14.582: International Trade II — Lecture 18: Economic Geography (Empirics III)

Plan for Today's Lecture

- The second of two lectures about estimating the size of agglomeration externalities

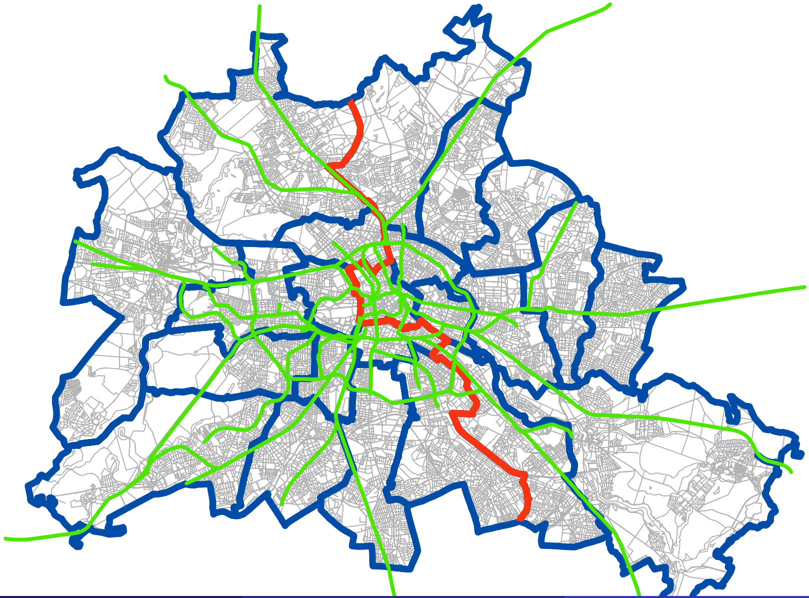
Ahlfeldt, Redding, Sturm and Wolf (ECMA, 2015)

- ARSW (2015) develop a similar approach to Redding and Sturm (AER 2008) but to the case of the division (and reunification) of Berlin. So this is about the importance of proximity at a very different spatial scale (neighborhoods rather than regions).
- Paper looks at the effect of the loss of access/proximity to the downtown region (CBD/"Mitte"), which was in East Berlin, on neighborhoods of West Berlin. And then the reverse for reunification.

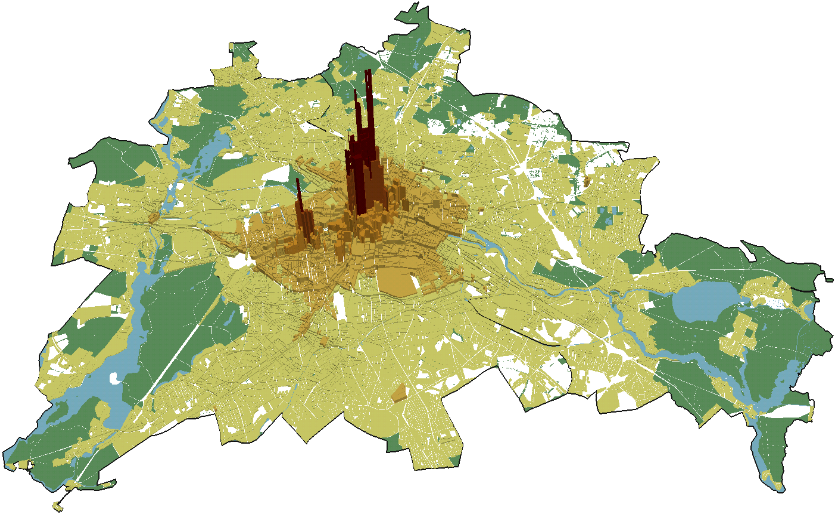
Historical Background

- A protocol signed during the Second World War organized Germany into American, British, French and Soviet occupation zones
- Although 200km within the Soviet zone, Berlin was to be jointly occupied and organized into four occupation sectors:
  - Boundaries followed pre-war district boundaries, with the same East-West orientation as the occupation zones, and created sectors of roughly equal pre-war population (prior to French sector)
  - Protocol envisioned a joint city administration ("Kommandatura")
- Following the onset of the Cold War
  - East and West Germany founded as separate states and separate city governments created in East and West Berlin in 1949
  - The adoption of Soviet-style policies of command and control in East Berlin limited economic interactions with West Berlin
  - To stop civilians leaving for West Germany, the East German authorities constructed the Berlin Wall in 1961

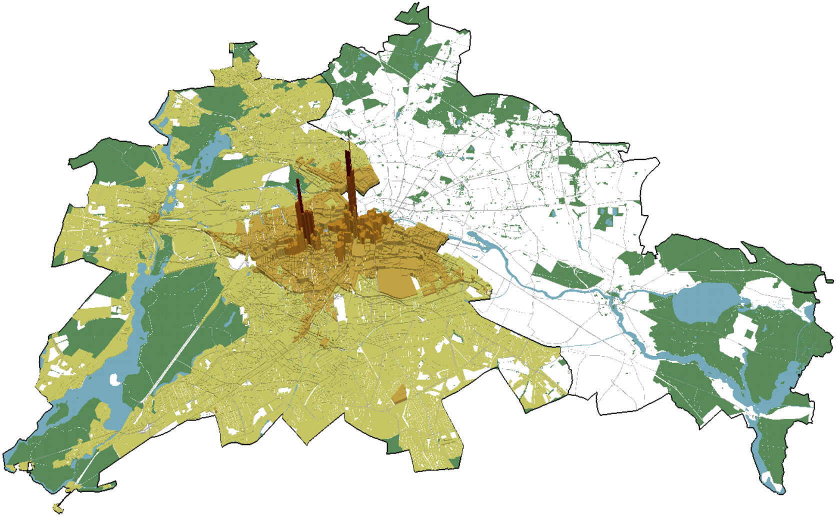
The division of Berlin: transport lines in green, wall in red



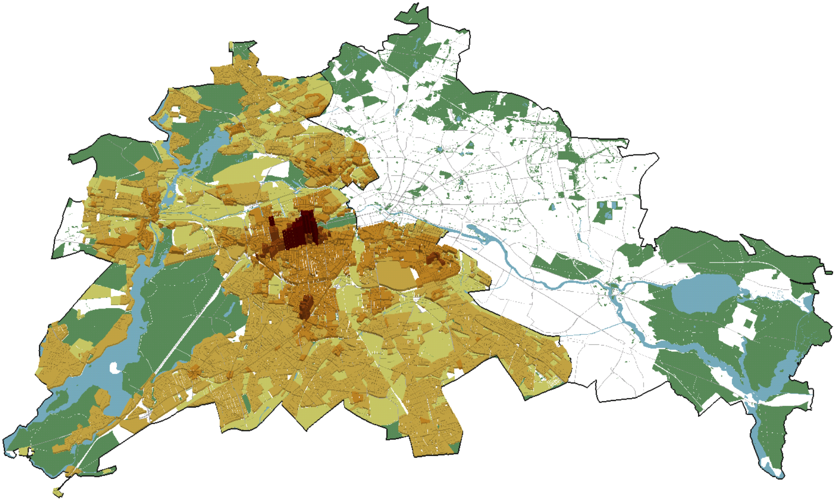
Berlin 1936: land rents



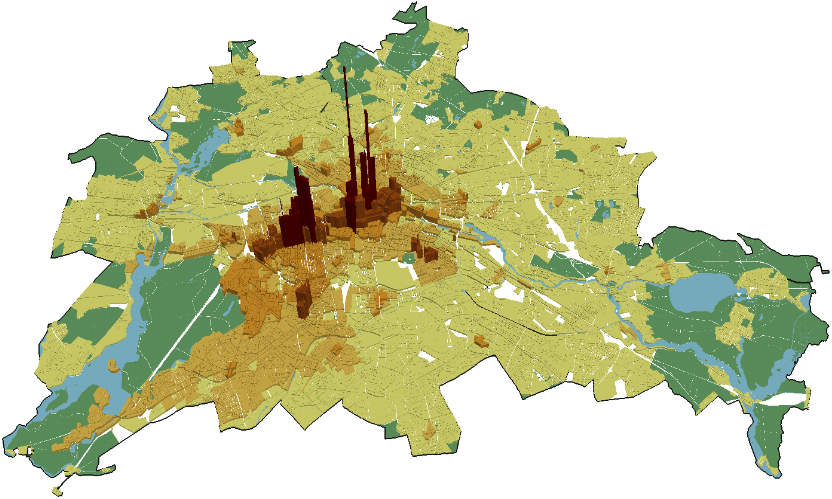
West Berlin 1936: land rents



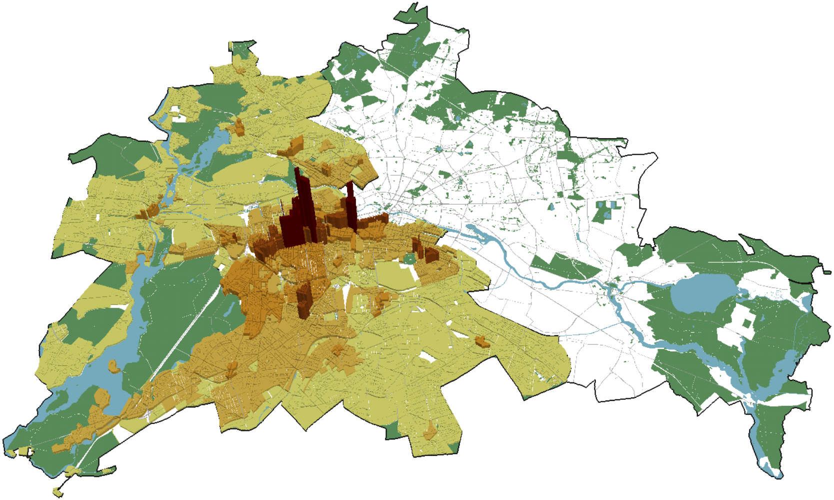
West Berlin 1986: land rents



Berlin 2006: land rents



West Berlin 2006: land rents



Difference-in-Differences Specification

- Long-differences specification using the change in log floor prices
- First-difference: before and after division
- Second-difference: areas of West Berlin close to and far from the pre-war CBD

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

- d_{ij} is a $(0, 1)$ dummy which equals one if block i lies within distance grid cell j and zero otherwise
- Allows for a fixed effect in the level of block land prices, which is differenced out when we take long differences
- Observable block characteristics (X_i): Land area, land use, distance to nearest U-Bahn station, S-Bahn station, school, lake, river or canal, and park, war destruction, government buildings and urban regeneration programs

Diff-in-diff on Division of Berlin

TABLE I

BASELINE DIVISION DIFFERENCE-IN-DIFFERENCE RESULTS (1936–1986)[a]

	(1) $\Delta \ln Q$	(2) $\Delta \ln Q$	(3) $\Delta \ln Q$	(4) $\Delta \ln Q$	(5) $\Delta \ln Q$	(6) $\Delta \ln$ EmpR	(7) $\Delta \ln$ EmpR	(8) $\Delta \ln$ EmpW	(9) $\Delta \ln$ EmpW
CBD 1	−0.800***	−0.567***	−0.524***	−0.503***	−0.565***	−1.332***	−0.975***	−0.691*	−0.639*
	(0.071)	(0.071)	(0.071)	(0.071)	(0.077)	(0.383)	(0.311)	(0.408)	(0.338)
CBD 2	−0.655***	−0.422***	−0.392***	−0.360***	−0.400***	−0.715**	−0.361	−1.253***	−1.367***
	(0.042)	(0.047)	(0.046)	(0.043)	(0.050)	(0.299)	(0.280)	(0.293)	(0.243)
CBD 3	−0.543***	−0.306***	−0.294***	−0.258***	−0.247***	−0.911***	−0.460**	−0.341	−0.471**
	(0.034)	(0.039)	(0.037)	(0.032)	(0.034)	(0.239)	(0.206)	(0.241)	(0.190)
CBD 4	−0.436***	−0.207***	−0.193***	−0.166***	−0.176***	−0.356**	−0.259	−0.512***	−0.521***
	(0.022)	(0.033)	(0.033)	(0.030)	(0.026)	(0.145)	(0.159)	(0.199)	(0.169)
CBD 5	−0.353***	−0.139***	−0.123***	−0.098***	−0.100***	−0.301***	−0.143	−0.436***	−0.340***
	(0.016)	(0.024)	(0.024)	(0.023)	(0.020)	(0.110)	(0.113)	(0.151)	(0.124)
CBD 6	−0.291***	−0.125***	−0.094***	−0.077***	−0.090***	−0.360***	−0.135	−0.280**	−0.142
	(0.018)	(0.019)	(0.017)	(0.016)	(0.016)	(0.100)	(0.089)	(0.130)	(0.116)
Inner Boundary 1–6			Yes	Yes	Yes		Yes		Yes
Outer Boundary 1–6			Yes	Yes	Yes		Yes		Yes
Kudamm 1–6				Yes	Yes		Yes		Yes
Block Characteristics					Yes		Yes		Yes
District Fixed Effects		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	6,260	6,260	6,260	6,260	6,260	5,978	5,978	2,844	2,844
R^2	0.26	0.51	0.63	0.65	0.71	0.19	0.43	0.12	0.33

[a] Q denotes the price of floor space. EmpR denotes employment by residence. EmpW denotes employment by workplace. CBD1–CBD6 are six 500 m distance grid cells for distance from the pre-war CBD. Inner Boundary 1–6 are six 500 m grid cells for distance to the Inner Boundary between East and West Berlin. Outer Boundary 1–6 are six 500 m grid cells for distance to the outer boundary between West Berlin and East Germany. Kudamm 1–6 are six 500 m grid cells for distance to Breitscheid Platz on the Kurfürstendamm. The coefficients on the other distance grid cells are reported in Table A.2 of the Technical Data Appendix. Block characteristics include the log distance to schools, parks and water, the land area of the block, the share of the block's built-up area destroyed during the Second World War, indicators for residential, commercial and industrial land use, and indicators for whether a block includes a government building and urban regeneration policies post-reunification. Heteroscedasticity and Autocorrelation Consistent (HAC) standard errors in parentheses (Conley (1999)). * significant at 10%; ** significant at 5%; *** significant at 1%.

Diff-in-diff on Division of Berlin

TABLE II

BASELINE REUNIFICATION DIFFERENCE-IN-DIFFERENCE RESULTS (1986–2006)[a]

	(1) $\Delta \ln Q$	(2) $\Delta \ln Q$	(3) $\Delta \ln Q$	(4) $\Delta \ln Q$	(5) $\Delta \ln Q$	(6) $\Delta \ln$ EmpR	(7) $\Delta \ln$ EmpR	(8) $\Delta \ln$ EmpW	(9) $\Delta \ln$ EmpW
CBD 1	0.398***	0.408***	0.368***	0.369***	0.281***	1.079***	1.025***	1.574***	1.249**
	(0.105)	(0.090)	(0.083)	(0.081)	(0.088)	(0.307)	(0.297)	(0.479)	(0.517)
CBD 2	0.290***	0.289***	0.257***	0.258***	0.191**	0.589*	0.538*	0.684**	0.457
	(0.111)	(0.096)	(0.090)	(0.088)	(0.087)	(0.315)	(0.299)	(0.326)	(0.334)
CBD 3	0.122***	0.120***	0.110***	0.115***	0.063**	0.340*	0.305*	0.326	0.158
	(0.037)	(0.033)	(0.032)	(0.032)	(0.028)	(0.180)	(0.158)	(0.216)	(0.239)
CBD 4	0.033***	0.031	0.030	0.034	0.017	0.110	0.034	0.336**	0.261
	(0.013)	(0.023)	(0.022)	(0.021)	(0.020)	(0.068)	(0.066)	(0.161)	(0.185)
CBD 5	0.025***	0.018	0.020	0.020	0.015	−0.012	−0.056	0.114	0.066
	(0.010)	(0.015)	(0.014)	(0.014)	(0.013)	(0.056)	(0.057)	(0.118)	(0.131)
CBD 6	0.019**	−0.000	−0.000	−0.003	0.005	0.060	0.053	0.049	0.110
	(0.009)	(0.012)	(0.012)	(0.012)	(0.011)	(0.039)	(0.041)	(0.095)	(0.098)
Inner Boundary 1–6			Yes	Yes	Yes		Yes		Yes
Outer Boundary 1–6			Yes	Yes	Yes		Yes		Yes
Kudamm 1–6				Yes	Yes		Yes		Yes
Block Characteristics					Yes		Yes		Yes
District Fixed Effects		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	7,050	7,050	7,050	7,050	7,050	6,718	6,718	5,602	5,602
R^2	0.08	0.32	0.34	0.35	0.43	0.04	0.07	0.03	0.06

[a] Q denotes the price of floor space. EmpR denotes employment by residence. EmpW denotes employment by workplace. CBD1–CBD6 are six 500 m distance grid cells for distance from the pre-war CBD. Inner Boundary 1–6 are six 500 m grid cells for distance to the Inner Boundary between East and West Berlin. Outer Boundary 1–6 are six 500 m grid cells for distance to the outer boundary between West Berlin and East Germany. Kudamm 1–6 are six 500 m grid cells for distance to Breitscheid Platz on the Kurfürstendamm. The coefficients on the other distance grid cells are reported in Table A.4 of the Technical Data Appendix. Block characteristics include the log distance to schools, parks and water, the land area of the block, the share of the block's built-up area destroyed during the Second World War, indicators for residential, commercial and industrial land use, and indicators for whether a block includes a government building and urban regeneration policies post-reunification. Heteroscedasticity and Autocorrelation Consistent (HAC) standard errors in parentheses (Conley (1999)). * significant at 10%; ** significant at 5%; *** significant at 1%.

Diff-in-diff on Division of Berlin

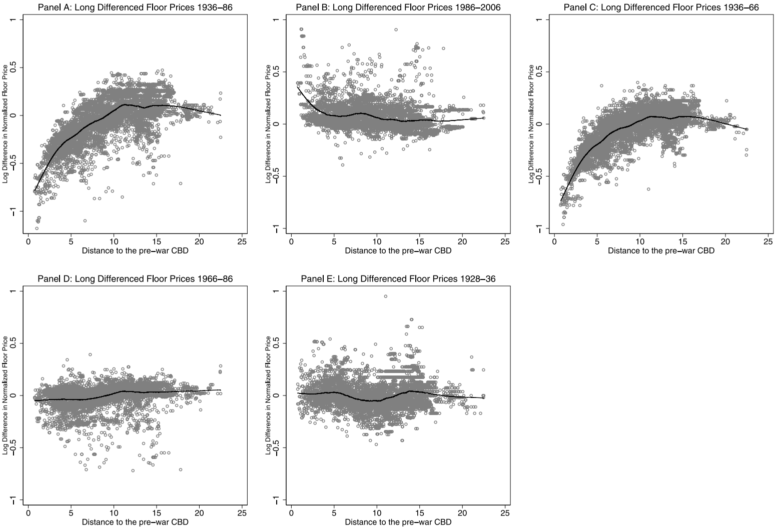


FIGURE 3.—Division and reunification treatments and placebos. Note: Log floor prices are normalized to have a mean of zero in each year before taking the long difference. Solid lines are fitted values from locally-weighted linear least squares regressions.

Model: Basic Setup

- 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 indexed by i, with supply of floor space depending on the density of development (φ_i)
- There is a single final good which is costlessly traded and is chosen as the numeraire
- Markets are perfectly competitive
- Workers choose a block of residence, a block of employment, and consumption of the final good and floor space to max utility
- Firms choose a block of production and inputs of labor and floor space to max profits
- Floor space within each block optimally allocated between residential and commercial use
- Productivity depends on fundamentals (a_i) & spillovers (Υ_i)
- Amenities depend on fundamentals (b_i) & spillovers (Ω_i)
- Workers face commuting costs

Consumption

- Utility for worker o residing in block i and working in block j:

$$U_{ijo} = \frac{B_i z_{ijo}}{d_{ij}} \left(\frac{c_{ij}}{\beta}\right)^{\beta} \left(\frac{\ell_{ij}}{1-\beta}\right)^{1-\beta}, \qquad 0 < \beta < 1,$$

  - Consumption of the final good (c_{ij}), chosen as numeraire ($p_i = 1$)
  - Residential floor space (ℓ_{ij})
  - Residential amenity B_i
  - Commuting costs d_{ij}
  - Idiosyncratic shock z_{ijo} that captures idiosyncratic reasons for a worker living in block i and working in block j
- Indirect utility

$$U_{ijo} = \frac{z_{ijo} B_i w_j Q_i^{\beta-1}}{d_{ij}},$$

- The idiosyncratic shock to worker productivity is drawn from a Fréchet distribution:

$$F(z_{ijo}) = e^{-T_i E_j z_{ijo}^{-\epsilon}}, \qquad T_i, E_j > 0, \ \epsilon > 1,$$

Commuting Decisions

- Probability worker chooses to live in block i and work in block j is:

$$\pi_{ij} = \frac{T_i E_j \left(d_{ij} Q_i^{1-\beta}\right)^{-\epsilon} (B_i w_j)^{\epsilon}}{\sum_{r=1}^{S} \sum_{s=1}^{S} T_r E_s \left(d_{rs} Q_r^{1-\beta}\right)^{-\epsilon} (B_r w_s)^{\epsilon}} \equiv \frac{\Phi_{ij}}{\Phi}.$$

- Residential and workplace choice probabilities

$$\pi_{Ri} = \sum_{j=1}^{S} \pi_{ij} = \frac{\sum_{j=1}^{S} \Phi_{ij}}{\Phi}, \qquad \pi_{Mj} = \sum_{i=1}^{S} \pi_{ij} = \frac{\sum_{i=1}^{S} \Phi_{ij}}{\Phi}.$$

- Conditional on living in block i, the probability that a worker commutes to block j follows a gravity equation:

$$\pi_{ij|i} = \frac{E_j \left(w_j / d_{ij}\right)^{\epsilon}}{\sum_{s=1}^{S} E_s \left(w_s / d_{is}\right)^{\epsilon}},$$

Commuting Decisions

- Workplace employment in block j equals the sum across all blocks i of residence employment times the probability of commuting from i to j:

$$H_{Mj} = \sum_{i=1}^{S} \frac{E_j \left(w_j / d_{ij}\right)^{\epsilon}}{\sum_{s=1}^{S} E_s \left(w_s / d_{is}\right)^{\epsilon}} H_{Ri}$$

- Expected utility

$$\mathbb{E}\left[U\right] = \gamma \left[\sum_{r=1}^{S} \sum_{s=1}^{S} T_r E_s \left(d_{rs} Q_r^{1-\beta}\right)^{-\epsilon} \left(B_r w_s\right)^{\epsilon}\right]^{1/\epsilon} = \bar{U},$$

Production

- A single final good (numeraire) is produced under conditions of perfect competition, constant returns to scale and zero trade costs with a larger economy:

$$y_j = A_j \left(H_{Mj}\right)^{\alpha} \left(L_{Mj}\right)^{1-\alpha}, \qquad 0 < \alpha < 1,$$

- H_{Mj} is workplace employment
- L_{Mj} is floor space used commercially
- Firms choose a block of production, effective employment and commercial land use to maximize profits taking as given goods and factor prices, productivity and the locations of other firms/workers

Land Market Clearing

- Floor space L can be allocated to either residential (price Q_i) or commercial (denote price q_i) use. Let θ_i be share put to commercial use.
- Let $\xi_i \geq 1$ be the tax-equivalent of restrictions on commercial use in block i
- Assume floor space will be put to its most profitable use (so actual price is $\max\{Q_i, q_i\}$)
- Floor space produced competitively using land (K) and capital (M): $L_i = M_i^{\mu} K_i^{1-\mu}$. Capital is elastically supplied to entire city, land is in fixed supply in amount K_i in each block.
- Floor space market clearing requires that floor space demand (sum from commercial and residential use) equals floor space supply (which is itself governed by land supply).

Externalities

- Now introduce two sorts of potential agglomeration externalities
- Residential amenities (B_i) are influenced by both fundamentals (b_i) and spillovers (Ω_i)

$$B_i = b_i \Omega_i^{\eta}, \qquad \Omega_i \equiv \left[\sum_{s=1}^{S} e^{-\rho \tau_{is}} \left(\frac{H_{Rs}}{K_s} \right) \right].$$

- Productivity (A_j) depends on fundamentals (a_j) and spillovers (Υ_j):

$$A_j = a_j \Upsilon_j^{\lambda}, \qquad \Upsilon_j \equiv \left[\sum_{s=1}^{S} e^{-\delta \tau_{is}} \left(\frac{H_{Ms}}{K_s} \right) \right],$$

- ρ and δ capture the rates of spatial decay of the spillovers
- η and λ capture the overall strength of spillovers to production
- τ_{ij} is travel time from block i to block j.

Equilibrium

- If we had exogenous fundamentals ($\rho = \delta = \eta = \lambda$) in this economy, then existence and uniqueness of an equilibrium (assuming all fundamentals are positive but finite) are straightforward to show (see Proposition 1, but of course a special case of the usual Arrow-Debreu results since everything here has non-increasing returns to scale, perfect competition, and homothetic preferences without strong complementarities).

- But with positive externalities ($\rho > 0$, $\delta > 0$, $\eta > 0$, and/or $\lambda > 0$) then uniqueness becomes unlikely (no results in paper but undoubtedly true)

Structural Estimation

- To go from the reduced-form (diff-in-diff) findings we saw earlier to an estimate of all of the model parameters (the fundamentals, and the spillover functions) we need to map the correlations in the data, plus assumptions about orthogonality, into implied parameter estimates

- In general, that will depend on three things:
  1. What endogenous variables in the model do we actually have data on?
  2. What are the orthogonality assumptions (about correlations between unobservables and observables) that we believe in?
  3. And hence, does the model have a unique mapping from the data we have plus the orthogonality assumptions we believe in to the parameters of interest? (That is, are the parameters identified?)

- This will not be easy to show here, since the historical data is limited (so #1 is hard), and the non-uniqueness of equilibrium makes #3 suspect.

Step #1: Commuting Gravity

- Gravity equation for commuting from residence i to workplace j can be written as:

$$\ln \pi_{ij} = -\nu\tau_{ij} + \vartheta_i + \varsigma_j + e_{ij}, \tag{1}$$

- where τ_{ij} is travel time in minutes and $\nu = \epsilon\kappa$ is semi-elasticity
- ϑ_i are residence fixed effects
- ς_j are workplace fixed effects

- Data: survey of commuting (where to, and travel time) from 2008 at the district (only 12 of them) level. (So footnote 47 discusses aggregation bias due to estimating block-level gravity model from district-level data. Bias is small in their model-based simulations.)

Commuting Gravity Equation: Results

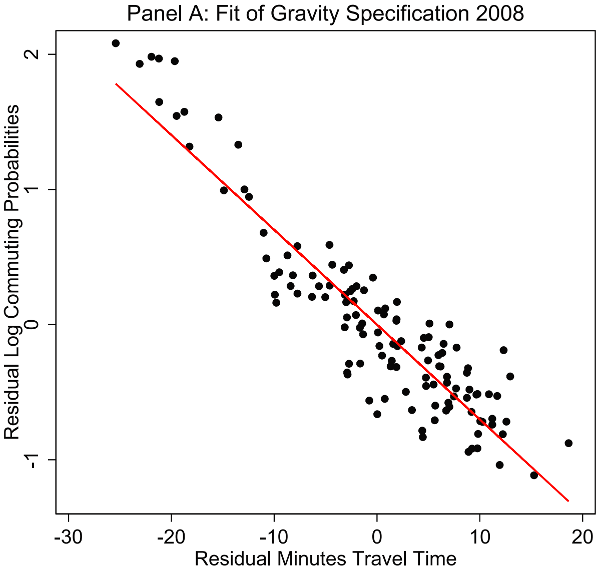
TABLE III

COMMUTING GRAVITY EQUATION[a]

	(1) ln Bilateral Commuting Probability 2008	(2) ln Bilateral Commuting Probability 2008	(3) ln Bilateral Commuting Probability 2008	(4) ln Bilateral Commuting Probability 2008
Travel Time ($-\kappa\varepsilon$)	-0.0697^{***}	-0.0702^{***}	-0.0771^{***}	-0.0706^{***}
	(0.0056)	(0.0034)	(0.0025)	(0.0026)
Estimation	OLS	OLS	Poisson PML	Gamma PML
More than 10 Commuters		Yes	Yes	Yes
Fixed Effects	Yes	Yes	Yes	Yes
Observations	144	122	122	122
R^2	0.8261	0.9059	–	–

[a] Gravity equation estimates based on representative micro survey data on commuting for Greater Berlin for 2008. Observations are bilateral pairs of 12 workplace and residence districts (post 2001 Bezirke boundaries). Travel time is measured in minutes. Fixed effects are workplace district fixed effects and residence district fixed effects. The specifications labelled more than 10 commuters restrict attention to bilateral pairs with 10 or more commuters. Poisson PML is Poisson Pseudo Maximum Likelihood estimator. Gamma PML is Gamma Pseudo Maximum Likelihood Estimator. Standard errors in parentheses are heteroscedasticity robust. * significant at 10%; ** significant at 5%; *** significant at 1%.

Commuting Gravity Equation: Fit



Step #2: Uncovering (adjusted) wages

- Recall that "commuting market clearing equation" looked like (in any time period t):

$$H_{Mjt} = \sum_{i=1}^{S} \frac{E_{jt} \left(w_{jt} / d_{ijt} \right)^{\epsilon}}{\sum_{s=1}^{S} E_{st} \left(w_{st} / d_{ist} \right)^{\epsilon}} H_{Rit}$$

- With data on H_{Mjt} and H_{Rjt} (number of residents and number of employees, by block), with a measure of d_{ijt}^{ϵ} one can solve this system of equations for "adjusted wages" $\omega_j \equiv E_{jt} w_{jt}^{\epsilon}$. ARSW show that this solution exists and is unique.

- ARSW have such data and set $d_{ijt}^{\epsilon} = e^{\epsilon \kappa \tau_{ijt}}$, where τ_{ijt} is travel time computed from knowledge of roads (and speeds), train/subway networks (and schedules), etc (and travel time-minimizing behavior) etc.

Step #3: Uncovering productivity and amenity terms

- Profit maximization can be written as:

$$\ln \widetilde{A}_{it} = \chi_t + (1-\alpha)\ln \widehat{Q}_{it} + \frac{\alpha}{\epsilon}\ln \omega_{it}$$

- Where $\widetilde{A}_{it} \equiv A_i E_i^{\alpha/\epsilon}$ and $\widehat{Q}_{it} \equiv \max\{q_{it}, Q_{it}\}$, and χ_t is a year fixed-effect.
- And the labor mobility and commuting expressions can be written as:

$$\ln \widetilde{B}_{it} = \eta_t + \frac{1}{\epsilon}\ln H_{Rit} + (1-\beta)\ln \widehat{Q}_{it} - \ln W_{it}$$

- Where $\widetilde{B}_{it} \equiv B_i T_i^{1/\epsilon}\xi_i^{1-\beta}$, $W_{it} \equiv \sum_s \omega_{st} e^{\epsilon\kappa\tau_{ist}}$, and η_t is a year fixed-effect
- With data on $\widehat{Q}_{it}$ and estimates of parameters ϵ, α and β, can solve for the productivity and amenity terms $\widetilde{B}_{it}$ and $\widetilde{A}_{it}$
- ARSW estimate ϵ from log wage dispersion (which is valid in the model, but may be quite exposed to risks of unobserved skill variation)

Do productivity and amenity terms correlate with diff-in-diff Berlin Wall treatment?

TABLE IV

PRODUCTIVITY, AMENITIES, AND COUNTERFACTUAL FLOOR PRICES[a]

	(1) $\Delta \ln A$ 1936–1986	(2) $\Delta \ln B$ 1936–1986	(3) $\Delta \ln A$ 1986–2006	(4) $\Delta \ln B$ 1986–2006	(5) $\Delta \ln QC$ 1936–1986	(6) $\Delta \ln QC$ 1986–2006
CBD 1	−0.207***	−0.347***	0.261***	0.203***	−0.408***	−0.010
	(0.049)	(0.070)	(0.073)	(0.054)	(0.038)	(0.020)
CBD 2	−0.260***	−0.242***	0.144**	0.109*	−0.348***	0.079**
	(0.032)	(0.053)	(0.056)	(0.058)	(0.017)	(0.036)
CBD 3	−0.138***	−0.262***	0.077***	0.059**	−0.353***	0.036
	(0.021)	(0.037)	(0.024)	(0.026)	(0.022)	(0.031)
CBD 4	−0.131***	−0.154***	0.057***	0.010	−0.378***	0.093***
	(0.016)	(0.023)	(0.015)	(0.008)	(0.021)	(0.026)
CBD 5	−0.095***	−0.126***	0.028**	−0.014*	−0.380***	0.115***
	(0.014)	(0.013)	(0.013)	(0.007)	(0.022)	(0.033)
CBD 6	−0.061***	−0.117***	0.023**	0.001	−0.354***	0.066***
	(0.015)	(0.015)	(0.010)	(0.005)	(0.018)	(0.023)
Counterfactuals					Yes	Yes
Agglomeration Effects					No	No
Observations	2,844	5,978	5,602	6,718	6,260	7,050
R^2	0.09	0.06	0.02	0.03	0.07	0.03

[a]Columns (1)–(4) based on calibrating the model for $\nu = \varepsilon\kappa = 0.07$ and $\varepsilon = 6.83$ from the gravity equation estimation. Columns (5)–(6) report counterfactuals for these parameter values. A denotes adjusted overall productivity. B denotes adjusted overall amenities. QC denotes counterfactual floor prices (simulating the effect of division on West Berlin). Column (5) simulates division holding A and B constant at their 1936 values. Column (6) simulates reunification holding A and B for West Berlin constant at their 1986 values and using 2006 values of A and B for East Berlin. CBD1–CBD6 are six 500 m distance grid cells for distance from the pre-war CBD. Heteroscedasticity and Autocorrelation Consistent (HAC) standard errors in parentheses (Conley (1999)). * significant at 10%; ** significant at 5%; *** significant at 1%.

Step #4: Constructing moments

- Now assume that exogenous components (a_i and b_i) of the productivity terms (A_i and B_i) do not change before/after the Berlin Wall is built/removed in a way that is correlated with distance to the CBD:

$$E[I_k \times \Delta \ln \widetilde{a}_{it}] = 0$$

- ...for any distance band (from the CDB) k. And similarly for b_i.

- How do we construct $\widetilde{a}_{it}$ (and hence sample analogs of these moments)? Previous step identified $\widetilde{A}_{it} \equiv \widetilde{a}_{it} \Upsilon_{it}^{\lambda}$, so can construct moment given data on H_{Mit} and K_{it} and value of spillover parameter δ. This implies that δ and λ are identified. (And analogously for amenity side.)

Estimated Parameters (GMM)

TABLE V

GENERALIZED METHOD OF MOMENTS (GMM) ESTIMATION RESULTS[a]

	(1) Division Efficient GMM	(2) Reunification Efficient GMM	(3) Division and Reunification Efficient GMM
Commuting Travel Time Elasticity ($\kappa\varepsilon$)	0.0951***	0.1011***	0.0987***
	(0.0016)	(0.0016)	(0.0016)
Commuting Heterogeneity (ε)	6.6190***	6.7620***	6.6941***
	(0.0939)	(0.1005)	(0.0934)
Productivity Elasticity (λ)	0.0793***	0.0496***	0.0710***
	(0.0064)	(0.0079)	(0.0054)
Productivity Decay (δ)	0.3585***	0.9246***	0.3617***
	(0.1030)	(0.3525)	(0.0782)
Residential Elasticity (η)	0.1548***	0.0757**	0.1553***
	(0.0092)	(0.0313)	(0.0083)
Residential Decay (ρ)	0.9094***	0.5531	0.7595***
	(0.2968)	(0.3979)	(0.1741)

[a]Generalized Method of Moments (GMM) estimates. Heteroscedasticity and Autocorrelation Consistent (HAC) standard errors in parentheses (Conley (1999)). * significant at 10%; ** significant at 5%; *** significant at 1%.

Estimated Parameters (GMM)—Implications

TABLE VI

EXTERNALITIES AND COMMUTING COSTS[a]

	(1) Production Externalities $(1 \times e^{-\delta\tau})$	(2) Residential Externalities $(1 \times e^{-\rho\tau})$	(3) Utility After Commuting $(1 \times e^{-\kappa\tau})$
0 minutes	1.000	1.000	1.000
1 minute	0.696	0.468	0.985
2 minutes	0.485	0.219	0.971
3 minutes	0.338	0.102	0.957
5 minutes	0.164	0.022	0.929
7 minutes	0.079	0.005	0.902
10 minutes	0.027	0.001	0.863
15 minutes	0.004	0.000	0.802
20 minutes	0.001	0.000	0.745
30 minutes	0.000	0.000	0.642

[a]Proportional reduction in production and residential externalities with travel time and proportional reduction in utility from commuting with travel time. Travel time is measured in minutes. Results are based on the pooled efficient GMM parameter estimates: $\delta = 0.3617$, $\rho = 0.7595$, $\kappa = 0.0148$.