Online Appendix: Estimating the Economic Value of Zoning Reform

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A Zoning Parameter Changes

Similar to zoning reforms around the world, the 2016 Sao Paulo reform changed multiple building relevant parameters with the aim of shaping the built environment in different neighborhoods. The policy was presented to the public in terms of assigning different blocks in to four qualitative zones.

In Table A2 we test whether treatment blocks are more likely to be generally classified as having certain development strategies (as we might expect). We find that treatment blocks are 21 percentage points more likely to be labeled “Transformation” zones (relative to a control mean of 11.2 percentage points). This was the main goal of the policy, i.e., increase densification around transportation corridors. On the other hand, we find that treatment blocks are six percentage points less likely to be classified as “Preservation” (relative to a control mean of 9.5 percentage points), and also 15.2 percentage points less likely to be defined as “Qualification” areas (relative to a control mean of 79.3 percentage points). The preservation and qualification areas usually kept the same Max BAR as the previous zoning code or had a reduction in allowed densification. These results suggest that other potential zoning parameter changes, aside from max BAR, could potentially change after the reform.

Before going into details on other zoning parameters, we note that in our main supply model estimates (Table 3), where we estimated the permit response to changes in Max BAR and prices, we control for the maximum shadow ratio, maximum height, minimum and Basic BAR of 2004 and 2016, max BAR of 2004, min and max front setback and maximum area of 2016. All of these zoning variables are averaged within the subprefetuira-quintile.[1] Controlling for these factors helps us focus on the variation in Max BAR.

Here we discuss two particularly salient zoning parameters and the extent to whether variation in them may contribute to our findings on the effect of the zoning reform. Focusing first on maximum building height: approximately 80% of blocks did experience a change in their maximum building height. This result makes sense in that increases in the built area ratio may not actually change the ability to build up if height restrictions are binding. Indeed, we find a strong correlation between the blocks that experienced increases in maximum height and BAR. This correlation implies that it is possible some portion of the Max BAR effects we identify are due to changes in building height allowances (although as noted above our supply estimate results control for

[1] which governs the fraction of a lot that can be covered by a building (The shadow ratio governs the building's footprint on the plot of land - it is the maximum allowed footprint of a building relative to land area.

building height changes).

The second alternative building parameter legislated by the Sao Paulo zoning reform is the shadow ratio. To assess the importance of shadow ratio changes in driving permitting behavior we recreated treatment and control blocks based on whether they experienced an increase in their shadow ratio. 90.17% experienced a max shadow ratio increase, 8.95% experienced no change, and less than 1% experienced a reduction in shadow ratio. With this set of treatment and control blocks, we estimate the effect of a shadow ratio increase on building permit issuances.

Table A19 reports results from RD regressions across all blocks where we include both treatment indicators for having an increase in max BAR, and a separate treatment indicator for having an increase in a block's shadow ratio. Column (1) replicates our main results only including the treatment indicator for an increase in max BAR. Column (2) only includes the treatment indicator for having an increase in the shadow ratio. The shadow ratio effect is significant at the 10 percent level. Column (3) includes both treatment indicators; the effect on the BAR coefficient is essentially unchanged. The coefficient on the shadow ratio indicator is no longer significant, suggesting that some of the effect of shadow ratio changes is picked up by the BAR change treatment indicator instead.

In Appendix Table A4 we estimate how four 2016 zoning parameters change as we move across the 2016 treatment/control boundary. We find that the level of Basic BAR is significantly higher, but economically the difference is small relative to the Basic BAR. We find a similar result for the "shadow ratio" parameter, the max height of a building, and the maximum lot area of the building. Treatment blocks do have significantly higher values of these building parameters, but the economic significance of the difference between control and treatment blocks is small. We note here that we may be "over-controlling", in the sense that by controlling for changes in maximum building height we are removing important variation in max BAR across the boundary.

In Table A5 we estimate how the first stage of our treatment variable predicts changes in Max BAR due to the reform after controlling for basic BAR, shadow ratio for lots under 500 square meters, maximum height and maximum lot size. After controlling for these factors the treatment effect on Max BAR is 1.04, which is somewhat lower than the specification in our main RD First stage table of 1.355 (Column 4, Panel B of 1) - but still statistically and economically large relative to changes in other zoning parameters. Column 2 of Table A5 estimates the effect of our treatment variable on quarterly new multi-family building permits after controlling for the above other zoning parameters - we find an effect size of .00199 permits per quarter, which is significant at the 10%

level. This effect size is also smaller than the .00313 effect size we find in 2, but still economically significant. These results suggest that even if we remove any variation in max BAR changes that is correlated with these other zoning reform parameter changes, we find economically meaningful increases in building activity.

Ultimately, we cannot completely rule out the possibility that some of the building responses we observe are due to changes in maximum height and shadow ratio parameter changes- but as noted before our full supply model controls for the direct impact of shadow ratio and many other alternative zoning parameters. We ultimately chose to focus on BAR for the following reasons 1) it theoretically is the most important parameter determining the amount of floorspace that can be built on a given piece of land; 2) it was emphasized in the zoning reform documents as the main parameter determining density; and 3) it is an internationally recognized concept used in basically all zoning regulations, so our results will hopefully be informative for other contexts.

B Supply side aggregation

Let q be the subprefeitura-quantile $\in [1, ..., Q]$. Then the predicted annual number of new building permits for q is:[2]

$$\hat{s}_q = \frac{1}{4}\exp(\hat{\alpha}^s p_q + \hat{\beta}^s X_q^s + \hat{\psi} M_q) \tag{11}$$

Each new permit is associated with a time-path of new housing units. To obtain this, we take a sample of permits which can be matched to our IPTU data and calculate the cumulative expected number of residential units $\hat{n}_t$ that will be constructed from the average permit, for each year t over a ten year horizon.[3] So each permit is associated with $\hat{s}_q \hat{n}_t$ units. The model-predicted number of new units for location q by year τ, then, is:

$$N_{q,\tau} = \sum_{t=0}^{\tau} \hat{n}_t \hat{s}_q \tag{12}$$

This formula accounts for the fact that, each year into our simulation, new permits are being filed at a constant rate implied by the predicted values of the supply equation. Finally, to obtain the market share of total units for q after 10 years, we add the new units to the existing stock,

[2] Note that we measure the outcome as the total number of permits for the four years from 2016-2019. So in order to annualize the predicted number of permits, we divide the fitted values by 4.

[3] In our matched sample, by year 10 the average new building permit will create 19 new residential units.

allowing for differential secular growth rates between the city, r_1, and the outside option, r_0.[4]

$$S_{q,\tau} = \frac{N_{q,\tau} + N_q^0(1+r_1)^\tau}{N_0^0(1+r_0)^\tau + \sum_{k=1}^{Q} N_{k,\tau} + N_k^0(1+r_1)^\tau} \tag{13}$$

S_q is defined at the subprefeitura-quantile-level but our equilibrium prices and quantities must be returned at the commuting zone-level. However, neighborhood-quantiles are not nested in commuting zones. As such, we construct the following mapping between the two. First, we overlay the maps of 1182 neighborhood-quantiles on to the 329 commuting zones and calculate the area of intersection between every q, j pair. Define weights $\omega_{qj} = \frac{km^2_{qj}}{km^2_q}$ as the share of the area in neighborhood-quantile q that falls into commuting zone j. Then, to translate a price vector p_j into p_q to be plugged into the supply equation, we calculate the weighted average of prices in all the zones that overlap with q:

$$p_q = \sum_{j=1}^{J} \omega_{qj} p_j \tag{14}$$

Similarly, to translate a set of shares S_q into S_j for the equilibrium calculation, we apportion each neighborhood-quantile share to each of its constituent zones in proportion to their area share and then aggregate up to the commuting zone level:

$$S_j = \sum_{q=1}^{Q} \omega_{qj} S_q \tag{15}$$

C Zoning reform effect on productivity

Our estimates of the productivity effects of zoning reform are heavily based on the assumptions and estimates from Glaeser and Gyourko (2018).[5] Let L_i be the quantity of labor in location i, F_L^i be the marginal product of labor in location i and W the average national wage. Their work assumes that differences in payroll per worker can be considered the true differences in marginal product of labor. From that assumption they consider the thought experiment of moving populations from all areas with low initial wages to all areas with high wages until wages equalize to a similar level (W) across all locations. In this context, the gains from relocation can be written as:

[4] We obtain these growth rates from census data on aggregate housing unit growth from 2000-2010, and estimate $r_1 = 0.01$ and $r_0 = 0.017$; over this period the suburbs have grown .7 percent per year faster in terms of housing units.

[5] See Appendix 3 of that paper for details on the calculation method and necessary assumptions.

$$Gains = \frac{1}{2\alpha} \sum_i L_i (F_L^i(L_i) - W) \tag{16}$$

α is the inverse elasticity of labor demand. In this set up equalizing wages will generate a reduction in the total wage bill and the output gain from reallocation will be proportionate to the total wage bill reduction.[6]

Glaeser and Gyourko (2018) use data across all MSAs in the U.S. and an estimate of α from the literature to calibrate a 2 percentage change in GDP resulting from a radical reallocation of labor that equalizes wages across all locations. If α=1, then a 33.3 percent increase in population will drop wages in the New York MSA to the national norm.

We use that information to estimate a simple back-of-the envelope calculation, only considering the effects of the Sao Paulo zoning reforming, and ignoring a potential equalization of wages across all cities in the country. Our counterfactual simulation estimates that the reform would increase population in Sao Paulo by an extra 2.2 percentage points in 10 years. Assuming that Sao Paulo plays a similar economic role in Brazil as that of of NYC in the US, the increase in population is 0.0661 of the effect required to equalize wages, assuming linearity of effects.

The Sao Paulo share of national GDP is 9.46%, which means that the reform would generate gains through reallocation of 2% GDP*9.46%*0.0661 = 0.0125% of the Brazilian GDP. That in turn corresponds to 0.132% of Sao Paulo GDP. A similar calculation was conducted for the double BAR simulations.

[6] The reduction in the total wage bill comes intuitively from the fact that formerly high wage areas with stringent zoning restrictions now attract a lot of labor leading to large wage declines relative to low-wage unrestricted places. The key assumption is that that curvature of the marginal product curve is stronger in the restricted versus non restricted areas. The output gain is proportional to this because the higher the wages where in the restricted areas, the greater the productivity gains from labor re-allocation.

D Appendix Tables

Table A1: RD balance of covariates

Panel A: Average Property Characteristics in 2015

	Block density (constructed area/m^2)	Average land value per m^2	Average constructed value per m^2	Number of buildings	Residential share of constructed area	Commercial share of constructed area
Treat BAR	-0.0273	26.66	23.03	-1.185	0.00296	-0.00547
	(0.0288)	(20.41)	(15.19)	(1.396)	(0.00931)	(0.00711)
Cubic	Y	Y	Y	Y	Y	Y
SP FE	Y	Y	Y	Y	Y	Y
Observations	41959	41959	41959	41959	41959	41959
Mean of Dep. Variable	0.930	621.8	822.8	54.97	0.771	0.154

Panel B: Average Labor Market Outcomes in RAIS Data in 2015

	Total employees in private firms	Log of mean private employee wages	Log of aggregate private employee wages	Number of private firms	Number of private firms with no employees	Number of private firms with employees
Treat BAR	4.125	0.0173	0.186**	-0.281	-0.385	0.104
	(12.05)	(0.0134)	(0.0635)	(1.084)	(0.691)	(0.445)
Cubic	Y	Y	Y	Y	Y	Y
SP FE	Y	Y	Y	Y	Y	Y
Observations	39582	31280	32251	39582	39582	39582
Mean of Dep. Variable	85.64	10.14	13.02	23.25	15.59	7.655

Standard errors clustered by commuting zones in parentheses. All specifications include a cubic polynomial of the running variable interacted with the treatment indicator. The polynomial is always interacted with the treatment indicator. Sample is all city blocks with zoning information. Mean of dependent variable calculated for control blocks within 0.1 km of the BAR boundary. *$p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table A2: RD reduced form: Poisson model

Outcome	New multi-family building permits			
	(1)	(2)	(3)	(4)
Panel A: No sub-prefeitura FE				
Treat BAR	0.261*	0.683***	0.645***	0.403*
	(0.103)	(0.094)	(0.121)	(0.162)
Specification	Base	Linear	Quadratic	Cubic
Observations	43231	43231	43231	43231
Mean of Dep. Variable	0.007	0.007	0.007	0.007
Panel B: With sub-prefeitura FE				
Treat BAR	0.300***	0.373***	0.424***	0.345*
	(0.077)	(0.088)	(0.118)	(0.150)
Specification	Base	Linear	Quadratic	Cubic
Observations	43225	43225	43225	43225
Mean of Dep. Variable	0.006	0.006	0.006	0.006

Standard errors clustered by commuting zones in parentheses. Specification refers to the order of the polynomial for the running variable, which is distance to the RD boundary. The polynomial is always interacted with the treatment indicator. Sample is all city blocks with zoning information. Mean of dependent variable calculated for control blocks within 0.1 km of the BAR boundary. All models are poisson regressions estimated with maximum likelihood. *$p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table A3: RD type of development strategy 2016

Outcome	Type of block			
	(1) Residential	(2) Preservation	(3) Qualification	(4) Transformation
Cubic specification with sub-prefeitura FE				
Treat BAR	0.0128	-0.0609***	-0.152***	0.212***
	(0.00791)	(0.0137)	(0.0286)	(0.0272)
Observations	43225	43225	43225	43225
Mean of Dep. Variable	0.967	0.0949	0.793	0.112

Standard errors clustered by commuting zones in parentheses. Outcome is an indicator variable at block level for whether the specific block allows residential construction (1) or is under the preservation, qualification, or transformation development strategy (2, 3, 4) according to 2016 zoning law. This table includes a cubic specification with sub-prefeitura fixed effects. The polynomial is always interacted with the treatment indicator. Sample is all city blocks with zoning information. Mean of dependent variable calculated for control blocks within 0.1 km of the BAR boundary. *$p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table A4: RD zoning parameters 2016

Outcome	Type of block			
	(1) Basic BAR	(2) Shadow ratio	(3) Max height	(4) Max lot area
Cubic specification with sub-prefeitura FE				
Treat BAR	0.0136***	0.0555***	3.179***	474.5**
	(0.00290)	(0.00647)	(0.755)	(148.7)
Observations	43225	43225	33175	42687
Mean of Dep. Variable	0.989	0.770	26.64	18885.6

Standard errors clustered by commuting zones in parentheses. Outcome is a 2016 zoning parameter at the block level: (1) basic built-area-ratio, (2) shadow ratio of building footprint to lot area for lots up to 500 square meters, (3) maximum height allowed in meters, and (4) maximum lot area allowed in square meters. Sample is all city blocks with zoning information. This table includes a cubic specification with sub-prefeitura fixed effects. Mean of dependent variable calculated for control blocks within 0.1 km of the BAR boundary. *$p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table A5: RD first stage and reduced form with 2016 zoning controls

Outcome		
	(1) Max BAR change	(2) New build
Cubic specification with sub-prefeitura FE		
Treat BAR	1.042***	0.00199*
	(0.0283)	(0.000855)
Observations	43225	43225
Mean of Dep. Variable	-0.153	0.0056

Standard errors clustered by commuting zones in parentheses. Specification refers to the order of the polynomial for the running variable, which is distance to the RD boundary. The polynomial is always interacted with the treatment indicator. Sample is all city blocks with zoning information. Models used are the same as in Table 1 column (4) and Table 2 column (4), with the addition of certain 2016 zoning parameters as controls: basic BAR, shadow ratio for lots under 500 square meters, maximum height in meters, and maximum lot area in square meters. Mean of dependent variable calculated for control blocks within 0.1 km of the BAR boundary. Outcome is at block level: (1) maximum BAR change or (2) average annual new multi-family building permits filed after 2016. *$p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table A6: RD reduced form: approved permits

Outcome	New multi-family building permits			
	(1)	(2)	(3)	(4)
Panel A: No sub-prefeitura FE				
Treat BAR	0.00113*	0.00266***	0.00303***	0.00260***
	(0.00046)	(0.00047)	(0.00050)	(0.00058)
Specification	Base	Linear	Quadratic	Cubic
Observations	43231	43231	43231	43231
Mean of Dep. Variable	0.00307	0.00307	0.00307	0.00307
Panel B: With sub-prefeitura FE				
Treat BAR	0.00130***	0.00157***	0.00174***	0.00190***
	(0.00035)	(0.00040)	(0.00046)	(0.00057)
Specification	Base	Linear	Quadratic	Cubic
Observations	43225	43225	43225	43225
Mean of Dep. Variable	0.00307	0.00307	0.00307	0.00307

Standard errors clustered by commuting zones in parentheses. Specification refers to the order of the polynomial for the running variable, which is distance to the RD boundary. The polynomial is always interacted with the treatment indicator. Sample is all city blocks with zoning information. Mean of dependent variable calculated for control blocks within 0.1 km of the BAR boundary. Outcome is the average annual new building permits filed after 2016 and approved in 2017 or later. $^{*}p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table A7: RD reduced form: listings difference 2022-2019

Outcome	Listings Difference 2022-2019			
	(1)	(2)	(3)	(4)
Panel A: No sub-prefeitura FE				
Treat BAR	1.289*	2.214***	2.586***	2.396**
	(0.500)	(0.599)	(0.655)	(0.778)
Specification	Base	Linear	Quadratic	Cubic
Observations	42504	42504	42504	42504
Mean Listings Left of Cut-off (2019)	20.4	20.4	20.4	20.4
Panel B: With sub-prefeitura FE				
Treat BAR	2.597***	2.534***	2.502***	2.103**
	(0.626)	(0.667)	(0.693)	(0.789)
Specification	Base	Linear	Quadratic	Cubic
Observations	42498	42498	42498	42498
Mean Listings Left of Cut-off (2019)	20.4	20.4	20.4	20.4

Standard errors clustered by commuting zones in parentheses. Specification refers to the order of the polynomial for the running variable, which is distance to the RD boundary. The polynomial is always interacted with the treatment indicator. Sample is all city blocks with zoning information. Outcome is the difference in number of real estate listings at block level between 2022 and 2019. Mean Listings Left of Cut-Off (2019) gives the mean level of listings for control blocks within 0.1 km of the BAR boundary, which can be used to calculate the proportionate increase in listings due to the reform. $^{*}p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table A8: RD reduced form: listings difference 2022-2019 using optimal bandwidths

Outcome	Listings Difference 2022-2019		
	(1)	(2)	(3)
Treat BAR	1.07377		
	(0.71653)		
Conventional		1.07377	0.99610
		(0.74500)	(0.63601)
Bias-corrected		0.87807	0.72096
		(0.74500)	(0.63601)
Robust		0.87807	0.72096
		(0.87284)	(0.77773)
Bandwidth	0.055	0.055	0.057
Order	0	0	0
Kernel	Uniform	Uniform	Triangular
Estimation	Linear	Nonparametric	Nonparametric
Mean Listings Left of Cut-off (2019)	20.4	20.4	20.4
Observations	6984	6984	7383

This table shows results from the optimal bandwidth and inference procedures, as recommended in Calonico et al. (2017), for the effect of the zoning reform on the change in listings from 2019 to 2022. The specification is the same as in Table A7 and does not include sub-prefeitura fixed effects. *$p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table A9: Change in Listings/Prices vs. Change in Average BAR Changes

Outcome	Listings Difference		Price Difference	
	(1)	(2)	(3)	(4)
Treat BAR	10.891***	6.992*	-5.692***	-3.233**
	(3.688)	(3.733)	(1.567)	(1.473)
R-squared	0.018	0.268	0.028	0.346
Observations	328	328	326	325
SP FE	N	Y	N	Y

Heteroskedasticity robust standard errors in parentheses. This table reports the correlation between the change in max BAR with the change in listings (2019-2022) (columns (1)-(2)) and the change in prices (columns (3) and (4)). All models including commuting zone fixed effects. The coefficients in columns (1) and (3) correspond to the slopes in Figures 6 respectively. *$p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table A10: Summary statistics for supply variables

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Permits	MF Permits	SF Permits	Max BAR	Price	Density	Age	Units	Historic
Mean	4.55	3.22	0.35	2.11	5.35	0.58	34.62	5.93	0.04
SD	5.91	5.05	0.85	0.66	1.81	0.41	8.41	12.41	0.10

Table shows means and standard deviations for all subprefeitura-bin-level variables that enter supply equation. Permits is the total count of permits in the post-reform years 2016 to 2019 (total new building, multi-family, or single-family). Max BAR is the average Max BAR in 2016 in the subprefeitura-bin. Price is measured in R$ ths, average age of building is in years, units is units per building for the average building in the subprefeitura-bin, density is constructed area per unit of subprefeitura-bin area, and historic is the share of subprefeitura-bin area under historic preservation.

Table A11: Bartik Instrument Correlation with Neighborhood Characteristics

	Health and Social Services (1)	Services to Firms (2)	Real estate (3)	Food and housing (4)	Associative Activities (5)
Age	0.063	0.583***	-0.078**	-0.023	0.062
	(0.095)	(0.112)	(0.035)	(0.036)	(0.064)
Density	-6.574*	-16.253***	0.980	0.347	-2.498
	(3.365)	(3.745)	(1.329)	(1.179)	(1.917)
Units	0.540	1.299***	-0.049	-0.104	0.291
	(0.382)	(0.458)	(0.133)	(0.101)	(0.201)
Land value	0.007**	0.016***	0.006***	0.006***	-0.001
	(0.003)	(0.004)	(0.001)	(0.001)	(0.001)
R-squared	0.047	0.305	0.318	0.246	0.012
Observations	336	336	336	336	336

Heteroskedasticity robust standard errors in parentheses. This table shows the correlation between the presence of the influential industries in our Bartik instrument for housing supply, and the major neighborhood characteristics average age of buildings, density of buildings, units, land value per square meter from the IPTU. Each column reports the result of a regression of employment share of the specified industry on the neighborhood characteristics listed as rows. *$p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table A12: Supply estimates: Poisson IV regressions, multiplicative error

Outcome	All new buildings			Single	Multi
	(1)	(2)	(3)	(4)	(5)
Max BAR	0.474***	0.896***	0.878***	0.727	0.978***
	(0.133)	(0.255)	(0.253)	(0.885)	(0.295)
Price	0.101*	0.104*	0.462	1.338*	0.091
	(0.047)	(0.047)	(0.246)	(0.662)	(0.270)
Density	0.130	0.031	-0.586	-0.799	-0.161
	(0.159)	(0.167)	(0.433)	(0.855)	(0.501)
Age	0.042***	0.040***	0.002	-0.112	0.033
	(0.011)	(0.011)	(0.028)	(0.079)	(0.034)
Units per building	0.008	0.007	-0.003	-0.099**	0.008
	(0.005)	(0.005)	(0.007)	(0.036)	(0.010)
Historical preservation	-1.132*	-1.206*	-1.396**	-1.331	-1.132
	(0.484)	(0.481)	(0.442)	(1.129)	(0.733)
Q	1.731e-27	9.673e-30	1.748e-30	7.511e-29	1.550e-29
Observations	1182	1182	1182	1182	1182
IVs	None	RD	RD, Bartik	RD, Bartik	RD, Bartik

Heteroskedasticity robust standard errors in parentheses. Results are from the estimation of fuzzy regression discontinuity (RD) exponential (Poisson) model, estimated with GMM, on the sample of subprefeitura-quantiles. The RD treatment indicator instruments for Max BAR, while the Bartik labor demand shock instruments for price. All models use a multiplicative error specification to form moment conditions. All specifications include controls for the running variable interacted with the treatment, and the following zoning parameters: maximum shadow ratio, minimum and basic BAR of 2004 and 2016, max BAR of 2004, maximum height, min and max. front setback and maximum area of 2016, (zoning variables averaged within subprefeitura-quantile). Q-statistic gives the value of the GMM criterion function at the optimal parameters. The outcome variable is the number of total new building, single-family, or multi-family permit applications between 2016-2019, as indicated. *$p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table A13: Supply estimates: Poisson IV regressions, approvals

Outcome	All new buildings			Single	Multi
	(1)	(2)	(3)	(4)	(5)
Max BAR	0.458***	0.806***	0.764***	-0.051	0.981***
	(0.103)	(0.171)	(0.167)	(0.339)	(0.208)
Price	0.183***	0.191***	0.479***	0.417	0.466**
	(0.036)	(0.037)	(0.109)	(0.214)	(0.169)
Density	0.241	0.148	-0.300	-0.106	-0.297
	(0.124)	(0.129)	(0.208)	(0.433)	(0.302)
Age	0.010	0.009	-0.029	-0.044	-0.039
	(0.008)	(0.008)	(0.016)	(0.035)	(0.024)
Units per building	-0.003	-0.004	-0.011	-0.026	-0.019
	(0.004)	(0.005)	(0.007)	(0.014)	(0.013)
Historical preservation	-0.540	-0.500	-0.250	0.020	-0.791
	(0.354)	(0.362)	(0.398)	(0.790)	(0.517)
Q	2.674e-29	6.592e-27	3.851e-29	4.810e-29	4.397e-30
Observations	1182	1182	1182	1182	1182
IVs	None	RD	RD, Bartik	RD, Bartik	RD, Bartik

Heteroskedasticity robust standard errors in parentheses. Results are from the estimation of fuzzy regression discontinuity (RD) exponential (Poisson) model, estimated with GMM, on the sample of subprefeitura-quantiles. The RD treatment indicator instruments for Max BAR, while the Bartik labor demand shock instruments for price. All models use an additive error specification to form moment conditions. All specifications include controls for the running variable interacted with the treatment, and the following zoning parameters: maximum shadow ratio, minimum and basic BAR of 2004 and 2016, max BAR of 2004, maximum height, min and max. front setback and maximum area of 2016, (zoning variables averaged within subprefeitura-quantile). Q-statistic gives the value of the GMM criterion function at the optimal parameters. The outcome variable is the number of total new building, single-family, or multi-family permit approvals between 2016-2019, as indicated. *$p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table A14: Supply estimates: 2SLS IV regressions

Outcome	All new buildings			Single	Multi
	(1)	(2)	(3)	(4)	(5)
Max BAR	1.969***	3.386***	3.334***	-0.226*	2.775***
	(0.521)	(0.818)	(0.835)	(0.098)	(0.700)
Price	0.694***	0.711***	2.308**	0.197*	1.159*
	(0.183)	(0.186)	(0.704)	(0.095)	(0.564)
Density	1.275*	0.897	-1.970	-0.059	-0.969
	(0.618)	(0.639)	(1.342)	(0.184)	(1.054)
Age	0.067*	0.064*	-0.108	-0.021	-0.036
	(0.030)	(0.030)	(0.081)	(0.011)	(0.065)
Units per building	-0.015	-0.017	-0.045**	-0.007***	-0.034*
	(0.010)	(0.011)	(0.017)	(0.002)	(0.015)
Historical preservation	-2.824	-2.895*	-3.316*	0.033	-3.657**
	(1.462)	(1.470)	(1.571)	(0.220)	(1.155)
F-statistic		369.680	34.289	34.289	34.289
Observations	1182	1182	1182	1182	1182
IVs	None	RD	RD, Bartik	RD, Bartik	RD, Bartik

Heteroskedasticity robust standard errors in parentheses. Results are from the estimation of a 2SLS fuzzy regression discontinuity (RD) model, on the sample of subprefeitura-quantiles. The RD treatment indicator instruments for Max BAR, while the Bartik labor demand shock instruments for price. All specifications include controls for the running variable interacted with the treatment, and the following zoning parameters: maximum shadow ratio, minimum and basic BAR of 2004 and 2016, max BAR of 2004, maximum height, min and max. front setback and maximum area of 2016, (zoning variables averaged within subprefeitura-quantile). F-statistic refers to the first-stage regression. The outcome variable is the number of total new building, single-family, or multi-family permit approvals between 2016-2019, as indicated. *$p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table A15: Summary statistics for demand variables

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Price	Travel time	RCMA	Age	Units	Density	Paved	Income	College
Mean	6.24	33.36	2.03	39.89	5.40	5.17	0.98	4.65	0.33
SD	2.35	30.61	1.11	10.38	16.89	4.74	0.05	2.28	0.26

Table shows means and standard deviations for all commuting zone-level variables that enter demand equation (4). Price is measured in R$ ths per square meter, travel time in minutes, RCMA is an index of market access (see description in-text), average age of building is in years, units is units per building for the average building in the zone, density is constructed area per unit of zone area, paved is the share of paved roads, income is measured in monthly R$ ths, and college is the share of residents with a college degree.

Table A16: Second-stage demand estimation: IVs

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Price	-0.793***	-2.274***	-1.383***	-1.521***	-2.690***	-2.491***	-1.222**	-3.884***	-1.975***
	(0.163)	(0.436)	(0.373)	(0.309)	(0.495)	(0.477)	(0.609)	(0.997)	(0.383)
RCMA	0.463***	0.822***	0.606***	0.640***	0.922***	0.874***	0.567***	1.211***	0.749***
	(0.145)	(0.198)	(0.165)	(0.167)	(0.220)	(0.206)	(0.212)	(0.337)	(0.183)
Age	-1.157***	-0.935***	-1.069***	-1.048***	-0.873***	-0.903***	-1.093***	-0.694***	-0.980***
	(0.099)	(0.111)	(0.109)	(0.100)	(0.120)	(0.118)	(0.122)	(0.197)	(0.105)
Units per building	-0.781***	-0.613***	-0.714***	-0.699***	-0.566***	-0.589***	-0.732***	-0.431***	-0.647***
	(0.049)	(0.072)	(0.066)	(0.059)	(0.079)	(0.077)	(0.081)	(0.132)	(0.067)
Density	0.708***	0.779***	0.736***	0.743***	0.799***	0.789***	0.729***	0.856***	0.765***
	(0.107)	(0.136)	(0.116)	(0.117)	(0.149)	(0.143)	(0.117)	(0.193)	(0.127)
Paved roads	0.083	0.092	0.087	0.087	0.094	0.093	0.086	0.101	0.090
	(0.064)	(0.074)	(0.067)	(0.068)	(0.078)	(0.076)	(0.065)	(0.090)	(0.071)
Average income	-0.600***	-0.375*	-0.510***	-0.489***	-0.312	-0.342	-0.535***	-0.130	-0.420**
	(0.174)	(0.220)	(0.185)	(0.187)	(0.240)	(0.229)	(0.205)	(0.322)	(0.206)
College share	0.104	0.691**	0.338	0.392*	0.855***	0.777***	0.274	1.329***	0.572**
	(0.196)	(0.278)	(0.248)	(0.232)	(0.302)	(0.297)	(0.295)	(0.495)	(0.260)
F-statistic		8.560	8.852	7.459	41.411	38.901	24.005	17.174	12.136
Observations	329	329	329	329	329	329	329	329	329
Instruments	None	X	Spatial	All	RCMA	Density	Pave	Favela	Strong

Heteroskedasticity robust standard errors in parentheses. Results are from the second step of a two-step demand estimation. The outcome variable is the mean location-specific utility term $\hat{\delta}_i$ estimated in the first step maximum likelihood procedure. All location characteristics including price are standardized relative to the zone-level sample mean and standard deviation. Instruments for housing prices are the average spatial and housing characteristics of all zones greater than 3 miles from a zone centroid. *X* instruments (2) are: paved road share, RCMA, housing stock age, average units per building, and density. Spatial instruments (3) are: favela share of zone area, flood-zone share of zone area, average slope, and metro station presence. Strong instruments (9) are the subset of jointly strongest instruments: favelas, slope, RCMA, and age.

Table A17: Decomposition of welfare effects

Scenario	2016 zoning (1)	Double BAR (2)
Price only	25.45	344.52
Price and age	90.78	1475.26
Price and units	25.33	333.84
Price and density	40.68	726.38
Price and all X	108.46	2188.10

Table shows average individual-level welfare changes, measured in Brazilian reais from equilibrium simulation of the 2016 zoning reform and Double BAR reform. Each row represents the welfare change, relative to the 2004, from updating the variable indicated in the first row label.

Table A18: Simulation results: individual-level consumer surplus, levels

Scenario	2016 zoning		
Update	P	X	τ
	(1)	(2)	(3)
By demographic group			
Owner	59.74	140.23	139.05
Renter	61.11	113.55	112.20
Non-college	56.21	119.93	118.93
College	74.23	183.42	181.37
By income quintile			
1	54.48	112.42	111.55
2	55.95	120.49	119.45
3	57.98	127.47	126.35
4	61.82	142.28	140.94
5	70.79	167.45	165.65
Totals			
Full sample	60.08	133.56	132.34
Aggregate consumer surplus (mm reales)	322.15	716.14	709.57

Table shows per-household expected change in consumer surplus from equilibrium simulation of the 2016 zoning reform and Double BAR reform for different subgroups, measured in Brazilian reais. Bottom row shows the total consumer surplus aggregating across all households in millions of reais. Column (1) updates only equilibrium prices from the 2016 reform scenario. Column updates both prices and the housing and neighborhood attributes included in X_j. Column (3) updates all variables, including travel time τ. All changes are evaluated relative to 2004 (status quo) zoning.

Table A19: Shadow Ratio Block Level Regression Discontinuity Design

Outcome	New multi-family building permits		
	(1)	(2)	(3)
Treat BAR	0.00409***		0.00411***
	(0.00072)		(0.00074)
Treat SR		0.00178*	0.00089
		(0.00099)	(0.00103)
Polynomial order	1	1	1
Observations	43231	43250	43222

Standard errors clustered by commuting zones in parentheses. Treat BAR is defined as 1 for blocks that had an increase in BAR in the 2016 reform, and 0 otherwise. Treat SR is defined as 1 for blocks that had an increase in the shadow ratio in the 2016 reform, and 0 otherwise. Specification refers to the order of the polynomial for the running variable, which is distance to the RD boundary. The polynomial is always interacted with the treatment indicator. Sample is all city blocks with zoning information. Mean of dependent variable calculated for control blocks within 0.1 km of the BAR boundary. Column (1) replicates our main results only including the treatment indicator for an increase in max BAR. Column (2) only includes the treatment indicator for having an increase in the shadow ratio. Column (3) includes both treatment indicators. *$p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

E Appendix Figures

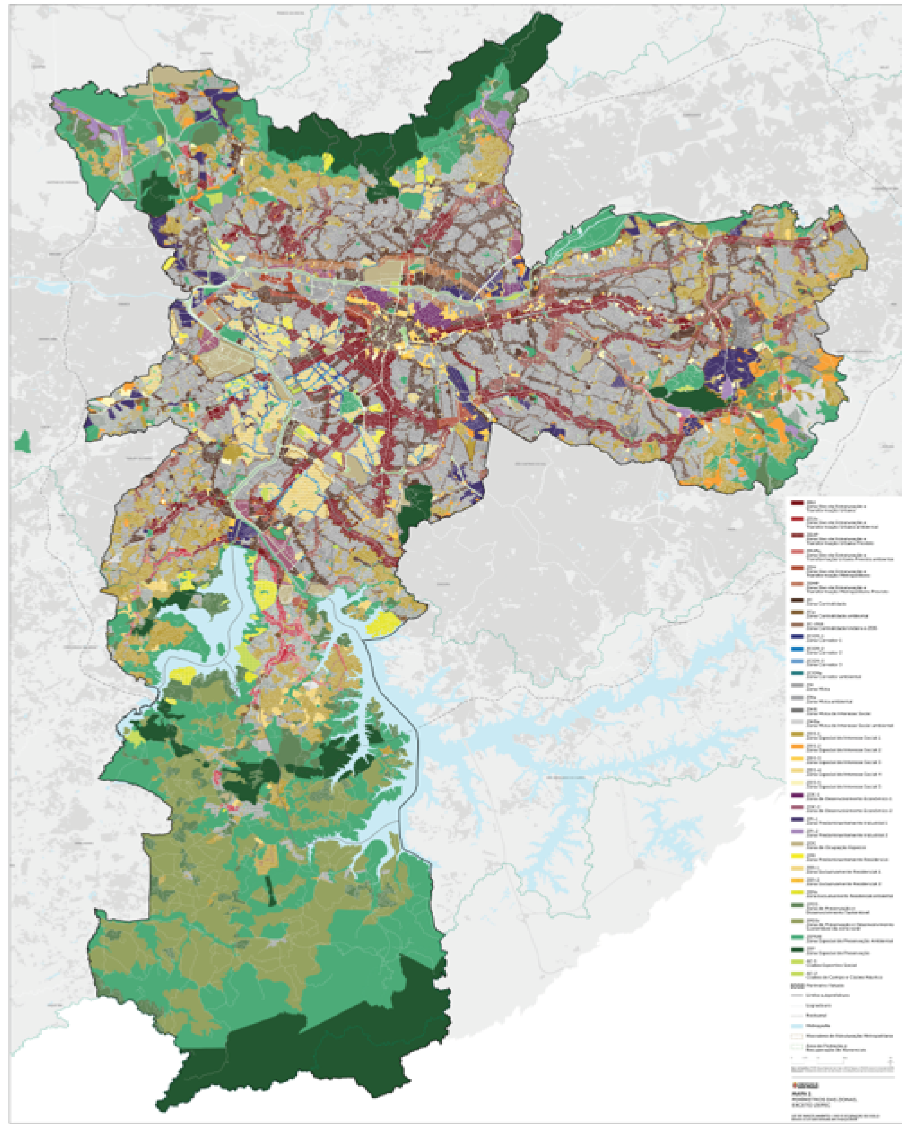

Figure A1: 2016 Zoning Reform Land Use

Map of Sao Paulo municipality shading blocks according to their associated zone type. Dark red areas correspond to transportation corridors.

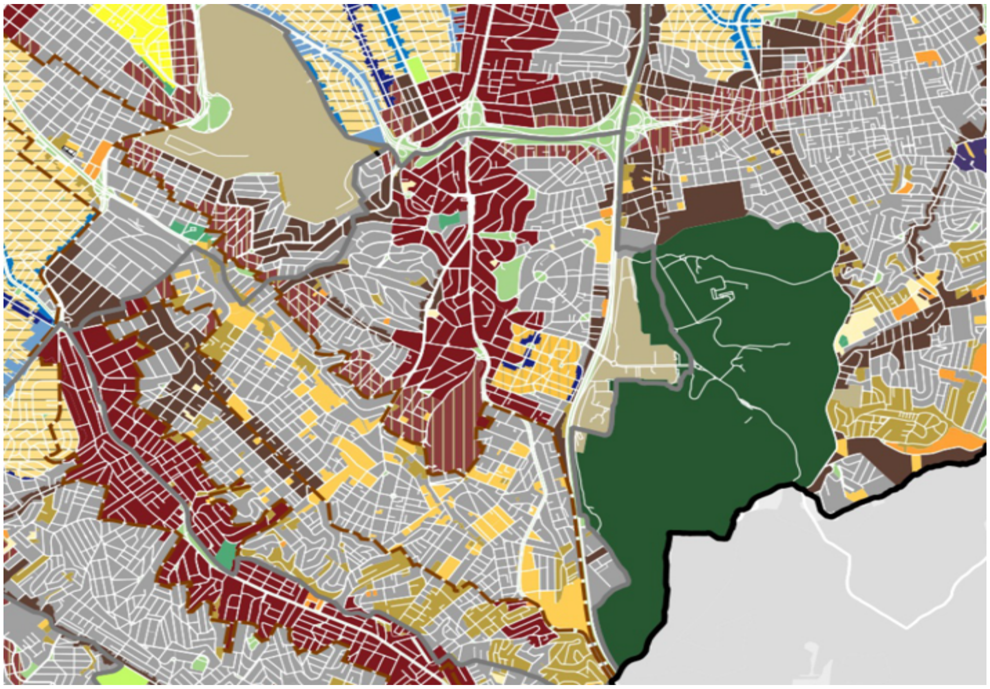

Figure A2: Block-by-block Land Use in Jabaquara Neighborhood

Map of Jabaquara neighbhorhood with blocks shaded according to their associate zone type.

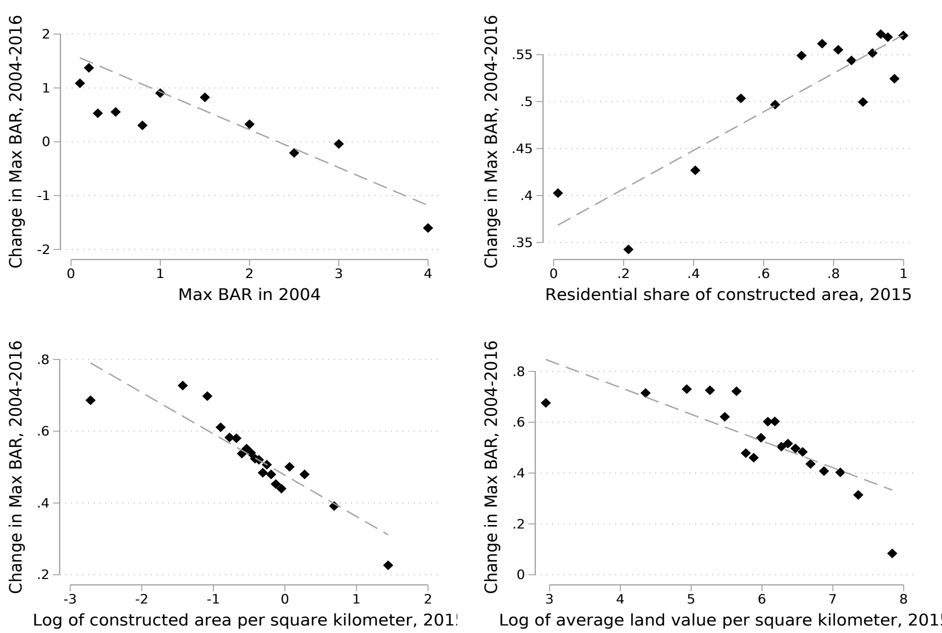

Figure A3: Correlates of Built Area Ratio Changes, Pre-to-Post 2016 Reform

This figure presents bin-scatters of neighborhood features on the x-axis and the change in max BAR that a block experienced from the 2004 to the 2016 zoning regime. The underlying data is at the block-level.

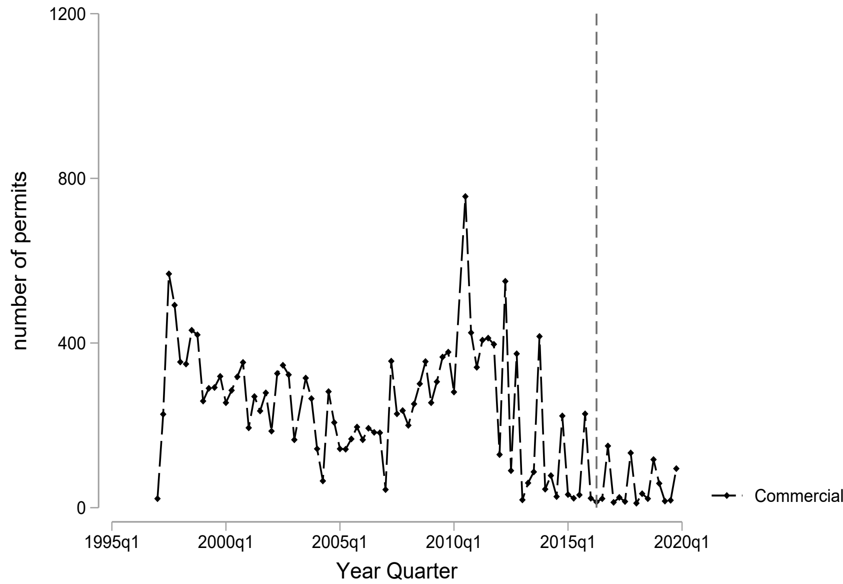

Figure A4: New Commercial Building Permit Filings by Quarter

This figure shows the aggregate quarterly number of commercial new building permit filings for developers in Sao Paulo municipality.

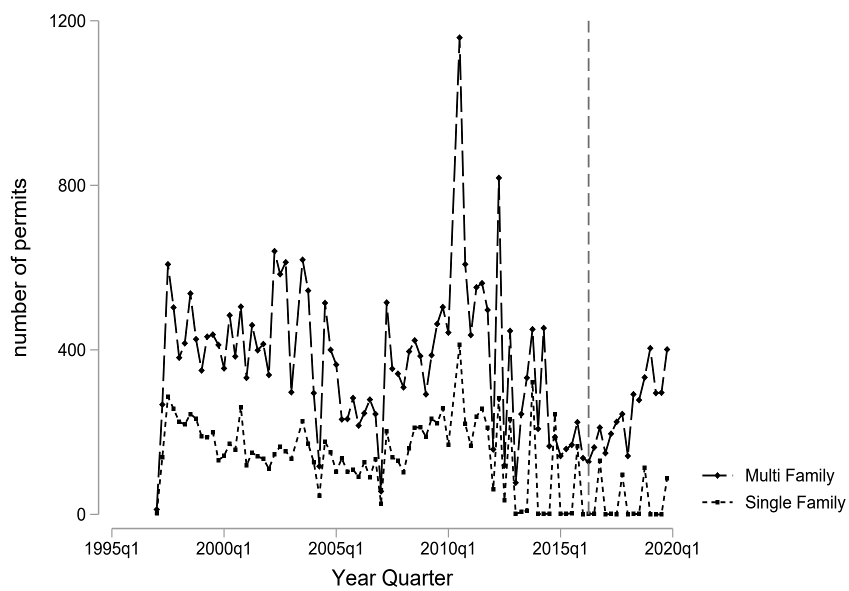

Figure A5: New Single and Multifamily Residential Building Permit Filings by Quarter

This figure shows the aggregate quarterly number of multi-family and single-family new building permit filings by developers in Sao Paulo municipality.

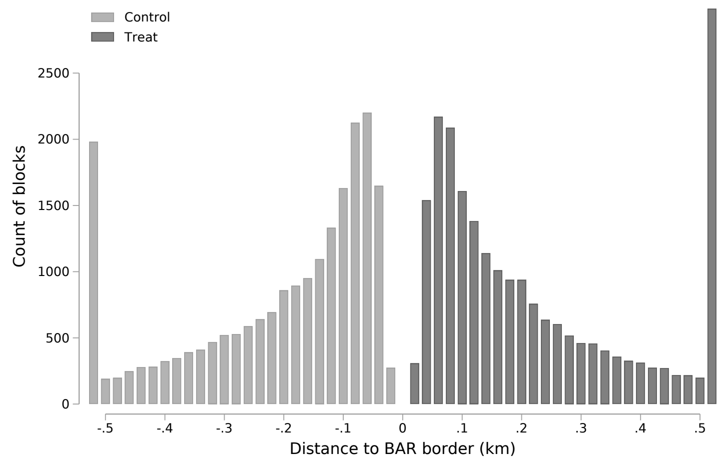

Figure A6: Histogram of blocks by running variable

This figure plots the number of blocks within a .02 kilometer bin of our running variable. Control blocks are to the left; treatment blocks are to the right. For control (treatment) blocks the running variable is the distance to the nearest treatment (control) block. A treatment block is defined as a block whose max BAR increased in the 2016 reform. Control blocks are those whose max BAR declined or stayed the same in the 2016 reform.

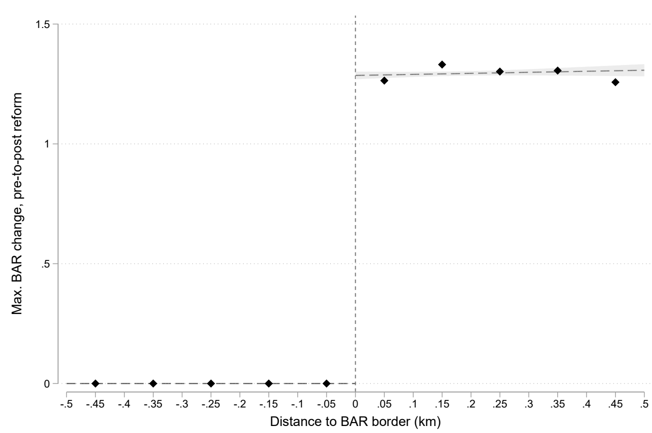

Figure A7: Control Blocks Defined as those With No Change in BAR: Built Area Ratio Change, Pre-to-Post 2016 Reform

This figure plots the change in the maximum BAR allowed for blocks within a .1 kilometer bin of our running variable. Control blocks are to the left of the dashed vertical line; treatment blocks are to the right. For control (treatment) blocks the running variable is the distance to the nearest treatment (control) block. A treatment block is defined as a block whose max BAR increased in the 2016 reform. Control blocks are those whose max BAR stayed the same.

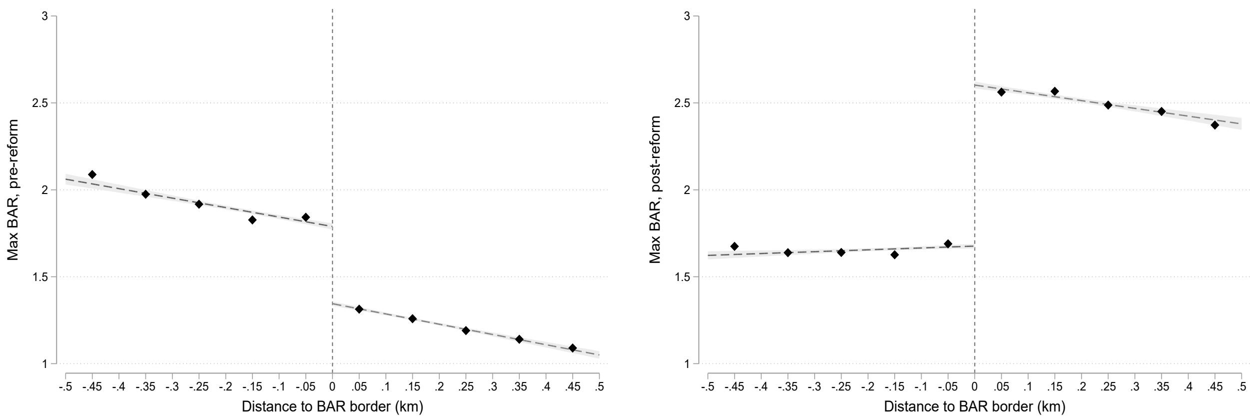

Figure A8: Built Area Ratios, Before and After 2016 Reform

The left figure plots average 2004 zoning regime max BAR for blocks within a .1 km bin of our running variable. The right figures does the same for the 2016 reform. Control blocks are to the left of the dashed vertical line; treatment blocks are to the left. For control (treatment) blocks the running variable is the distance to the nearest treatment (control) block. A treatment block is defined as a block whose max BAR increased in the 2016 reform. Control blocks are those whose max BAR declined or stayed the same in the 2016 reform.

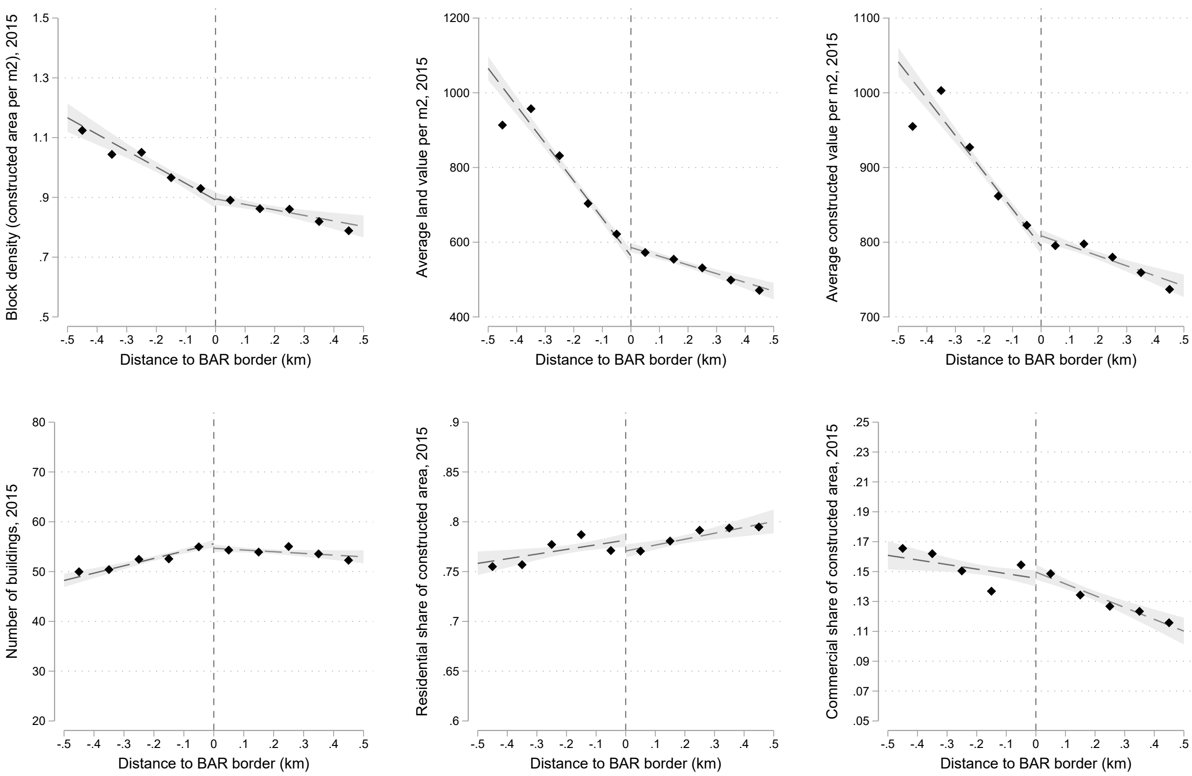

Figure A9: Average Property Characteristics in 2015 (Year Prior to 2016 Zoning Reform)

This figure plots average 2015 (i.e. just before the reform) block characteristics within a .1 km bin of our running variable. Control blocks are to the left of the dashed vertical line; treatment blocks are to the right. For control (treatment) blocks the running variable is the distance to the nearest treatment (control) block. A treatment block is defined as a block whose max BAR increased in the 2016 reform. Control blocks are those whose max BAR declined or stayed the same in the 2016 reform. For the Number of Buildings outcome block level data is normalized by the area of the block before averaging into bins.

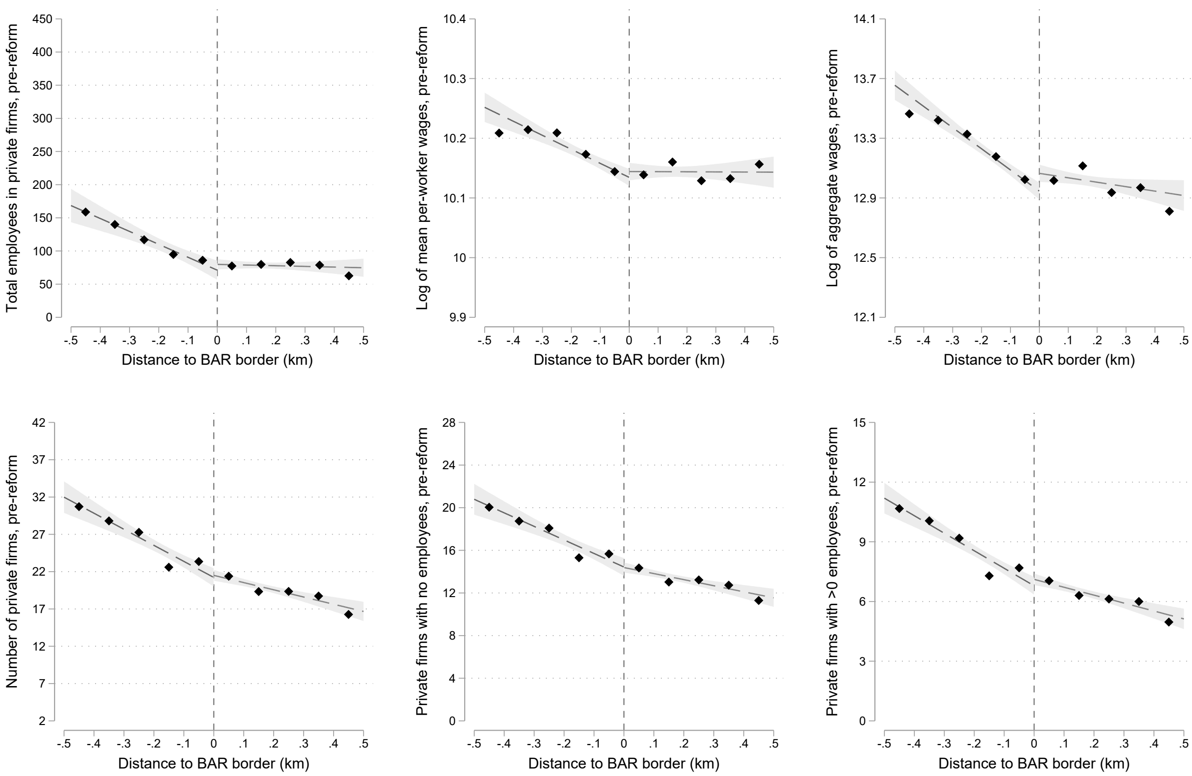

Figure A10: Average Labor Market Outcomes in RAIS Data in 2015 (Year Prior to 2016 Zoning Reform)

This figure plots average 2015 (i.e. just before the reform) formal sector labor market outcomes from the RAIS data within a .1 km bin of our running variable. Control blocks are to the left of the dashed vertical line; treatment blocks are to the right. For control (treatment) blocks the running variable is the distance to the nearest treatment (control) block. A treatment block is defined as a block whose max BAR increased in the 2016 reform. Control blocks are those whose max BAR declined or stayed the same in the 2016 reform. All outcome variables except "Log of mean per-worker wages" and "Log of aggregate wages" are normalized by the area of the block before averaging into bins.

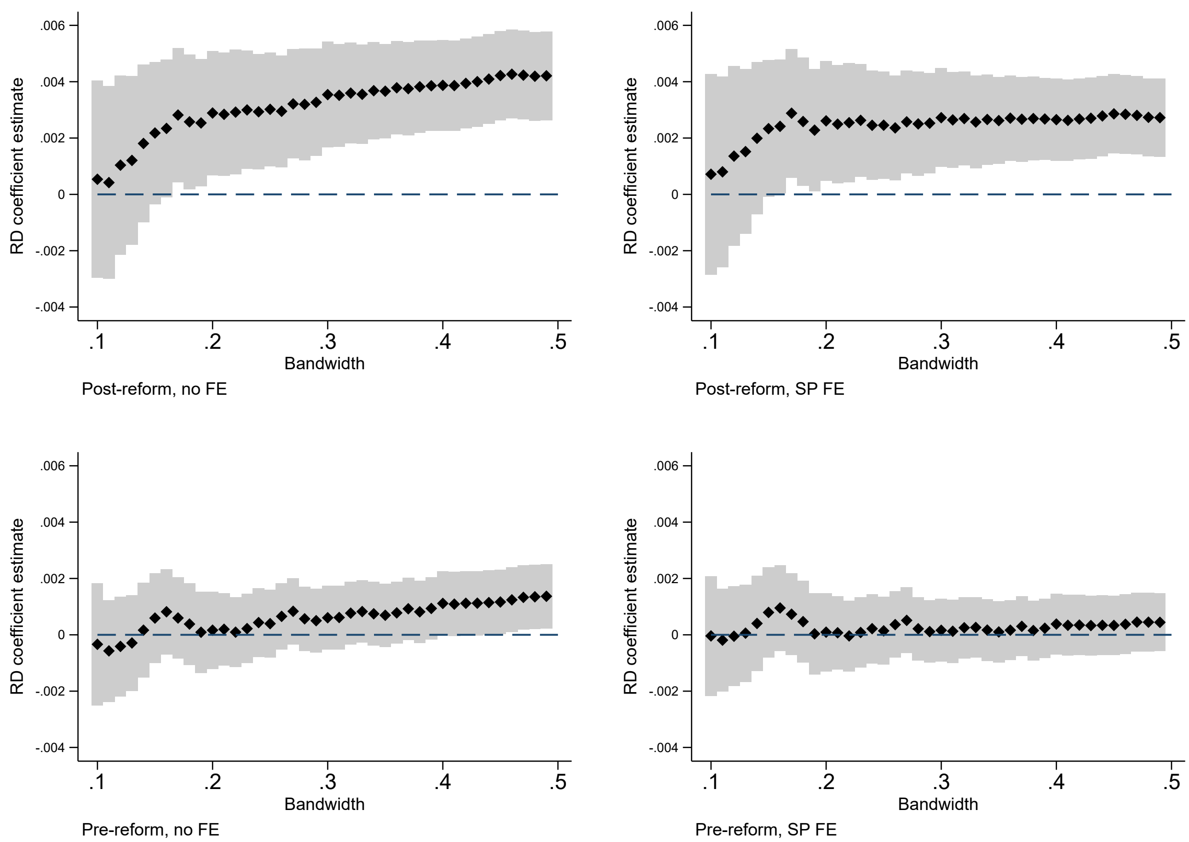

Figure A11: Multi-Family Permit Filings by Bandwidth of Running Variable

This figure shows RD coefficient estimates with a linear specification considering larger windows around the cut-off (bandwidths). The outcome variable is quarterly filed building permits. The pre-reform period includes quarters 2012Q2-2016Q1; the post-reform period includes quarters 2016Q2-2019Q4. SP FE indicates subprefeitura fixed effects. Standard errors clustered at commuting zone level.

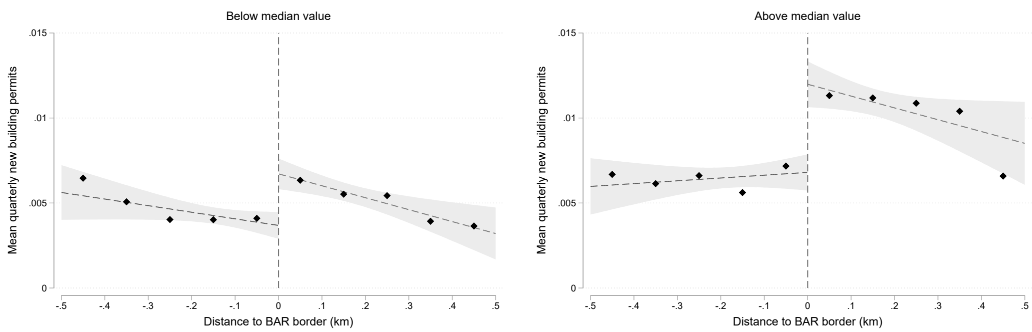

Figure A12: Heterogeneity: land values

This figure splits the sample by whether a block's average land value per square meter falls below (left) or above (right) the median block land value, and then reports the mean quarterly new building permits issued in the post-reform period (2016Q2-2019Q1). Control blocks are to the left of the dashed vertical line; treatment blocks are to the right. For control (treatment) blocks the running variable is the distance to the nearest treatment (control) block. A treatment block is defined as a block whose max BAR increased in the 2016 reform. Control blocks are those whose max BAR declined or stayed the same in the 2016 reform.

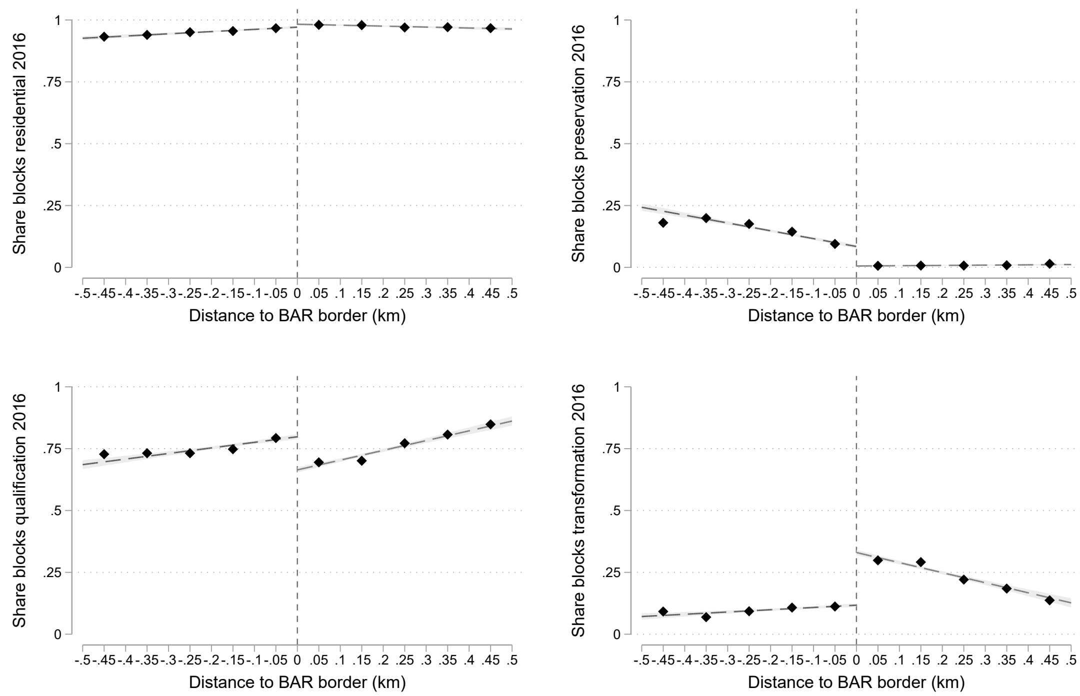

Figure A13: Share of Blocks by Development Strategy 2016

This figure plots share of blocks that allow residential construction or belong to a certain development strategy (preservation, qualification, or transformation) starting with the 2016 reform within a .1 km bin of our running variable. Control blocks are to the left of the dashed vertical line; treatment blocks are to the right. For control (treatment) blocks the running variable is the distance to the nearest treatment (control) block. A treatment block is defined as a block whose max BAR increased in the 2016 reform. Control blocks are those whose max BAR declined or stayed the same in the 2016 reform.

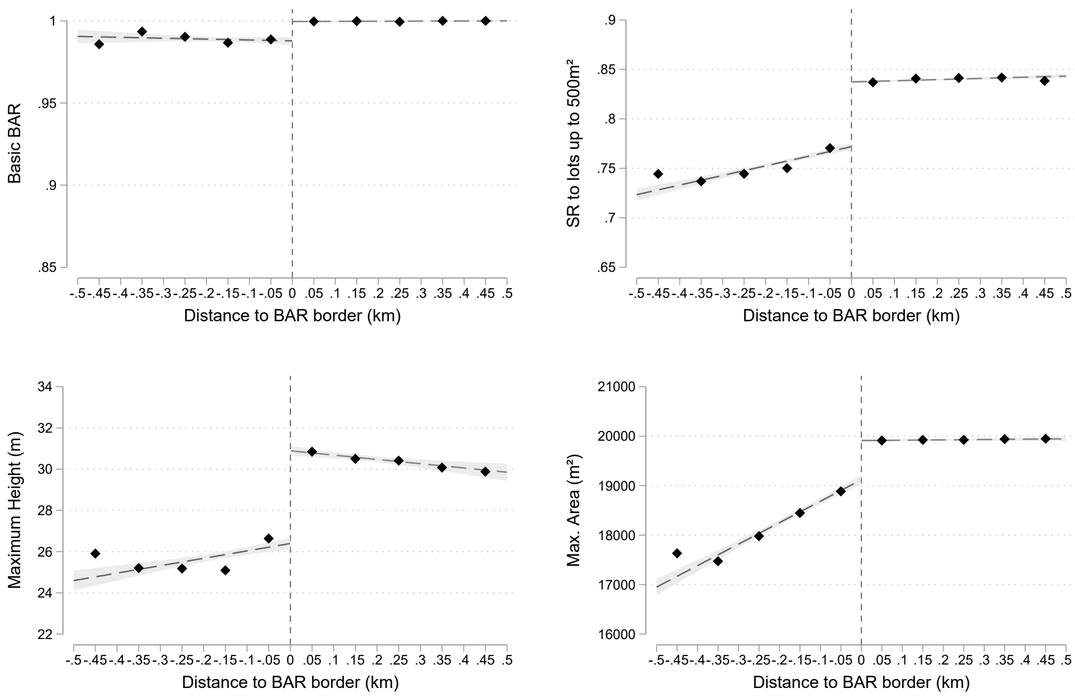

Figure A14: Average Zoning Parameters 2016

This figure plots the average of 2016 reform zoning parameters for blocks within a .1 km bin of our running variable. The zoning parameters are: basic built-area-ratio (BAR), shadow ratio (SR) of building footprint to lot area for lots under 500 square meters, maximum allowed height in meters, and maximum allowed lot area in square meters. Control blocks are to the left of the dashed vertical line; treatment blocks are to the right. For control (treatment) blocks the running variable is the distance to the nearest treatment (control) block. A treatment block is defined as a block whose max BAR increased in the 2016 reform. Control blocks are those whose max BAR declined or stayed the same in the 2016 reform.

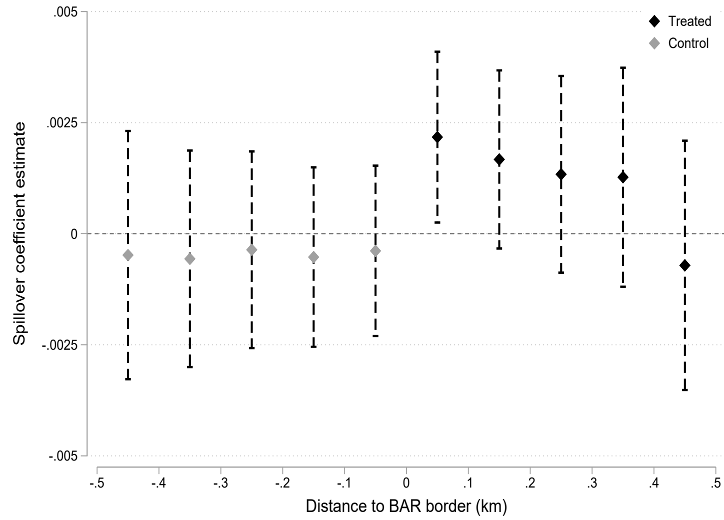

Figure A15: Estimates of Spillover Effects

This figure reports regression coefficients on the interaction between the treatment status of a block with its distance to the nearest opposite status block; the omitted group are control blocks that are .5 km away from the nearest treatment block. See regression equation 2 for underlying specification.

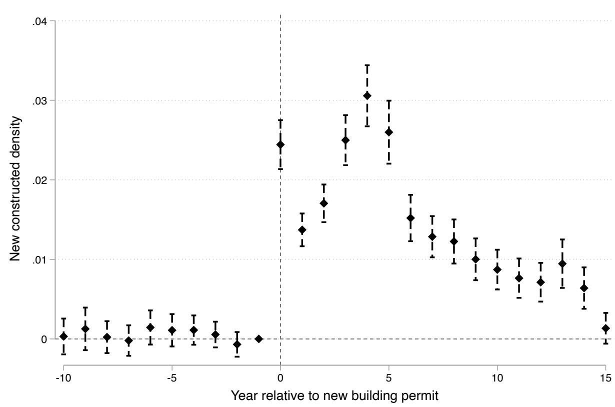

Figure A16: Event-Study Evidence on Relationship Between Block-Level Permit Issuance and Future New Construction Density

This figure presents coefficients from a block-level annual event-study model of the impact of a permit being issued/approved on the density of new construction, measured as new constructed area divided by total land area in all blocks in the IPTU data, in the period 2000-2019. The model includes block and year fixed effects. Coefficients reported are on estimates on leads and lags of the permitting treatment.

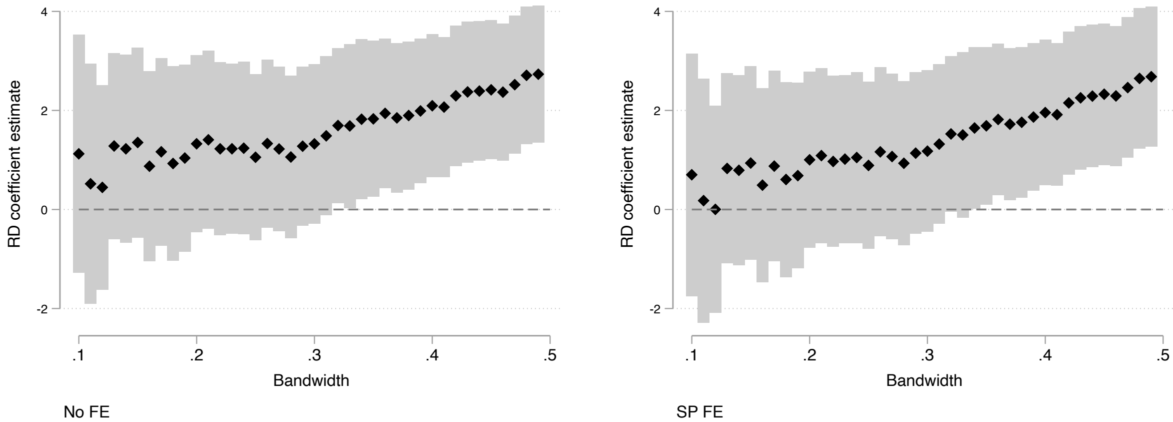

Figure A17: Listings Difference from 2019-2022 by Bandwidth of Running Variable

This figure shows RD coefficient estimates with a linear specification considering larger windows around the cut-off (bandwidths). The outcome variable is the listings difference from 2019-2022. Standard errors clustered at commuting zone level.

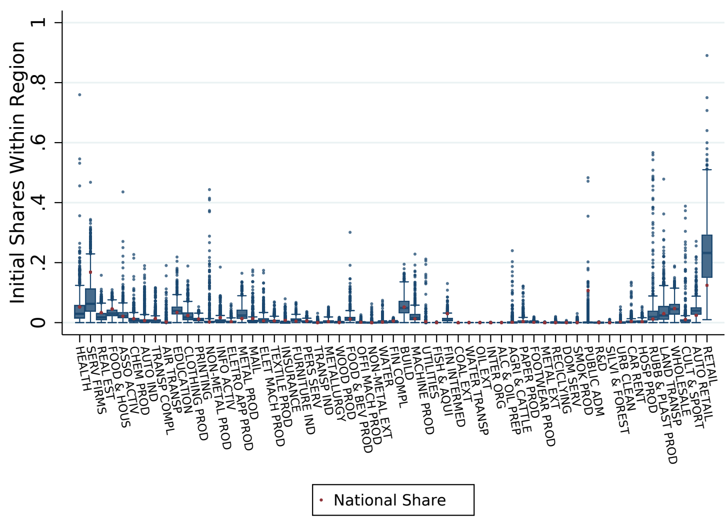

Figure A18: National and Commuting Zone Average †Employment Shares from RAIS Data

This figure shows a box plot summarizing variation in the 2007 formal sector employment shares in each of our 59 sectors.

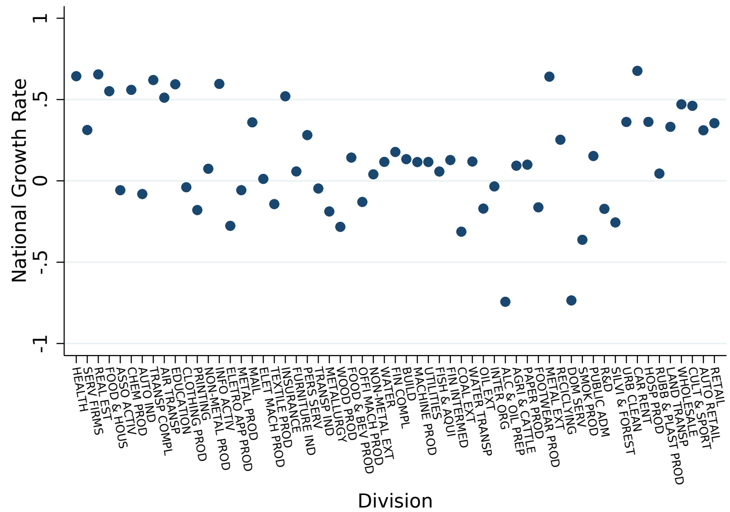

Figure A19: National Formal Sector Labor Growth Rate from 2007 - 2017

This figure shows the national level growth rate of formal sector employment in our 59 sectors. The growth rates exclude Sao Paulo municipality.

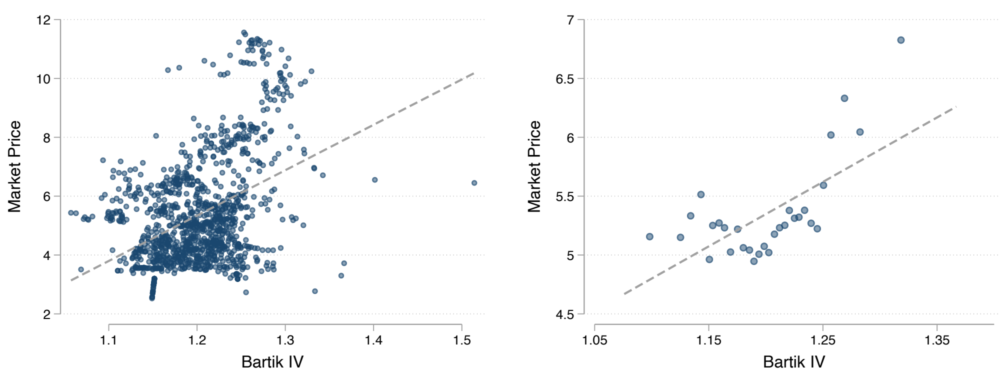

Figure A20: First Stage Relationship Between Price and Bartik Instrument

The left panel shows a scatterplot of average price (measured in our multiple listing service data) against our Bartik instrument variable using the raw data. See text for IV variable construction. The right figure is a binned scatterplot version of the left figure, where both x and y variables are residualized by the control variables we use in a our IV supply model. We implement the residualized binscatter methodology in Cattaneo et al. (2024) in the right-hand figure.

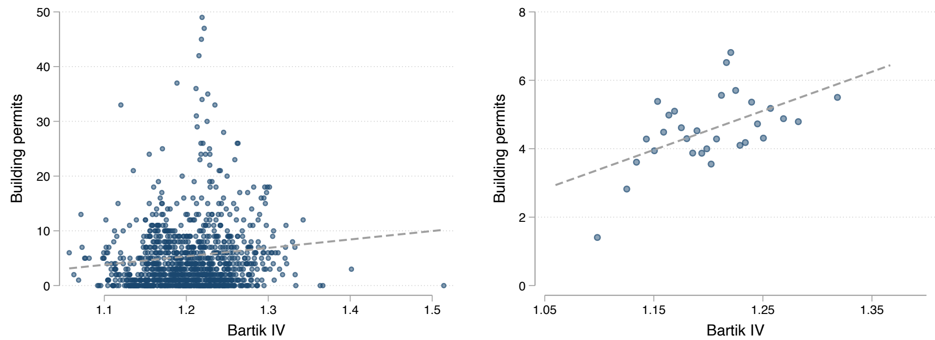

Figure A21: Reduced Form Relationship Between New Permits and Bartik Instrument

The left panel shows a scatterplot of number of new permits issued against our Bartik instrument variable. See text for IV variable construction. The right figure is a binned scatterplot version of the left figure, where both x and y variables are residualized by the control variables we use in a our IV supply model. We implement the residualized binscatter methodology in Cattaneo et al. (2024) in the right-hand figure.

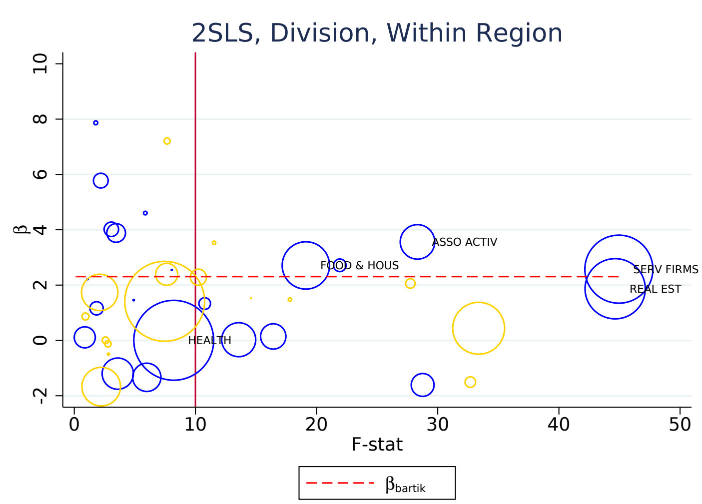

Figure A22: Heterogeneity of β_k: Bartik National Employment Growth Price Instrument

This figure plots the estimate of industry k's coefficient as the sole instrument for price against the instrument's F-statistic. The size of the circle for each point is proportional to the estimate's "Rotemberg weight" (i.e. this instrument's weight in our overall instrument's coefficient as in Goldsmith-Pinkham, Sorkin and Swift (2020)). The blue circles indicate positive Rotemberg weights and the yellow indicate negative Rotemberg weights. The horizontal dashed line shows the two-stage least squares coefficient with our Bartik instrument (Table 3, Column (3)).

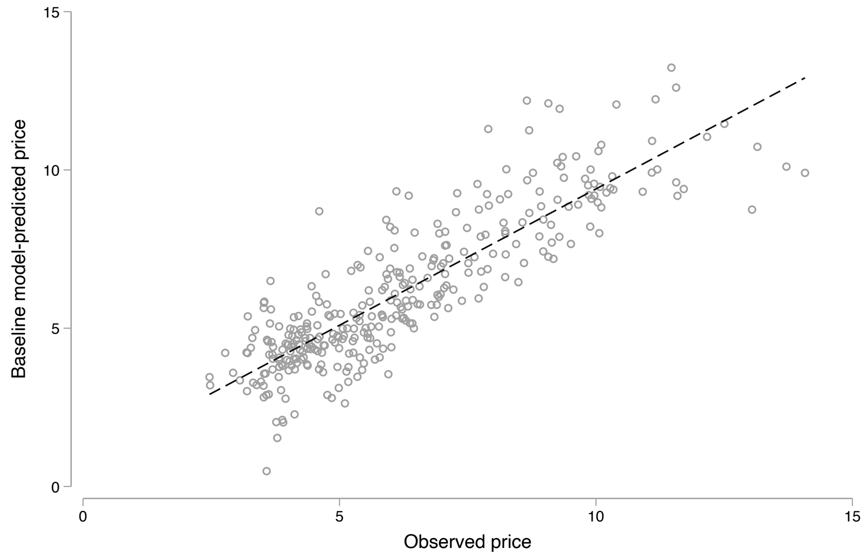

Figure A23: Model validation: prices

Figure plots the relationship between observed market prices and equilibrium model-predicted market prices from the baseline scenario using fixed supply for 329 commuting zones. Dashed line indicates linear fit.

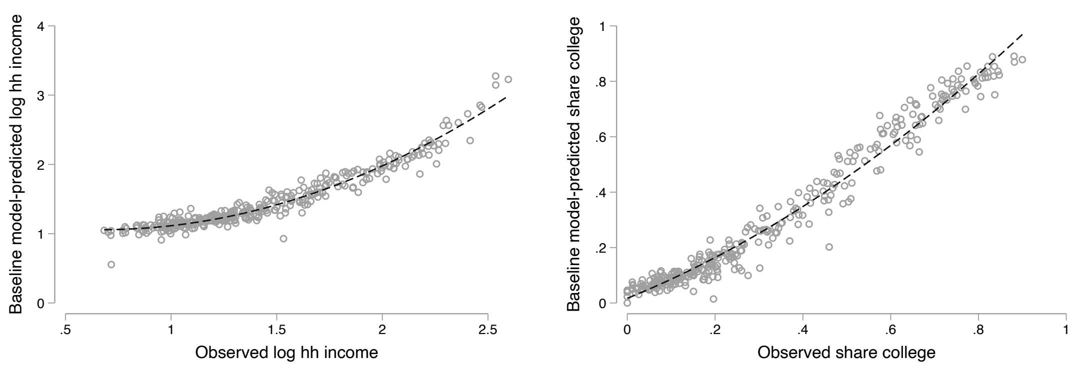

Figure A24: Model validation: demographics

Figure shows the relationship between observed and model-predicted demographics from the baseline scenario using fixed supply for 329 commuting zones. Left panel uses log of household income, while right panel plots the share of college-educated households. Dashed line indicates quadratic fit.

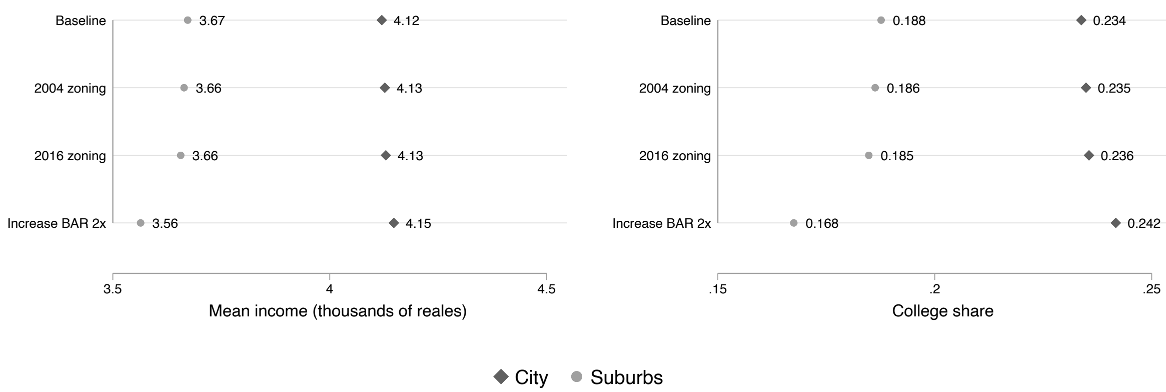

Figure A25: Demographic change in the suburbs and city under policy counterfactuals

Figure shows aggregate model-predicted demographics within the city (329 commuting zones) and the suburbs (outside option) under 4 different counterfactual scenarios, as indicated in categorical axis. Left panel shows mean household income in thousands of reais while right panel shows share of college-educated.

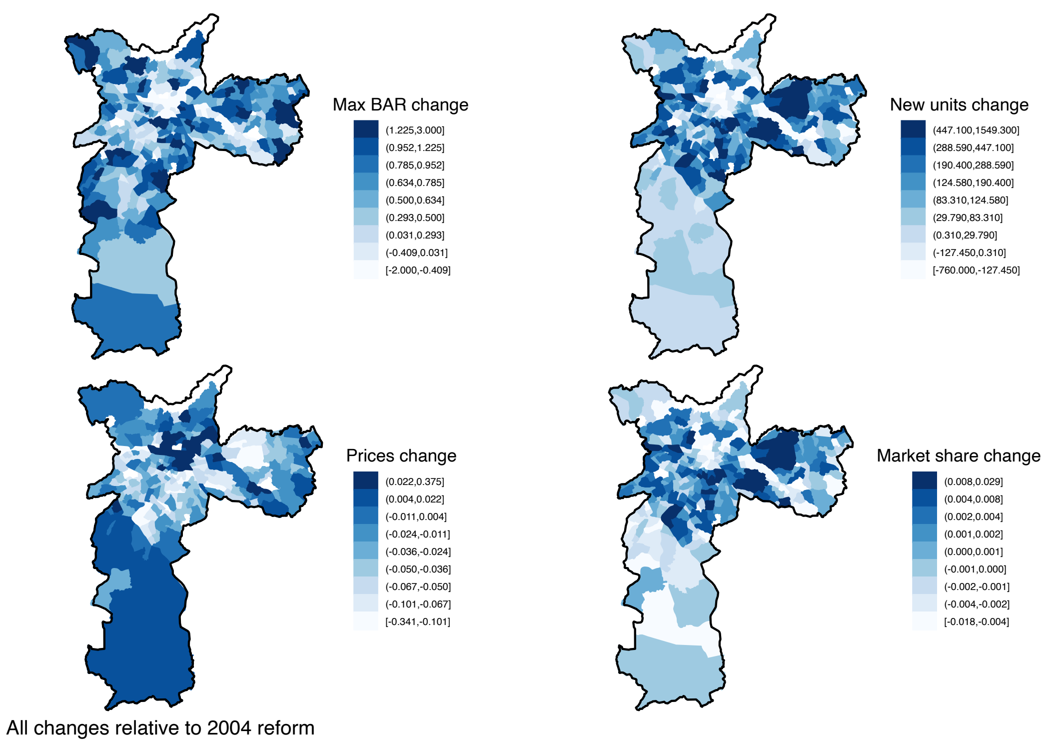

Figure A26: Equilibrium changes under the 2016 reform: map

The top-left figure shows the 2016 reform induced change max BAR by commuting zone. The other three figures show model simulated changes in new housing units (measured as number of units), prices (measured in thousands of reais per square meter) and market shares. Change means relative to the simulation where the 2004 zoning regime remained in place for 10 years after the 2016 reform.

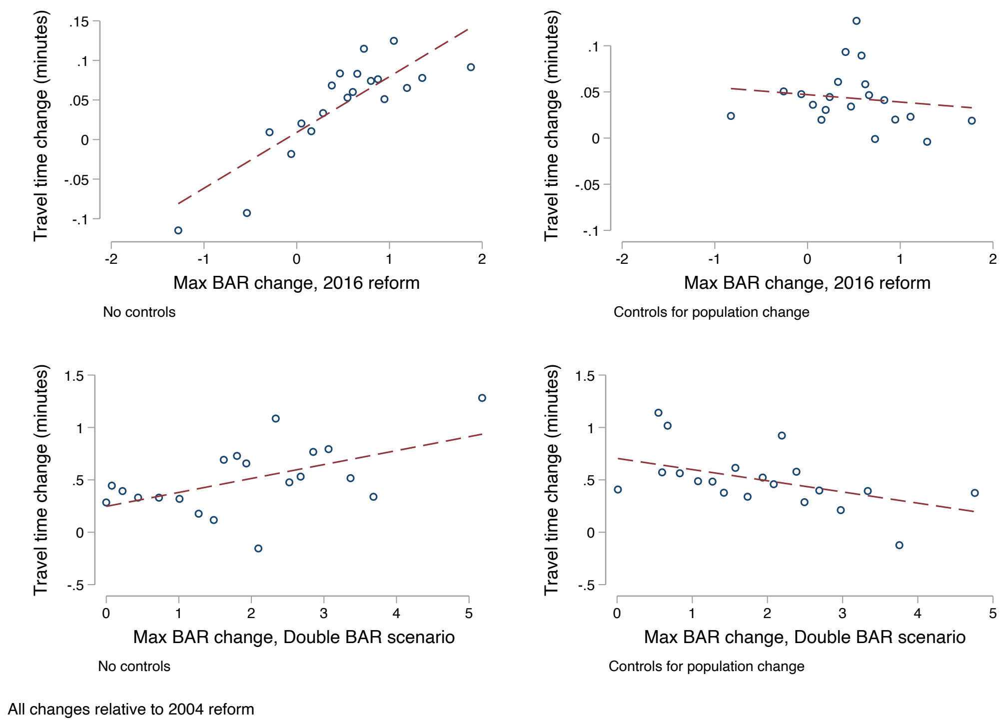

Figure A27: Travel time changes under policy counterfactuals

Figure shows the relationship between the change in average zone-level commuting time and BAR change under the 2016 (top panel) and Double BAR (bottom panel) 2026 counterfactual scenarios. Plots are presented with (right panel) and without (left panel) controls for predicted population change under the counterfactual. All changes are relative to the 2004 reform equilibrium.