THE ECONOMICS OF DENSITY: EVIDENCE FROM THE BERLIN WALL*

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Abstract

This paper develops a quantitative model of city structure to separate agglomeration forces, dispersion forces and fundamentals as determinants of location choices. The model remains tractable and amenable to empirical analysis because of stochastic shocks to worker productivity, which yield a gravity equation for commuting flows. To empirically disentangle alternative determinants of location choices, we use Berlin's division and reunification as a source of exogenous variation in the surrounding concentration of economic activity. Using disaggregated data on land prices, workplace employment and residence employment for thousands of city blocks for 1936, 1986 and 2006, we find that the model can account both qualitatively and quantitatively for the observed changes in city structure.

Keywords: agglomeration, dispersion, density, cities

JEL: N34, O18, R12

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1 Introduction

Economic activity is highly unevenly distributed across space, as reflected in the existence of cities and the concentration of economic functions 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 a range of economic and policy questions. These forces shape the size and internal structure of cities, with implications for the incomes of immobile factors, congestion costs and city productivity. They also determine the impact of public policy interventions, such as transport infrastructure investments and urban development and taxation policies.

Although there is a long literature on economic geography and urban economics dating back to at least Marshall (1920), a central challenge remains distinguishing agglomeration and dispersion forces from variation in locational fundamentals. While high land prices and levels of economic activity in a group of neighboring locations are consistent with strong agglomeration forces, they are also consistent with shared amenities that make these locations attractive places to live (e.g. leafy suburbs and scenic views) or common natural advantages that make these locations attractive for production (e.g. access to natural water). This challenge has both theoretical and empirical dimensions. To develop tractable models of cities, the existing theoretical literature makes simplifying assumptions such as monocentricity or symmetry, which abstracts from variation in locational fundamentals and limits their usefulness for empirical work. To empirically disentangle agglomeration and dispersion forces from variation in locational fundamentals, exogenous variation in the surrounding concentration of economic activity is required.

In this paper, we develop a quantitative theoretical model of city structure. This model incorporates both agglomeration and dispersion forces and variation in locational fundamentals, while remaining tractable and amenable to empirical analysis. In the model agglomeration forces take the form of production externalities, which are increasing in the surrounding density of employment, and residential externalities, which are increasing in the surrounding population density. Together with locational fundamentals, these agglomeration forces determine productivity and residential amenities. Congestion forces take the form of an inelastic supply of land and commuting costs that are increasing in travel time.

We combine this quantitative theoretical model with the natural experiment of Berlin's division in the aftermath of the Second World War and its reunification following the fall of the Iron Curtain. The key idea behind our approach is that division and reunification provide an exogenous source of variation in the surrounding concentration of economic activity that can be used to separate agglomeration and dispersion forces from locational fundamentals. Following division, the model implies that parts of West Berlin closer to concentrations of employment and residents in East Berlin experience larger reductions in productivity from foregone production externalities, larger increases in wages from lost access to commuters, larger reductions in residential amenities from foregone residential externalities, and larger reductions in residential income from lost commuting possibilities. Together these forces imply falls in land prices, employment and residents in these parts of West Berlin relative to those further from Eastern concentrations of employment and residents, with the reverse pattern predicted following reunification.

Using the structure of the model and given values for its parameters, we show how cross-section data on land prices, workplace employment, residence employment, geographical land area and the transport network can be used to solve for the unobserved locational fundamentals for which the observed data are an equilibrium of the model. To implement this procedure, we have assembled a remarkable dataset for Berlin that contains this information for thousands of city blocks for 1936 prior to division, 1986 during division and 2006 after reunification. This methodology for solving for locational fundamentals is broadly applicable and could be implemented in other contexts where the same data are available, such as evaluating the effects of constructing new transport infrastructure.

To estimate the model's parameters, we use the time-series variation provided by Berlin's division and reunification and Generalized Method of Moments (GMM) estimation. Since Berlin's division stemmed from military considerations during the Second World War, and since its reunification originated in the wider collapse of Communism, the resulting changes in access to the surrounding concentration of economic activity across blocks within West Berlin are unlikely to be correlated with the pre-existing characteristics of these blocks. We therefore use moment conditions based on the assumption that the change in locational fundamentals in West Berlin blocks following division and reunification is uncorrelated with their change in access to the surrounding concentration of economic activity. These moment conditions require the systematic changes in the pattern of economic activity within West Berlin following division and reunification to be explained by the model's endogenous agglomeration and dispersion forces rather than by changes in locational fundamentals.

Before estimating the full structural model, we report reduced-form results for the impact of division and reunification on the structure of economic activity within West Berlin. We show that division led to a substantial reorientation of the gradients in land prices and employment in West Berlin away from the main pre-war concentration of economic activity in the district "Mitte" in East Berlin, while reunification led to a reemergence of these gradients. We find little effect of division or reunification on land prices or employment along other sections of the Berlin Wall, suggesting that our results are indeed capturing a change in access to surrounding concentrations of economic activity rather than other considerations associated with proximity to the Berlin Wall such as its disamenity value. We also find that these results are robust to controlling for a host of observable block characteristics, including hedonic controls for access to the transport network, schools, parks and lakes, and other controls such as the percentage of a block's area destroyed during the Second World War, land use and government construction post reunification.

To provide further evidence in support of the model's predictions, we make use of variation across West Berlin blocks in their transport access. By severing underground ("U-Bahn") and suburban ("S-Bahn") railway connections with East Berlin and East Germany, division reduced the transport access advantage of West Berlin blocks close to an U/S-Bahn station. These blocks were more adversely affected by the loss of access to the surrounding concentration of economic activity because they had lower travel times to Eastern locations prior to division. Consistent with this role for transport access, we find that West Berlin blocks within 250 meters of a U/S-Bahn station experience a larger decline in land prices following division than other blocks at the same distance from the pre-war Central Business District (CBD). Similarly, these same blocks experience a larger increase in land prices following reunification than other blocks at the same distance from the pre-war CBD. These results not only provide additional evidence in support of the model's mechanism using a different source of variation in the data, but also show that it is at work even away from the central city.

Having found reduced-form evidence in support of the model's predictions, we next proceed to its structural estimation. We find a similar pattern of estimated coefficients for division and reunification, which suggests that a single underlying model can explain the impact of these two different events. Using our within-city data, we find somewhat higher elasticities of productivity with respect to employment density ($0.12-0.15$) than reduced-form estimates using data across cities or regions (0.05 as reviewed in Rosenthal and Strange 2004). We also find comparable elasticities of residential amenities with respect to population density, consistent with the view that consumption externalities are an important agglomeration force in addition to production externalities (as argued, for example, by Glaeser, Kolko and Saez 2001). We find that both production and residential externalities are highly localized (consistent with Arzaghi and Henderson 2008) and are far more sensitive to travel times than commuting costs. We show that the model can account quantitatively for most of the effect of reunification and a substantial part of the effect of division and provide additional evidence in support of its predictions.

Our paper builds on the large theoretical literature on urban economies. Much of this literature has analyzed the monocentric city model, in which firms are assumed to locate in a Central Business District (CBD) and workers decide how close to live to this CBD.[1] Lucas and Rossi-Hansberg (2002) were the first to develop a model of a two-dimensional city, in which equilibrium patterns of economic activity can be non-monocentric. In their model, space is continuous and the city is assumed to be symmetric, so that distance from the center is a summary statistic for the organization of economic activity within the city. Empirically cities are, however, not perfectly symmetric because of variation in locational fundamentals, and most data on cities are reported for discrete spatial units such as blocks or census tracts.

Our contribution is to develop a quantitative theoretical model of internal city structure that allows for a large number of discrete locations within the city that can differ arbitrarily in terms of their natural advantages for production, residential amenities, land supply and transport infrastructure. The model remains tractable despite the large number of asymmetric locations because of the stochastic formulation of workers' commuting decisions following Eaton and Kortum (2002). This stochastic formulation yields a system of equations that can be solved for unique equilibrium wages given observed workplace and residence employment in each location. It also provides microeconomic foundations for a gravity equation for commuting flows that has been found to be empirically successful.

Our paper is also related to the broader literature on the nature and sources of agglomeration economies, as reviewed in Duranton and Puga (2004) and Rosenthal and Strange (2004). A large empirical literature has regressed wages, land prices, productivity or employment growth on population density.[2] While this line of

[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.

[2]See, for example, Ciccone and Hall (1996), Deckle and Eaton (1999), Glaeser and Mare (2001), Glaeser et al. (1992), Hender-

research has established strong correlations, establishing causality is more challenging, because omitted third variables can affect wages or the other dependent variables above and also influence population density. Another related empirical literature has investigated the relationship between economic outcomes and transport infrastructure, considering a number of potential sources of exogenous variation in transport infrastructure.[3] But there have been few attempts to estimate agglomeration forces structurally, to separate agglomeration forces from dispersion forces, or to distinguish both sets of forces from locational fundamentals.[4]

Our paper is also related to the empirical literature in economic geography, which has examined the impact of natural experiments on the location of economic activity, including Bleakley and Lin (2012), Brakman et al. (2004), Davis and Weinstein (2002, 2008), Hanson (1996, 1997), Redding and Sturm (2008), and Redding et al. (2010). One of the main themes of this literature is the extent to which temporary shocks have permanent effects on the location of economic activity. In contrast, we estimate a structural model of agglomeration and dispersion forces that incorporates heterogeneity in locational fundamentals, and we focus on the distribution of economic activity within rather than across cities.[5]

The remainder of the paper is structured as follows. Section 2 discusses the historical background. Section 3 outlines the model. Section 4 introduces our data. Section 5 presents reduced-form empirical results on the impact of Berlin's division and reunification. Section 6 reports the structural estimation of the model's parameters. Section 7 concludes.

2 Historical Background

The city of Berlin in its current boundaries was created in 1920 when the historical city and its surrounding agglomeration were incorporated under the Greater Berlin law ("Gross Berlin Gesetz"). The city comprises 892 square kilometers of land compared to 606 square kilometers for Chicago, and includes substantial parks, forests and lakes. The city was originally divided into 20 districts ("Bezirke"), which had minimal administrative autonomy.[6] The political process that ultimately led to the construction of the Berlin Wall had its origins in war-time planning during the Second World War. A protocol signed in London in September 1944 delineated zones of occupation in Germany for the American, British and Soviet armies after the eventual defeat of Germany. The protocol also stipulated that Berlin, although located around 200 kilometers East of the Western border of the Soviet occupation zone, should be jointly occupied. For this purpose, Berlin was

son, Kuncoro and Turner (1995), Rauch (1993), Roback (1982) and Sveikauskas (1975).

[3]Donaldson (2008) examines the development of the railway network in Colonial India; Baum-Snow (2007), Duranton and Turner (2012), 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.

[4]For empirical estimates of congestion costs, see Combes, Duranton and Gobillon (2011). For structural estimates of the city-size wage gap using a search model, see Baum-Snow and Pavan (2010).

[5]For other research using within-city data, see Arzaghi and Henderson (2008) on the location of advertising agencies in Manhattan, and Rossi-Hansberg et al. (2010) for an analysis of urban revitalization policies in Richmond, Virginia.

[6]The boundaries of these 20 districts were slightly revised in April 1938. During division, the East Berlin authorities created three new districts (Hellersdorf, Marzahn and Hohenschönhausen), which were sub-divisions of Weissensee and Lichtenberg. Except for a few other minor changes, as discussed in Elkins and Hofmeister (1988), the district boundaries remained unchanged during the post-war period until an administrative reform in 2001, which reduced the overall number of districts to twelve.

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

The London protocol specifying the occupation sectors also created institutions for a joint administration of Berlin (and Germany more generally). The intention was for Berlin to be governed as a single economic and administrative unit by a joint council ("Kommandatura") with Soviet, American, British and French representatives. However, with the onset of the Cold War, the relationship between the Western allies and the Soviet Union began to deteriorate. In June 1948 the Western allies unilaterally introduced a new currency in their occupation zones and the Western sectors of Berlin. In retaliation the Soviet Union decided to block all road and rail access to the Western sectors of Berlin for nearly eleven months and West Berlin was supplied through the Berlin airlift during this time. The foundation of East and West Germany as separate states in 1949 and the creation of separate city governments in East and West Berlin further cemented the division of Germany and Berlin into Eastern and Western parts.

Following the adoption of Soviet-style policies of command and control in East Germany, the main border between East and West Germany was closed in 1952. While the implementation of these policies in East Berlin limited economic interactions with the Western sectors, the boundary between East and West Berlin remained formally open.[8] This open border resulted in some commuting of workers between East and West Berlin and became a conduit for refugees fleeing to the West.[9] To stem this flow of refugees, the East German authorities constructed the Berlin Wall in 1961, which ended all local economic interactions between East and West Berlin.[10]

As shown in Map 1, the Berlin Wall consisted of an inner boundary between West and East Berlin and

[7]The occupation sectors were based on the April 1938 revision of the boundaries of the 20 pre-war districts, and we use these boundaries for all years in our data. For further discussion of the diplomatic history of the division of Berlin, see Franklin (1963) and Sharp (1975).

[8]While East Berlin remained the main concentration of economic activity in East Germany after division, only around 2 percent of West Berlin's exports from 1957-1967 were to East Germany (including East Berlin) and other Eastern block countries (see Lambrecht and Tischner 1969).

[9]Approximately 122,000 people commuted from West to East Berlin in the fall of 1949, but this number quickly declines after waves of mass redundancies of Western workers in East Berlin and stands at about 13,000 workers in 1961 just before the construction of the Berlin Wall. Commuting flows in the opposite direction are estimated to be 76,000 in 1949 and decline to 31,000 in 1953 before slowly climbing to 63,000 in 1961 (Roggenbuch 2008).

[10]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.

an outer boundary between West Berlin and East Germany. The inner boundary ran along the Western edge of the district Mitte, which contained the pre-war CBD. As a result, West Berlin was separated from the pre-war commercial heart of the city, which contained Berlin's main administrative, cultural and educational institutions and by far the largest pre-war concentration of employment. The Berlin Wall cut through the pre-war transport network, intersecting underground railway ("U-Bahn") and suburban railway ("S-Bahn") lines, which were closed off at the boundaries with East Berlin or East Germany.[11] During the period of division West Germany introduced a number of policies to support economic activity in West Berlin, such as subsidies to transportation between West Berlin and West Germany, reduced tax rates and an exemption from military service for residents of West Berlin. Whereas our empirical analysis exploits relative variation across locations within West Berlin, these policies applied equally to all of Berlin.

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. The reunification of the city was also accompanied by some urban regeneration initiatives and we include controls for these policies in our empirical analysis below.

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 agglomeration forces (in the form of production and residential externalities) and dispersion forces (in the form of commuting costs and an inelastic supply of land).[13] Our key contribution is to develop an empirically tractable quantitative version of the canonical urban model, which allows for asymmetries in locational fundamentals and transport access across locations, and can be taken to real world data on economic activity within cities.

We consider a city embedded within a larger economy, which provides a reservation level of utility $\bar{U}$. The city consists of a set of discrete blocks, which are indexed by $i = 1, ..., S$, and have an effective supply of land L_i, which depends on both geographical land area and the density of development, as discussed further

[11] 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.

[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 1992).

[13] A more detailed discussion of the model and the technical derivations of all expressions and results reported in this section are contained in a separate web appendix.

below. Land can be used commercially or residentially, and we denote the endogenous fractions of land allocated to commercial and residential use by θ_i and $1-\theta_i$, respectively.

Firms produce a single final good, which is costlessly traded within the city and larger economy, and is chosen as the numeraire. Firms choose a block of production and inputs of labor and land to maximize their profits under conditions of perfect competition. The city is populated by an endogenous measure of $\bar{H}$ workers, who are perfectly mobile within the city and larger economy. Each worker chooses a block of residence, a block of employment, consumption of the final good and residential land use to maximize their utility. City blocks are connected by a bilateral transport network, which workers can use to commute between their locations of residence and employment.

3.1 Workers

Workers are risk neutral and have preferences that are linear in an aggregate consumption index: $U_{ij\omega} = C_{ij\omega}$, where $C_{ij\omega}$ denotes the aggregate consumption index for worker ω residing in block i and working in block j.[14] This aggregate consumption index is defined over consumption of the final good ($c_{ij\omega}$) and residential land ($\ell_{ij\omega}$), and is assumed for simplicity to take the Cobb-Douglas form:[15]

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

where the parameter $B_i \geq 0$ captures residential amenities that make a block a more or less attractive place to live, as emphasized in Albouy (2008) and Roback (1982).

An individual worker's decision to commute between different parts of the city is influenced by many idiosyncratic factors that are often hard to observe before living and working in the city. We capture this idea by assuming that workers choose a block of residence before observing their productivities for different employment locations throughout the city. Once a worker has chosen her block of residence, she observes her productivity for each employment location, and decides *ex post* where to work and how much of the final good and residential land to consume.[16] We begin by examining the worker's *ex post* decisions conditional on having chosen a location of residence, before later considering her *ex ante* decision of where to live.

Workers choose *ex post* where to work based on their heterogeneous productivities across possible employment locations. These heterogeneous productivities capture all idiosyncratic factors that can induce workers residing in the same block to make different commuting decisions when faced with the same wages and commuting costs. Worker productivity also depends on the time spent commuting, because travel time is forgone labor time and the effort involved in commuting can itself reduce productivity. Therefore income net of commuting costs for worker ω residing in block i and working in block j ($v_{ij\omega}$) equals the wage per

[14] To simplify the exposition, throughout the paper, we index a worker's block of residence by i and her block of employment by j unless otherwise indicated.

[15] 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 (2011).

[16] While we assume that workers first choose their block of residence before observing their productivities and choosing their block of employment, there is an isomorphic formulation of the model in which workers first choose their block of employment before observing their realizations of stochastic residential amenities and choosing their block of residence.

effective unit of labor at block j (w_j) times the worker's productivity at this location ($z_{ij\omega}$) and divided by the proportional reduction in productivity from commuting (d_{ij}):

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

where the commuting costs iceberg factor $d_{ij} \in [1, \infty)$ increases with the travel time between blocks i and j (τ_{ij}); $\kappa \geq 0$ parameterizes the magnitude of commuting costs. While we interpret $z_{ij\omega}$ as a stochastic shock to effective units of labor, we note that z has an isomorphic interpretation in the model as a stochastic shock to commuting costs, so that some workers find commuting more costly than others.

We model heterogeneity in worker productivity following Eaton and Kortum (2002). For each worker ω residing in location i, productivities for each employment location j in the city ($z_{ij\omega}$) are drawn from an independent Fréchet distribution:

$$F(z_{ij\omega}) = e^{-T z_{ij\omega}^{-\epsilon}}, \qquad T > 0,\ \epsilon > 1, \tag{3}$$

where the scale parameter $T > 0$ determines the average level of worker productivity and the shape parameter $\epsilon > 1$ determines the dispersion of worker productivity across employment locations. While we assume that the Fréchet scale parameter T is the same for all employment locations, this is without loss of generality because a higher value of T for an individual employment location has the same general equilibrium effect in the model as a higher value of final goods productivity for that employment location, and we allow final goods productivity to vary across locations in a general way, as discussed further below.

Using the monotonic relationship between worker income and productivity (2), income net of commuting costs for workers residing in block i and working in block j inherits a Fréchet distribution: $G_{ij}(v_{ij}) = e^{-T v_{ij}^{-\epsilon} d_{ij}^{-\epsilon} w_j^{\epsilon}}$. From the set of all possible employment locations j, each worker chooses the one that offers the maximum income net of commuting costs. Since the maximum of a sequence of Fréchet distributed random variables is itself Fréchet distributed, the distribution of income net of commuting costs for workers residing in block i is given by: $G_i(v_i) = e^{-\Phi_i v_i^{-\epsilon}}$, where $\Phi_i = \sum_{s=1}^{S} T \left(\frac{w_s}{d_{is}}\right)^{\epsilon}$. Combining these bilateral and multilateral distributions of income, $G_{ij}(v_{ij})$ and $G_i(v_i)$, the probability that a worker commutes between blocks i and j (π_{ij}) exhibits the following gravity equation relationship:

$$\pi_{ij} = \frac{(w_j/d_{ij})^{\epsilon}}{\sum_{s=1}^{S} (w_s/d_{is})^{\epsilon}}, \qquad d_{ij} = e^{\kappa \tau_{ij}}, \tag{4}$$

where the probability of commuting to location j depends on its wage and commuting costs in the numerator ("bilateral resistance") but also on the wage and commuting costs for all other possible employment locations s in the denominator ("multilateral resistance").

This expression for commuting probabilities provides microeconomic foundations for the reduced-form gravity equations estimated in the empirical literature on commuting patterns.[17] Using these commuting

[17]For reduced-form evidence of the explanatory power of a gravity equation for commuting flows, see for example Erlander and Stewart (1990) and Sen and Smith (1995). For empirical evidence on the relationship between commuting flows and travel times for pre-war Berlin, see Feder (1939).

probabilities, the measure of workers employed in each location j (H_{Mj}) equals the sum across all locations i of their measures of residents (H_{Ri}) times their probabilities of commuting to j (π_{ij}):

$$H_{Mj} = \sum_{i=1}^{S} \frac{(w_j/d_{ij})^{\epsilon}}{\sum_{s=1}^{S} (w_s/d_{is})^{\epsilon}} H_{Ri}, \qquad d_{ij} = e^{\kappa \tau_{ij}}, \tag{5}$$

where, since there is a continuous measure of workers residing in each location, there is no uncertainty in the supply of workers to each employment location.

Given observed data on workplace employment (H_{Mj}), residence employment (H_{Ri}) and bilateral travel times (τ_{ij}), the commuting market clearing condition (5) provides a system of equations in the unknown wages for each location (w_i), which can be solved for unique equilibrium wages as shown in the web appendix. In general, wages vary across production locations to compensate workers for the commuting costs incurred in working at those locations. Since workers from any given location of residence i have different productivity draws and make different commuting decisions when faced with the same wages and commuting costs, the supply of commuters to each employment location j in (5) is a continuously increasing function of its wage relative to other locations.[18]

Having characterized a worker's *ex post* decision of where to work conditional on a location of residence, we now turn to her *ex ante* decision of where to live. Each worker chooses her block of residence to maximize her expected utility, taking as given the distribution of worker productivity, goods and factor prices, and the location decisions of firms and other workers. Since workers are *ex ante* identical, population mobility implies that they must obtain the same *ex ante* expected utility across all blocks populated in equilibrium, equal to the reservation level in the larger economy. Substituting for equilibrium goods consumption and residential land use in worker utility (1) and taking expectations over the distribution of worker productivity, we obtain the following population mobility condition:

$$\mathbb{E}\left[U_i\right] = \beta^{\beta}(1-\beta)^{1-\beta} Q_i^{\beta-1} B_i \bar{v}_i = \bar{U}, \tag{6}$$

where $\mathbb{E}$ denotes the expectations operator and we have used the fact that all workers residing in a given block face the same price of the final good ($p_i = 1$) and the same residential land price (Q_i);[19] $\bar{v}_i$ denotes expected worker income net of commuting costs conditional on residing in block i. Expected utility in each populated block is increasing in residential amenities (B_i) and expected worker income ($\bar{v}_i$), and is decreasing in residential land prices (Q_i), but must be equal in equilibrium to the reservation level of utility ($\bar{U}$).

Expected worker income conditional on residing in block i depends on commuting probabilities (π_{ij}) and the Fréchet distributions of income net of commuting costs ($G_{ij}(v_{ij})$) for all possible employment locations.

[18]This feature of the model is not only consistent with the gravity equation literature on commuting flows discussed above but also greatly simplifies the quantitative analysis of the model. In the absence of heterogeneity in worker productivity, small changes in wages can induce all workers residing in one location to start or stop commuting to another location, considerably complicating the determination of equilibrium with discrete and asymmetric locations.

[19]We make the standard assumption in the urban literature that income from land is accrued by absentee landlords and not spent within the city, although it is also possible to consider the case where it is redistributed lump sum to workers.

Together these imply:

$$\bar{v}_i = \Gamma\left(\frac{\epsilon-1}{\epsilon}\right)\left[\sum_{s=1}^{S} T\left(w_s/d_{is}\right)^{\epsilon}\right]^{1/\epsilon}, \qquad d_{ij} = e^{\kappa\tau_{ij}}, \tag{7}$$

where $\Gamma(\cdot)$ is the Gamma function. Intuitively, blocks with low travel times to high-wage employment locations (d_{is} close to one for high w_s) have attractive commuting possibilities and hence high expected worker income.[20]

We allow residential amenities to depend on the surrounding density of economic activity. Specifically, we assume that residential amenities (B_i) have a locational fundamentals component (b_i) and a residential externalities component (Ω_i). While the locational fundamentals component depends on exogenous characteristics of locations, such as access to parks and lakes, the residential externalities component changes endogenously over time with the travel-time weighted sum of population density in surrounding locations:

$$B_i = b_i\Omega_i^{\eta}, \qquad \Omega_i \equiv \sum_{s=1}^{S} e^{-\rho\tau_{js}}\left(\frac{H_{Rs}}{K_s}\right), \qquad \eta \geq 0, \rho \geq 0, \tag{8}$$

where K_s denotes geographical land area; residential externalities decline with travel time (τ_{ij}) through the iceberg factor $e^{-\rho\tau_{js}} \in (0,1]$; ρ determines their rate of spatial decay and η controls their relative importance in overall residential amenities.[21] These externalities capture all residential amenities associated with population density, such as local public goods.

3.2 Production

The final good is produced under conditions of constant returns to scale and perfect competition and is costlessly traded within the city and the larger economy.[22] For simplicity, we assume that the production technology takes the Cobb-Douglas form, so that output of the final good in block j (X_j) is:

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

where A_j is final goods productivity; $\widetilde{H_{Mj}}$ denotes effective employment, which depends the measure of workers employed (H_{Mj}), the distribution of these workers' productivities ($z_{ji\omega}$), and the reduction in their productivities from commuting (d_{ij}).

Firms choose their block of production, effective employment and commercial land use to maximize their profits, taking as given the distribution of worker productivity, goods and factor prices, productivity and the

[20]For simplicity, we model agents and workers as synonymous, which implies that labor is the only source of income. More generally, 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/or to allow agents to have a constant amount of non-labor income.

[21]As discussed further below, geographical land area (K_s) differs from the effective supply of land (L_s), because blocks can differ in their density of development (e.g. building height). Since residential externalities are likely to increase with the density of development, we follow the standard approach in the urban literature of modeling externalities as depending on density per unit of geographical area (K_s) rather than density per unit of effective land (L_s).

[22]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).

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 land prices (q_j) in each block with positive production must satisfy:

$$q_j = (1-\alpha)\left(\frac{\alpha}{w_j}\right)^{\frac{\alpha}{1-\alpha}} A_j^{\frac{1}{1-\alpha}}. \tag{9}$$

Intuitively, firms in blocks with higher productivity (A_j) and/or lower wages (w_j) are able to pay higher commercial land prices and still make zero profits.

The labor market clearing condition equating the demand for and supply of labor can be written in value terms as the requirement that payments to labor net of commuting costs at each production location equal the income net of commuting costs received by residents commuting to that location:

$$w_j \widetilde{H_{Mj}} = \sum_{i=1}^{S} \frac{(w_j/d_{ij})^{\epsilon}}{\left[\sum_{s=1}^{S}(w_s/d_{is})^{\epsilon}\right]} \bar{v}_i H_{Ri}. \tag{10}$$

We allow final goods productivity in each location to depend on the surrounding density of economic activity. We assume that productivity (A_i) has a locational fundamentals component (a_i) and a production externalities component (Υ_i). While the locational fundamentals component depends on exogenous characteristics of locations, such as topography and access to natural water, the production externalities component changes endogenously over time with the travel-time weighted sum of effective employment densities in surrounding locations:[23]

$$A_j = \Upsilon_j^{\lambda} a_j, \qquad \Upsilon_j \equiv \sum_{s=1}^{S} e^{-\delta\tau_{js}}\left(\frac{\widetilde{H_{Ms}}}{K_s}\right), \qquad \lambda \geq 0, \delta \geq 0. \tag{11}$$

where production externalities decline with travel time (τ_{js}) through the iceberg factor $e^{-\delta\tau_{js}} \in (0,1]$; δ determines their rate of spatial decay and λ controls their relative importance in determining overall final goods productivity.[24]

3.3 Land Market Clearing

Residential land market clearing for each location i implies that the total demand for residential land equals the effective supply of land allocated to residential use ($(1-\theta_i)L_i$). Combining utility maximization and population mobility, we obtain:

$$\mathbb{E}[\ell_i] H_{Ri} = \bar{v}_i(1-\beta)\frac{H_{Ri}}{Q_i} = (1-\theta_i)L_i, \tag{12}$$

[23] While the canonical interpretation of these production externalities in the urban economics literature is knowledge spillovers, as in Alonso (1964), Fujita and Ogawa (1982), Lucas (2000), Mills (1967), Muth (1969), and Sveikauskas (1975), other interpretations are possible, as considered in Duranton and Puga (2004).

[24] As for residential externalities above, we follow the standard approach in the urban literature of modeling production externalities as depending on density per unit of geographical land area (K_s).

where $\mathbb{E}[\ell_i]$ denotes expected residential land use per worker and the expectation is taken over the distribution of worker productivity.

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

$$\widetilde{H_{Mj}} \left(\frac{w_j}{\alpha A_j} \right)^{\frac{1}{1-\alpha}} = \theta_j L_j. \tag{13}$$

Land market equilibrium also requires no arbitrage between alternative possible uses of land. Therefore, within each block, land is either allocated entirely to commercial use ($q_i > Q_i$ and $\theta_i = 1$), allocated entirely to residential use ($Q_i > q_i$ and $\theta_i = 0$), or commercial and residential land prices are equalized if positive fractions of land are allocated to both uses ($q_i = Q_i$ and $\theta_i \in (0,1)$). We assume that commercial and residential land prices are equalized when blocks are incompletely specialized, because in our data we only observe a single land price for each block ($\mathbb{Q}_i$). In the model, however, it is straightforward to allow for a wedge between commercial and residential land prices as a result for example of land use regulation, so that $q_i = \chi_i Q_i$ for incompletely specialized blocks, where $\chi_i \neq 1$. A change in the wedge χ_i is isomorphic to a change in final goods productivity (A_i) relative to residential amenities (B_i). In our quantitative analysis of the model, we calibrate the values of A_i and B_i for which the observed data on land prices, workplace employment and residence employment are an equilibrium of the model, as discussed further below. It follows that we can allow an arbitrary value of the wedge (χ_i) for each block, because a change in the assumed value of χ_i for any block is exactly offset by a change in the relative calibrated values of A_i and B_i for this block, as shown formally in the web appendix.

Combining residential and commercial land market clearing, the total demand for land must equal the effective supply of land (L_i), which depends on geographical land area (K_i) and the density of development (φ_i):

$$(1-\theta_i) L_i + \theta_i L_i = L_i = \varphi_i K_i. \tag{14}$$

3.4 General Equilibrium

The general equilibrium of the model is characterized by the price of the final good ($p_i = 1$ for all i), vectors of wages and land prices for each location $\{w_i, Q_i, q_i\}$, and vectors of workplace employment, residence employment and allocations of land between commercial and residential use for each location $\{H_{Mi}, H_{Ri}, \theta_i\}$. At these equilibrium prices and allocations, workers are *ex ante* indifferent across alternative possible locations of residence, and make *ex post* decisions about their employment location, residential land use and consumption of the final good to maximize their utility. Firms choose employment and commercial land use to maximize their profits and zero profits are made in each location with positive production. Finally, in each location, land is either allocated entirely to the activity that offers the highest return, or if land is used both commercially and residentially the returns to these two activities are equalized.

The solution of the model is a mapping from the parameters $\{\alpha, \beta, \lambda, \delta, \kappa, \epsilon, \eta, \rho, T, \bar{U}\}$ and locational fundamentals $\{a_i, b_i, \varphi_i, K_i, \tau_{ij}\}$ to the endogenous prices $\{1, w_i, Q_i, q_i\}$ and allocations $\{H_{Mi}, H_{Ri}, \theta_i\}$. In our quantitative analysis, we instead use observed data on endogenous variables and fundamentals $\{\mathbb{Q}_i, H_{Mi}, H_{Ri}, K_i, \tau_{ij}\}$ to solve for the remaining unobserved endogenous variables $\{w_i, \theta_i, Q_i, q_i\}$ and fundamentals $\{a_i, b_i, \varphi_i\}$ for which the observed data are consistent with an equilibrium of the model. The following proposition shows that for any given parameter vector, this mapping from observables to unobservables is unique.

Proposition 1 *Given the parameters* $\{\alpha, \beta, \lambda, \delta, \kappa, \epsilon, \eta, \rho, T, \bar{U}\}$ *and observed data* $\{\mathbb{Q}_i, H_{Mi}, H_{Ri}, K_i, \tau_{ij}\}$, *there exist unique values of the unobserved locational fundamentals and endogenous variables* $\{a_i, b_i, \varphi_i, w_i, \theta_i, Q_i, q_i\}$ *for which the observed data are consistent with an equilibrium of the model.*

Proof. See the web appendix. ■

As shown formally in the proof of the proposition, we use the recursive structure of the model to solve for the unobserved locational fundamentals and endogenous variables given the observed data and parameters. In a first step, a unique wage vector can be determined using workplace employment, residence employment and travel times in the commuting market clearing condition (5). Having solved for wages and hence expected worker income, we can determine residential fundamentals (b_i) using population mobility and utility maximization from (6) and (8). Similarly, we can determine production fundamentals (a_i) using wages, profit maximization and zero profits from (9) and (11). Finally, we can solve for the density of development (φ_i) from the requirement that the implied demands for commercial and residential land equal the effective supply of land in land market clearing (14).

In solving for locational fundamentals, we allow for both zero workplace and residence employment. For locations with zero workplace employment, we set production fundamentals (a_i) equal to zero, which implies zero productivity (A_i), zero wages (w_i) and hence zero commuting probabilities (π_{si}) to that location, which rationalizes the zero workplace employment as an equilibrium outcome. Similarly, for locations with zero residence employment, we set residential location fundamentals (b_i) equal to zero, which implies zero residential amenities (B_i) and zero indirect utility (U_i) for that location, which rationalizes the zero residence employment as an equilibrium outcome.

The solutions for the unobservables $\{a_i, b_i, \varphi_i\}$ are key inputs into our structural estimation of the model's parameters in Section 6 below. For any given parameter vector $\{\alpha, \beta, \lambda, \delta, \kappa, \epsilon, \eta, \rho, T, \bar{U}\}$, we can use cross-section data on the observables $\{\mathbb{Q}_i, H_{Mi}, H_{Ri}, K_i, \tau_{ij}\}$ to solve for the unobservables $\{a_i, b_i, \varphi_i\}$ for which the observed data are an equilibrium of the model. It follows that the model's parameters cannot be identified using cross-section data on the observables, since for each alternative value of the parameters, there are values for the unobservables that rationalize the observed data as an equilibrium. This reflects the identification problem of separating spillovers (as captured by the model's agglomeration and dispersion parameters $\{\lambda, \delta, \kappa, \eta, \epsilon, \rho\}$) from locational fundamentals (as captured by the unobservables $\{a_i, b_i, \varphi_i\}$). To overcome this identification problem, we use the time-series variation provided by the natural experiment of Berlin's division and reunification, as discussed further in Section 6 below.

As in most agglomeration models, there can be multiple equilibria in the model depending on the strength of the agglomeration and dispersion forces (as captured by $\{\lambda, \delta, \kappa, \epsilon, \eta, \rho\}$) relative to the differences in fundamentals across locations (as captured by $\{a_i, b_i, \varphi_i\}$). A key advantage of our quantitative approach is that it can be implemented irrespective of whether the model has a single equilibrium or multiple equilibria. The reason is that we calibrate the unobservables $\{a_i, b_i, \varphi_i\}$ to the observed equilibrium $\{\mathbb{Q}_i, H_{Mi}, H_{Ri}, K_i, \tau_{ij}\}$. From Proposition 1, there is a unique mapping from the observed equilibrium $\{\mathbb{Q}_i, H_{Mi}, H_{Ri}, K_i, \tau_{ij}\}$ to the unobservables $\{a_i, b_i, \varphi_i\}$, irrespective of whether or not there exists another possible equilibrium with different observables for the same values of the unobservables.

Before embarking on our structural estimation of the model, we discuss its qualitative predictions for the impact of Berlin's division and reunification, introduce our data, and present some reduced-form evidence in support of these predictions.

3.5 Berlin's Division and Reunification

We focus in our empirical analysis on West Berlin, since it remained a market-based economy after division and we would therefore expect the mechanisms in the model to apply.[25] The model points to four 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 centers in East Berlin. This reduction in production externalities reduces productivity, which in turn reduces land prices and employment. Second, firms in West Berlin lose access to 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 land prices and employment. Third, residents in West Berlin lose access to employment centers in East Berlin. This reduction in employment opportunities reduces expected worker income, which in turn reduces land prices and residential population. Fourth, residents in West Berlin cease to benefit from residential externalities from population concentrations in East Berlin. This reduction in residential externalities reduces expected utility, which in turn reduces land prices and residents.

Each of these effects is stronger for parts of West Berlin close to employment and residential concentrations in East Berlin, reducing land prices, employment and residents in these parts of West Berlin relative to those elsewhere in West Berlin. All four channels operate 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 land prices and residential land prices. Employment and residents reallocate across locations within West Berlin and to and from the larger West German economy until wages and land prices 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.

[25] 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.

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 four of the above channels together, a key qualitative prediction of the model is that division leads to a decline in land prices, workplace employment and residence employment in areas of West Berlin close to the pre-war CBD relative to other parts of West Berlin.[26]

Since 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. But reunification need not necessarily have exactly the opposite effects from division. As discussed above, if agglomeration forces are sufficiently strong relative to the differences in fundamentals across locations, there can be multiple equilibria in the model. 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 could have changed between the pre-war and division periods, so that reunification is a different shock from division. Notwithstanding these points, reintegration with employment and residential concentrations in East Berlin is predicted to raise relative land prices, workplace employment and residence employment in areas of West Berlin close to those concentrations.

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 ("Blöcke"). Blocks can be aggregated up to areas, which can in turn be aggregated to districts.[27] There are currently 15,937 blocks in Berlin, of which just under 9,000 are in West Berlin.[28] These blocks have an average area of approximately 50,000 square meters and an average 2005 population of 263, permitting a relatively fine characterization of the spatial distribution of economic activity. The quantitative analysis of the model requires four key sets of data: workplace employment, residence employment, land prices and commuting times between locations in Berlin. We have compiled this data at the block level for three years that cover the pre-war, division and reunification period. Our land price data are for 1936, 1986, and 2006, while our data for the other variables are either for these same years or for the closest possible year for which data are available. A more detailed discussion of the data is contained in the web appendix.

Our land price data for 1986 and 2006 are standard land values ("Bodenrichtwerte") per square meter of geographical land area as measured by a German committee of valuation experts ("Gutachterausschuss für

[26] 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 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 the parts of West Berlin close to the pre-war CBD.

[27] As discussed in Section 2, we use the 1938 district boundaries upon which the occupation sectors were based for all years.

[28] There are a number of typically larger blocks that only contain water areas, forests, parks and other uninhabited areas. Approximately twenty percent of the area of Berlin is covered by forests and parks, while another six percent is accounted for by lakes and rivers (Friedensburg 1967).

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 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 land area ("GFZ"), and on land use, which is classified in terms of commercial, industrial, residential and mixed.

Our source of land price data for the pre-war period is Kalweit (1937). Kalweit was a 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 meter of geographical land area in a street atlas, which contains representative land values for each street or segment of street in 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, again measured as the ratio of building floor space to land area (GFZ). Using Geographical Information Systems (GIS) software, we matched the streets or segments of streets in Kalweit (1937) to the blocks in which they were located, and aggregated the street-level land price data to the block-level.[29]

While the land price in the model is measured per effective unit of land (L_i), the land price in the data is measured per unit of geographical land area (K_i). To ensure that land prices in the data are measured in the same way as in the model, we convert all land prices in the data into prices per unit of floor space by using the reported data on the ratio of floor space to land area ("GFZ") and the reported official coefficients for adjusting land prices for different values of this ratio. Finally, since our empirical analysis is based on relative variation in land prices across locations within Berlin, we normalize land prices in each year by their mean, so that the resulting distribution of normalized land prices has a mean of one.

Our measure of employment at the place of work for the reunification period is a count of the 2003 social security employment ("Sozialversicherungspflichtig Beschäftigte") in each block, which was provided by the Statistical Office of Berlin ("Senatsverwaltung für Berlin") in electronic form. We scale up social security employment in each block by the ratio of social security employment to total employment for Berlin as a whole. Data for the division period come from the printed records of the 1987 census, which reports total workplace employment by block.[30] We construct comparable data for the pre-war period by combining data

[29]In robustness checks, we compare our 1936 land value data from Kalweit (1937) with data for 1928 from Kalweit (1929) and data for 1938 compiled by Runge (1950) as part of an official commission for the post-war occupation authorities.

[30]The 1987 census is the most recent census undertaken by Germany.

on district total private-sector workplace employment published in the 1933 census with the postal addresses of all firms on the Berlin company register ("Handelsregister") in 1931. We first use the number of firms in each block to construct a predicted share of that block in total district private-sector workplace employment. We next use these predicted employment shares to allocate the district totals for private-sector workplace employment across blocks within districts. Finally we allocate public-sector workplace employment across blocks using detailed information on the location of public administration buildings (including ministries, utilities and schools) immediately prior to the Second World War.

To construct employment at residence for the reunification period, we use data on the registered population of each block in 2005 from the Statistical Office of Berlin and scale the population data using district-level information on labor force participation, assuming a constant rate of labor force participation across blocks within each district.[31] Employment at residence for the division period is reported by block in the printed records of the 1987 census. To construct pre-war data on employment at residence, we use a tabulation in the 1933 census that lists the population of each street or segment of street in Berlin. We combine these data with a concordance between contemporary streets and blocks from the Statistical Office of Berlin and historical information on changes in street names over time. Mapping each street or segment of street to the blocks to which it is contiguous, we distribute the population of the street or segment of street evenly across all contiguous blocks. We then again use labor force participation rates at the district level to scale the population data to obtain employment at residence by block.

To determine commuting costs in the model we need to know the minimum travel time between each of the 15,937 blocks in our data, i.e. nearly 254 million (15,937$\times$15,937) bilateral connections. We have computed these travel times in 1936, 1986 and 2006. In 1936, commuting to work by car was rare, and hence we construct minimum travel times using the public transport network.[32] In 1986 and 2006, we construct minimum travel times by combining information on the public transport network and driving times by car.

To construct minimum travel times by public transport for the three years, we collected information on the underground railway ("U-Bahn"), suburban railway ("S-Bahn"), tram ("Strassenbahn") and bus ("Bus") network of Berlin in each year and use ArcGIS to compute the fastest connection between each pair of blocks. In this computation, we allow passengers to combine all modes of public transport and walking to minimize travel time. To construct minimum driving times by car in 1986 and 2006, we use an ArcGIS shape file of the modern street network of Berlin to compute the minimum driving times between each pair of blocks. To combine the minimum travel times by public transport and car, we use district-level data on the proportion of journeys undertaken with these two modes of transport to compute a weighted average of the travel times by public transport and car.

Finally, we combine our data on land prices, workplace employment, residence employment, and travel times with ArcGIS information on the geographical land area of blocks, the location of S-Bahn and U-Bahn stations, and other block characteristics, such as proximity to parks, lakes, rivers, canals and schools, the

[31] Empirically, labor force participation is relatively constant across districts within Berlin in all years of our dataset.

[32] Leyden (1933) reports data on travel by mode of transport in pre-war Berlin, in which travel by car accounts for less than 10 percent of all journeys.

extent of destruction during the Second World War, eligibility for government subsidies post reunification, and the location of government buildings post reunification.

5 Reduced-Form Results

In this section, we examine the qualitative predictions of the model for the impact of division and reunification on the distribution of economic activity within West Berlin. We first display the evolution of Berlin's land price gradient over time. We next present reduced-form evidence on the impact of division and reunification using a "difference-in-differences" econometric specification. Finally, we provide evidence on how division and reunification interacted with the pre-existing transport network to shape the evolution of economic activity within West Berlin.

5.1 Evolution of the Land Price Gradient over Time

In Map 1, we display the distribution of land prices across blocks within Berlin in 1936 prior to division, where land prices are normalized to have a mean of one as discussed above. In the map, blocks are shaded according to whether their land price lies within five discrete classes, where the boundaries between classes are chosen to group together similar values within classes and to maximize the differences in 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 land price gradient in 1936 was in fact approximately monocentric, with the highest values concentrated in the district Mitte. Based on the peak in land prices, we determine the center of the pre-war Central Business District (CBD) as the intersection of Friedrich Strasse and Leipziger Strasse, close to the U-Bahn station "Stadtmitte." Around this central point, there are concentric rings of progressively lower land prices surrounding the pre-war CBD. Map 1 also shows the boundaries between the districts of Berlin and the future line of the Berlin Wall, including the inner boundary between East and West Berlin (shown in bolder font) and the outer boundary that separated West Berlin from its East German hinterland. The future line of the Berlin Wall intersected Leipziger Strasse at Potsdamer Platz, around one kilometer West of the center of the pre-war CBD, with the minimum distance to the pre-war CBD in West Berlin equal to around 0.75 kilometers for blocks in Kreuzberg.

In Figures 1-4, we display the distribution of land prices across blocks for each year as a three dimensional surface using a latitude and longitude grid.[33] Since we use the same vertical scale for each figure, and land prices are normalized to have a mean of one in each year, the levels of the land price surfaces in each figure are comparable. Figure 1 displays the 1936 distribution of land prices, with the pre-war CBD in Mitte again evident as the highest land price peak. Also evident are the concentric rings of progressively lower

[33]To construct the figures, 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 land price gradient for a wide range of intervals for the discrete grid.

land prices around the pre-war CBD. Towards the Western edge of these concentric rings is the Kudamm ("Kurfürstendamm") in Charlottenburg and Wilmersdorf, which had developed into a fashionable shopping area in the decades leading up to the Second World War. This area lies to the West of the Tiergarten Park, which explains the gap in land prices between the Kudamm and Mitte in Figure 1 and Map 1.

To show relative land values in locations that subsequently became part of West Berlin, Figure 2 displays the 1936 distribution of land prices for only these locations. The two areas of West Berlin with the highest pre-war land prices were parts of the concentric ring around the pre-war CBD: the area around the Kudamm discussed above and a second area just West of Potsdamer Platz and the future line of the Berlin Wall. This second area was a concentration of commercial and retail activity surrounding the "Anhalter Bahnhof" mainline and suburban rail station. Neither of these areas contained substantial government administration, which was instead concentrated in Mitte in the future East Berlin, particularly around Wilhelmstrasse.

In Figure 3, we examine the impact of division by displaying the 1986 distribution of land prices across blocks within West Berlin. Comparing Figures 2 and 3, three main features stand out. First, land prices exhibit less dispersion and smaller peak values in West Berlin during division than in Greater Berlin during the pre-war period. Second, one of the pre-war land price 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. Third, West Berlin's CBD during division coincided with the other area of high pre-war land values in West Berlin around the Kudamm, which was relatively centrally located within West Berlin and experienced some westwards consolidation of high land values during the division period.

To examine the impact of reunification, Figure 4 displays the 2006 distribution of land prices across blocks within Berlin as a whole, while Figure 5 shows the same distribution but only for blocks in the former West Berlin. Comparing these two figures with the previous two figures, three main features are again apparent. First, land prices are more dispersed and have higher peak values following reunification than during division. Second, the area just West of Potsdamer Platz is again emerging as a concentration of high land values in the former West Berlin, with these high land values concentrated around the commercial and retail development in the Sony Center. Again this area is distinct from the main centers of government construction and administration, which are concentrated either around the parliament building ("Reichstag") around one kilometer North or in Mitte in the former East Berlin. Third, Mitte is again a center of high land values as in the pre-war period, although the land price peaks in Mitte and Kudamm are now closer in magnitude to one another than in the pre-war period.

In Maps A1 and A2 of the web appendix, we provide further evidence on the impact of division and reunification by displaying the log difference in land prices from 1936-1986 and 1986-2006 for each block, where the data are again grouped into five discrete classes. As evident from Map A1, the largest declines in land prices are observed along those segments of the Berlin Wall around the pre-war CBD. In contrast, there is little evidence of comparable declines in land prices along other sections of the Berlin Wall, which suggests that it is not proximity to the Berlin Wall *per se* that matters but rather the loss of access to the pre-war CBD. The only other location within West Berlin with comparable declines in land prices is found in Spandau, which was the site of Siemens's vast industrial and residential complex ("Siemensstadt"), which relocated to Munich following the Second World War. As shown in Map A2, the highest rates of growth of land prices following reunification are also concentrated along those segments of the former Berlin Wall around the pre-war CBD, with little evidence of comparable land price growth along other sections of the Berlin Wall. Indeed, comparing Maps A1 and A2, it is striking the extent to which the areas that experienced the highest decline in land prices from 1936-1986 are also the areas that experienced the highest growth in land prices from 1986-2006.

5.2 Difference-in-Difference Estimates

To provide evidence on the statistical significance of the above findings and their robustness to controlling for potential alternative explanations, we now present reduced-form evidence on the impact of division and reunification using a "differences-in-differences" econometric specification. The level of economic activity in each location is influenced by two sets of determinants in the model: exogenous differences in locational fundamentals and endogenous differences in production and residential externalities, which depend on the surrounding density of economic activity. To examine the role of these two sets of determinants without imposing the full structure of the model, we consider the following empirical specification:

$$\ln O_{it} = \psi_i + f(D_{it}) + \ln M_i \mu_t + \nu_t + u_{it}, \tag{15}$$

where i denotes blocks and t corresponds to time.

The dependent variable $O_{it} \in \{\mathbb{Q}_{it}, H_{Mit}, H_{Rit}\}$ is a measure of the level of economic activity in each block (land prices, workplace employment or residence employment); the block fixed effect ψ_i allows for unobserved heterogeneity in locational fundamentals that can be correlated with the other explanatory variables; D_{it} is a measure of the surrounding density of economic activity and $f(\cdot)$ is a function that determines how each block is influenced by the surrounding density of economic activity; M_i are time-invariant observable block characteristics (such as proximity to parks and lakes), where the coefficients on these observables μ_t are allowed to vary over time; ν_t is a time fixed effect that captures the effect of division or reunification on the overall level of economic activity across all blocks; and u_{it} is a stochastic error.

Taking differences between the division and pre-war periods, or between the reunification and division periods, we obtain the following regression specification:

$$\triangle \ln O_i = \tilde{\nu} + \tilde{f}(D_{it}, D_{it-T}) + \ln M_i \tilde{\mu} + \tilde{u}_i, \tag{16}$$

where $\triangle$ is the difference operator between year t and $t-T$; $\tilde{\nu} = \nu_t - \nu_{t-T}$ is the regression constant; $\tilde{f}(D_{it}, D_{it-T}) = f(D_{it}) - f(D_{it-T})$ captures the effect of the change in the surrounding density of economic activity; $\tilde{\mu} = \mu_t - \mu_{t-T}$ captures the effect of changes in the coefficients on observable block characteristics; and $\tilde{u}_i = u_{it} - u_{it-T}$ is a stochastic error.

A key empirical challenge in estimating a specification such as (16) is that economic activity in each block is jointly and endogenously determined with economic activity in neighboring blocks, so that the term capturing the change in the surrounding density of economic activity ($\tilde{f}(D_{it}, D_{it-T})$) is correlated with the error term for each block ($\tilde{u}_i$). To address this challenge, we exploit the exogenous source of variation in the surrounding density of economic activity provided by Berlin's division and reunification. We capture this exogenous change in the surrounding density of economic activity for each block in West Berlin by including a non-parametric function of its distance from the pre-war CBD in East Berlin, which yields our baseline empirical specification:

$$\triangle \ln O_i = \tilde{\nu} + \sum_{k=1}^{K} d_{ik}\xi_k + \ln M_i \tilde{\mu} + \tilde{u}_i, \tag{17}$$

where d_{ik} is dummy variable for whether block i lies within a distance grid cell k from the pre-war CBD; and ξ_k is a coefficient to be estimated for each distance grid cell. We begin by considering distance grid cells of 500 meter intervals. Since the minimum distance to the pre-war CBD in West Berlin is around 0.75 kilometers, our first distance grid cell is for blocks with distances less than 1.25 kilometers. We include grid cells for blocks with distance up to 3.25-3.75 kilometers, so that the excluded category is blocks more than 3.75 kilometers from the pre-war CBD.[34] While this grid cells specification allows for a flexible functional form for the relationship between changes in block economic outcomes and distance from the pre-war CBD, we find similar results using other related approaches such as locally-weighted linear least squares specifications, as discussed in the next section. To allow the error terms for neighboring blocks to be correlated, we cluster the standard errors by the 90 statistical areas ("Gebiete") in our sample.[35]

Our baseline econometric specification (17) has a "difference-in-difference" interpretation, where the first difference is over time and the second difference is between areas of West Berlin at varying distances from the pre-war CBD in East Berlin. We estimate this specification separately for division (taking differences between 1936 and 1986) and for reunification (taking differences between 1986 and 2006). The key coefficients of interest are those on the distance grid cells (ξ_k), which capture the treatment effects of division or reunification on blocks in West Berlin proximate to the pre-war CBD.

In the baseline econometric specification (17), time-invariant unobserved heterogeneity in the level of economic activity within each block (ψ_i) is differenced out when we take long differences. The terms in time-invariant observable block characteristics (M_i) are not differenced out when we take long differences, because we allow their effect to change over time ($\tilde{\mu} = \mu_t - \mu_{t-T}$), so that for example proximity to lakes and parks can become more or less valuable over time. We include a wide range of controls for observable block characteristics: log distances to the nearest U-Bahn station and S-Bahn station (in both the final year t and initial year $t - T$), log distance to the nearest park, canal, lake, river and school, log block land area, the percentage of the block's land area destroyed during the Second World War, and dummy variables for commercial, industrial and residential land use (where the excluded category is mixed land use), whether a block is eligible for government subsidy programs post reunification, and whether a block contains a government building post reunification.

Table 1 reports the results of estimating our baseline specification (17) for division. The dependent

[34] There are 87 West Berlin blocks with distances to the pre-war CBD of less than 1.25 kilometers and 1,749 West Berlin blocks within distances of less than 3.75 kilometers. The maximum distance to the pre-war CBD in West Berlin is around 23 kilometers.

[35] 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.

variable in Columns (1)-(5) is the log difference in land prices between 1936 and 1986. In Column (1) we include only the distance grid cells, and find a negative and statistically significant effect of proximity to the pre-war CBD, which declines monotonically with distance from the pre-war CBD. In this reduced-form specification, the estimated coefficients on the grid cell dummies capture both the direct effect of the loss in access to the pre-war CBD and the indirect general equilibrium effects from reallocations in economic activity within West Berlin following division. On average, West Berlin blocks within the first distance grid cell experience around a 95 percent reduction in land prices between 1936 and 1986 (since $1-e^{-3.016} = 0.95$) relative to those more than 3.75 kilometers away from the pre-war CBD. Together the six distance grid cells alone explain around one fifth of the variation in land price changes following division ($R^2 = 0.21$), suggesting 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 policies across districts and occupation sectors based on these districts. Although districts differ substantially in terms of their centrality relative to the pre-war CBD (as shown in Map 1), this specification abstracts entirely from these differences. Nonetheless, even when we focus solely on variation in proximity to the pre-war CBD within districts, we continue to find negative and statistically significant effects although of a somewhat smaller magnitude. Column (3) examines whether it is really proximity to the pre-war CBD that matters by including analogous 500 meter grid cells for distance to the closest point on the inner boundary between East and West Berlin and distance to the closest point on the outer boundary between West Berlin and its East German hinterland. Again we find a negative and statistically significant effect of proximity to the pre-war CBD. In contrast, the coefficients on the distance grid cells for the inner and outer boundaries are substantially smaller in magnitude and either statistically insignificant or positive. This pattern of results is reassuring, because it suggests that the reorientation of West Berlin's land price gradient following division does 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.[36] In Column (4), we show that we find a similar pattern of results if we also include analogous 500 meter grid cells for distance to the Kudamm, providing further confirmation that our results are capturing a loss of access to the pre-war CBD. In Column (5), we further augment the specification from Column (4) with our controls for observable block characteristics, and again find a similar pattern of results.[37]

In the next two Columns, we report results for employment residence. While Column (6) includes only our distance grid cells for proximity to the pre-war CBD and district fixed effects, Column (7) augments this specification with the distance grid cells for proximity to the inner boundary, outer boundary and the Kudamm. In both cases, we find that West Berlin blocks close to the pre-war CBD experienced a decline in employment residence relative to other parts of West Berlin following division, although the effects are

[36] 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 Berlin, which together ensured small net commuting even prior to the Second World War. In 1933, total workplace and residence employment in Berlin were 1,628,622 and 1,591,723, respectively, implying net inward commuting of 36,899.

[37] As an additional robustness check, we included a quadratic in observable block characteristics to allow for a more flexible functional form for these controls, and again found a similar pattern of results.

smaller in magnitude and sometimes less precisely estimated than for land prices. Columns (8) and (9) confirm a similar pattern of results for employment workplace. In the employment workplace specifications, the estimated coefficient for the first grid cell is somewhat smaller in magnitude and less precisely estimated than for the second grid cell. This pattern of results is consistent with attempts to promote employment opportunities in areas of West Berlin in the immediate shadow of the Berlin Wall, such as the construction of the Axel-Springer building by the Springer publishing house. To the extent that these interventions were successful, our estimates provide a lower bound to the negative treatment effects of proximity to the pre-war CBD following division.

In Table 2, we report analogous specifications for reunification. Consistent with the predictions of the model, we observe the reverse pattern of results for reunification. The absolute magnitude of the estimated coefficients for reunification is somewhat smaller than for division, which is consistent with both the lower relative levels of economic activity in East Berlin and East Germany at the time of reunification than at the time of division and the shorter time interval since reunification. In Column (1), we include only the distance grid cells. We find that West Berlin blocks within the first distance grid cell experience around a 350 percent increase in land prices between 1986 and 2006 ($e^{1.514} - 1 = 3.54$) relative to those more than 3.75 kilometers away from the pre-war CBD, which is less than would be required to achieve the same relative level of land prices as in 1936 ($e^{3.016} - 1 = 19.41$). Together the six distance grid cells now explain around one tenth of the observed variation in land price growth ($R^2 = 0.09$).

In Columns (2)-(5), we augment this specification to include district fixed effects, distance grid cells for proximity to the inner and outer boundaries of the Berlin Wall; distance grid cells for proximity to the Kudamm, and our full set of controls for observable block characteristics. Across each of these specifications, we continue to find positive and statistically significant effects of proximity to the pre-war CBD. Again the coefficients for proximity to the inner and outer boundaries are substantially smaller in magnitude and either statistically insignificant or opposite in sign to those for proximity to the pre-war CBD, confirming that our results are indeed capturing the change in access to the pre-war CBD. In Column (5), we include controls for government urban regeneration programs and the location of contemporary government buildings to address the concern that the increase in land prices following reunification in areas of West Berlin close to the pre-war CBD could be driven by government intervention. As already discussed, the largest increases in land prices in West Berlin following reunification are in areas of commercial rather than government development, and government buildings are concentrated in East Berlin.

In Column (6)-(9), we report results for employment residence and employment workplace. In each case, we find positive and statistically significant effects of proximity to the pre-war CBD that are robust to controlling for proximity to the inner boundary, outer boundary and Kudamm. The results using employment residence provide further evidence against an explanation based on the location of government buildings, since government buildings reduce the land area available for residential use and hence are likely to reduce rather than increase employment by residence.

We have also undertaken a number of further robustness checks. One potential concern is that the areas that would become parts of West Berlin close to the pre-war CBD could have been experiencing a relative decline even prior to the Second World War (e.g. in the aftermath of the Great Depression of the early 1930s or following the accession of the Nazi party to power in 1933). To address this concern, we use land price data for 1928 from Kalweit (1929) to undertake a placebo exercise using land price growth from 1928-1936. We find no evidence that land price growth in the future West Berlin is related to distance from the pre-war CBD over this period.[38] Another related concern is that areas of West Berlin close to the pre-war CBD could have been expanding even prior to reunification. However, using district ("Bezirke") data on employment by workplace and residence, we find no evidence of a resurgence in economic activity in the West Berlin districts immediately adjacent to the pre-war CBD prior to 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 Hofmeister (1988). A final concern is that our results could be driven by a few blocks in a single locality within West Berlin. To address this concern, we re-estimated our specifications for division and reunification sequentially excluding individual districts ("Bezirke") from the sample, and found a similar pattern of results.

Taken together, the results of this section provide strong empirical support for the qualitative predictions of the model. In the aftermath of division, there is a reorientation of the gradient in land prices and economic activity within West Berlin away from the main pre-war concentration of economic activity in East Berlin. Following reunification, we find a reemergence of this gradient.

5.3 Transport Access Results

The mechanism underlying the effects of division and reunification in the model is a change in access to the surrounding concentration of economic activity. To provide further evidence on this mechanism, we use variation in the access of locations in West Berlin to the U/S-Bahn rail network, which was a central part of Berlin's transport infrastructure prior to the Second World War and remains an important mode of transport for commuting today. Since division substantially reduced the extent of the U/S-Bahn network accessible from West Berlin by closing off links to East Berlin and East Germany, it reduced the transport access advantage from proximity to an U/S-Bahn station. Locations in West Berlin close to U/S-Bahn stations were more adversely affected by division, because they lost access to locations in East Berlin to which they previously had low travel times. In contrast, the effect on blocks in West Berlin further from U/S-Bahn stations was more muted, because they had higher travel times to East Berlin prior to division.

To provide evidence on the extent to which there were heterogeneous treatment effects of division and reunification on land values depending on transport access, we split West Berlin blocks into two groups based on whether they are less than or more than 250 meters from a U/S-bahn station in the 1936 network.[39] In Figure 6, we display the log difference in land prices from 1936-1986 for each West Berlin block against distance from the pre-war CBD, where blocks less than 250 meters from a U/S-bahn station are denoted by

[38] Since our estimates of employment residence and workplace for 1936 are based on the results of the 1933 population census, our results for these outcomes are unlikely to have been affected by events that occurred after 1933.

[39] While we choose a threshold of 250 meters for proximity to a U/S-bahn station because it divides blocks within the 500 meter distance grid cells considered in the previous section into two roughly equal groups, we find similar results using other distance thresholds.

circles, while those more than 250 meters away are denoted by crosses. The solid lines in the figure show the fitted values from separate locally-weighted linear least squares regressions of the log difference in land prices on distance from the pre-war CBD for the two groups. The dashed lines around these fitted values show the 95 percent point confidence intervals. Confirming the results from our distance grid cells specification in the previous section, we find a sharp, non-linear and negative relationship between land price growth and distance from the pre-war CBD. Additionally, at a given distance from the pre-war CBD, we find that blocks closer to a U/S-bahn station experience a larger reduction in land prices following division, consistent with their greater transport access loss.

Figure 7 displays analogous results for reunification. To focus on the exogenous impact of the reconnection of historical transport links, we again categorize West Berlin blocks based on their distance to a 1936 U/S-bahn station, which ensures that the composition of blocks in the two groups is the same as in the previous figure. We again find a reverse pattern of results for reunification, with a pronounced, non-linear and positive relationship between land price growth and distance from the pre-war CBD. Furthermore, at a given distance from the pre-war CBD, we find that blocks closer to a U/S-bahn station experience a larger increase in land prices following reunification, consistent with their greater transport access gain.

While proximity to a U/S-bahn station provides a simple and transparent measure of transport access, we find similar results using other related measures.[40] As a robustness check, we constructed a measure of Eastern transport access loss for each West Berlin block, which is equal to its average travel time using the 1936 U/S-bahn network to blocks in East Berlin weighted by the relative land prices of those blocks. To focus on differential changes in transport access among blocks at similar distances from the pre-war CBD, we split West Berlin blocks into two groups based on whether they had above or below median changes in Eastern transport access within each 500 meter distance grid cell from the pre-war CBD. Repeating the analysis in Figures 6 and 7 using this alternative sample split, we find the same pattern of results.

Therefore, using a different source of variation in the data, the results of this section provide further evidence in support of the model's mechanism of a change in access to the surrounding concentration of economic activity. While the evidence in the previous section exploited variation within a few kilometers of the pre-war CBD, the variation induced by changes in transport access extends much further into West Berlin. This makes it less likely that our results are picking up something that is specific to central locations, such as the location of government buildings.

6 Structural Estimation

While the previous section provided reduced-form evidence in support of the model's qualitative predictions, we now examine the extent to which the model can account quantitatively for the impact of division and reunification. In Proposition 1 of Section 3, we showed that unobserved locational fundamentals $\{a_i, b_i, \varphi_i\}$

[40] In principle, one could envision distinguishing between U/S-bahn lines depending on whether or not they were intersected by the Berlin Wall. However, the U/S-bahn network in pre-war Berlin was closely interconnected through an S-bahn ring that encircled the pre-war CBD, with the result that all U/S-bahn lines were in some way affected by the Berlin Wall.

can be uniquely determined from observed cross-section data on land prices, workplace employment, residence employment, geographical land area and travel times $\{\mathbb{Q}_i, H_{Mi}, H_{Ri}, K_i, \tau_{ij}\}$ for given values of the model's parameters $\{\alpha,\ \beta,\ \lambda,\ \delta,\ \kappa,\ \epsilon,\ \eta,\ \rho,\ T,\ \bar{U}\}$. Therefore each of the model's locational fundamentals can be written as an implicit function of observables and parameters. In this section, we show how these implicit functions can be used together with the time-series variation from Berlin's division and reunification to construct moment conditions to structurally estimate the model's parameters.

6.1 Structural Parameters

The model has ten parameters $\{\alpha, \beta, \lambda, \delta, \kappa, \epsilon, \eta, \rho, T, \bar{U}\}$. Of these ten parameters, a choice for the value of the reservation utility in the larger economy ($\bar{U}$) is equivalent to a choice of units in which to measure residential fundamentals (b_i), and hence we impose the normalization that $\bar{U} = 1,000$. Similarly, changes in the Fréchet scale parameter (T) lead to exactly offsetting changes in the calibrated values of locational fundamentals, and hence we impose the normalization that $T = 1$.

Of the remaining eight parameters, the share of residential land in consumer expenditure $(1 - \beta)$ and the share of commercial land in firm costs $(1 - \alpha)$ are hard to determine from our data, because information on consumer expenditures and factor payments at the block level is not available over our long historical sample period. As there is a degree of consensus about the value of these parameters, we set them equal to central estimates from the existing empirical literature. We set the share of residential land in consumer expenditure $(1 - \beta)$ equal to 0.25, which is consistent with the estimates in Davis and Ortalo-Magne (2011). We assume that the share of commercial land in firm costs $(1 - \alpha)$ is 0.20, which is in line with the findings of Valentinyi and Herrendorf (2008).

Using these normalized values of $\{\bar{U}, T\}$ and calibrated values of $\{\alpha, \beta\}$, we estimate the remaining six parameters of the model $\{\lambda, \delta, \kappa, \epsilon, \eta, \rho\}$ using the Generalized Method of Moments (GMM).

6.2 Moment Conditions

We begin by using results from our theoretical analysis in Section 3 to express unobserved fundamentals in terms of observables and parameters. From population mobility (6) and residential amenities (8), residential fundamentals (b_{it}) can be expressed as follows:

$$\ln b_{it} = (1-\beta)\ln \mathbb{Q}_{it} + \ln \bar{U} - \beta \ln \beta - (1-\beta)\ln(1-\beta) - \ln \bar{v}_{it} - \eta \ln \Omega_{it}, \tag{18}$$

where land prices ($\mathbb{Q}_{it}$) are observed; expected worker income ($\bar{v}_{it}$) depends solely on wages (w_{it}) from (7); wages are a function of observed workplace employment (H_{Mit}), residence employment (H_{Rit}) and bilateral travel times (τ_{ij}) from commuting market clearing (5); residential externalities (Ω_{it}) are a function of observed residents (H_{Rit}), bilateral travel times (τ_{ij}) and land area (K_i) from our specification of residential externalities (8).

From zero-profits (9) and productivity (11), production fundamentals (a_{it}) can be written as follows:

$$\ln a_{it} = (1-\alpha)\ln \mathbb{Q}_{it} - (1-\alpha)\ln(1-\alpha) - \alpha \ln\left(\frac{\alpha}{w_{it}}\right) - \lambda \ln \Upsilon_{it}, \tag{19}$$

where land prices ($\mathbb{Q}_{it}$) are observed; wages (w_{it}) are a function of observables as discussed above; production externalities (Υ_{it}) are a function of observed land area (K_i), bilateral travel times (τ_{ij}) and effective employment ($\widetilde{H_{Mjt}}$) from our specification of production spillovers (11); effective employment is a function of observed residents (H_{Rit}), wages (w_{it}) and expected worker income ($\bar{v}_{it}$) from labor market clearing (10); wages and expected worker income are a function of observables as discussed above.

From the demand for residential land (12), the demand for commercial land (13) and land market clearing (14), the density of development (φ_{it}) can be expressed as:

$$\ln \varphi_{it} = \ln \left[\widetilde{H_{Mit}} \left(\frac{w_{it}}{\alpha A_{it}} \right)^{\frac{1}{1-\alpha}} + \frac{H_{Rit} \left(1-\beta\right) \bar{v}_{it}}{\mathbb{Q}_{it}} \right] - \ln K_i, \tag{20}$$

where residence employment (H_{Rit}), land prices ($\mathbb{Q}_{it}$) and land area (K_i) are observed; productivity (A_{it}) depends solely on wages and observed land prices in (11); effective employment, wages and expected worker income are a function of observables as discussed above.

We allow the density of development (φ_{it}) to vary in an unrestricted way across blocks and over time. Given the total demand for effective land in the model and observed geographical land area in the data, we solve for the value that the density of development must take in order for the effective supply of land to equal the effective demand for land. This approach enables us to avoid making assumptions about the elasticity of the effective supply of land, which depends in part on land regulation and is implicitly captured in our solutions for the density of development.

To identify the model's parameters, we assume that residential and production fundamentals ($\ln a_{it}$ and $\ln b_{it}$) consist of time-invariant fixed effects ($\ln a_{Fit}$ and $\ln b_{Fit}$) and time-varying components ($\ln a_{Vit}$ and $\ln b_{Vit}$):

$$\ln b_{it} = \ln b_{Fi} + \ln b_{Vit}, \tag{21}$$

$$\ln a_{it} = \ln a_{Fi} + \ln a_{Vit}. \tag{22}$$

Substituting (18) and (19) into (21) and (22) and taking differences between the pre-war and division periods or between the division and reunification periods, changes in residential and production fundamentals can be written in terms of observables and parameters as:

$$\Delta \ln b_{Vit} = \left(1-\beta\right) \Delta \ln \mathbb{Q}_{it} - \Delta \ln \bar{v}_{it} - \eta \Delta \ln \Omega_{it}, \tag{23}$$

$$\Delta \ln a_{Vit} = \left(1-\alpha\right) \Delta \ln \mathbb{Q}_{it} + \alpha \Delta \ln w_{it} - \lambda \Delta \ln \Upsilon_{it}, \tag{24}$$

where $\Delta \ln b_{Vit}$ and $\Delta \ln a_{Vit}$ correspond to model-based residuals that ensure the model replicates the observed changes in land prices, workplace employment and residence employment.

Our goal is to examine whether the reorientation of economic activity within West Berlin following division and reunification can be explained quantitatively by the model's agglomeration and dispersion forces. To the extent that this is the case, the model will be able to explain the observed reorientation of economic activity through the changes in agglomeration and dispersion forces induced by division and reunification, without requiring systematic changes in residential and production fundamentals ($\triangle \ln b_{Vit}$ and $\triangle \ln a_{Vit}$). In terms of the right-hand side of (23) and (24), the observed changes in land prices ($\triangle \ln \mathbb{Q}_{it}$) in parts of West Berlin close to and far from the pre-war CBD will be explained by the changes in expected worker income ($\triangle \ln \bar{v}_{it}$), wages ($\triangle \ln w_{it}$), residential externalities ($\eta \triangle \ln \Omega_{it}$) and production externalities ($\lambda \triangle \ln \Upsilon_{it}$). Under these circumstances, the changes in residential fundamentals ($\triangle \ln b_{Vit}$) and production fundamentals ($\triangle \ln a_{Vit}$) on the left-hand side of (23) and (24) will not vary systematically with geographical location within West Berlin.

Our identification assumption is that the mean and variance of changes in residential and production fundamentals are constant across blocks within West Berlin: $\triangle \ln b_{Vit} \sim$ i.i.d (μ_b, σ_b^2) and $\triangle \ln a_{Vit} \sim$ i.i.d (μ_a, σ_a^2). Under this assumption, the mean and variance of these changes do not vary with geographical location within West Berlin. We therefore estimate the model's parameters by minimizing the difference between unweighted and distance-weighted means and variances of changes in residential and production fundamentals:

$$\begin{array}{rcrcl} \left[\omega' \triangle \ln b_{Vt}\right] & - & \left[\frac{1}{N} I' \triangle \ln b_{Vt}\right] & = & 0, \\ \left[\omega' \triangle \ln a_{Vt}\right] & - & \left[\frac{1}{N} I' \triangle \ln a_{Vt}\right] & = & 0, \\ \left[\omega' \left(\triangle \ln b_{Vt} - \frac{1}{N} I' \triangle \ln b_{Vt}\right)^2\right] & - & \left[\frac{1}{N} I' \left(\triangle \ln b_{Vt} - \frac{1}{N} I' \triangle \ln b_{Vt}\right)^2\right] & = & 0, \\ \left[\omega' \left(\triangle \ln a_{Vt} - \frac{1}{N} I' \triangle \ln a_{Vt}\right)^2\right] & - & \left[\frac{1}{N} I' \left(\triangle \ln a_{Vt} - \frac{1}{N} I' \triangle \ln a_{Vt}\right)^2\right] & = & 0, \end{array} \tag{25}$$

where $\triangle \ln b_{Vt}$ is the vector of changes in residential fundamentals; $\triangle \ln a_{Vt}$ is the vector of changes in production fundamentals; ω is a vector of distance weights; I is a vector of ones.

Our identification assumption allows the time-invariant fixed effects ($\ln b_{Fi}, \ln a_{Fi}$) to vary in a general way across blocks within Berlin and to be correlated with the observed values of rents, workplace employment and residence employment. Our choice of distance weights is guided by our reduced-form analysis in Section 5. We construct three distance weights for each block based on proximity to the pre-war CBD, the inner boundary between East and West Berlin, and the outer boundary between West Berlin and its East German hinterland: $\omega_i = \text{dist}_i / \sum_{s \in \text{West}} \text{dist}_s$, where dist_i is either distance to the pre-war CBD, inner boundary or outer boundary; ω_i sums to one across blocks within West Berlin for each distance measure. Each of the four vectors in (25) has three elements for the three distance weights, which yields twelve moment conditions to estimate the model's six parameters.

The sources of variation used to identify the six parameters $\{\lambda, \delta, \kappa, \epsilon, \eta, \rho\}$ are evident from residential fundamentals (23) and production fundamentals (24). In residential fundamentals (23), changes in residential externalities ($\eta \triangle \ln \Omega_i$) depend solely on $\{\eta, \rho\}$ and observed changes in residence employment. While η determines the overall importance of residential externalities for land prices, ρ dictates their spatial decay with residential population densities. Similarly, in production fundamentals (24), changes in production externalities ($\lambda \triangle \ln \Upsilon_i$) depend solely on $\{\lambda, \delta\}$ and observed changes in effective workplace employment. While λ determines the overall importance of production externalities for land prices, δ determines their spatial decay with effective employment densities. Therefore $\{\eta, \rho\}$ are identified from the spatial distribution of changes in land prices relative to changes in residence employment, while $\{\lambda, \delta\}$ are identified from the spatial distribution of changes in land prices relative to changes in effective workplace employment.

Finally, in residential fundamentals (23) and production fundamentals (24), changes in expected worker income ($\triangle \ln \bar{v}_i$) and wages ($\triangle \ln w_i$) depend solely on the parameters $\{\kappa, \epsilon\}$. Together these two parameters determine the changes in wages required for the labor market to clear given the observed changes in workplace employment and residence employment. While η determines the elasticity of commuting flows with respect to wages for given commuting costs, $\kappa\epsilon$ determines the elasticity of commuting flows with respect to travel time for given wages. Therefore $\{\kappa, \epsilon\}$ are identified from the spatial distribution of changes in land prices relative to the joint spatial distribution of changes in workplace employment and residence employment.

The theoretical model imposes restrictions on some parameters. A finite variance of expected worker income across blocks requires $\epsilon > 2$. A non-degenerate distribution of workplace employment is ensured by $\lambda < 1 - \alpha$, while a non-degenerate distribution of residence employment is ensured by $\eta < 1 - \beta$.[41] Since we observe a finite variance of land prices (which requires a finite variance of expected worker income), and since we observe non-degenerate distributions of workplace and residence employment in the data, we impose these theoretical restrictions on parameters.

6.3 Parameter Estimates

We estimate the model separately for the difference between the pre-war and division periods and the difference between the division and reunification periods. We estimate the six parameters using the twelve moment conditions discussed above and the Generalized Method of Moments (GMM).

For each parameter vector $\{\lambda, \delta, \kappa, \epsilon, \eta, \rho\}$, we use the observed data on land prices, workplace employment and residence employment $\{\mathbb{Q}_i, H_{Mi}, H_{Ri}\}$ to solve for unobserved locational fundamentals $\{a_i, b_i, \varphi_i\}$. Prior to division or after reunification, this involves solving for a fixed point in wages for 15,937 blocks in Greater Berlin, which in turn involves computing nearly 254 million (15,937 $\times$ 15,937) bilateral commuting flows. During division, we solve for wages and bilateral commuting flows for around 9,000 of these blocks that lie within West Berlin. Given the resulting solutions for locational fundamentals in each year for each parameter vector, we compute the moment conditions for changes in locational fundamentals (25). We estimate the parameters by minimizing the sum of squared deviations of the moments from their theoretical value of zero using Matlab's Simulated Annealing algorithm. We find that the estimated parameter vector is not sensitive to the initial parameter vector assumed, which suggests that the moment conditions are able to determine the parameters.

Table 3 reports both the one-step GMM results that use the identity matrix to weight the moment conditions and the two-step GMM results that use the efficient weighting matrix. We find a similar pattern of estimated coefficients for division and reunification. We also find comparable results using the one-step and two-step weighting matrices. Our structural estimates using block-level data within cities exhibit a higher elasticity of productivity with respect to employment density ($\lambda \simeq 0.12 - 0.15$) than reduced-form estimates

[41] If $\lambda > 1 - \alpha$, the value marginal product of labor is increasing in block employment, and hence all workplace employment can be concentrated in a single block. If $\eta > 1 - \beta$, the marginal utility from residing in a location is increasing in the number of residents, and hence all residence employment can be concentrated in a single block.

using variation across cities or regions ($\lambda \simeq 0.05$ as reviewed in Rosenthal and Strange 2004). This stronger productivity effect of density is consistent with the much smaller spatial scale of our data and the sharp land price peaks observed in central business districts within cities. We find somewhat stronger density effects for residential externalities than for production externalities, with an estimated elasticity of indirect utility with respect to population density (η) of around 0.21−0.24. This pattern of results is consistent with the view that consumption externalities are an important agglomeration force in addition to production externalities (as argued for example by Glaeser, Kolko and Saez 2001).

We find that production externalities within cities are highly localized, with an estimated exponential decay parameter for travel times (in minutes) in Table 3 of $\delta \simeq 0.52 - 0.88$. We use this estimated exponential decay parameter in Table 4 to evaluate the proportional reduction in production externalities as travel time increases. The effect of employment density on productivity drops below one percent after around eight minutes travel time, which corresponds to a distance traveled of around 0.66 kilometers by foot (at an average speed of five kilometers per hour) and 3.33 kilometers by U-bahn or S-bahn (at an average speed of 25 kilometers per hour). These findings are consistent with Arzaghi and Henderson (2008)'s results for advertising agencies in mid-town Manhattan, in which there is little evidence of knowledge spillovers beyond 500 meters in their baseline specification. These findings are also in line with the concentration of economic activities within narrow neighborhoods of cities, such as financial services in the Square Mile of London. Residential externalities are also localized, but extend over longer travel times, with an estimated exponential decay parameter in Table 3 of $\rho \simeq 0.25 - 0.60$. As a result, the effect of residential externalities on indirect utility falls below one percent after around 12 minutes travel time, which corresponds to a distance traveled of around 1 kilometer by foot or 5 kilometers by U-bahn or S-bahn. These findings are in line with residence employment densities being typically more dispersed than workplace employment densities.

Our structural model enables us to separate out commuting costs from agglomeration forces. As reported in Table 3, we find that the growth of commuting costs with travel time is much lower than the decay of production and residential externalities ($\kappa \simeq 0.001$). As shown in Table 4, worker productivity falls by less than five percent even after around thirty minutes travel time. This pattern of results is consistent with commutes of thirty minutes being not unusual in urban areas and with residential population concentrations occurring at substantial distances from central business districts.

Comparing the results for division and reunification in Table 3, we find a similar pattern of estimated structural parameters. The estimated decay parameters for production and residential externalities (λ and η) are slightly larger for 2006 than 1936, which reflects the smaller and more localized effects of reunification. While the estimated decay parameter for commuting costs (κ) falls between division and reunification, the estimated Fréchet shape parameter (ϵ) rises. The net effect is a fall in the elasticity of commuting costs with respect to travel time ($\kappa\epsilon$), which is consistent with a shift of economic activity to lower densities over time.

Since division and reunification have a number of idiosyncratic features (e.g. division is accompanied by Second World War destruction), the similarity of the estimated coefficients suggests that our underlying model of agglomeration and dispersion forces is generalizable across different contexts. One of these idiosyncratic features is changes in transport technology over time, which we control for by measuring travel times separately for division and reunification, as discussed above. Our findings suggest that once we control for changes in travel times a common set of structural parameters can explain the data.

6.4 Model Fit

Figures 8 and 9 examine the model's fit for division and reunification for our estimated parameter values. Panel A of Figure 8 shows the sharp decline in land prices close to the pre-war CBD that is observed in the data. Both production externalities (Panel B) and residential externalities (Panel D) in the model exhibit a similar sharp decline close to the pre-war CBD as a result of the loss in access to concentrations of employment and residents in East Berlin. For blocks between 5-10 kilometers from the pre-war CBD, both changes in production fundamentals (Panel C) and residential fundamentals (Panel E) are largely unrelated to distance from the pre-war CBD, which suggests that production and residential externalities explain most of the relative decline in land prices for these blocks. For blocks less than 5 kilometers from the pre-war CBD, production and residential fundamentals decline, which suggests that the externalities in the model do not completely explain the relative decline in land prices close to the pre-war CBD. In contrast, the change in the density of development (Panel F) is relatively constant and indeed rises for blocks closest to the pre-war CBD, which implies that the reorientation of economic activity in West Berlin following division can be explained by changes in relative productivity and amenities across blocks without systematic changes in building density.

As shown in Figure 9, the sharp rise in land prices close to the pre-war CBD following reunification (Panel A) can be largely explained by the model's agglomeration forces of production externalities (Panel B) and residential externalities (Panel D). As a result, production fundamentals (Panel C) and residential fundamentals (Panel E) are relatively flat across blocks at different distances from the pre-war CBD. Again the density of development (Panel F) is relatively flat, suggesting that the reorientation of economic activity following reunification can be largely explained by productivity and amenities rather than by changes in building density.

These results provide support for the model's mechanisms in understanding the impact of Berlin's division and reunification. Although the model's agglomeration and dispersion forces do not completely explain the reorientation of economic activity, leaving some role for changes in production and residential fundamentals, this reflects in part the strong simplifying assumptions that we have made in considering the canonical urban model. For example, while we have assumed an exponential functional form for production and residential externalities, both could be allowed to vary non-parametrically across grid cells at varying distances from the pre-war CBD. Despite these simplifying assumptions, we find that the model is relatively successful in accounting quantitatively for the reorientations of economic activity observed in the data.

6.5 Additional Predictions

Having demonstrated the model's fit, we now provide some additional evidence in its support based on its predictions for other variables not used in the estimation. One key output of the estimation of the model is a measure of the density of development (φ_i) for each block. In our data, we have separate information on the ratio of building floor space to geographical land area ("GFZ"), which provides the basis for a first additional test of the model's predictions. Although the units in which these variables are measured are not directly comparable, we find that they are strongly correlated. Regressing the log rank of the density of development in the model on the log rank of the GFZ in the data, we find coefficients (standard errors) of 0.3056 (0.0157) and 0.3955 (0.01438) for 1936 and 1986 respectively. We find a similar results for 1986 and 2006 using our estimates for reunification.

Another output of the estimation of the model is the probability of commuting between each pair of blocks, which can be compared to separate data on commuting patterns. For 1935, we have information on the fraction of workers with commuting travel times in a number of discrete intervals (e.g. less than 20 minutes, 20-30 minutes, and so on) from a survey of over 24,000 workers summarized in Feder (1939). Using the bilateral probabilities of commuting in the model, we evaluate its predictions for the fraction of workers with commuting travel times in these intervals. We find a strong correlation between the model's predictions and the data. Regressing the fraction of workers in each travel time interval in the model on the corresponding fractions in the data, we find an estimated coefficient (standard error) of 0.7118 (0.2238) and a regression R2 of 0.6306.

7 Conclusions

While the strength of agglomeration and dispersion forces is one of the most central questions in economics, it is hard to empirically distinguish these forces from variation in locational fundamentals. In this paper, we develop a quantitative theoretical model of city structure that incorporates agglomeration and dispersion forces, while allowing for asymmetries in locational fundamentals and remaining tractable and amenable to empirical analysis. To empirically disentangle agglomeration and dispersion forces, we combine the model with the exogenous source of variation in the surrounding concentration of economic activity provided by Berlin's division and reunification.

Using a remarkable dataset on thousands of city blocks for 1936, 1986 and 2006, we find strong empirical support for the model's predictions. Division leads to a reorientation of the gradient in land prices and employment in West Berlin away from the main concentration of economic activity in East Berlin, while reunification leads to a reemergence of this gradient. In contrast, there is little effect of division or reunification on land prices or employment along other more economically remote sections of the Berlin Wall. Consistent with the model's mechanism of access to the surrounding concentration of economic activity, we find heterogeneous effects of division and reunification across West Berlin blocks depending on their transport access. West Berlin blocks less than 250 meters from a 1936 U/S-Bahn station experience larger declines (larger increases) in land prices following division (reunification).

Using the structure of the model and given values for its parameters, we show how cross-section data on land prices, workplace employment, residence employment, geographical land area and travel times can be used to solve for the unobserved locational fundamentals for which the observed data are an equilibrium of the model. To estimate the model's parameters, we use the time-series variation provided by Berlin's division and reunification, invoking moment conditions based on the assumption that changes in locational fundamentals are uncorrelated with the resulting exogenous change in the surrounding concentration of economic activity.

We find that for similar parameters the model can account for the observed reorientations of economic activity following Berlin's division and reunification. While we focus on the exogenous variation provided by Berlin's division and reunification, the tractability of our quantitative theoretical framework lends itself to a variety of further applications, such as the evaluation of transport infrastructure improvements.

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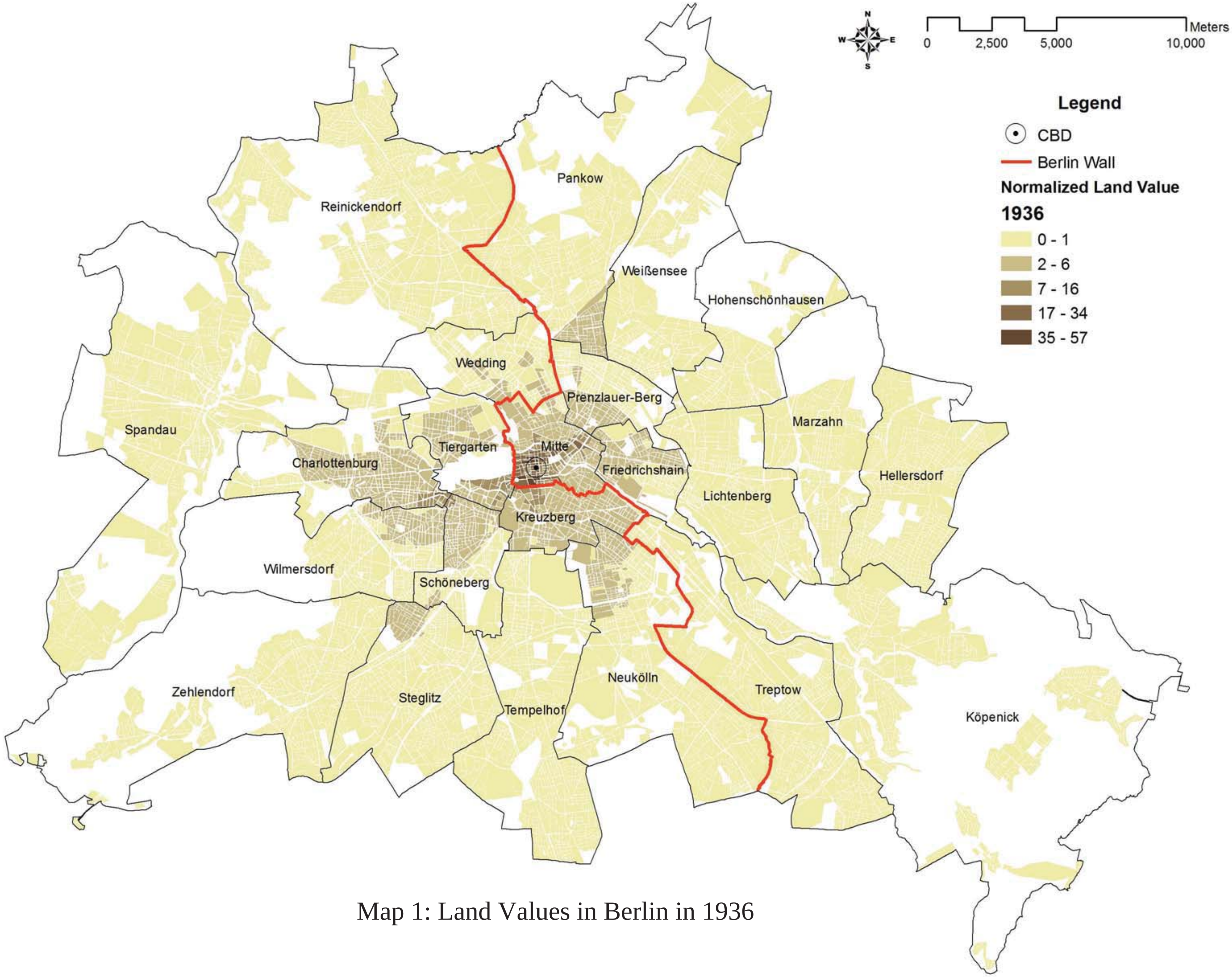


Map 1: Land Values in Berlin in 1936

Figure 1: Greater Berlin Land Rents 1936

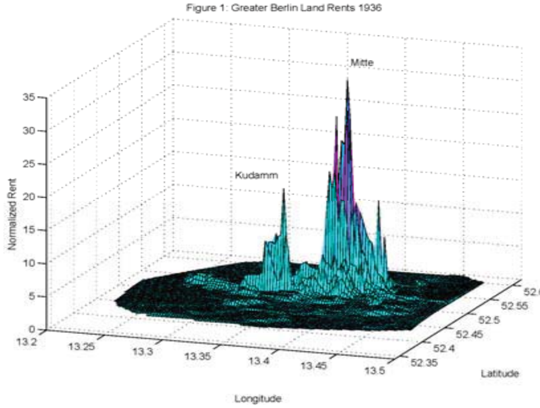


Figure 2: West Berlin Land Rents 1936

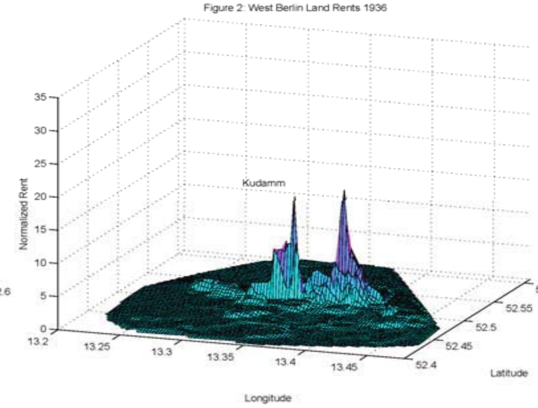


Figure 3: West Berlin Land Rents 1986

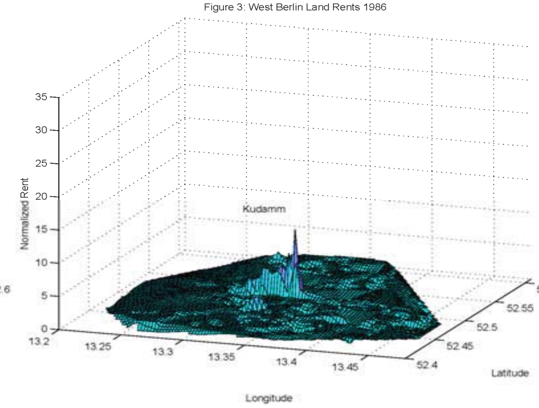


Figure 4: Greater Berlin Land Rents 2006

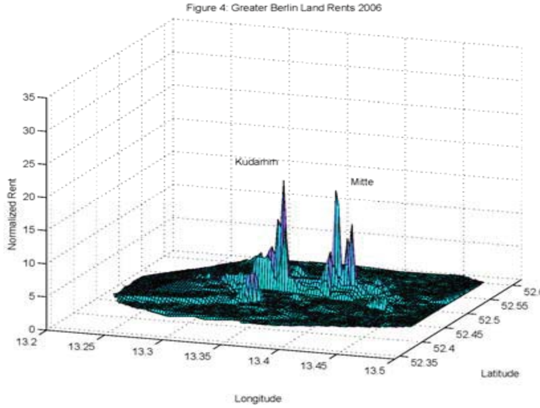


Figure 5: West Berlin Land Rents 2006

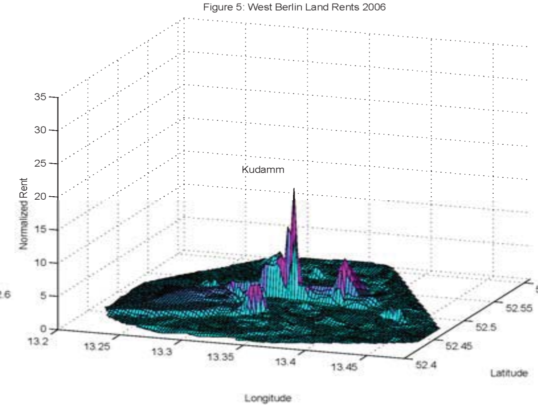
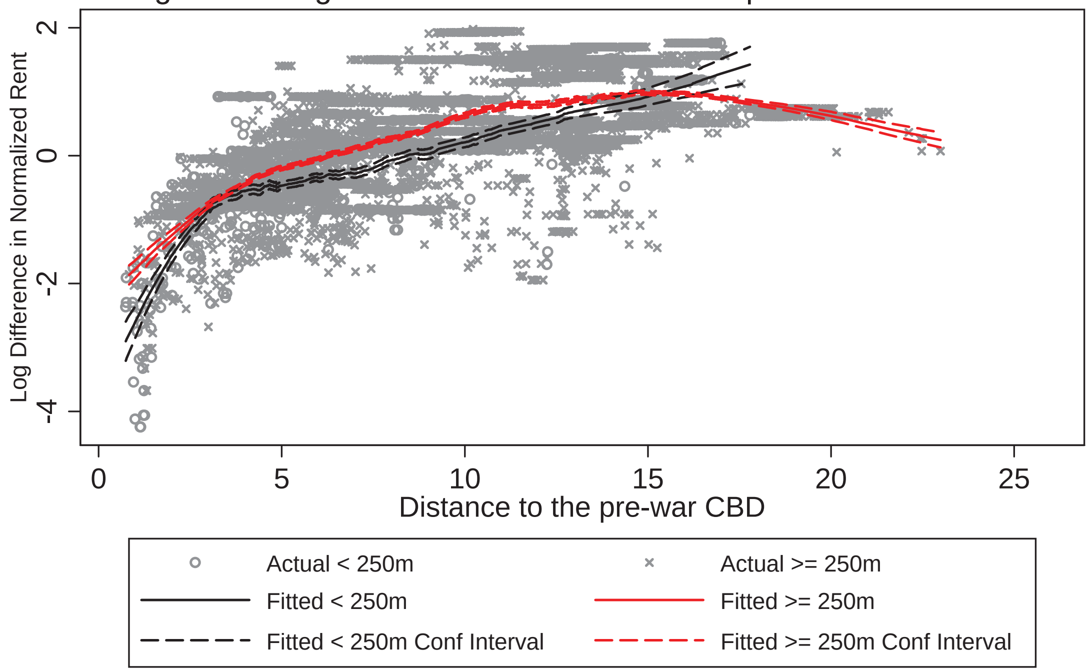
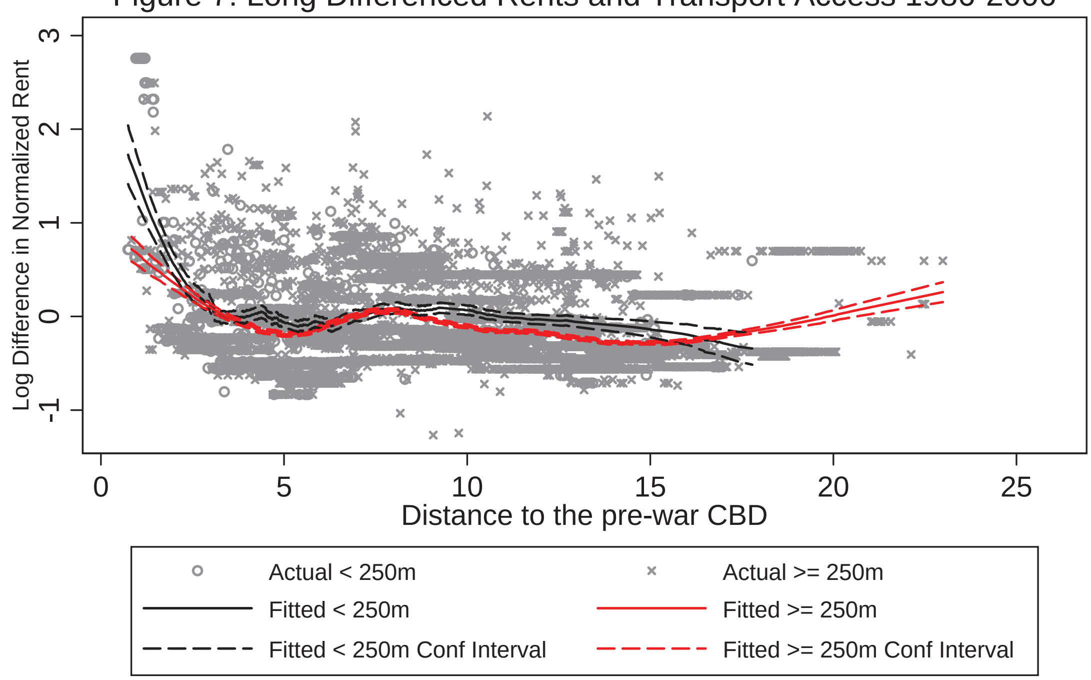


Figure 6: Long Differenced Rents and Transport Access 1936-86



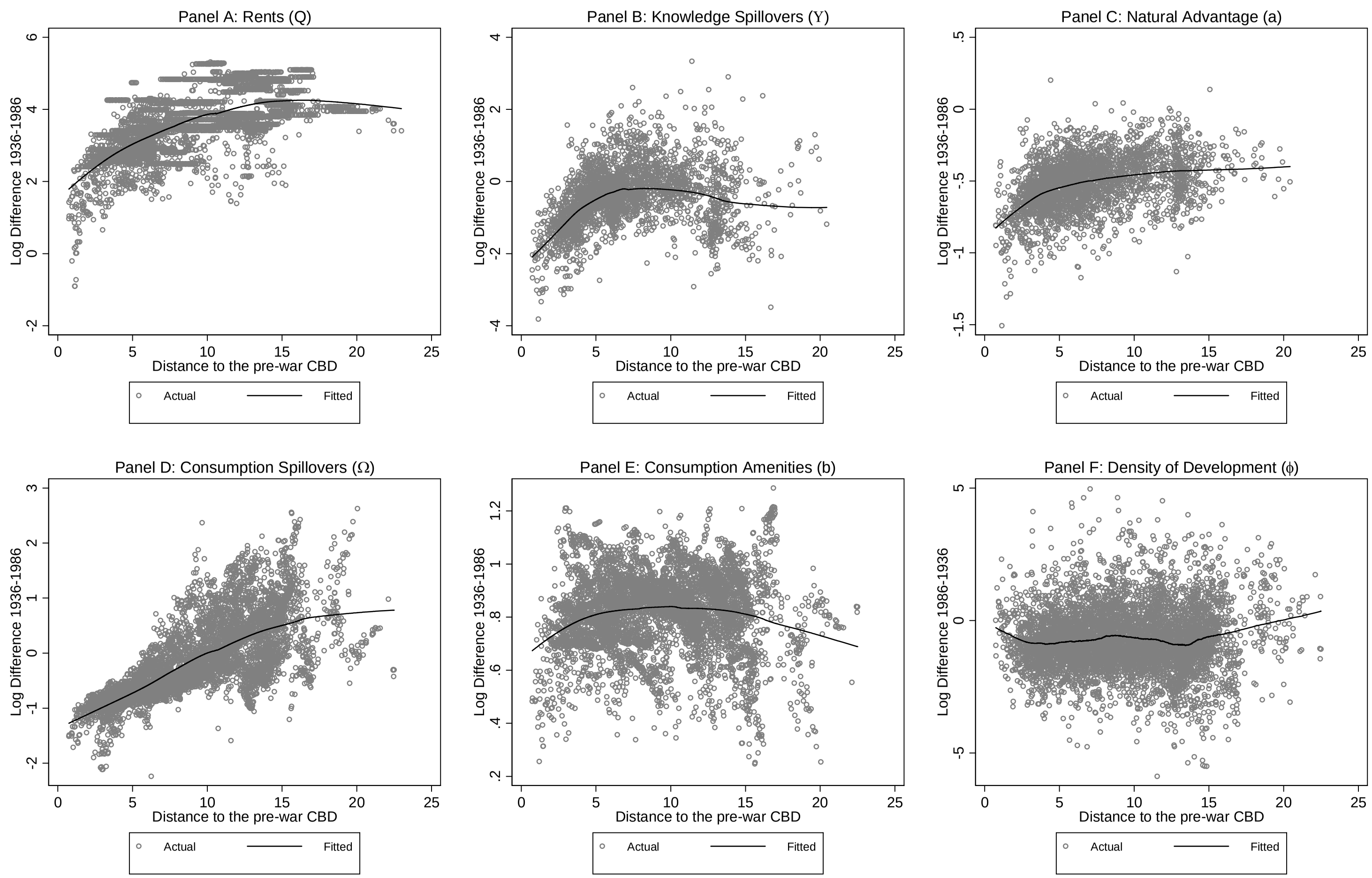
Note: Rents are normalized to have a mean of one in each year before taking the long difference.
Solid lines are fitted values based on locally-weighted linear least squares. Separate fitted values estimated for blocks within and beyond 250 metres of U-Bahn or S-Bahn station in 1936. Dashed lines are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

Figure 7: Long Differenced Rents and Transport Access 1986-2006



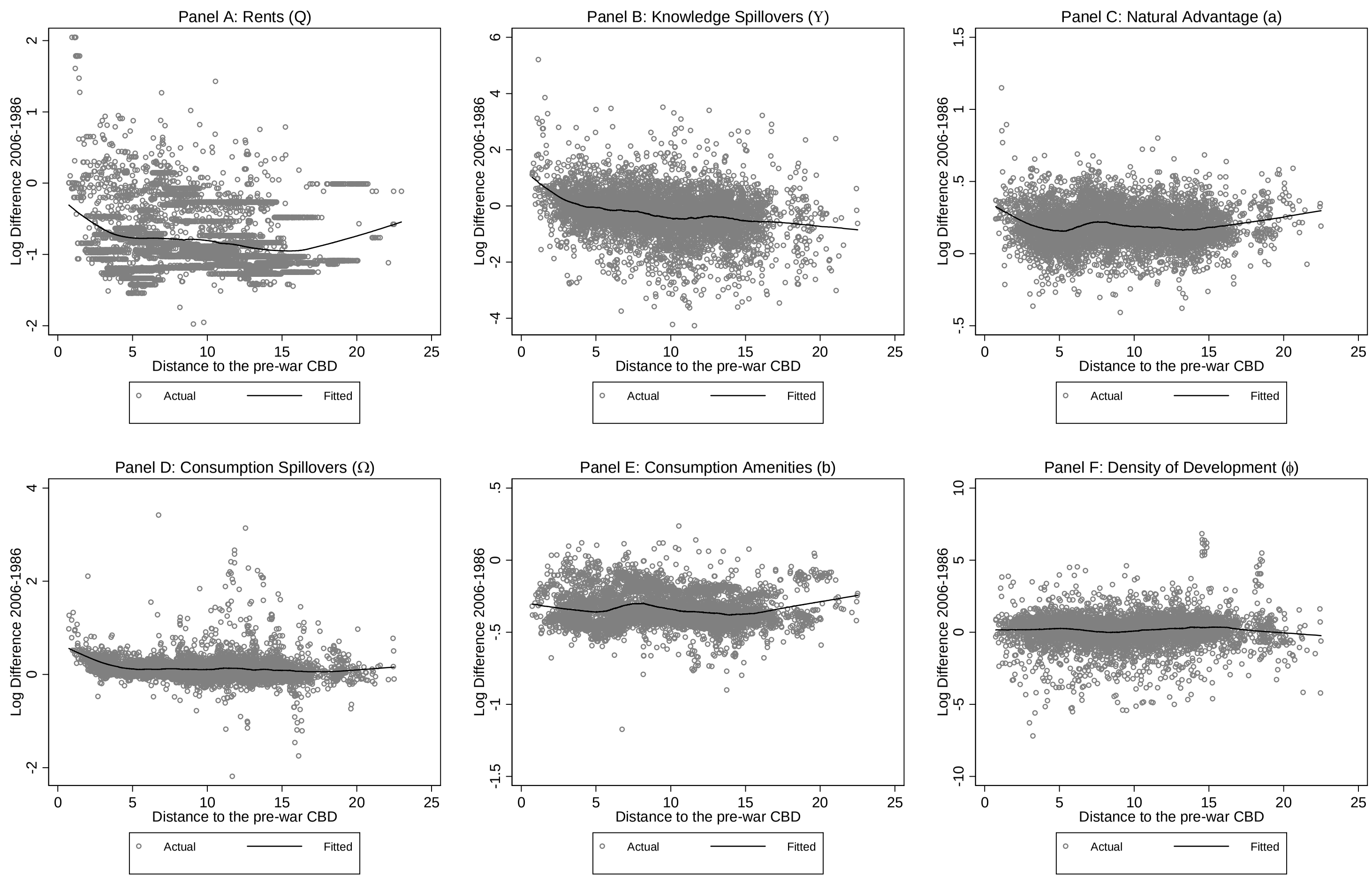
Note: Rents are normalized to have a mean of one in each year before taking the long difference.
Solid lines are fitted values based on locally-weighted linear least squares. Separate fitted values estimated for blocks within and beyond 250 metres of U-Bahn or S-Bahn station in 1936. Dashed lines are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

Figure 8: Model Predictions for Division



Note: Solid lines are fitted values based on locally-weighted linear least squares.

Figure 9: Model Predictions for Reunification



Note: Solid lines are fitted values based on locally-weighted linear least squares.

Table 1: Baseline Division Results (1936-1986)

	(1) Δ ln Land Value	(2) Δ ln Land Value	(3) Δ ln Land Value	(4) Δ ln Land Value	(5) Δ ln Land Value	(6) Δ ln Emp Residence	(7) Δ ln Emp Residence	(8) Δ ln Emp Workplace	(9) Δ ln Emp Workplace
CBD 1	-3.016***	-2.159***	-1.980***	-1.944***	-1.732***	-0.835***	-0.693***	-0.619	-0.381
	(0.529)	(0.449)	(0.441)	(0.447)	(0.368)	(0.164)	(0.215)	(0.471)	(0.452)
CBD 2	-2.411***	-1.559***	-1.441***	-1.377***	-1.158***	-0.423*	-0.338	-1.197***	-1.196***
	(0.388)	(0.345)	(0.332)	(0.327)	(0.281)	(0.217)	(0.246)	(0.339)	(0.292)
CBD 3	-1.619***	-0.791***	-0.708***	-0.644***	-0.476***	-0.812***	-0.634**	-0.341	-0.352
	(0.177)	(0.206)	(0.211)	(0.194)	(0.151)	(0.230)	(0.275)	(0.304)	(0.291)
CBD 4	-1.395***	-0.598***	-0.515***	-0.459***	-0.415***	-0.267*	-0.109	-0.506***	-0.525***
	(0.160)	(0.154)	(0.170)	(0.162)	(0.138)	(0.152)	(0.157)	(0.171)	(0.177)
CBD 5	-1.189***	-0.479***	-0.393**	-0.341**	-0.256**	-0.272*	-0.157	-0.431***	-0.475***
	(0.139)	(0.148)	(0.156)	(0.151)	(0.109)	(0.151)	(0.169)	(0.163)	(0.157)
CBD 6	-0.950***	-0.394***	-0.266**	-0.212*	-0.140	-0.338**	-0.196	-0.259*	-0.345**
	(0.179)	(0.136)	(0.132)	(0.125)	(0.090)	(0.141)	(0.137)	(0.138)	(0.157)
Inner Boundary 1			-0.169	-0.153	0.039		0.028		-0.255
			(0.195)	(0.197)	(0.159)		(0.259)		(0.263)
Inner Boundary 2			-0.044	-0.024	0.123		0.189		0.113
			(0.186)	(0.187)	(0.150)		(0.218)		(0.257)
Outer Boundary 1			0.800***	0.804***	-0.006		1.035***		-1.358***
			(0.139)	(0.138)	(0.130)		(0.203)		(0.380)
Outer Boundary 2			0.855***	0.861***	0.112		1.113***		-0.471**
			(0.129)	(0.129)	(0.123)		(0.147)		(0.234)
Inner Boundry 3-6			Yes	Yes	Yes		Yes		Yes
Outer Boundary 3-6			Yes	Yes	Yes		Yes		Yes
Kudamm 1-6				Yes	Yes		Yes		Yes
Hedonic Controls					Yes				
Further Controls					Yes				
District Fixed Effects		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	7617	7617	7617	7617	7617	5832	5832	2844	2844
R-squared	0.21	0.51	0.66	0.67	0.79	0.18	0.28	0.11	0.14

Note: Emp Residence denotes employment by residence. Emp Workplace denotes employment by workplace. CBD1-CBD6 are six 500m distance grid cells for distance from the pre-war CBD. Inner Boundary 1-6 are six 500m grid cells for distance to the Inner Boundary between East and West Berlin. Outer Boundary 1-6 are six 500m grid cells for distance to the outer boundary between West Berlin and East Germany. Kudamm 1-6 are six 500m grid cells for distance to Breitscheid Platz on the Kurfürstendamm. Hedonic controls include the log distance to schools, parks, water and underground or suburban stations. Further controls include the land area of the block, the percentage of the block area destroyed during the Second World War and indicators for residential, commercial and industrial land use. Robust Standard Errors in Parentheses adjusted for clustering by statistical area ("Gebiete"). * significant at 10%; ** significant at 5%; *** significant at 1%.

Table 2: Baseline Reunification Results (1986-2006)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Δ ln Land Value	Δ ln Land Value	Δ ln Land Value	Δ ln Land Value	Δ ln Land Value	Δ ln Emp Residence	Δ ln Emp Residence	Δ ln Emp Workplace	Δ ln Emp Workplace
CBD 1	1.514**	1.502***	1.425***	1.475***	0.997**	0.758***	0.792***	1.498**	1.482**
	(0.645)	(0.446)	(0.428)	(0.449)	(0.463)	(0.071)	(0.077)	(0.710)	(0.701)
CBD 2	1.110**	1.112***	1.082***	1.167***	0.820***	0.187**	0.187**	0.436	0.397
	(0.480)	(0.338)	(0.319)	(0.338)	(0.276)	(0.072)	(0.075)	(0.290)	(0.298)
CBD 3	0.298	0.331*	0.333*	0.384**	0.300**	0.283	0.271	0.305	0.305
	(0.188)	(0.185)	(0.185)	(0.192)	(0.118)	(0.207)	(0.206)	(0.184)	(0.199)
CBD 4	0.118	0.174	0.212*	0.248**	0.225***	0.070	0.037	0.316*	0.337*
	(0.114)	(0.116)	(0.119)	(0.115)	(0.073)	(0.064)	(0.068)	(0.178)	(0.191)
CBD 5	0.109	0.177*	0.201**	0.214**	0.214***	-0.041	-0.049	0.100	0.105
	(0.104)	(0.096)	(0.097)	(0.092)	(0.057)	(0.061)	(0.060)	(0.130)	(0.144)
CBD 6	0.077	0.072	0.068	0.050	0.088**	0.056*	0.075**	0.049	0.045
	(0.103)	(0.073)	(0.075)	(0.061)	(0.042)	(0.032)	(0.035)	(0.087)	(0.089)
Inner Boundary 1			0.040	0.036	-0.021		-0.061		-0.008
			(0.069)	(0.070)	(0.065)		(0.047)		(0.130)
Inner Boundary 2			-0.058	-0.058	-0.096*		-0.009		0.049
			(0.061)	(0.061)	(0.050)		(0.038)		(0.135)
Outer Boundary 1			-0.181***	-0.181***	-0.144**		0.019		0.106
			(0.044)	(0.044)	(0.066)		(0.034)		(0.086)
Outer Boundary 2			-0.187***	-0.188***	-0.151**		0.001		0.047
			(0.046)	(0.046)	(0.062)		(0.033)		(0.082)
Inner Boundary 3-6			Yes	Yes	Yes		Yes		Yes
Outer Boundary 3-6			Yes	Yes	Yes		Yes		Yes
Kudamm 1-6				Yes	Yes		Yes		Yes
Hedonic Controls					Yes				
Further Controls					Yes				
District Fixed Effects		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	8022	8022	8022	8022	8022	6763	6763	5624	5624
R-squared	0.09	0.49	0.51	0.53	0.71	0.02	0.03	0.03	0.03

Note: Emp Residence denotes employment by residence. Emp Workplace denotes employment by workplace. CBD1-CBD6 are six 500m distance grid cells for distance from the pre-war CBD. Inner Boundary 1-6 are six 500m grid cells for distance to the Inner Boundary between East and West Berlin. Outer Boundary 1-6 are six 500m grid cells for distance to the outer boundary between West Berlin and East Germany. Kudamm 1-6 are six 500m grid cells for distance to Breitscheid Platz on the Kurfürstendamm. Hedonic controls include the log distance to schools, parks, water and underground or suburban stations. Further controls include the land area of the block, the percentage of the block area destroyed during the Second World War, a dummy for whether the block qualified for government subsidy programs post reunification, a dummy for whether each block contains a government building post reunification, and indicators for residential, commercial and industrial land use. Robust Standard Errors in Parentheses adjusted for clustering by statistical area ("Gebiete"). * significant at 10%; ** significant at 5%; *** significant at 1%.

Table 3: Generalized Method of Moments (GMM) Results

	1936-1986		1986-2006	
	One-step Coefficient	Two-step Coefficient	One-step Coefficient	Two-step Coefficient
Productivity Elasticity (λ)	0.1261***	0.1455***	0.1314***	0.1369***
	(0.0156)	(0.0165)	(0.0062)	(0.0031)
Productivity Decay (δ)	0.5749***	0.6091***	0.5267***	0.8791***
	(0.0189)	(0.1067)	(0.0128)	(0.0025)
Commuting Decay (κ)	0.0014**	0.0010*	0.0009	0.0005
	(0.0006)	(0.0006)	(0.0024)	(0.0016)
Commuting Heterogeneity (ε)	4.8789***	5.2832***	5.6186***	6.5409***
	(0.0423)	(0.0074)	(0.0082)	(0.0031)
Residential Elasticity (η)	0.2212***	0.2400***	0.2232***	0.215***
	(0.0038)	(0.0037)	(0.0093)	(0.0041)
Residential Decay (ρ)	0.2529***	0.2583***	0.5979***	0.5647***
	(0.0087)	(0.0075)	(0.0124)	(0.0019)

Note: Generalized Method of Moments (GMM) estimates using twelve moment conditions based on the difference between the distance-weighted and unweighted mean and variance of production fundamentals and residential fundamentals. Distance weights use the distance of each West Berlin block from the pre-war CBD, inner boundary between East and West Berlin, and outer boundary between West Berlin and its East German hinterland. One-step estimates use the identity matrix as the weighting matrix. Two-step estimates use the efficient weighting matrix. Standard errors in parentheses. See the text of the paper for further discussion.

Table 4: Production Externalities, Residential Externalities and Commuting Costs by Travel Time

	Production Externalities $(1 \times e^{-\delta\tau})$	Residential Externalities $(1 \times e^{-\rho\tau})$	Commuting Costs $(1 \times \varepsilon^{-\kappa\tau})$
0 minutes	1.000	1.000	1.000
1 minute	0.553	0.663	0.999
2 minutes	0.306	0.439	0.998
3 minutes	0.169	0.291	0.997
4 minutes	0.094	0.193	0.996
6 minutes	0.029	0.085	0.994
8 minutes	0.009	0.037	0.992
10 minutes	0.003	0.016	0.990
12 minutes	0.001	0.007	0.988
14 minutes	0.000	0.003	0.986
22 minutes	0.000	0.000	0.978
30 minutes	0.000	0.000	0.970

Note: Proportional reduction in production and residential externalities with travel time and proportional increase in commuting costs with travel time. Results based on median GMM parameter estimates: δ=0.5920, ρ=0.4115, κ=0.0010.