of pre-trends for division and reunification is confirmed in historical discussions of the spatial distribution of economic activity within Berlin, as for example in Elkins and Hoffmeister (1988).

5.3 Transport Access

Another source of variation in our data is the way in which the Berlin Wall intersected the pre-war transport network. To the extent that the value of proximity to a railway station depends on the size of the network to which the station is connected, division could differentially affect land values for blocks close to and far from railway stations. To examine this differential impact, we split our sample into blocks less than and more than 250 metres from a pre-war suburban or underground railway station, and estimate locally-weighted linear least squares regressions of the long difference in normalized land rents against distance from the pre-war CBD. This specification has a "difference-in-difference-in-difference" interpretation, where the first difference is over time, the second difference is between areas of West Berlin at varying distances from the pre-war CBD, and the third difference is between areas of West Berlin close to and far from a railway station at a given distance from the pre-war CBD.

Figure 5 displays the results for division. Consistent with our findings from the distance grid cells specification above, there is a negative and non-linear relationship between changes in rents and distance to the pre-war CBD. In line with division reducing the overall size of the transport network, blocks close to railway stations typically experienced a reduction in rents relative to those further from railway stations at a given distance from the pre-war CBD. Figure 6 displays the results for reunification using the same sample split based on the pre-war transport network. Here, we observe the reverse pattern of results, with a positive and non-linear relationship between changes in rents and distance to the pre-war CBD. Consistent with reunification increasing the overall size of the transport network, blocks close to railway stations experienced an increase in rents relative to those further from railway stations at a given distance from the pre-war CBD.

While distance to the nearest suburban or underground railway station provides a simple measure of connectivity to the transport network, we find similar results in other specifications. As a robustness check, we calculated for each West Berlin block a measure of Eastern transport access loss, equal to its average travel time to all blocks in East Berlin weighted by normalized rents in each East Berlin block. To examine blocks at a similar distance from the pre-war CBD with different levels of Eastern transport access loss, we consider distance grid cells of 500 meter intervals from the pre-war CBD, and split the sample of blocks within each cell into those with above and below-median Eastern transport access loss for that cell. Repeating the analysis in Figures 5 and 6 using this alternative sample split, we find a similar pattern of results. Following division, blocks with above average Eastern transport access loss experience declines in rents relative to other blocks within the same distance grid cell, whereas these blocks experience rises in relative rents following re-unification.

6 Quantitative Analysis

Taken together, the results of the previous sections provide robust evidence of an impact of division and reunification on West Berlin's rent gradient and support the idea that this change in the rent gradient is driven by the change in access to the surrounding concentration of economic activity. In this section, we now turn to examine whether the model can account quantitatively for the observed changes in the distribution of rents, workplace employment and residence employment following division and reunification. We use the quantitative analysis to determine the values of the model's parameters, including the strength of agglomeration and congestion forces.

Our analysis of the model's quantitative properties proceeds as follows. First, for a given value of the model's parameters $\{\alpha,\ \beta,\ \gamma,\ T,\ \epsilon,\ \kappa,\ \delta,\ \bar{U}\}$, we calibrate the unobserved values of natural production advantages (a_i), residential consumption amenities (B_i), and effective land services (φ_i) such that the observed distribution of rents, workplace employment and residence employment across blocks is an equilibrium of the model. These unobservables are determined as residuals using the structure of the model and we undertake this calibration for each year separately (1936, 1986, 2006).

Second, we search over parameter values to minimize the change in the spatial pattern of the residuals as a result of division or reunification. That is, we search for the parameter values for which the impact of division or reunification on the organization of economic activity within Berlin is largely explained by endogenous changes in agglomeration and dispersion forces rather than by changes in natural advantages, consumption amenities and effective land services. We undertake this search over parameter values separately for the comparisons of the pre-war and division periods and the division and reunification periods to allow parameters, such as the strength of agglomeration and dispersion forces, to change over time.

One key advantage of this approach to determining agglomeration and dispersion forces is that we allow for arbitrary variation in unobserved natural production advantages, residential consumption amenities and effective land services across blocks. We identify the model's parameters by minimizing the change in the spatial pattern of these residuals. Another key advantage of this approach is that it is robust to multiple equilibria, whose potential existence is a generic feature of models of agglomeration forces. We show below that natural production advantages, residential consumption amenities and effective land services can be uniquely determined in the model from the observed distribution of rents, workplace employment and residence employment across blocks, irrespective of whether another possible equilibrium distribution of these variables exists.[36]

6.1 Model Calibration

Throughout this section, we take the model's parameter values $\{\alpha,\ \beta,\ \gamma,\ T,\ \epsilon,\ \kappa,\ \delta,\ \bar{U}\}$ as given, before discussing the search over alternative possible values of the parameters in the next section. As the model has a recursive structure, the determination of unobserved natural production advantages, residential consumption amenities and effective land services as residuals is straightforward. We first use a system of equations for labor market equilibrium to uniquely determine wages in each location based on observed workplace and residence employment. Having solved for wages, we use a second bloc of equations for consumer equilibrium to determine expected worker income and residential consumption amenities. We next use a third bloc of equations for producer equilibrium to determine

[36] Another approach is to calibrate the model to the pre-war (or re-unification) period and simulate the impact of division, holding natural advantages, consumption amenities and effective land services constant at their values in the base period. Depending on the strength of agglomeration forces relative to the asymmetries in these characteristics across locations, the model can exhibit a unique equilibrium or multiple equilibria for the simulated impact of division. Both approaches can be implemented using our data and the results compared.

productivity, effective labor input and natural production advantages. Finally, combining consumer and producer equilibrium, we solve for effective land services and the equilibrium fraction of land allocated to commercial and residential use.

In the data, we observe a single value for average land rents for each block ($\mathbb{Q}_i$), which can be related to the residential and commercial rents in the model as follows: $\mathbb{Q}_i = I_i^C q_i + \left(1 - I_i^C\right) Q_i$, where I_i^C is an indicator variable that is equal to one if a positive fraction of land is allocated to commercial use and zero otherwise. In the web appendix, we show that variation in the tax equivalent of land use regulations (Δ_i) across blocks has similar effects on the equilibrium allocation of land as variation in consumption amenities (B_i) relative to natural advantages (a_i). We impose the normalization $\Delta_i = 1$, in which case variation in the tax equivalent of land use regulations across blocks is captured in the calibrated values of consumption amenities. Under this normalization, no-arbitrage between alternative uses of land requires $q_i = Q_i$ for blocks that are incompletely specialized between commercial and residential land use.

6.1.1 Labor Market Clearing

Labor market clearing implies that workplace employment equals the sum of commuting flows from all blocks with positive residence employment:

$$H_{Mj} = \sum_{i=1}^{S} \pi_{ij} H_{Ri} = \sum_{i=1}^{S} \frac{\left(w_j/d_{ij}\right)^{\epsilon}}{\sum_{s=1}^{S} \left(w_s/d_{is}\right)^{\epsilon}} H_{Ri}, \qquad d_{ij} = e^{\kappa \tau_{ij}}, \tag{17}$$

where the π_{ij} sum to one across blocks of employment j for each block of residence i.

Given the model parameters $\{\alpha,\ \beta,\ \gamma,\ T,\ \epsilon,\ \kappa,\ \delta,\ \bar{U}\}$, observed workplace employment (H_{Mj}), observed residence employment (H_{Ri}) and observed travel times (τ_{ij}), the labor market clearing condition (17) provides a system of S equations that determines unique equilibrium values of the S unknown wages (w_j), as shown in the web appendix. Intuitively, observed workplace and residence employment and the gravity structure of commuting flows in the model uniquely determine the value that wages must take in order for the data to be consistent with an equilibrium of the model.

In solving the system of equations (17), we require that total workplace employment for Berlin as a whole equals total residence employment, which we impose by multiplying workplace employment in each block by a constant equal to the ratio of total residence employment to total workplace employment.[37] By inspection of (17), the solution to the labor market clearing condition implies that blocks with zero workplace employment have a zero equilibrium wage. In these blocks, either the entire effective supply of land can be more profitably employed residentially or there is neither

[37] As noted above in footnote 35, net commuting into Greater Berlin was small prior to the Second World War, and net commuting into West Berlin from West Germany during division was essentially non-existent.

commercial nor residential land use (e.g. parks and lakes with both zero workplace employment and zero residence employment).[38]

6.1.2 Consumer Equilibrium

Having solved for equilibrium wages, expected worker income ($\bar{v}_i$) follows immediately from the Fréchet distribution for worker productivity in (5), which is reproduced for clarity below:

$$\bar{v}_i = \left[\sum_{s=1}^{S} T \left(w_s / d_{is} \right)^{\epsilon} \right]^{1/\epsilon} \Gamma \left(\frac{\epsilon - 1}{\epsilon} \right), \qquad d_{ij} = e^{\kappa \tau_{ij}}. \tag{18}$$

Given expected worker income, consumption amenities (B_i) for each block with positive residents follow immediately from observed rents ($\mathbb{Q}$) and utility maximization and population mobility (4), as reproduced below:

$$B_i = \frac{\bar{U} \mathbb{Q}_i^{1-\beta}}{\beta^{\beta} (1-\beta)^{1-\beta} \bar{v}_i}. \tag{19}$$

In blocks with zero residents, either the block's entire effective supply of land can be more profitably employed commercially or there is neither commercial nor residential land use. For these blocks, we set consumption amenities equal to zero, which implies zero equilibrium residents from utility maximization and population mobility: $H_{Ri} = \beta^{\frac{\beta}{1-\beta}} \bar{U}^{-\frac{1}{1-\beta}} \bar{v}_i^{\frac{\beta}{1-\beta}} B_i^{\frac{1}{1-\beta}} (1-\theta_i) L_i$.[39]

From (17), (18) and (19), any change in the Fréchet scale parameter (T) results in an immediate and offsetting change in the calibrated value of consumption amenities (B_i). Therefore, we impose the normalization $T = 1$. Additionally, from (19), any change in the reservation level of utility in the larger economy ($\bar{U}$) leads to an immediate and offsetting change in the calibrated value of consumption amenities (B_i). The choice of $\bar{U}$ is therefore equivalent to a choice of units in which to measure consumption amenities and we impose the normalization $\bar{U} = 1$.

6.1.3 Producer Equilibrium

Given observed rents ($\mathbb{Q}_j$) and the solution for wages (w_j) from the first bloc of equations, profit maximization and zero profits determine productivity for each block of employment (A_j) in (10), which is again reproduced for clarity below:

$$A_j = \left(\frac{w_j}{\alpha} \right)^{\alpha} \left(\frac{\mathbb{Q}_j}{1-\alpha} \right)^{1-\alpha}. \tag{20}$$

[38] Parks, forests and lakes account for around 25 percent of the area of West Berlin. Empty blocks with neither commercial nor residential land use can arise in the model as a result of zero consumption amenities, zero natural advantages and/or prohibitive land use regulations. While these empty blocks do not themselves contain economic activity, they influence the general equilibrium of the model to the extent that they influence bilateral travel times between other blocks containing positive workplace and/or residence employment.

[39] For blocks with zero residence employment but positive workplace employment, consumption amenities must satisfy an inequality constraint. Consumption amenities lie in between zero and the value at which residential rents are equal to commercial rents net of the tax equivalent of land use regulations. As in the case where blocks have both zero residence employment and zero workplace employment, we set consumption amenities equal to zero.

Intuitively, wages and observed rents together determine the value that unobserved productivity must take in a zero-profit equilibrium with positive production. As discussed above, the solution to the labor market clearing condition implies zero equilibrium wages for blocks with zero workplace employment. For these blocks, we set natural advantages (a_j) equal to zero, which implies zero productivity (A_j) and hence zero equilibrium wages.[40]

With the solutions for wages (w_j) and expected worker income ($\bar{v}_i$) from the previous blocs of equations in hand, observed residence employment (H_{Ri}) and travel times (τ_{ij}) can be used together with labor market clearing to solve for effective labor input for each block of employment ($\widetilde{H_{Mj}}$):

$$w_j \widetilde{H_{Mj}} = \sum_{i=1}^{S} \frac{(w_j/d_{ij})^{\epsilon}}{\sum_{s=1}^{S} (w_s/d_{is})^{\epsilon}} \bar{v}_i H_{Ri}, \qquad d_{ij} = e^{\kappa \tau_{ij}}, \tag{21}$$

where blocks with zero workplace employment have a zero wage and hence zero effective labor input.

Having solved for productivity (A_j) and effective labor input ($\widetilde{H_{Mj}}$), natural production advantages (a_j) can be determined from observed geographical land area (K_j) and travel times (τ_{ij}) using the specification of knowledge spillovers in (9), as again reproduced below:

$$a_j = A_j \left[\sum_{s=1}^{S} e^{-\delta \tau_{js}} \left(\frac{\widetilde{H_{Ms}}}{K_s} \right) \right]^{-\gamma}, \qquad d_{ij} = e^{\kappa \tau_{ij}}. \tag{22}$$

Therefore observed workplace employment, residence employment and rents, together with the recursive structure of the model, allow us to uniquely determine productivity and the contribution of knowledge spillovers to productivity irrespective of whether the model has a unique equilibrium or multiple equilibria. Intuitively, the observed variables and the structure of the model allow us to determine the values that these unobservables must take in order for the observed variables to be an equilibrium of the model, irrespective of whether another possible equilibrium exists.

6.1.4 Land Market Equilibrium

Given the solutions for consumption amenities (B_i) and expected worker income ($\bar{v}_i$) from consumer equilibrium, and using observed residence employment (H_{Ri}), we immediately obtain total demand for residential land in each block with positive residence employment:

$$(1-\theta_i) L_i = \frac{H_{Ri} \bar{U}^{\frac{1}{1-\beta}}}{\beta^{\frac{\beta}{1-\beta}} B_i^{\frac{1}{1-\beta}} \bar{v}_i^{\frac{\beta}{1-\beta}}}, \tag{23}$$

Given the solutions for wages (w_i), productivity (A_i) and effective labor input ($\widetilde{H_{Mi}}$) from producer equilibrium, we immediately obtain total demand for commercial land in each block with positive

[40] For blocks with zero workplace employment but positive residence employment, natural advantages must satisfy an inequality constraint. Natural advantages lie in between zero and the value at which commercial rents net of the tax equivalent of land use regulations are equal to residential rents. As in the case where blocks have both zero residence employment and zero workplace employment, we set natural advantages equal to zero.

workplace employment:

$$\theta_i L_i = \widetilde{H_{Mi}} \left(\frac{w_i}{\alpha A_i} \right)^{\frac{1}{1-\alpha}}, \tag{24}$$

Combining the demands for residential land (23) and commercial land (24) with observed geographical land area (K_i), we can solve for effective land services (φ_i):

$$\varphi_i = \frac{L_i}{K_i} = \frac{\theta_i L_i + (1 - \theta_i) L_i}{K_i}, \tag{25}$$

where effective land services captures the fraction of the geographical land area that is developed and the ratio of building floor space to developed land area, as noted above. Having determined φ_i, and hence $L_i = \varphi_i K_i$, we can recover θ_i and $(1 - \theta_i)$ immediately from (23) and (24).

This completes the determination of unobserved natural production advantages (a_i), residential consumption amenities (B_i) and effective land services (φ_i), and all other endogenous variables of the model, for given parameter values $\{\alpha, \beta, \gamma, T, \epsilon, \kappa, \delta, \bar{U}\}$ and for given observed values of rents ($\mathbb{Q}_i$), workplace employment (H_{Mi}) and residence employment (H_{Ri}).

6.2 Determination of Parameter Values

To determine the model's parameters, we search over possible parameter values to minimize the change in the spatial pattern of natural production advantages, residential consumption amenities and effective land services between the pre-war and division periods or between the division and reunification periods. We undertake the analysis separately for division and reunification to allow model parameters, such as the strength of agglomeration and dispersion forces, to change over time.

[Work in progress]

7 Conclusions

[To be written]

A Data Appendix

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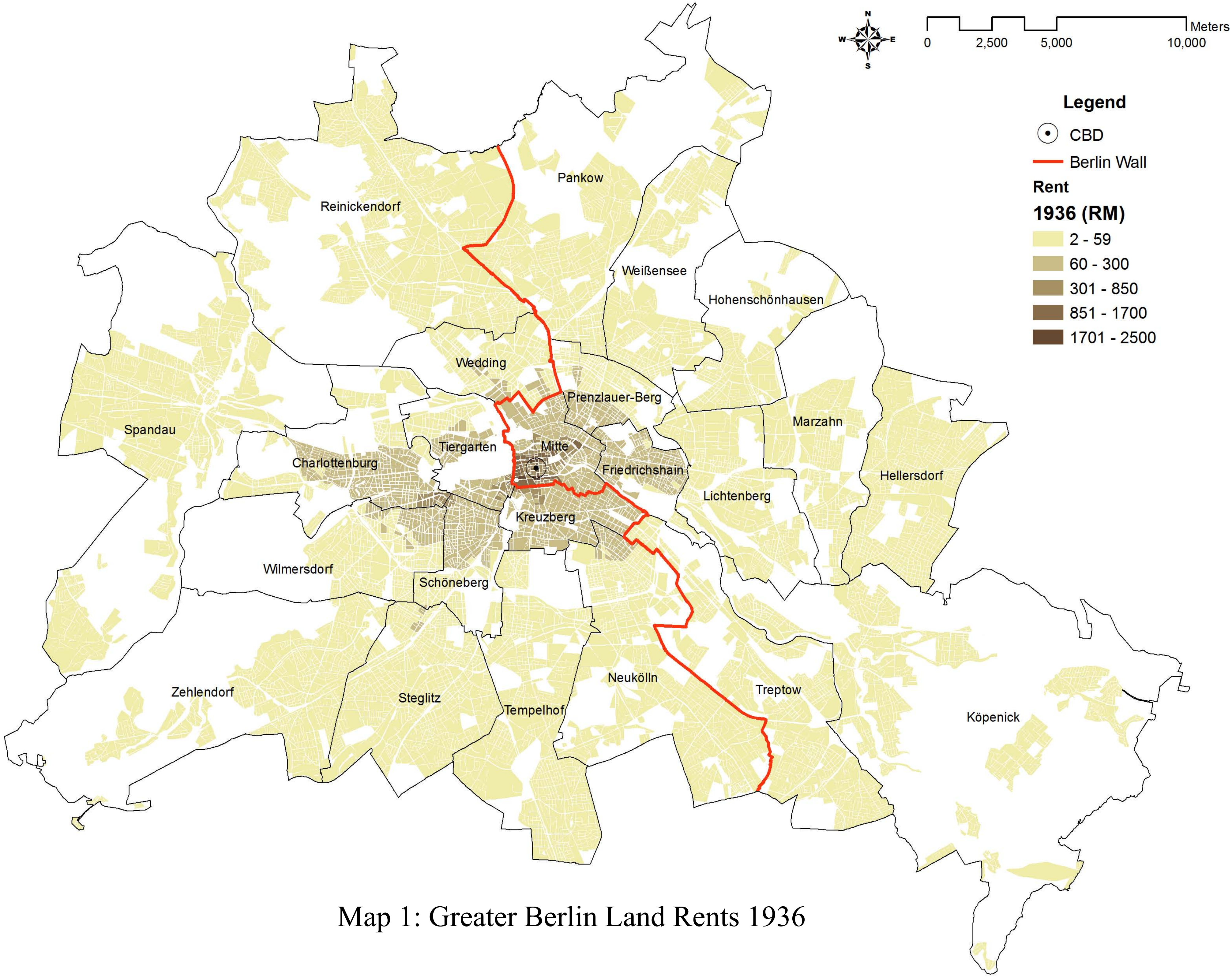
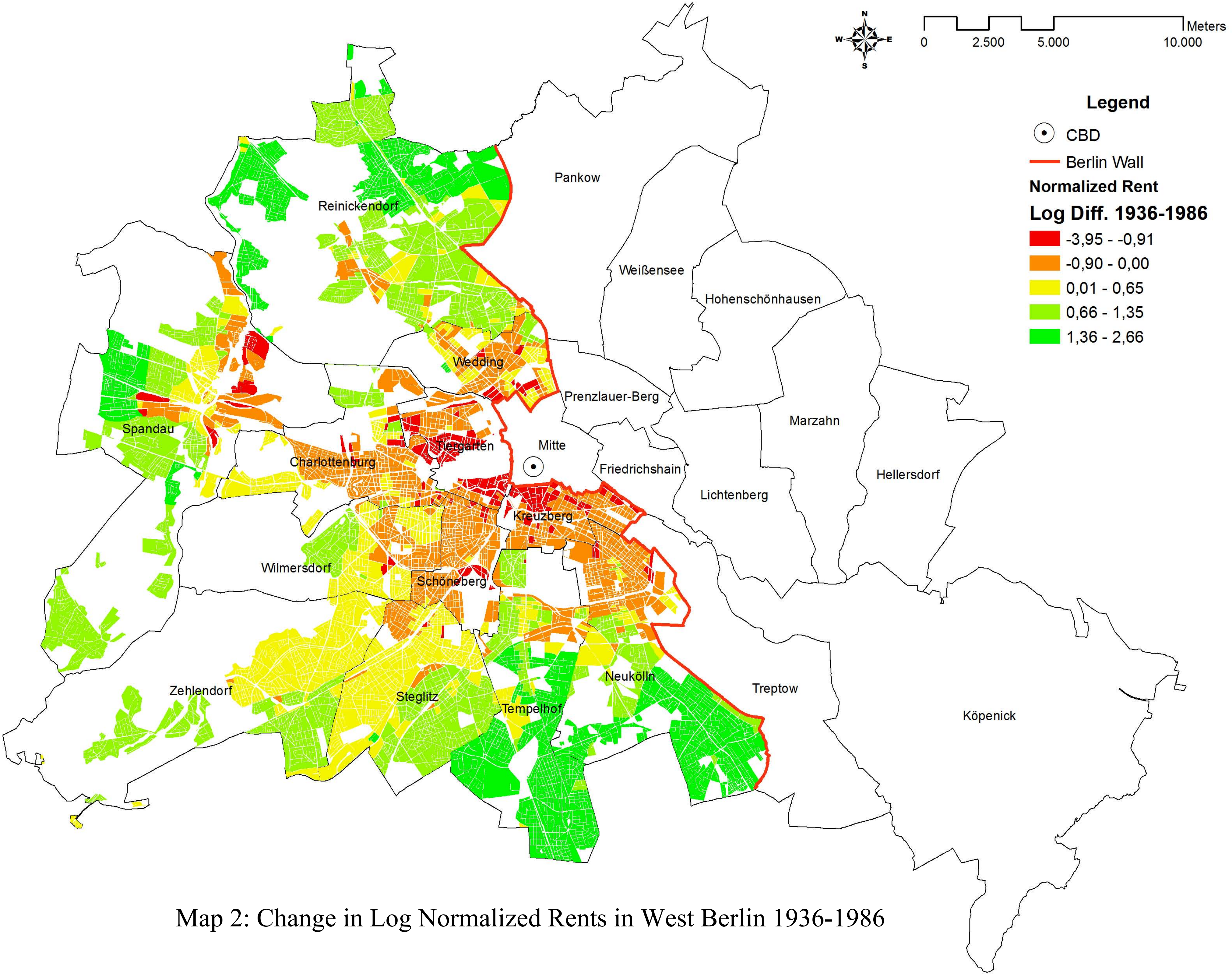
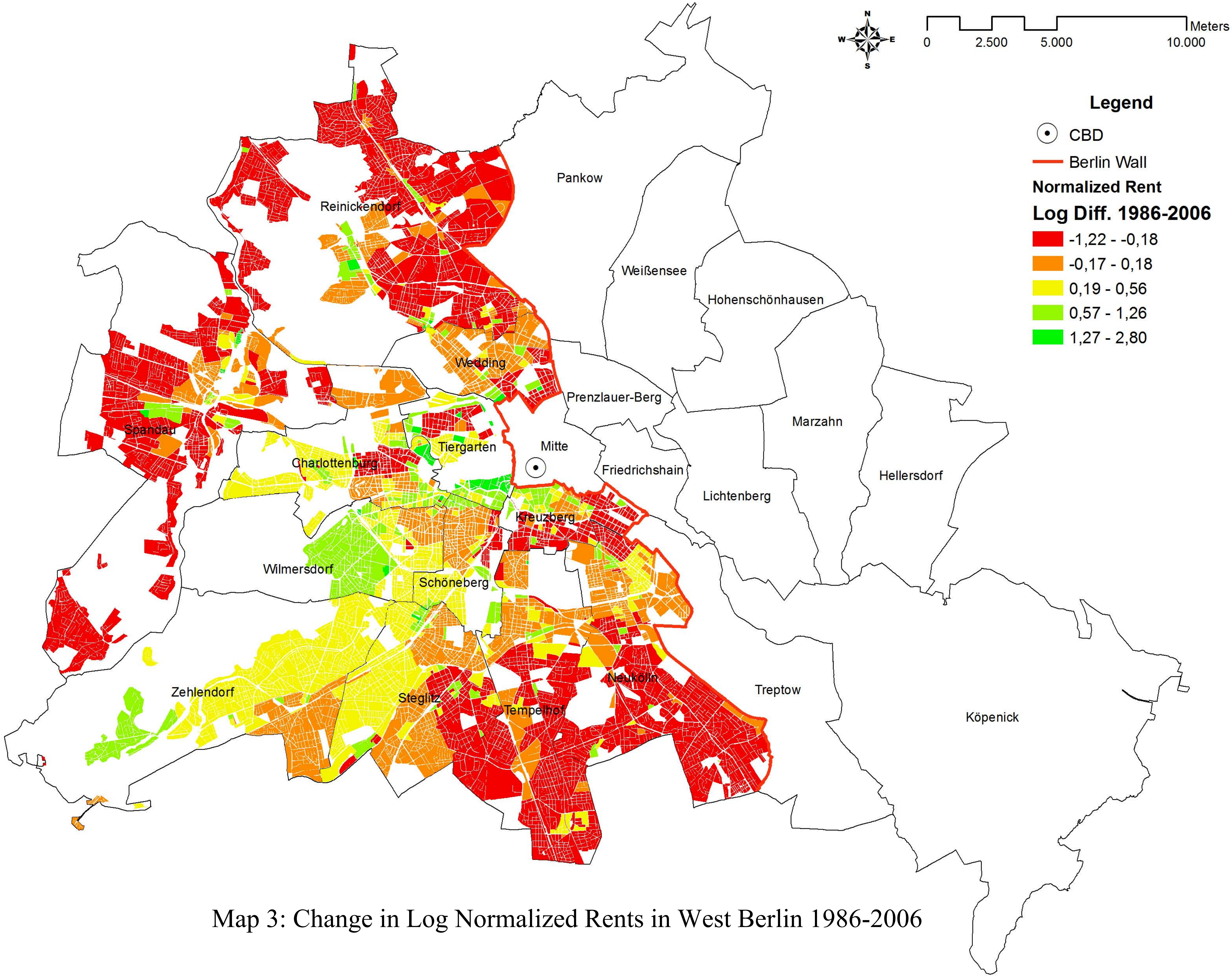


Map 1: Greater Berlin Land Rents 1936



Map 2: Change in Log Normalized Rents in West Berlin 1936-1986



Map 3: Change in Log Normalized Rents in West Berlin 1986-2006

Figure 1: Greater Berlin Land Rents 1936

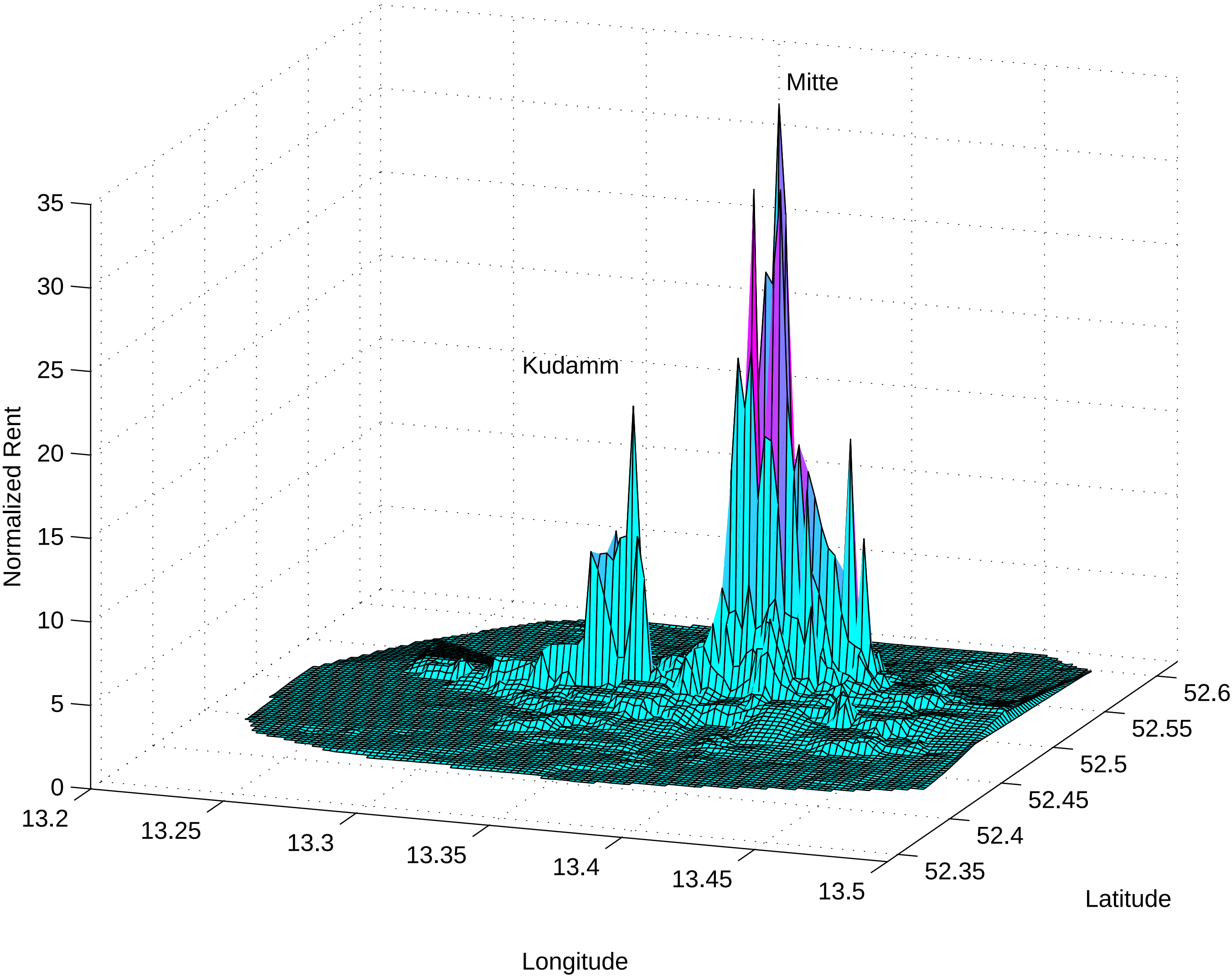


Figure 2: West Berlin Land Rents 1936

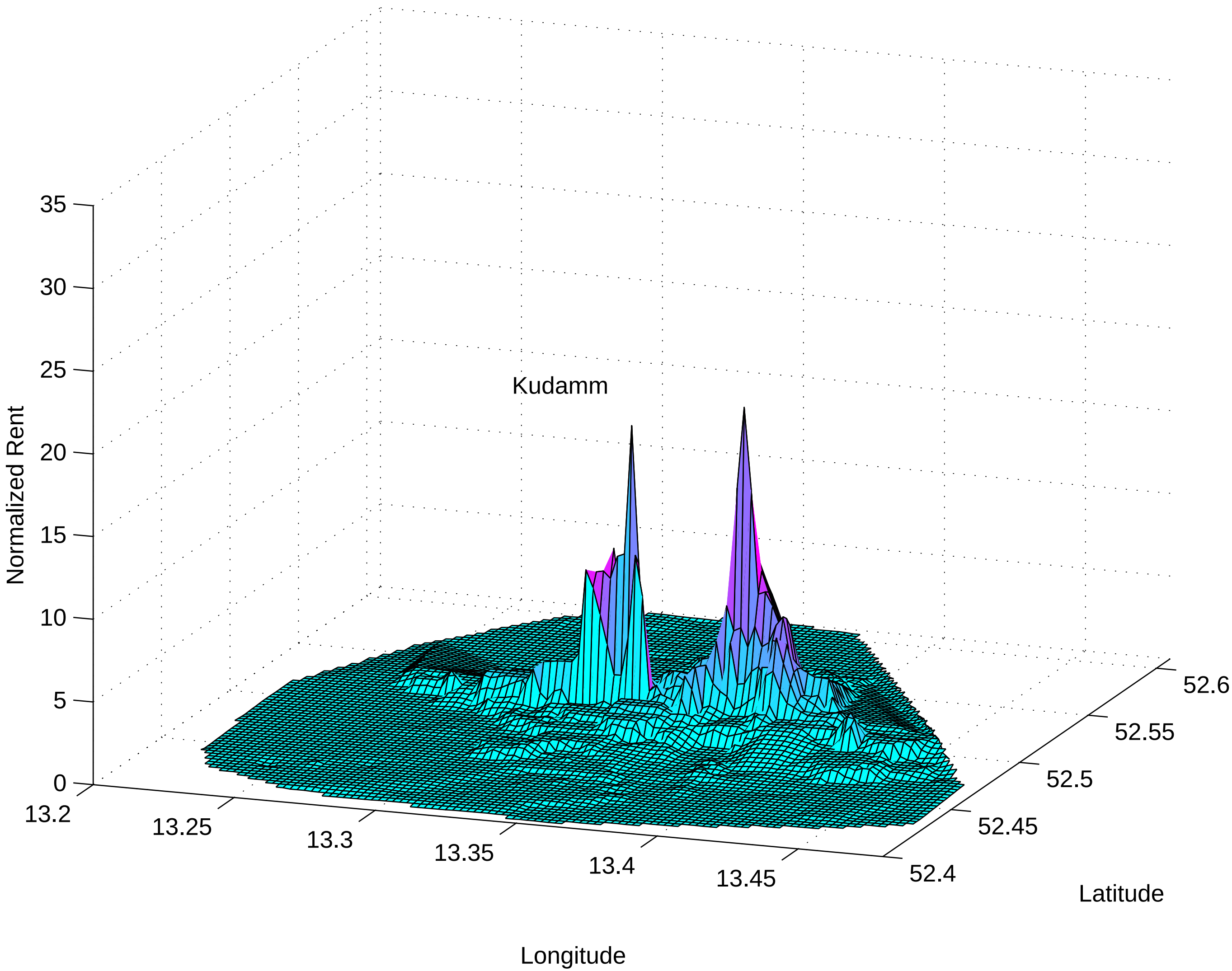


Figure 3: West Berlin Land Rents 1986

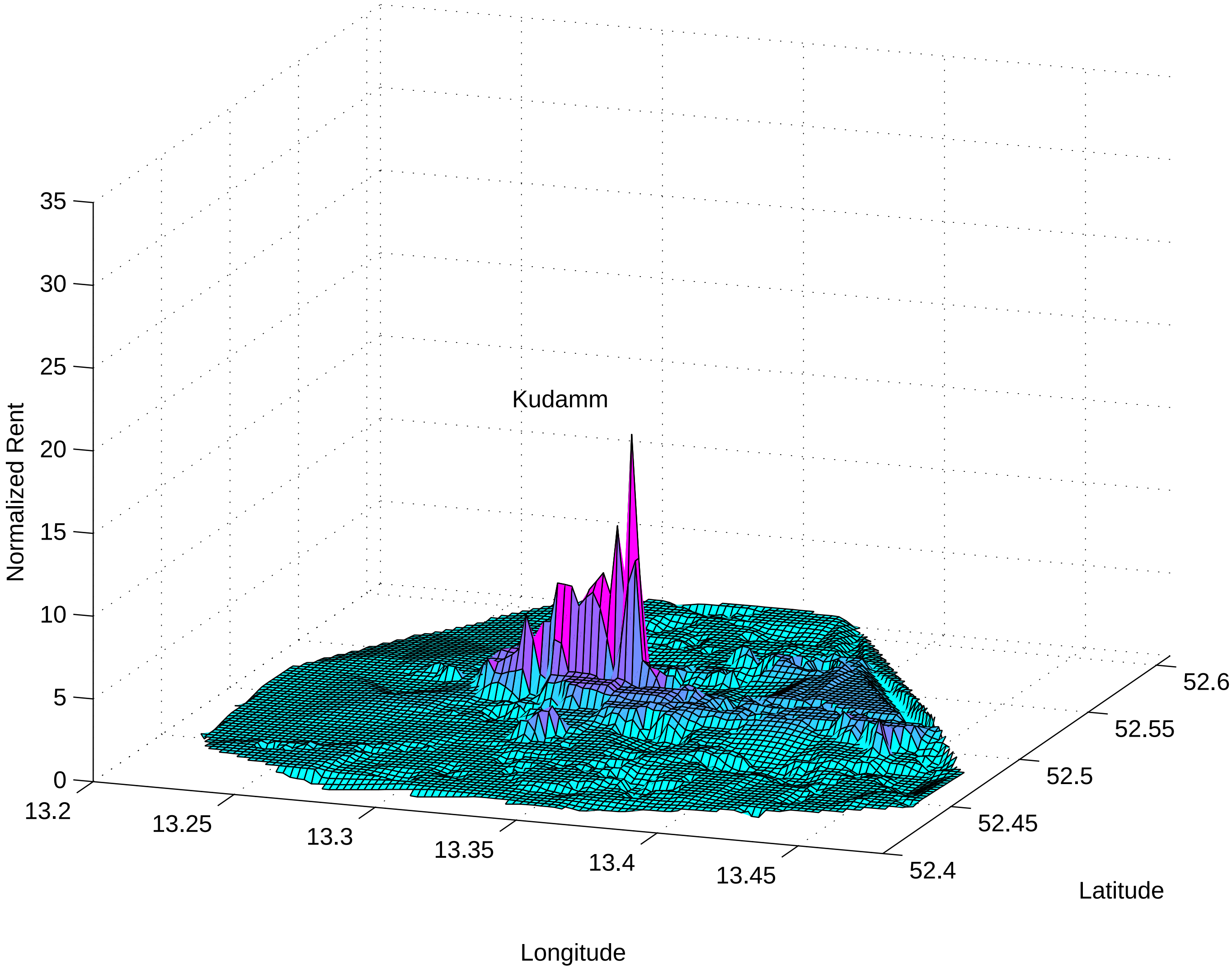


Figure 4: Greater Berlin Land Rents 2006

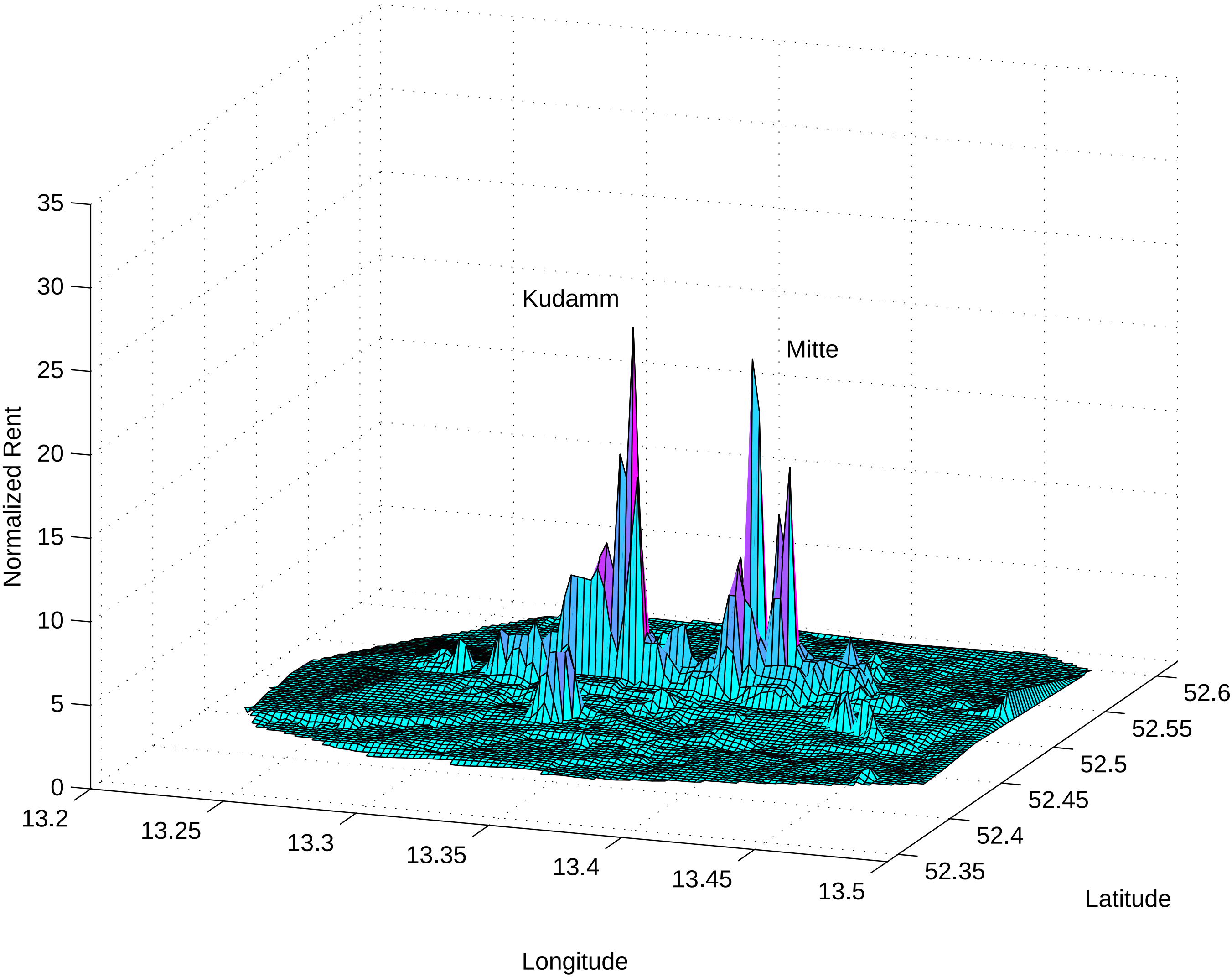
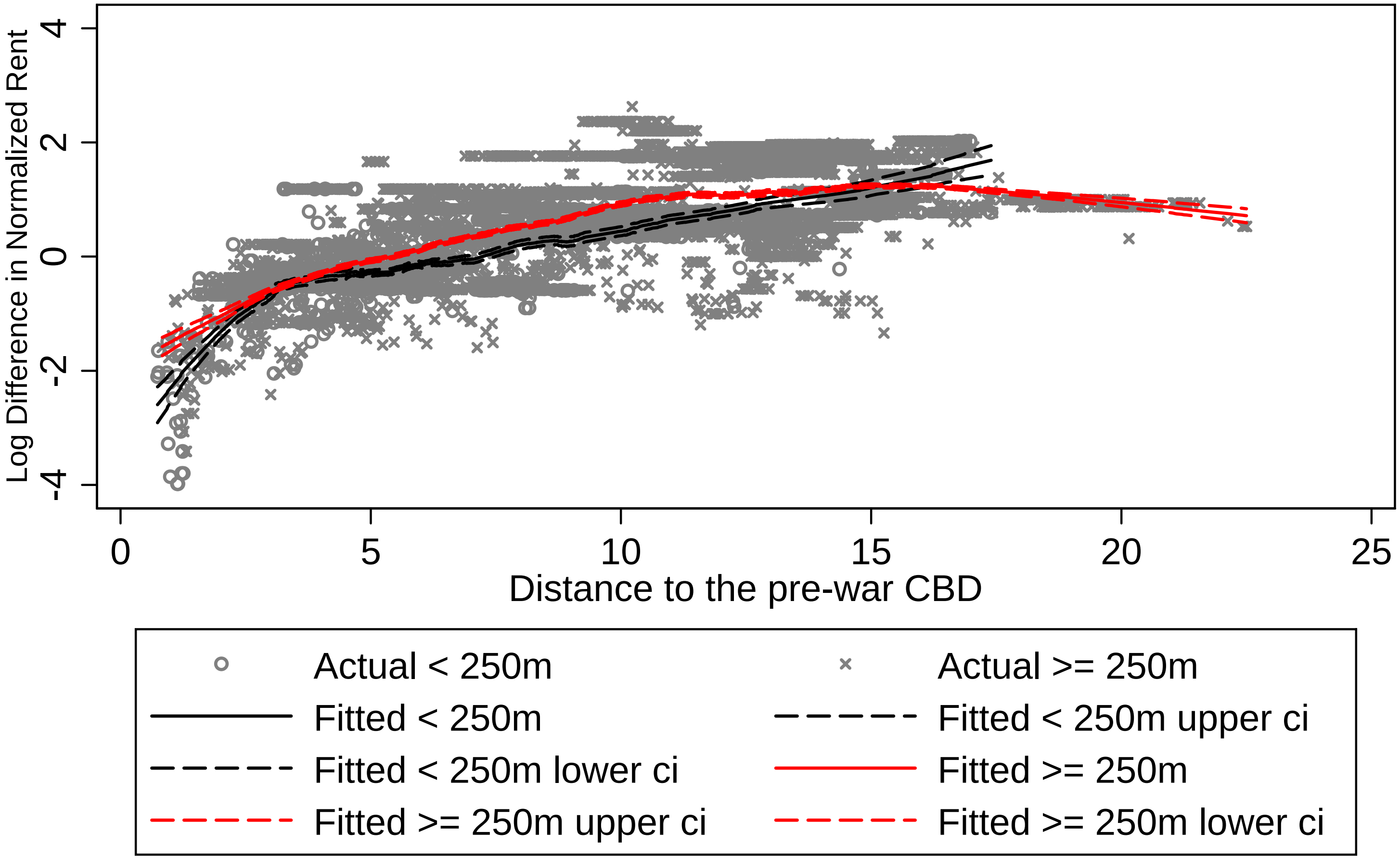
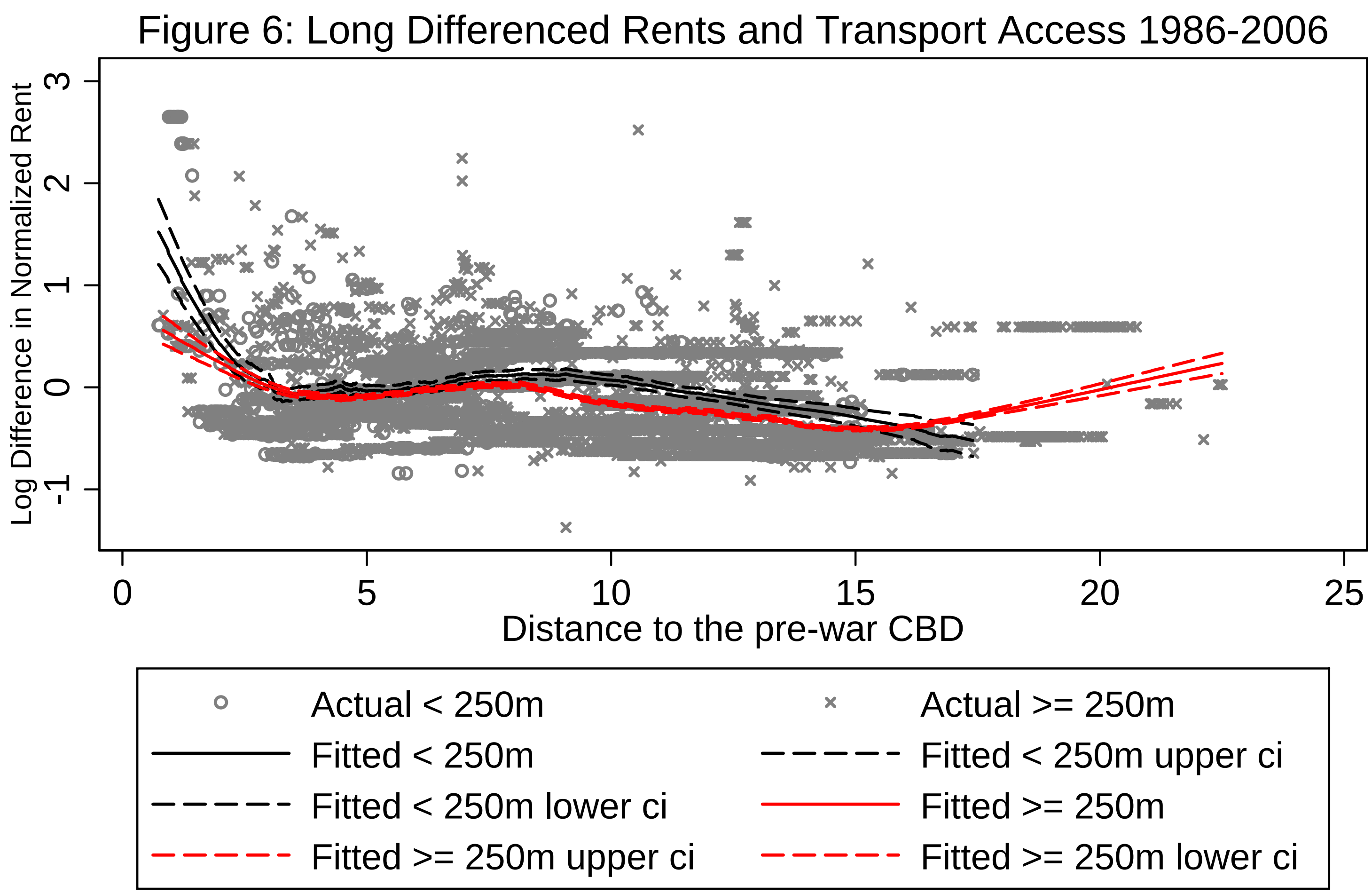


Figure 5: Long Differenced Rents and Transport Access 1936-86



Note: Rents are normalized to have a mean of one in each year before taking the long difference.
Solid lines are fitted values based on locally-weighted linear least squares. Separate fitted values estimated for blocks within and beyond 250 metres of U-Bahn or S-Bahn station in 1936. Dashed lines are pointwise confidence intervals.



Note: Rents are normalized to have a mean of one in each year before taking the long difference.
Solid lines are fitted values based on locally-weighted linear least squares. Separate fitted values estimated for blocks within and beyond 250 metres of U-Bahn or S-Bahn station in 1936. Dashed lines are pointwise confidence intervals.

Table 1: Long Differenced Rents for West Berlin Blocks 1936-1986

	(1)	(2)	(3)	(4)	(5)	(6)
	Δ ln Rent 1936-86	Δ ln Rent 1936-86	Δ ln Rent 1936-86	Δ ln Rent 1936-86	Δ ln Rent 1936-1986	Δ ln Rent 1936-1986
PWCBD1	-2.983***	-2.003***	-1.719***	-1.710***	-1.878***	-1.749***
	(0.543)	(0.414)	(0.281)	(0.283)	(0.307)	(0.294)
PWCBD2	-2.439***	-1.453***	-1.111***	-1.103***	-1.291***	-1.211***
	(0.370)	(0.294)	(0.238)	(0.240)	(0.259)	(0.242)
PWCBD3	-1.614***	-0.672***	-0.269*	-0.243*	-0.381**	-0.297**
	(0.186)	(0.196)	(0.145)	(0.139)	(0.165)	(0.146)
PWCBD4	-1.350***	-0.426***	-0.156	-0.150	-0.234*	-0.216*
	(0.138)	(0.133)	(0.095)	(0.096)	(0.120)	(0.115)
PWCBD5	-1.189***	-0.318**	-0.019	-0.012	-0.078	-0.072
	(0.146)	(0.134)	(0.079)	(0.077)	(0.096)	(0.092)
PWCBD6	-1.023***	-0.322***	0.061	0.063	-0.018	0.017
	(0.205)	(0.121)	(0.053)	(0.052)	(0.063)	(0.061)
INNER1					0.188	
					(0.139)	
INNER2					0.216	
					(0.136)	
INNER3					0.128	
					(0.130)	
INNER4-INNER6					yes	
OUTER1					0.101	
					(0.107)	
OUTER2					0.201**	
					(0.099)	
OUTER3					0.297***	
					(0.094)	
OUTER4-OUTER6					yes	
KUDAMM1-KUDAMM6						yes
District Fixed Effects		yes	yes	yes	yes	yes
Block controls			yes	yes	yes	yes
Policy controls				yes	yes	yes
Observations	7315	7315	7315	7315	7315	7315
R-squared	0.21	0.57	0.85	0.85	0.86	0.85

Notes: Regression sample includes blocks in West Berlin for which rent data are available for 1936, 1986 and 2006. PWCBD1-PWCBD6 are distance grid cells in 500m intervals from the pre-war CBD. INNER1-INNER6 are distance grid cells in 500m intervals from the inner boundary where the Berlin Wall separated East and West Berlin. OUTER1-OUTER6 are distance grid cells in 500m intervals from the outer boundary where the Berlin Wall separated West Berlin from East Germany. KUDAMM1-KUDAMM6 are distance grid cells in 500m intervals from the CBD of West Berlin during division on the Kudamm. District fixed effects are for the 11 pre-war districts ("Bezirke") of West Berlin. Block controls are: log block geographical land area, log one plus the ratio of building floor space to geographical land area for 1936 and 1986, dummy variables for some commerical land use and some industrial land use (the excluded category is purely residential land use), log distance to the nearest U-Bahn station, log distance to the nearest S-Bahn station, log distance to the nearest school, log distance to the nearest canal, lake or river, log distance to the nearest park, and the proportion of the block's area destroyed during the Second World War. Distance to the nearest U-Bahn and S-Bahn station are measured in 1936, while all other distance variables are measured in 2006. Policy controls are: whether the block qualified for government financial support in 2006 and whether the block contained a federal government building in 2006. Robust standard errors in parentheses are adjusted for clustering on statistical areas ("Gebiete"), 90 Clusters. * significant at 10%; ** significant at 5%; *** significant at 1%.

Table 2: Long Differenced Rents for West Berlin Blocks 1986-2006

	(1)	(2)	(3)	(4)	(5)	(6)
	Δ ln Rent 1986-2006	Δ ln Rent 1986-2006	Δ ln Rent 1986-2006	Δ ln Rent 1986-2006	Δ ln Rent 1986-2006	Δ ln Rent 1986-2006
PWCBD1	1.428**	1.511***	0.954**	0.955**	0.993**	0.919**
	(0.644)	(0.440)	(0.449)	(0.454)	(0.438)	(0.453)
PWCBD2	1.019**	1.094***	0.690***	0.692***	0.772***	0.745***
	(0.461)	(0.316)	(0.246)	(0.247)	(0.239)	(0.250)
PWCBD3	0.212	0.348*	0.147	0.158	0.238*	0.199
	(0.210)	(0.186)	(0.130)	(0.135)	(0.131)	(0.144)
PWCBD4	0.046	0.134	0.026	0.054	0.126	0.108
	(0.123)	(0.135)	(0.089)	(0.085)	(0.083)	(0.085)
PWCBD5	0.017	0.055	-0.016	-0.005	0.068	0.036
	(0.114)	(0.100)	(0.077)	(0.074)	(0.073)	(0.069)
PWCBD6	0.050	-0.015	-0.094*	-0.092*	-0.014	-0.050
	(0.104)	(0.079)	(0.055)	(0.054)	(0.049)	(0.047)
INNER1					-0.136***	
					(0.051)	
INNER2					-0.177***	
					(0.045)	
INNER3					-0.120***	
					(0.043)	
INNER4-INNER6					yes	
OUTER1					-0.314***	
					(0.085)	
OUTER2					-0.317***	
					(0.081)	
OUTER3					-0.266***	
					(0.071)	
OUTER4-OUTER6					yes	
KUDAMM1-KUDAMM6						yes
District Fixed Effects		yes	yes	yes	yes	yes
Block Controls			yes	yes	yes	yes
Policy Controls				yes	yes	yes
Observations	7315	7315	7315	7315	7315	7315
R-squared	0.08	0.49	0.66	0.66	0.69	0.69

Notes: Regression sample includes blocks in West Berlin for which rent data are available for 1936, 1986 and 2006. PWCBD1-PWCBD6 are distance grid cells in 500m intervals from the pre-war CBD. INNER1-INNER6 are distance grid cells in 500m intervals from the inner boundary where the Berlin Wall separated East and West Berlin. OUTER1-OUTER6 are distance grid cells in 500m intervals from the outer boundary where the Berlin Wall separated West Berlin from East Germany. KUDAMM1-KUDAMM6 are distance grid cells in 500m intervals from the CBD of West Berlin during division on the Kudamm. District fixed effects are for the 11 pre-war districts ("Bezirke") of West Berlin. Block controls are: log block geographical land area, log one plus the ratio of building floor space to geographical land area for 1986 and 2006, dummy variables for some commercial land use and some industrial land use (the excluded category is purely residential land use), log distance to the nearest U-Bahn station, log distance to the nearest S-Bahn station, log distance to the nearest school, log distance to the nearest canal, lake or river, log distance to the nearest park, and the proportion of the block's area destroyed during the Second World War. Distance to the nearest U-Bahn and S-Bahn station are measured in 1986, while all other distance variables are measured in 2006. Policy controls are: whether the block qualified for government financial support in 2006 and whether the block contained a federal government building in 2006. Robust standard errors in parentheses are adjusted for clustering on statistical areas ("Gebiete"), 90 Clusters. * significant at 10%; ** significant at 5%; *** significant at 1%.