THE INCIDENCE OF LAND USE REGULATIONS

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Abstract

In this paper, I study the welfare consequences of land use regulations for low- and high-skilled workers within a city. I use detailed geographic data for Cook County and the City of Chicago in 2015-2016, together with a spatial quantitative model with two types of workers and real estate developers who face regulations. For identification, I use the 1923 Zoning Ordinance, which was the first comprehensive ordinance in Chicago. I find that an increase of 10 percentage points in the share of residential zoning in a block group, relative to block groups with more commercial zoning, leads to a 1.7% increase in housing prices, a 2.6% decrease in wages and to higher concentration of high-skilled residents. Welfare changes can be decomposed into changes in housing prices, sorting, wages and land rents. I find that more mixed-use zoning and looser floor-to-area limits lead to welfare improvements, specially for low-skilled residents, and to a reduction in welfare inequality.

JEL: O18, R14, R23, R31, R54.

Keywords: zoning, FAR, skills, welfare, inequality.

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1 Introduction

Regulations on the use of land are prevalent in almost every city in the modern world, and their effects on housing prices (e.g., Glaeser et al. (2005)), housing supply (e.g., Saiz (2010)) and other local outcomes (e.g., Saks (2008); Shertzer et al. (2018)) have been widely studied in the literature.[1] Most of this research follows a reduced form analysis and does not consider the general equilibrium and welfare effects of land use regulations (LUR). These effects are relevant since LUR potentially affects wages, amenities and household location choices through their effects on the residential and commercial real estate markets. On the other hand, recent research by Allen et al. (2015) studies general equilibrium and welfare effects of zoning using quantitative spatial models, but does not consider the distributional effects of these policies and do not provide treatment effects.

This paper fills these gaps in the literature by investigating the general equilibrium effects of zoning and floor-to-area (FAR) restrictions and, ultimately, on the welfare of low- and high-skilled residents within a city. In particular, I use a quantitative model of a city, together with well-identified reduced form estimates, to study the effects of these policies on real estate prices, location choices and wages of low- and high-skilled workers, amenities, local productivity, land prices and welfare by skill type. Zoning and FAR restrictions are among the most popular tools used by city governments in order to organize land use and economic activity. Specifically, zoning specifies the permitted uses or activities inside a location, while FAR specifies the scale and volume of these activities and is regarded as a good predictor for permitted building heights.

Among other results, I find that an increase of 10 percentage points in the share of residential zoning in a block group leads to a 1.7% increase in housing prices, a 5.4% and 5.8% decrease in the wages of high-skilled and low-skilled workers, respectively, a 2.5% increase in amenities and a 5.1% decrease in local productivity. On the other hand, an equivalent increase in the share of mixed-use designations leads to a decrease of 5.4% in housing prices, a lower concentration of high-skilled residents, a 2.6% increase in the wages of both types of workers and a similar increase in local productivity. Finally, relaxing FAR limits in a location leads to reductions in housing prices and amenities, increases in wages and productivity, and an concentration of low-skill workers in such

[1] I am not aware of any large city without land use regulations. Even Houston, which is well-known for not having a comprehensive Zoning Ordinance, uses other tools, such as restrictive covenants and deed restrictions (Siegan, 1970).

location.

Since zoning and FAR restrictions are affecting sorting patterns and skill-specific wages, my findings highlight the importance of including worker heterogeneity when studying the effects of LUR. In this paper, I focus on the distinction between high- and low-skilled workers, given at least three differences between these types of workers found in the literature. First, there are significant differences in real wages between them within and across urban areas (Baum-Snow and Pavan, 2013; Moretti, 2013). Second, low-income households spend a higher share of their income on housing (Notowidigdo, 2019). Since low-skilled workers are more likely to earn low wages relative to high-skilled workers (Mincer, 1974), higher housing expenditure shares would make them more susceptible to changes in housing prices. Third, high-income workers have a higher opportunity cost of commuting time (Wheaton, 1977). These differences cause different types of workers to have different location preferences and react differently to changes in LUR.

To study these issues, I collect detailed geographic data for Cook County and the City of Chicago for 2015-2016, including the universe of real estate transactions and assessments from Zillow (2017) and the geographic distribution of zoning districts within city boundaries. Using these data, I build residential and commercial real estate price indices and different measures of LUR at the Census block group level. I complement these data with public data from the US Census Bureau containing commuting flows and counts of people by education category at the block level, and with Cook County's Land Use Inventory CMAP (2016). The real estate data show that residential and commercial prices are significantly different in more than 90% of the city block groups. These price gaps indicate the existence of inefficiencies in the real estate market and that city residents might benefit from changes in the zoning ordinance.

Identification of causal effects of LUR is cumbersome given the endogeneity of zoning and FAR regulations. For example, low-density zoning is more likely to happen in neighborhoods with a larger share of high income population (Fischel, 2001) or in locations with more desirable amenities (Hilber and Robert-Nicoud, 2013). On the other hand, less stringent zoning could be more prevalent in locations that face a high demand for floor space (Wallace, 1988). I tackle these issues using an instrumental variables approach, in which I instrument current regulations with the 1923 Chicago Zoning Ordinance. This ordinance was the first comprehensive zoning ordinance adopted in Chicago. In particular, Shertzer et al. (2018) show that the 1923 Zoning Ordinance is a good predictor of current zoning and current land uses. Following Shertzer et al. (2016a), who show that neighborhood demographic and geographic characteristic had an effect on the initial zoning ordinance, I include in my empirical strategy a large set of historical covariates to control for these characteristics.

Afterward, I present a quantitative model of a city that builds on Ahlfeldt et al. (2015). Contrary to their model, I introduce two types of workers: low- and high-skilled, who differ in their income and housing expenditures. Moreover, in the spirit of Muth (1969) and Fujita and Ogawa (1982), my model includes the microfoundations of a real estate market in which developers supply both residential and commercial floor space subject to zoning and FAR restrictions. The inclusion of developers and LUR into a spatial quantitative model constitutes an important contribution of my paper. The model suggests that the change in welfare given by a change in LUR can be decomposed as the sum of four effects: (i) changes in housing prices, (ii) changes in skill-specific amenities coming from changes in sorting, (iii) changes in wages and market access, and (iv) changes in the income coming from the rents of land.

Using this model, I follow the methodologies proposed by Ahlfeldt et al. (2015) and Tsivanidis (2019) in order to recover block group measures of wages, amenities and productivity, given observed data and values for the model's parameters. Moreover, I lay out a solution for the equilibrium of the real estate market with LUR. The proposed solution lets me recover the price of land and the shadow price of FAR regulations at the block group level. After recovering these unobservables, I study how zoning and FAR restrictions affect them. Following the instrumental variables approach, I find that tighter regulations in a block group lead to lower local wages. In particular, a 10 percentage points increase in the share of residential zoning, relative to block groups with more commercial zoning, leads to a decrease of 5.8% in the wage of low-skilled workers and of 5.4% in the wage of high-skilled workers. The effect on wages of a one unit decrease in FAR limits is a decrease of 19% for both types of residents. These lower wages are compensated by increases in amenities of around 2.5% and 3% for the respective policies. These policies also have a significantly negative effect on local productivity of 5% and 18%, respectively.

Finally, counterfactual exercises suggest an important welfare enhancing role of large changes in the zoning code, as well as their role decreasing welfare inequality. In particular, I simulated the effects of four policies. First, a policy that allows more residential zoning in block groups displaying an excess relative supply of commercial real estate, and viceversa. Second, a policy that increases the FAR limit by 0.5 in those blocks where this constraint binds the most. Third, a policy that sets a minimum FAR of 1.2 everywhere in Chicago. Fourth, a policy that sets a minimum of land zoned for mixed-uses at 25% in each block group. All of these policies lead to similar welfare improvements for low-skilled residents, and to a decrease in the welfare gap between residents. These quantitative exercises also suggest that the current zoning ordinance is a regressive policy that benefits high-skilled residents more, but that it can be modified to reduce welfare inequality between residents.

This paper is related to the literature studying the effects of LUR.[2] Theoretically, Helsley and Strange (1995) and Rossi-Hansberg (2004) study some welfare effects of different types of LUR. Empirically, most of the literature agrees that LUR leads to i) higher land and housing values, and to a more inelastic supply of floor space (Mayer and Somerville, 2000; McMillen and McDonald, 2002; Glaeser et al., 2005; Glaeser and Ward, 2009); and ii) to decreases in total welfare, with potentially large distributional impacts (Cheshire and Sheppard, 2002; Turner et al., 2014; Hsieh and Moretti, 2015). My paper also relates to a series of papers studying zoning in Chicago and the 1923 Zoning Ordinance (McMillen and McDonald, 2002; Zhou et al., 2008; Shertzer et al., 2016a, 2018). In particular, Shertzer et al. (2018) conclude that, zoning in Chicago has been more important than geography or transportation networks determining the distribution of economic activity. My paper contributes to this literature by providing a general equilibrium evaluation of LUR. Specifically, by showing the effects of zoning and FAR on a wide range of outcomes—such as housing and land prices, wages, productivity, sorting and welfare—, I study in one single framework different effects of some of these policies.

This paper also relates to the articles that explore how LUR affects heterogeneous residents. In particular, Kahn et al. (2010) and Levine (1999) find that areas with more low density zoning experience more gentrification, affecting mostly minorities and low-income households. On the

[2] Fischel (2015) and Gyourko and Molloy (2015) provide superb summaries about the recent state of the literature.

other hand, Muehlegger and Shoag (2015) suggest that tighter LUR are associated with increases in commuting time, especially for more educated and wealthier individuals. Ganong and Shoag (2017) show that stringent LUR in productive cities has caused a decrease in the returns to living in these cities (net of housing costs) for low-skilled people, but remain constant for high-skilled people. These changes have come with a sharp sorting of high-skilled workers into high rents-high wages-high productivity states. This paper contributes to this literature in three ways. First, by analyzing the impact of LUR on the distribution of skills across locations within a city. Second, by disentangling the effects that zoning and height restrictions have on the wages and welfare of both high- and low-skilled workers. Third, by contributing to the debate on whether zoning is a regressive measure, which benefits high-skilled people more than low-skilled.

Furthermore, my paper is part of a recent literature using quantitative models in urban economics such as Ahlfeldt et al. (2015); Allen et al. (2015); Tsivanidis (2019); Baum-Snow and Han (2019), among others. There are three important departures of my model with respect to the standard models in the literature. First, similar to Tsivanidis (2019), my model includes different types of workers by skill. The inclusion of worker heterogeneity is important given the potential distributional impacts of LUR. Second, my model includes a detailed model of real estate supply into this quantitative setting, which allows me to study the general equilibrium effects of LUR. Third, my framework allows me to decompose changes in welfare in changes in rent, wages, sorting and income from land rents, to study the specific mechanisms through which LUR affects residents.

The paper proceeds as follows. In Section 2, I describe my data sources. In Section 3, I briefly discuss the 1923 Zoning Ordinance and study the relationship between LUR, real estate prices and sorting by skill within Chicago. Section 4 presents the quantitative model with heterogeneous workers and LUR. Section 5 exploits the recursive structure of the model in order to solve the model, given some data and values for different parameters. In Section 6, I explore the effect of zoning and FAR restrictions on wages, amenities, productivity, and land prices. In this section, I also present the policy counterfactuals that show how some changes in LUR can lead to reductions in welfare inequality. The final section concludes and highlights directions for future research.

2 Data and Descriptive Statistics

In order to investigate the effects of zoning and FAR restrictions on real estate prices and the distribution of people and wages across residential and work locations, I combine data from five sources. First, I use data on workplace and residence area characteristics from the Origin-Destination Employment Statistics of the US Census Bureau. Second, I use data from Zillow Economic Research containing the universe of real estate transactions for the United States. The LODES and Zillow data are available for any city in the country. The main challenge is finding a city with detailed data on land use regulations. Fortunately, the Data Portal of the City of Chicago contains a geographic database of all the zoning districts within city boundaries, which I complement with the Land Use Inventory for the rest of Cook County. Finally, I use historical zoning, demographic and geographic variables for Chicago in the 1920s, collected and studied by Shertzer et al. (2016a), Shertzer et al. (2016b) and Shertzer et al. (2018). In the rest of this section, I describe these data and present descriptive statistics.

2.1 Real Estate Prices

I use data of real estate prices and stocks from Zillow Economic Research. The Zillow ZTRAX data sets contains real estate transactions for around 3,000 counties in the United States. These data are constructed from information in local deed transfers and mortgages for mostly residential properties, but also include commercial properties in the more recent years and in larger metropolitan areas.(Zillow, 2017).[3] Among other variables, these data include sales price, transaction date and coordinates of the property. I merge this dataset with assessment data collected by Zillow, which include property characteristics, geographic information, current and prior valuations.[4]

Using the ZTRAX transactions and assessment data, I build quality-adjusted residential and commercial real estate price indices for each census block group in Cook County in the period

[3] Data provided by Zillow through the Zillow Transaction and Assessment Dataset (ZTRAX). More information on accessing the data can be found at http://www.zillow.com/ztrax. The results and opinions are those of the author and do not reflect the position of Zillow Group.

[4] Baum-Snow and Han (2019) use these data for the whole United States and compare their tract-level price and stock indices with similar measures built using Census data. They find that the correlation between both prices indices is rather low, but generate similar estimates of housing supply elasticities. However, the flow and stock of units generated by both data are quite similar and highly correlated.

2015-2016.[5] For the construction of these indices, I drop governmental, institutional, historical, communication, recreational, miscellaneous and transportation properties, group quarters, trailer parks and parking garages. Moreover, I use only arm's length transactions, drop those with a sales price below 10,000 USD, and drop census block groups with fewer than 4 transactions. After imposing these restrictions, I estimate the following hedonic regression:

$$ln(P_{him,T}) = X_{him,T}\beta + ln(r_{Ti}) + \delta_m + \varepsilon_{him,T},$$

where $ln(P_{him,T})$ denotes the log sale price of a property h of type T (residential R or commercial F) in a census block group i sold in month m; $X_{him,T}$ represents a vector of property characteristics; $ln(r_{Ti})$ denote census block group fixed effects; and δ_m are month of sale fixed effects, which account for the seasonality of the real estate market. The vector of characteristics includes a polynomial of degree two of age and size, and other discrete categories, such as number of rooms, bathrooms, flooring, roofing, fireplace, condition and type of property (e.g., single-detached, townhouse, etc., for residential, or office, retail, industrial, etc., for commercial properties).

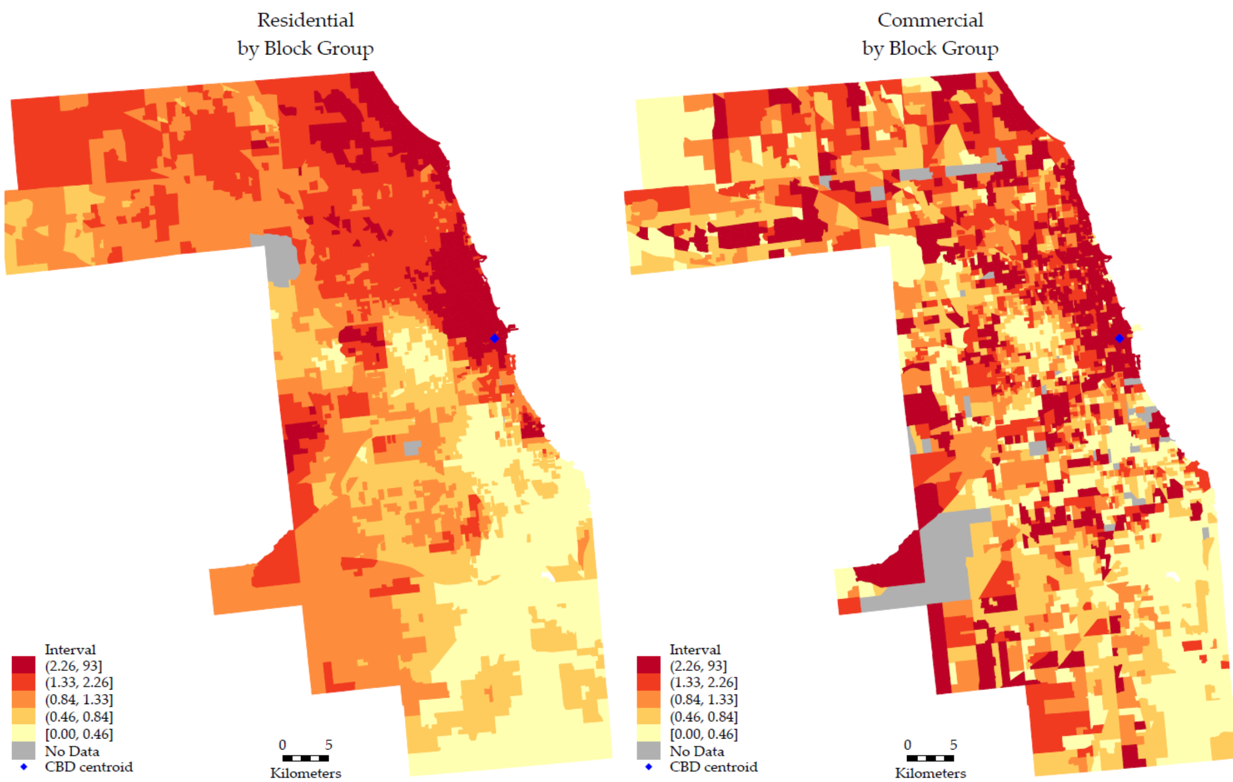
The estimated block group fixed effects capture the average quality-adjusted log price of type $T \in \{R, F\}$ in all block groups. The residential price index (r_{Ri}) covers around 97% of all block groups in my sample between 2015-2016, while the commercial price index (r_{Fi}) has a coverage of 43%. To increase coverage, I use an inverse distance weighted interpolation for those block groups with missing price indices. For those blocks where the missing value persists, I use the mean within the block group's census tract. These imputations raise the coverage of the residential and commercial price indices to 99.9% and to 97.5%, respectively. Since these prices are identified up to scale, I normalize their geometric mean to 1.

Figure 1 presents the distribution of real estate prices across block groups in Cook County, and Table 1 presents descriptive statistics for these indices. The most expensive residential real estate in the county in 2015-2016 was found in the blocks surrounding the CBD, as well as the area north of downtown. On the other hand, the cheapest areas are located in the south part of the city and west of downtown. For commercial real estate, the patterns are similar, but less smooth, with high

[5] A block group is the US Census classification lying between a tract and a block. There are 809 tracts in Chicago containing on average 2.7 block groups, and there are 2,194 block groups containing on average 17 blocks.

commercial prices in the CBD and along the northern coast. Comparing both indices, I find that the distribution of commercial real estate prices is significantly more skewed, with 5.4% of the block groups having commercial real estate more expensive than any block group's residential real estate.

Figure 1: Real Estate Hedonic Prices in Cook County, 2015-2016



Notes: This figure shows the residential (left) and commercial (right) real estate price indices for every block group in Cook County for the period 2015-2016. These prices are estimated using a hedonic regression approach for both types of properties, separately, and an inverse distance weighted interpolation for those locations without enough observations. Price indices are normalized to a geometric mean or 1. Blue dot represents Chicago's CBD.

Furthermore, when we explore the relation between residential and commercial prices in each block group, we find that there is significant variation across locations. On average, residential real estate is more expensive than commercial real estate. Moreover, the data show that residential prices are higher than commercial prices in around 45% of the block groups, commercial is more expensive than residential in 46%, and only in around 8% of the block groups the ratio lies between 0.9 and 1.1. The existence of these price gaps is interesting from a theoretical perspective since canonical models of real estate supply suggest that developers provide both residential and commercial floor space until their price equalize. Therefore, these gaps indicate the existence

Table 1: Real Estate Hedonic Price Indices, 2015-2016

	(1) Residential	(2) Commercial	(3) Ratio R/C
N. Block Groups	3,985	3,890	3,889
Mean	1.36	2.41	1.49
Std. Dev.	1.12	5.07	3.57
Min	0.09	0.00	0.01
Median	1.09	1.01	0.95
Max	12.97	87.79	117.5
Corr with Res HI	1.0	0.41	
Corr with Com HI	0.41	1.0	

Notes: This table shows descriptive statistics for the residential and commercial hedonic price indices, and for the ratio between between them. These prices are estimated using a hedonic regression approach for both types of properties, separately, and an inverse distance weighted interpolation for those locations without enough observations. Price indices are normalized to a geometric mean or 1.

of inefficiencies in the real estate market, and a potential role for changes in LUR to solve these unbalances between supply and demand. Figure A1 shows the geographic distribution of such gaps.

Finally, I use the assessment data to measure the stock of residential and commercial floor space in each block group as the sum of the built square footage of all properties within type. Figure A2 shows that the block groups with the largest amount of residential space are located downtown and in the suburbs, while the stock of commercial real estate is concentrated downtown, along the main avenues and in the suburbs.

2.2 Land Use Regulations

The data on land use and its regulations comes from two sources. First, from the Data Portal of the City of Chicago, which contains a geographic database of all the zoning districts within city boundaries. Second, from the 2015 Land Use Inventory for Cook County, which is built and published by the Chicago Metropolitan Agency for Planning (CMAP).

The zoning data contain coordinates and specific zone class categories for 2016. The detailed specifications of each zone class are available in the Chicago Zoning and Land Use Ordinances (City of Chicago, 2019). In total, there are 66 zone classes, 15 Planned Manufacturing Developments

(PMD) and more than a thousand Planned Developments (PD) within the city. [6] Out of the total land area in Chicago, around 52% is currently categorized as residential (R), while manufacturing (M), commercial (C) and business (B) districts use approximately 11%, 3% and 7%, respectively. Locations categorized as downtown districts (D) use about 1% of the area.[7] PMD and PD cover 6% and 12%, respectively. Weighted by their allowed floor-to-area ratio, these shares correspond to 29% for residential, 15% for manufacturing, 4% for commercial, 9% for business, 6% for downtown, 11% for PMD and 27% for PD. These differences indicate that residential districts have relatively low allowed densities compared to any other district.

I group all districts into three categories: those designated for residential purposes only (R and DR), for commercial only (M, PMD, DS and some C and B) and for mixed-uses (some B, C, DC and DX). I also categorized each Planned Development into a categories based on their characteristics.[8] In the left panel of Figure 2, I present a map of the city using this categorization. The land that can be used by firms only (red) is spread along and around the main highways and waterways, while areas designated for mixed uses (purple) are located mainly in the downtown area and along the main streets of the city. Areas designated for residential purposes only (blue) are located mainly within mixed use areas. In the right panel, I map the maximum FAR allowed in each zoning district. The map shows that high density (red and pink) is allowed mostly in the downtown area and in some sections of the coast; medium density (greens) is allowed along the coast of Lake Michigan and in the areas where only commercial purposes are allowed; low density (blues) is allowed in the rest of the city, in particular, in residential zoned areas.[9]

Using these maps, I build measures of the share of land designated for residential, mixed-uses or commercial purposes, and the average allowed FAR in each block group. I also build a measure of the share of residential space allowed in each block group using the districts' allowed FAR—as

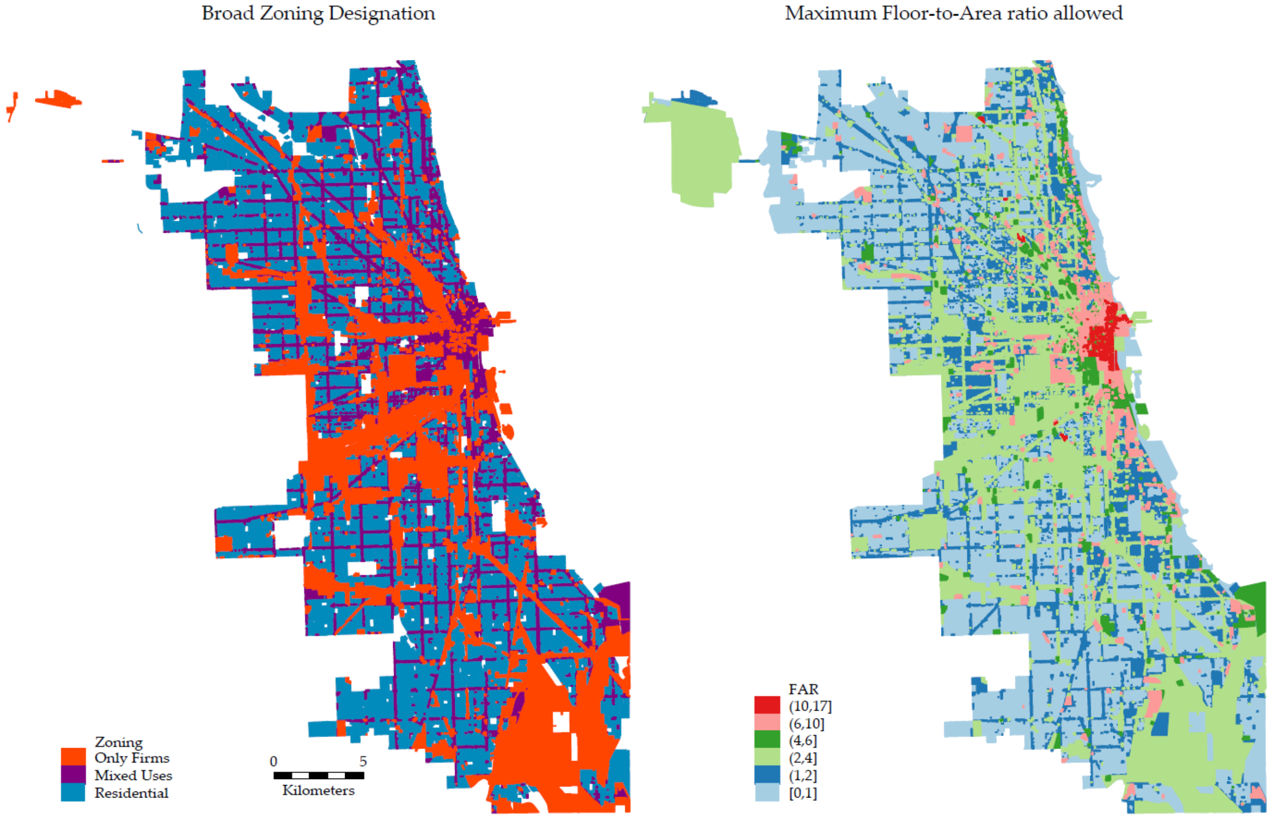
[6] An example of zone class is **RS-3**, which corresponds to a detached, single family home in a Residential Single-Unit District, with a maximum FAR of 0.9, a maximum height of 30 feet and a minimum lot size of 2500 square feet, with no commercial activity allowed.

[7] Downtown districts can be Residential (DR), Core (DC), Service (DS) or Mixed-Use (DX) districts.

[8] Planned Developments correspond to tall buildings and other large developments in which developers must work with the City to ensure that the project integrates with surrounding neighborhoods (2nd City Zoning, nd). The City of Chicago keeps pdf files for each Planned Development in https://gisapps.chicago.gov/gisimages/zoning_pds. PD range from Airports and Spectator Sports arenas, to mixed used developments or waterway residential developments. The complete list of types is available on request.

[9] In Figure A3, I present a map of the distribution of all nine broad zoning designations.

Figure 2: Land Use Regulations in Chicago



Notes: This figure shows two current land use regulations in the City of Chicago. The left map presents the areas where only commercial (red), residential (blue) or mixed-uses (purple) are allowed. The right panel shows the maximum FAR allowed in each zoning district, where reds denote high allowed density, greens denote medium allowed density, and blues denote low allowed density.

a proxy for the permitted number of floors—together with details inside the Ordinance regarding the number of residential stories allowed. I denote this measure as λ.[10] This measure is used calibrating the model as it captures the share of floor space in mixed-use districts that can be used for residential purposes. The coefficient of correlation between this measure and (i) the share of land zoned for residential purposes only is 0.75, (ii) the share of land zoned for commercial uses is -0.89, both significantly different from zero at the 99% confidence level.

The zoning data is only available for the City of Chicago, which only contains around 35% of the

[10] For example, **B3-3** zoning districts have an allowed FAR of 3, with apartments only permitted above the ground floor. In this case, I assume that the first floor is used for commercial purposes, while the two remaining floors are used for residential purposes. Hence, I set $\lambda = 2/3$. Moreover, $\lambda = 1$ for residential-only districts, and $\lambda = 0$ for commercial-only districts. For Planned Developments, I assumed $\lambda = 0.8$ for those categorized as mixed-used.

residents of its metropolitan area. Ignoring land uses outside the city might render an incomplete picture of the effects of LUR on the distribution of economic activity in this labor market. For this reason, I include data on the use of land in the rest of Cook County from the 2015 Land Use Inventory. This inventory contains the specific uses of land everywhere in Northeastern Illinois and is built to develop long-range population and employment forecasts that support Chicago Metropolitan Agency's planning strategies (CMAP, 2016). Using these data, I build measures of the share of land area used for residential, mixed-uses or commercial purposes in each block group outside the City.

In Table 2, I present descriptive statistics of the different measures of zoning across block groups in Cook County. The table shows that the average block group has 75% of its land zoned for residential purposes, 15% for commercial purposes and 10% for mixed-uses. The average allowed FAR is 1.8. Furthermore, out of the 10% zoned for mixed-uses, around 77% of it can be used for housing. Compared to the average, the median block group is even more residential and has lower FAR. In fact, 75% of the block groups in the city have an average allowed FAR of less than two.

Table 2: Descriptive Statistics - Zoning Measures

	Mean	SD	Min	p25	p50	p75	max
Sh. Res. Only	0.75	0.24	0	0.66	0.83	0.93	1
Sh. Mixed Uses	0.10	0.15	0	0	0.02	0.14	1
Sh. Firm Only	0.15	0.21	0	0	0.06	0.21	1
Mean FAR	1.82	1.60	0.5	0.94	1.24	2.01	14.2
Sh. Res. Space Allowed	0.77	0.22	0	0.70	0.85	0.92	1

Notes: This table shows descriptive statistics for different measures of land use regulations across block groups for Cook County in 2016.

For my empirical strategy, I also use the 1923 Zoning Ordinance together with a large set of demographic and geographic characteristics from the early 1920's. The 1923 zoning data was digitized by Allison Shertzer, Tate Twinam and Randall Walsh from the University of Pittsburgh. The authors provided me with the shapefiles containing the four use-districts and the five volume-districts used in this ordinance. I provide further details of this Zoning Ordinance in Section 3.1. Moreover, I use different demographic and geographic data from the 1920 census, which is provided in the supplementary material from Shertzer et al. (2016a). The authors collect these data at the enumeration district level from a variety of sources, including Ancestry.com, National Archives and the 1922 Chicago Land Use Survey.

2.3 Distribution of Skills and Commuting

For data on population by workplace and residential areas, I use version 7.2 of the US Census Bureau Longitudinal Employer-Household Dynamics (LEHD) Origin-Destination Employment Statistics (LODES) for 2015 and 2016. The LODES data contains information about the location of jobs and residences as provided by state unemployment insurance records and federal worker earning records. These data contain counts for the total number of people living and working in each census block. This information can be further split by earnings categories, educational attainment, among other characteristics. The LODES data also contain the number of commuters between every pair of blocks, but this information can only be separated by age and earnings categories. I complement these data with bilateral distances and travel times between block group pairs calculated using an Open Source Routing Machine method (Huber and Rust, 2016).

Out of the total working population of age 30 or older in Cook County in 2015-2016, 14% had less than a high school degree, 23% had a high school degree only, 30% had a college or an associate degree, and 33% had a bachelors or an advanced degree. I categorize as low-skilled those workers within the first two categories. Table A1 presents the number of residents and workers by education category in the mean and median block group. These statistics suggest hat the distribution of workers across block groups is more skewed than the distribution of residents. This skweness comes from a relatively high concentration of high-skilled workers into some block groups (both of work and residence). Figure 3 presents the share of high-skilled people for every block group of residence (left) and of work (right) in the county. These maps show a high concentration of high-skilled residents, especially in the downtown area and north of it. Low-skilled residents are concentrated in the south and west portions of the county.

The LODES data also contain for each block the number of residents and workers in each educational category for three earnings categories: \$1250/month or less, \$1251/month to \$3333/month, and greater than \$3333/month. I define high wage workers as those within the top category and

Figure 3: Distribution of Skills–Cook County, 2015-2016

Notes: The left figure shows the share of high-skilled residents for every block group in Cook County in 2015-2016. The right figure shows the share of high-skilled workers for every block group in Cook County in 2015-2016. Blue dot represents Chicago's CBD.

calculate the share of low- and high-wage workers in each skill category.[11] Under this definition, approximately 37% of residents in Cook county are in the high-skilled high-wage category, while one fourth are in the low-skilled low-wage category. I show the distribution of workers by earnings and skills in the average block group of residence and of work in Table A2.

3 Land Use Regulations, Prices and the Distribution of Skills

In this section, I explore the effects of zoning and FAR restrictions on the distribution of real estate prices, wages and people by skill across block groups. Real estate prices and wages are relevant

[11]According to the American Community Survey (ACS), out of the full-time year-round workers with positive earnings, approximately 4.7% makes less than \$1250 each month, 34.5% earns between \$1251 and \$3333, and 60.8% makes more than \$3333 a month.

since they affect households' expenditures and income, and potentially welfare. In addition, the distribution of people by skill across locations is relevant as local amenities and productivity tend to respond positively to higher population density. Moreover, if each block group is considered to be a small opened economy, the spatial concentration of residents could be a rough measure of local welfare. In order to identify the effects of current regulations, I use the 1923 Chicago Zoning Ordinance, together with an instrumental variables approach. I start by briefly describing this ordinance, but the reader should refer to Shertzer et al. (2016a) and Shertzer et al. (2018) for more detailed information.

3.1 The 1923 Chicago Zoning Ordinance

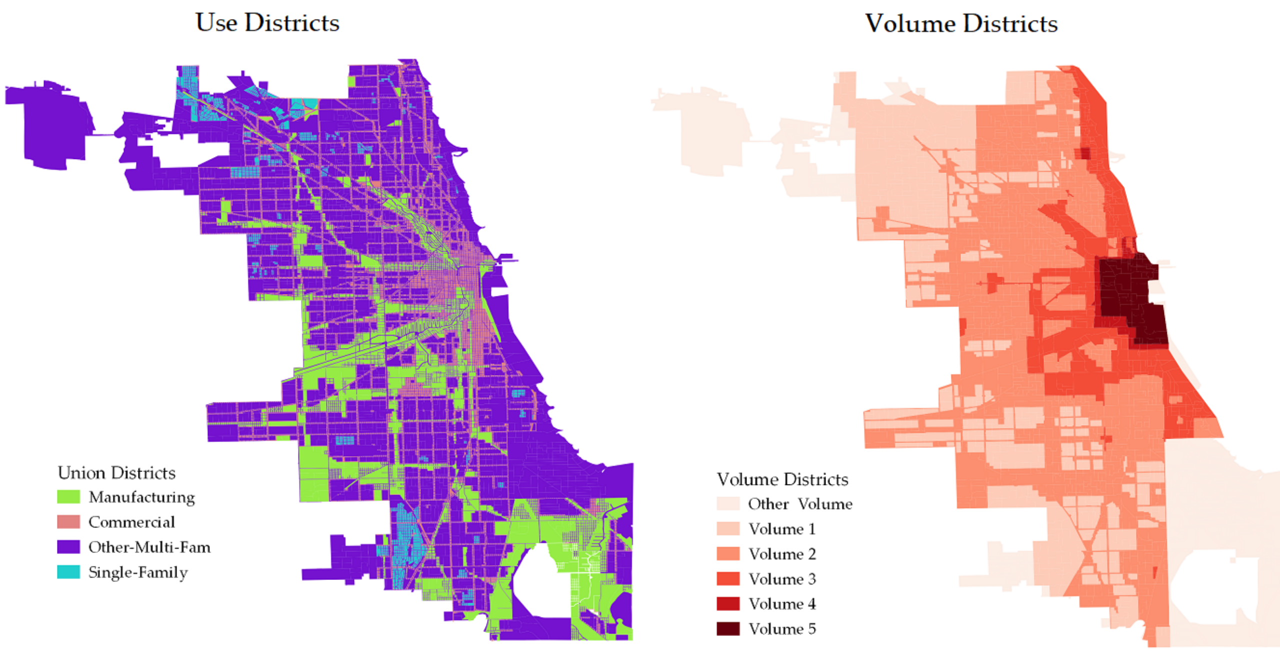
There are at least three threats to causal identification of the effects of land use regulations on the spatial distribution of economic activity. First, low-density zoning is more likely in neighborhoods with a larger share of high income population. Since richer households are more likely to own properties, if LUR leads to higher housing prices owners might want to strengthen the regulations to increase the value of their homes. This phenomenon is known as the Homevoter Hypothesis (Fischel, 2001; Parkhomenko, 2020). Second, locations with more desirable amenities (such as parks, lakes or historical buildings) might have tighter LUR in order to prevent developments around these areas (Hilber and Robert-Nicoud, 2013). Third, changes in zoning could be caused by changes in the demand for certain locations (Wallace, 1988).

I tackle these issues by instrumenting current LUR using the 1923 Chicago zoning ordinance, which was the first comprehensive zoning ordinance adopted in Chicago. Even though Chicago's city government had made previous attempts to control undesirable land uses, these approaches were insufficient to meet public demand in a constantly growing city. Therefore, in 1921 the local government created a Zoning Commission, which spent 18 months surveying existing land uses and organizing public hearings, until the final ordinance was adopted in 1923. The ordinance regulated land by restricting allowed uses and building volumes: it included four use districts (single-family residential, multi-family residential, commercial and manufacturing), and five volume districts, that imposed restrictions on height and lot coverage.[12] Figure 4 shows the distribution of use and volume

[12]Use districts were hierarchical, which means that multi-family districts allowed single-family residences, commer-

districts according to the 1923 zoning ordinance. In particular, Shertzer et al. (2018) show that zoning in 1923 is a good predictor of current LUR.

Figure 4: 1923 Chicago Zoning Ordinance



Notes: This figure the distribution of use and volumn districts given by the 1923 Chicago Zoning Ordinance. The left map presents the four use districts: single-family residential, multi-family residential, commercial and manufacturing. The right map presents the five volume districts.

Using the use and volume districts from the 1923 zoning ordinance, I build measures of the share of each district for each block group. I use these shares as instruments for 2016 regulations following this specification:

$$LUR_{2016,i} = \pi Zoning_{1923,i} + \psi X_i + \epsilon_i \tag{1}$$

where $LUR_{2016,i}$ corresponds to one of the block group level measures of LUR in 2016 presented in Table 2; $Zoning_{1923,i}$ is a vector that includes the 1923 shares of land designated as manufacturing or commercial (single- and multi-family residential are the omitted categories), and as volume districts 1, 2 or 3 (volume districts 4 and 5 are the omitted categories); X_i is a vector of control variables at the block group level, which includes total land area, interactions between distance to

cial districts allowed multi- and single-family residences, and manufacturing districts allowed any use.

the CBD and the closest body of water,[13], a transit accessibility index,[14] 1927-wards fixed effects, and a set of 1922 neighboorhood demographic and land use characteristics.[15] These historical variables control for different covariates affecting the spatial structure of the city in the 1920s. This large set of controls and fixed effects implies that I am comparing highly similar block groups inside 1927-wards, thus, I am using rather local variation in order to identify the causal effects of zoning and FAR restrictions. Demographic and economic characteristics are available for around 67% of the block groups within Chicago. Therefore, identification of my estimates come from the impact of zoning and FAR restrictions in this portion of the city. Nonetheless, the quantitative exercises from Sections 5 and 6.4 use data for the entire county.

Finally, ϵ_i corresponds to the error term. All of the regressions include spatial heteroscedasticity and autocorrelation consistent (SHAC) standard errors (Conley, 1999). Specifically, I use the routine developed by Hsiang (2010) with a linear Bartlett window. I calibrate the distance cutoff of the spatial kernel to 1.5 km based on results derived from bootstrapping the spatial correlation between residual real estate prices. I present these results in Figure A4 and show that the residual covariance between real estate prices is almost zero among block groups located 1.25 and 1.75km away, for residential and commercial real estate prices, respectively.

I present the estimation results from equation (1) in Table 3. Columns (1)-(2) use the share of land where only residential or mixed-uses are allowed as dependent variable, respectively. Results from these columns are similar to those from Table A.4 in Shertzer et al. (2018): block groups with a higher share of land designated for manufacturing and/or commercial purposes in the 1923 ordinance were significantly less likely to be zoned for residential-only uses in 2016, relative to similar and nearby block groups with a lower share of these designations. Moreover, these blocks were more likely to have a higher share of land zoned for mixed-uses. Column (3) shows that block

[13]Including Lake Michigan, Chicago River (south and north branches), Des Plaines River, Little Calumet River, and a small number of large lakes within city boundaries.

[14]The raster map used to compute this index was provided by Tate Twinam, who obtained it from www.walkscore.com.

[15]I use the same set of control variables from Shertzer et al. (2016a) and Shertzer et al. (2018). These controls are: percent of northern- or southern-born black population; percentage of first- or second immigration immigrants; population density; maids per household; indicator for presence and distance to a major street, coast, main or ancillary railroads, and Union Stockyards; number of warehouses; indicator and density of commercial uses, manufacturing uses, 4,...,10,11-25 story buildings; number of manufacturing uses within 500ft and between 500ft and 1000ft; indicator for alderman living in district; 1913 land values.

groups with a higher share of land designated for manufacturing and/or commercial purposes in the 1923 ordinance are more likely to have high allowed FAR today. Regarding volume, larger shares of low volume districts in 1923 are positively correlated with lower FAR limits in 2016, relative to block groups with a larger share of high volume districts in 1923. Finally, Column (4) uses the maximum share of residential space allowed in a block group, as described in Section 2.2. Results suggests that a larger share of land designated as a commercial, manufacturing or low-volume district in 1923 (relative to residential and high volume districts, respectively) is negatively correlated with the share of allowed residential space in the current regulation.

Table 3: First Stage Regressions: 2016 Zoning as a Function of 1923 Zoning

1923 / 2016	(1) Sh. Only Residential	(2) Sh. Mixed Uses	(3) Mean FAR	(4) Sh. Res Allowed
Share Commercial	-0.37***	0.41***	0.51***	-0.18***
	(0.00)	(0.00)	(0.00)	(0.00)
Share Manufacture	-0.44***	0.03***	1.09***	-0.48***
	(0.00)	(0.00)	(0.00)	(0.00)
Share Volume 1	-0.13***	0.11***	-1.83***	-0.07***
	(0.00)	(0.00)	(0.00)	(0.00)
Share Volume 2	-0.15***	0.12***	-1.57***	-0.11***
	(0.00)	(0.00)	(0.00)	(0.00)
Share Volume 3	-0.13***	0.07***	-1.01***	-0.12***
	(0.00)	(0.00)	(0.00)	(0.00)
R-squared	0.96	0.80	0.93	0.97

Notes: This table shows the results of regressions of 2016 measures of land use regulations as function of the share of allowed uses and volumes given by the 1923 Chicago Zoning Ordinance. These measures are constructed at the block group level. Omitted 1923 zoning types are residential uses and volume districts 4 and 5. (1)-(2) correspond to the share of land in districts where only residences or mixed uses are allowed, respectively. The share of land where only firms are allowed is the omitted category. (3) corresponds to the mean FAR. (4) corresponds to the maximum share of residential space allowed in a block group. Controls include block group's land area, distance to the CBD and to major waterways, and historical covariates. Number of block groups is 1,427. Spatial Heteroscedasticity and Autocorrelation Consistent (SHAC) standard errors in parentheses (Conley, 1999); *** p<0.01, ** p<0.05, * p<0.1.

3.2 LUR and the Real Estate Market

Using the previous identification strategy, I now explore the effects of current regulations on the real estate market by estimating the following regression:

$$ln(r_{Ti}) = \beta_1 LUR_{2016,i} + \psi_1 X_i + \varepsilon_{1,i}, \tag{2}$$

where $ln(r_{Ti})$ corresponds to the quality-adjusted price index for type T properties (residential or commercial) in block group i; $LUR_{2016,i}$ corresponds to one of the measures for current LUR; X_i denotes the set of control variables described in equation (1); ε_{1i} is the error term. I start by estimating equation (2) using OLS. These estimates–which are presented in Table A3–show a non-significant relationship between LUR and real estate prices. As discussed previously, estimating this regression using OLS would lead to biased results since homeowners in locations with high housing prices could lobby for more stringent regulation in order to keep the prices up.

Therefore, I estimate equation (2) using two-stage least squares (2SLS), where the first stages are given by equation (1). Identification under this strategy requires that historical LUR only affect real estate prices through their impact on current LUR, once controlling for the large set of historical controls and geographic characteristics. Ward fixed effects and controls imply that the estimates from my 2SLS regressions are identified using within-wards variation, comparing block groups that were similar in terms of 1920 demographic and current geographic characteristics, but that differed in their current regulations.

Table 4 presents the results of these regressions. Estimates from Panel A suggest that block groups with a larger share of area designated for residential uses, relative to similar block groups with more commercial-only uses, have higher residential prices and built area. In particular, an increase of 10 percentage points (pp) in the share of residential-only area (e.g., going from the median to the 75th percentile block group) leads to an increase of 1.7% in the average price of residential properties, relative to block groups with more commercial zoning. Moreover, it leads to a 3.5% increase in the price of commercial real estate. A similar increase in the share of mixed-use zoning would lead to reductions of 5.4% and 4.6% in residential and commercial prices, respectively.

In Panel B, I show that a one unit increase in the mean allowed FAR would lead to a decrease of 2% in housing prices, but could lead to a 5% increase in the price for commercial real estate. The weak effect of more relaxed FAR on housing prices can be driven by two effects: an increase in the stock of floor space (as suggested by Column 2), together with a potential increase in population density, which could lead to more amenities. The positive effect for commercial prices could be driven by increases in productivity brought by a higher density of workers and businesses.

Table 4: Effects of LUR on the Real Estate Market

	(1)	(2)	(3)	(4)
	Ln Price	Ln Stock	Ln Price	Ln Stock
Type	Residential		Commercial	
Panel A				
Sh. Res. Only	0.17***	1.11***	0.33***	-2.05***
	(0.00)	(0.00)	(0.00)	(0.00)
Sh. Mixed Uses	-0.56***	0.66***	-0.48***	12.91***
	(0.00)	(0.00)	(0.00)	(0.00)
F-Test	13.09	11.86	15.31	11.86
Panel B				
Mean FAR	-0.02***	0.12***	0.05***	0.97***
	(0.00)	(0.00)	(0.00)	(0.00)
F-Test	20.06	18.61	20.59	18.61
Observations	1,424	1,421	1,376	1,421

Notes: This table shows the results of 2SLS regressions of the effects of different LUR measures on prices and stock in the real estate market. The estimations use the 1923 zoning ordinance as instrument and include controls for block group's land area, distance to the CBD and to major waterways, transit access, and historical covariates. Price measures are quality adjusted (hedonic) and are defined in Section 2.1. Spatial Heteroscedasticity and Autocorrelation Consistent (SHAC) standard errors in parentheses (Conley, 1999); *** p<0.01, ** p<0.05, * p. <0.1.

3.3 LUR and the Spatial Distribution of Skills and Wages

In this subsection, I explore the effects of current LUR on the distribution of high- and low-skilled workers within and across block groups. I do this by estimating the following regressions:

$$ln(Skills_i) = \beta_2 LUR_{2016,i} + \psi_2 X_i + \varepsilon_{2,i}, \tag{3}$$

where $Skills_i$ denotes one of the following measures of skill composition of block group i: (i) the share of high-skilled people (h_i) inside the block group ($h_i/(h_i + l_i)$), where l_i denotes the number of low-skilled people; (ii) the number of high-skilled people in the block group relative to the city total ($h_i/\sum_j h_j$), and (iii) the number of low-skilled people in a block group relative to the city total ($l_i/\sum_j l_j$). The first measure captures the skill composition of a given block group, while the latter two capture the spatial concentration of a particular group of people. I compute these measures for block groups of residence and work, separately, and present their respective regression results in Columns (1)-(3) and Columns (4)-(6) from Table 5.[16]

The results from Panel A suggest that, a 10pp increase in the share of residential-only zoning leads to a small (but significant) increase of 0.2% in the block group share of high-skilled residents, relative to those block groups with more firm-only designations. Estimates in columns (2) and (3) suggest that more residential zoning also leads to higher spatial concentration of both types of residents relative to every other block in the city. On the other hand, a 10pp increase in the share of land zoned for mixed uses in a block group, leads to a decrease of 1% in the share of high-skilled residents. This change in skill composition comes from an increase of 8.3% in the spatial concentration of low-skilled residents inside the block group, relative to an increase of 6.4% in the spatial concentration of high-skilled residents. Column (4) shows that increases in mixed-use zoning lead to increases in the spatial concentration of both types of workers.

Regarding changes in the average FAR, Panel B shows that a one unit increase in the allowed FAR leads to spatial decentralization of residents and to a spatial concentration of workers, specially low-skilled. In particular, a one unit increase in the allowed FAR leads to an increase in the relative spatial concentration of high-skilled workers of 78%, and an increase of 92% for low-skilled workers. This result suggests that higher FAR is associated with more mixed-use or commercial zoning, relative to residential.

Finally, I investigate the effects of current LUR on the distribution of wages for both types of

[16]Not controlling for the endogeneity of LUR could also lead to biased coefficients in these regressions, since locations with a larger share of high-skilled and high-income residents may have more influential groups lobbying for more stringent regulation. Moreover, higher demand for floor space in some parts of the city, may result in a higher share of mixed-use districts and allowed FAR. Columns (5)-(10) from Table A3 confirms the existence of these biases.

Table 5: Effects of LUR on the Distribution of Skills

Block Type	(1) Sh. High Skilled (w)	(2) Sh. Low Skilled (a) Residence	(3) Sh. High Skilled (a)	(4) Sh. High Skilled (w)	(5) Sh. Low Skilled (a) Work	(6) Sh. High Skilled (a)
Panel A						
Sh. Res Only	0.02***	0.98***	1.06***	0.10***	-2.91***	-2.36***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Sh. Mixed Uses	-0.10***	0.80***	0.62***	-0.03***	0.95***	1.16***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
F-Test	11.77	12.89	12.89	12.21	12.89	12.89
Panel B						
Mean FAR	0.00***	-0.14***	-0.14***	-0.04***	0.92***	0.78***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
F-Test	19.04	20.42	20.42	20.82	20.42	20.42
Observations	1,423	1,427	1,427	1,389	1,427	1,427

Notes: This table shows the results of 2SLS regressions of the effects of different LUR measures on the spatial distribution of high- and low-skilled workers within and across block groups of residence (Columns 1-3) and work (4-6). The estimations use the 1923 zoning ordinance as instrument and include controls for block group's land area, distance to the CBD and to major waterways, transit access, and historical covariates. Dependent variables are in logs; (w) denotes the share within blocks (e.g., high-skilled as proportion to the block's population); (a) denotes the share across blocks (e.g., high-skilled in a block as proportion of total high-skilled in the city). Spatial Heteroscedasticity and Autocorrelation Consistent (SHAC) standard errors in parentheses (Conley, 1999); *** p<0.01, ** p<0.05, * p. <0.1.

workers estimating the following regressions:

$$ShLowWage_{e,i} = \beta_3 LUR_{2016,i} + \psi_3 X_i + \varepsilon_{3,i}, \tag{4}$$

where $ShLowWage_{e,i}$ denotes the share of low wage workers in a given skill group e and block group i. Columns (1) and (2) from Table 6 presents the results of these regressions for low-skilled and high-skilled workers, respectively.

The results from Panel A suggest that block groups with a higher share of area zoned for residential or mixed uses have a higher share of low-wage workers, both low- and high-skilled. In particular, a 10pp increase in the share of residential zoning leads to an increase in the share of low-wage workers of 3.9% for low-skilled, and 5.4% for high-skilled. For a 10pp increase in the share of mixed-uses, the increase are of 4.3% and 3.1%, respectively. Similarly, results from Panel

Table 6: Effects of LUR on Wages

	(1)	(2)
	Sh. Low Wage	
Skill Cat.	Low	High
Panel A		
Sh. Res. Only	0.38***	0.54***
	(0.00)	(0.00)
Sh. Mixed Uses	0.42***	0.32***
	(0.00)	(0.00)
F-Test	12.11	12.21
Panel B		
Mean FAR	-0.10***	-0.18***
	(0.00)	(0.00)
F-Test	20.14	20.82
Observations	1,389	1,389

Notes: This table shows the results of 2SLS regressions of the effects of different LUR measures on the log share of low wage workers by skill categories. The estimations use the 1923 zoning ordinance as instrument and include controls for block group's land area, distance to the CBD and to major waterways, transit access, and historical covariates. Spatial Heteroscedasticity and Autocorrelation Consistent standard errors in parentheses (Conley, 1999); ** p<0.05, * p. <0.1.

B suggest that tighter FAR limits lead to a higher share of low-wage workers, regardless of their skill level: 10% increase for low-skilled and 18% increase for high-skilled, after a one unit decrease in the allowed FAR.

Recall from Table 4 that more stringent LUR lead to higher commercial real estate prices. These results together could imply that, firms adjust to higher real estate prices by offering lower wages. Alternatively, these results could suggest that low-wage firms (or sectors) sort into more residential areas, while high-wages firms into locations where taller buildings are allowed. I expand the analysis of the effect of LUR on wages in Section 6 using a model-recovered measure of wages.

4 A Quantitative Model of a City

The empirical results presented in Section 3 suggest that more residential zoning and tighter FAR limits in a given location lead to higher housing prices and lower wages. Moreover, block groups with a higher share of mixed-use zoning have cheaper housing, and larger concentration of low-skilled workers. In this section, I develop a spatial equilibrium model of a city. This model will allow me to identify the mechanisms driving these effects and study the effect of LUR in other unobserved outcomes, such as amenities, productivities, land prices, and skill-specific welfare.

In this model, individuals—who are either high- or low-skilled—choose where to live and work, and their consumption of goods and floor space. Both types differ in their total income and in the fraction of it spent on housing. Firms choose the number of each type of workers and amount of floor space for production. This part of the model builds mainly on Ahlfeldt et al. (2015), but also draws some elements from Diamond (2016) and Tsivanidis (2019). As a contribution to the literature, I add microfoundations for the real estate market, by modeling real estate developers who face LUR and, subject to them, use land and capital to provide floor space.

Consider a closed city consisting of a set $\{1, 2, ..., L\}$ of block groups, each with a total land area of L_i. The closed-city assumption implies that population of each skill group is exogenous, but the expected utility is endogenously determined. Block groups differ in terms of final good productivity, residential amenities and their access to the rest of the city. Throughout this section, residence locations are indexed with i or m, and work locations with j or n.

4.1 Individuals

There are two types of people: high-(s) and low-skilled (u), with a fixed total population of N_s and N_u, respectively. Both types receive income from their labor and rents from land, which are paid to every individual in the city. Individuals are indexed by o and are endowed with one unit of labor that is supplied inelastically. Every worker o of type $e \in \{s, u\}$ living in location i and working in location j faces a commuting cost $d_{ij} \in [1, \infty)$ and solves:

$$\max_{c_{io}, h_{Rio}} u_{ijeo} = B_{ei} \left(\frac{c_{io}}{\beta_e} \right)^{\beta_e} \left(\frac{h_{Rio}}{1 - \beta_e} \right)^{1-\beta_e} v_{ieo} \quad (5)$$

$$\text{s.t.} \qquad c_{io} + r_{Ri} h_{Rio} \leq y_{eij} = \frac{w_{ej}}{d_{ij}} \epsilon_{jeo} + \varphi_e,$$

where B_{ei} denotes skilled-specific residential amenities and reflect the average preference of living in i by type e residents; h_{Rio} and c_{io} represent the amount of housing and final good demanded by worker o living in block i. Commuting costs act as a dispersion force, reducing the productivity and wages at work. I assume these costs take an iceberg form $d_{ij} = e^{\kappa\tau_{ij}} \geq 1$, where $\tau_{ij} \in [0, \infty)$ represents travel time between two locations and κ represents the size of these commuting costs. Additionally, individuals receive productivity shocks over workplace locations (ϵ_{jeo}) and preference shocks over residential locations (v_{ieo}), which differ by skill-type. Furthermore, I assume $\beta_s \geq \beta_u$ following recent literature showing that low-skilled people spend a higher share of their income on housing relative to high-skilled people (Notowidigdo, 2019; Ganong and Shoag, 2017).

In the budget constraint, the price of consumption goods is the same across locations and is normalized to one; and r_{Ri} is the price of housing in location i. In this model, all land is owned by people. Therefore, total income comes from the wage earned at work w_{ej}, discounted by commuting costs, plus a transfer (φ_e), which represents the payments received by households from the rents of land. These transfers are aggregates that do not vary across space, and are the same for all residents within skill type. In particular, I assume that these payments are larger for high-skilled residents ($\varphi_s > \varphi_u$).[17] The sum of these payments across all workers must equal total rents of land in the city, $R = \sum_i^L (p_i L_i)$, where p_i denotes the price of the land in location i.

The solution the maximization problem in equation(6) yields an expression for the indirect utility function:

$$u_{ijeo} = B_{ei} \left(\frac{w_{ej}}{d_{ij}} \epsilon_{jeo} + \varphi_e \right) r_{Ri}^{1-\beta_e} v_{ieo}. \tag{6}$$

Given this indirect utility, individuals first choose where to live and then where to work. Consider first the workplace location problem for type e residents of location i. Assume that residents draw a vector of iid match-productivities over workplace locations from a Fréchet distribution with cdf $F(\epsilon_{je}) = \exp\{-T_e \epsilon_{je}^{-\theta_e}\}$. The scale parameter T_e determines the average productivity of type e workers and $\theta_e > 1$ the dispersion of worker productivity within a skill-group, with a higher θ_e

[17] According to the 2015 5-year ACS, around 48% of low-skilled households in Cook County lived in their own home, compared to 61.4% for high-skilled households. Moreover, this latter group received a larger amount of rent income.

implying a lower degree of unobserved heterogeneity. Residents choose the work location that offers the highest commuting-discounted wage: $\max_j\{w_{ej}\epsilon_{jeo}/d_{ij}\}$. Properties of the Fréchet distribution imply that the probability of a type-e resident of working in location j conditional on living in i is:

$$\pi_{j|ie} = \frac{N_{eij}}{N_{Rei}} = \frac{w_{ej}^{\theta_e} e^{-\kappa\theta_e\tau_{ij}}}{\sum_{n=1}^{L} w_{en}^{\theta_e} e^{-\kappa\theta_e\tau_{in}}} = \frac{w_{ej}^{\theta_e} e^{-\kappa\theta_e\tau_{ij}}}{RMA_{ei}}. \tag{7}$$

This probability depends positively on the wage offered in that location net of commuting costs, relative to all other locations. Differences in the dispersion parameters θ_s and θ_u determine differences in the incidence of commuting costs across skill groups. In addition, RMA_{ei} denotes block i's residential market access of type e workers and is defined as $RMA_{ei} = \sum_{n=1}^{L} w_{en}^{\theta_e} e^{-\kappa\theta_e\tau_{in}}$. This measure summarizes the access to employment opportunities of type e workers from residential block i. Since there is a continuum of agents, by the law of large numbers this probability also corresponds to the number of type e individuals living in i and working j (N_{eij}) relative to the total type-e residents from location i (N_{Rei}).

Before productivity shocks are revealed, the expected income of type e residents living in i is:

$$\bar{y}_{ei} = \tilde{T}_e RMA_{ei}^{1/\theta_e} + \varphi_e, \tag{8}$$

where $\tilde{T}_e = T_e^{1/\theta_e}\gamma_{\theta_e}$, and γ_{θ_e} is the gamma constant evaluated at $1 - \frac{1}{\theta_e}$. This expression suggests that workers receive higher income in those locations with better access to jobs, as measured by residential market access.

In the first stage, individuals choose their residential location by drawing a vector of iid preference shocks over locations from a Fréchet distribution with cdf $F(v_{ie}) = \exp\{-v_{ie}^{-\eta_e}\}$. Properties of the Fréchet distribution imply that the expected utility of a type e resident of the city is:

$$\bar{u}_e = \gamma_{\eta_e} \left[\sum_{m=1}^{L} r_{Rm}^{-\eta_e(1-\beta_e)} B_{em}^{\eta_e} \left(\tilde{T}_e RMA_{em}^{1/\theta_e} + \varphi_e \right)^{\eta_e} \right]^{1/\eta_e}, \tag{9}$$

where γ_{η_e} is the gamma constant evaluated at $1 - \frac{1}{\eta_e}$. This expression shows that the expected utility of a type e city dweller depends on the average price of housing, the average expected income and the average skill-specific amenities received across all locations. Similarly, the probability that a type e resident chooses to live in location i is given by:

$$\pi_{Rei} = \frac{N_{Rei}}{N_e} = \frac{r_{Ri}^{-\eta_e(1-\beta_e)} B_{ei}^{\eta_e} (\tilde{T}_e RMA_{ei}^{1/\theta_e} + \varphi_e)^{\eta_e}}{\sum_{m=1}^{L} r_{Rm}^{-\eta_e(1-\beta_e)} B_{em}^{\eta_e} (\tilde{T}_e RMA_{em}^{1/\theta_e} + \varphi_e)^{\eta_e}}, \tag{10}$$

which also corresponds to the number of type e residents in location i (N_{Rei}) relative to their total in the city (N_e). This expression suggests that locations with relatively more amenities, lower rents and higher residential market access will be more desirable and attract more residents.

Commuting market clearing requires that the measure of type e workers employed in each location j equals the measure of type e residents commuting to j:

$$N_{Fej} \quad = \quad \sum_{i=1}^{L} \pi_{j|ie} N_{Rei} = \sum_{i=1}^{L} \frac{w_{ej}^{\theta_e} e^{-\kappa\theta_e\tau_{ij}}}{\sum_{n=1}^{L} w_{en}^{\theta_e} e^{-\kappa\theta_e\tau_{in}}} N_{Rei} = w_{ej}^{\theta_e} FMA_{ej}, \tag{11}$$

where FMA_{ej} denotes firm market access, which measures the access to type e workers by firms in location j, and is greater when a location is close from highly populated residential locations. In particular, FMA_{ej} and RMA_{ei} can be defined as:

$$FMA_{ej} = \sum_{i=1}^{L} \frac{e^{-\kappa\theta_e\tau_{ij}} N_{Rei}}{RMA_{ei}}, \qquad RMA_{ei} = \sum_{j=1}^{L} \frac{e^{-\kappa\theta_e\tau_{ij}} N_{Fej}}{FMA_{ej}}. \tag{12}$$

Finally, total demand for residential floor space by type e workers is given by:

$$H_{Rei} \quad \equiv \quad \mathbb{E}[h_{Rei}] N_{Rei} = \frac{(1-\beta_e)}{r_{Ri}} \left(\tilde{T}_e RMA_{ei}^{1/\theta_e} + \varphi_e\right) N_{Rei}. \tag{13}$$

As expected, demand for housing depends positively on the mass of residents of each type and their expected income, and negatively on the price of residential floor space in that location.

Amenities

Amenities are an important factor determining residential location choices. For instance, Bayer et al. (2007) show that households have higher willingness to pay to live in locations densely populated by high-skilled workers. On the other hand, people living in locations with natural amenities or historical buildings, might prefer lower population densities. Similar to Tsivanidis

(2019), I assume that amenities in a location depend on two components: residential fundamentals and residential externalities. The first one, denoted by b_{ei}, captures features of physical geography that affects the willingness to live in location i by type-e workers. The latter, represents how population density of high-skilled workers affect amenities.[18] In particular, amenities in location i are given by:

$$B_{ei} = b_{ei} \left(\frac{N_{Rsi}}{L_i} \right)^{\sigma_e}, \tag{14}$$

where L_i denotes land area, and σ_e controls the relative importance of the externalities in overall residential amenities by type e individuals.

4.2 Firms

Firms produce a single final good under perfect competition and constant returns to scale. Therefore, firm level input demand translates directly to block level aggregate labor demand. The final good is costlessly traded, and is produced using floor space and both types of labor according to the following production function:

$$Y_j \quad = \quad A_j \tilde{N}_{Fj}^{\alpha} H_{Fj}^{1-\alpha},$$

where $\tilde{N}_{Fj} = \left[\alpha_u N_{Fju}^{\rho} + \alpha_s N_{Fjs}^{\rho} \right]^{\frac{1}{\rho}}$ corresponds to the total effective units of labor force used by firms in location j and is a CES aggregator over low- and high-skilled workers with an elasticity of substitution of $\frac{1}{1-\rho}$; H_{Fj} corresponds to commercial floor space; A_j is the block-specific productivity, which is exogenous to firms, but endogenous in the model; $\alpha = \alpha_u + \alpha_s$ denotes the total labor share, and α_e the share of type e labor.

Firms in location j choose the quantity of inputs that maximize their profit function, taking wages (w_{ju}, w_{js}) and commercial real estate prices (r_{Fj}) as given. From the first order conditions, I obtain expressions that show how firms substitute between both types of labor and the demand

[18] I assume that both of these components are skill-specific as recent evidence suggest that different types of workers have different valuation for different types of amenities (Albouy, 2016; Couture and Handbury, 2017).

of total effective labor:

$$\frac{w_{ju}N_{Fju}^{1-\rho}}{\alpha_u} = \frac{w_{js}N_{Fjs}^{1-\rho}}{\alpha_s}, \tag{15}$$

$$\tilde{N}_{Fj} = (\alpha A_j)^{\frac{1}{1-\alpha}} \left[\alpha_u^{\frac{1}{1-\rho}} w_{ju}^{\frac{-\rho}{1-\rho}} + \alpha_s^{\frac{1}{1-\rho}} w_{js}^{\frac{-\rho}{1-\rho}}\right]^{\frac{1-\rho}{\rho(1-\alpha)}} H_{Fj}. \tag{16}$$

Note that labor demand in location j increases when local productivity or available floor space increase, or when wages decrease. Finally, using the zero profit condition, the equilibrium price of commercial floor space in location j can be derived as:

$$r_{Fj} = \alpha^{\frac{\alpha}{1-\alpha}}(1-\alpha)A_j^{\frac{1}{1-\alpha}} \left[\alpha_u^{\frac{1}{1-\rho}} w_{ju}^{\frac{-\rho}{1-\rho}} + \alpha_s^{\frac{1}{1-\rho}} w_{js}^{\frac{-\rho}{1-\rho}}\right]^{\frac{\alpha(1-\rho)}{\rho(1-\alpha)}}. \tag{17}$$

This equation states that, firms are able to pay higher rents in blocks with higher productivity and/or lower wages.

Productivity

I assume that local productivity depends on two components. First, an exogenous component a_j that represents production fundamentals from location j. Second, a term that summarizes production externalities of both types of workers in that location, as captured by their density.[19] Specifically,

$$A_j = a_j \left(\frac{N_{Fuj}}{L_j}\right)^{\delta_u} \left(\frac{N_{Fsj}}{L_j}\right)^{\delta_s}, \tag{18}$$

where N_{uj}^F/L_j and N_{sj}^F/L_j correspond to employment density of low- and high-skilled workers in location j, respectively. In these expressions, δ_u and δ_s control the relative importance of skill-specific externalities on determining productivity.

[19]The standard interpretation of these externalities is that density facilitates knowledge spillovers, input sharing or labor market pooling. See Rosenthal and Strange (2004) for a detailed review on agglomeration economies.

4.3 Real Estate Market with LUR

Based on the canonical models of housing proposed by Muth (1969) and Fujita (1989), I present a simple model of real estate developers who face LUR. Assume that the production of floor space takes place in a competitive market. In order to produce floor space, developers use capital and land with a production technology that exhibits constant returns to scale. Furthermore, assume that the owners of capital do not live in the city and that the price of capital is determined in a national market and normalized to one.

Total demand for residential and commercial floor space in every location is given by the respective solutions of the residents' and firms' maximization problems. Given these assumptions, in a world with no LUR, developers would build floor space for the group of agents (residents or firms) with the highest willingness to pay, until the price of commercial and residential floor space equalize.[20] This rent equalization leads to an optimal distribution of land between residential and commercial uses. However, when city authorities regulate the use of land, the price of both types of floor space could differ in equilibrium. Among other factor, prices would depend on the demand for residential and commercial floor space and on the local levels of LUR.

To incorporate these forces into the model, consider a Zoning Ordinance given by the matrix $\mathbb{Z} \in \{\omega_R, \omega_F, \omega_M, \lambda, \bar{h}_R, \bar{h}_F, \bar{h}_M\}$, where ω_T is a vector containing the shares of land that can be used for type T space (residential, mixed-use, commercial) in every block group, with $\omega_{Ri}+\omega_{Mi}+\omega_{Fi} = 1$; λ corresponds to the allowed share of residential space within each block group's mixed-use districts; and $\bar{h}_T$ denotes the maximum allowed FAR for type T structures. Assuming that land in a block group is fixed and can be divided between uses, a representative developer chooses the level of capital that maximizes his profits given the price of land in block i, p_i, and subject to a FAR constraint. In residential and commercial districts, his problem is given by:

$$\max_{K_i} r_{Ti} H_T(\omega_{Ti} L_i, K_i) - p_i \omega_{Ti} L_i - K_i \quad \text{s.t.} \quad \left(\frac{K_i}{\omega_{Ti} L_i}\right)^{1-\mu} \leq \bar{h}_{Ti},$$

where $T \in \{R, F\}$; $H_T(.) = \nu_{Ti} \left(\omega_{Ti} L_i\right)^{\mu} K_i^{1-\mu}$; $\left(\frac{K_i}{\omega_{Ti} L_i}\right)^{1-\mu}$ approximates the unconstrained FAR;

[20] This is the implicit assumption in recent quantitative models, such as Ahlfeldt et al. (2015) and Tsivanidis (2019)

and ν_{Ti} denotes the productivity of developers in block i for developing type-T space. This term accounts for all the unobserved factors (including other regulations) that affect construction of either residential or commercial floor space in a location. In mixed-use districts, the developer solves:

$$\max_{K_i} r_{Ri}\lambda_i H_R(\omega_{Mi}L_i, K_i) + r_{Fi}(1-\lambda_i)H_F(\omega_{Mi}L_i, K_i) - p_i\omega_{Mi}L_i - K_i \quad \text{s.t.} \left(\frac{K_i}{\omega_{Ti}L_i}\right)^{1-\mu} \leq \bar{h}_{Ti}.$$

The solutions from these problems, together with the zero profit conditions, yield the total supply of residential and commercial floor space, and the price of land in block group i. In particular when the constraint is binding, the solution is given by:

$$\begin{aligned} H^S_{Ri} &= \nu_{Ri}L_i\left[\omega_{Ri}\bar{h}_{Ri} + \omega_{Mi}\lambda_i\bar{h}_{Mi}\right], & (19)\\ H^S_{Fi} &= \nu_{Fi}L_i\left[\omega_{Fi}\bar{h}_{Fi} + \omega_{Mi}(1-\lambda_i)\bar{h}_{Mi}\right], & (20)\\ p_i &= \sum_T \omega_{Ti}p_{Ti} \quad \text{with} \quad p_{Ti} = \bar{h}_{Ti}\left[\lambda_i r_{Ri}\nu_{Ri} + (1-\lambda_i)r_{Fi}\nu_{Fi} - \bar{h}_{Ti}^{\frac{\mu}{1-\mu}}\right], & (21)\\ \chi_{Ti} &= \lambda_i r_{Ri}\nu_{Ri} + (1-\lambda_i)r_{Fi}\nu_{Fi} - \frac{1}{1-\mu}\bar{h}_{Ti}^{\frac{\mu}{1-\mu}}, & (22)\end{aligned}$$

where $T \in \{R, M, F\}$; $\lambda_i = 1$ when $T = R$ and $\lambda_i = 0$ when $T = F$; and χ_{Ti} denotes the Lagrangian multiplier of this optimization problem. This multiplier represents the shadow costs of FAR restrictions (i.e., the marginal profits of relaxing them), and its solution comes from the first order and the complementary slackness conditions. Residential and commercial floor space market clearing must satisfy that total demand equals total supply for each type of space in every block group i.

4.3.1 Equilibrium with LUR

Given the model's parameters $\{\{\beta_e, \theta_e, \eta_e, \tilde{T}_e, \sigma_e, \delta_e\}_{e\in\{u,s\}}, \kappa, \alpha, \rho, \mu\}$, exogenous location-specific characteristics $\{\mathbf{b_u}, \mathbf{b_s}, \mathbf{a}, \boldsymbol{\tau}, \boldsymbol{\alpha_S}, \boldsymbol{L}, \boldsymbol{\nu_R}, \boldsymbol{\nu_F}\}$, the city-type total population $\{N_u, N_s\}$ and a zoning code $\mathbb{Z} = \{\omega_R, \omega_M, \omega_F, \lambda, \bar{h}_R, \bar{h}_M, \bar{h}_F\}$, the general equilibrium of the model is given by the vectors $\{\{\mathbf{N_{Re}}, \mathbf{N_{Fe}}, \mathbf{w_e}\}_{e\in\{u,s\}}, \mathbf{r_R}, \mathbf{r_F}, \mathbf{p_R}, \mathbf{p_F}, \mathbf{p_M}, \boldsymbol{\chi_R}, \boldsymbol{\chi_F}, \boldsymbol{\chi_M}\}$, the city-wide expected utility for both types of workers $\{\bar{u}_u, \bar{u}_s\}$ and transfers from the rents of land $\{\varphi_u, \varphi_s\}$, such that both types of workers maximize their utility given their budget constraint, firms maximize their profits, developers maximize their profits subject to the zoning and FAR restrictions, there are zero profits in the good and real estate markets, markets clear, and block-level working and residential population add up to the city-type total.

In particular, the equilibrium is determined by the following system of 13 equations: expected utility (9), residential choice probabilities (10), labor supply (11), optimal substitution between high- and low-skilled workers (15), zero profits in the market for final goods (17), residential floor space market clearing ((19) and (13) for both skill types), commercial floor space market clearing ((20) and (16)), zero profits in real estate markets (21), and the shadow costs of FAR restrictions (22).[21]

5 Calibration

In this section, I show how to recover the model's unobservable variables using block group level data on real estate prices, LUR and skill-composition, and given values for the different parameters. I build on the methodologies from Ahlfeldt et al. (2015) and Tsivanidis (2019) to recover unobserved wages, amenities and productivities. Afterward, I solve for the real estate market equilibrium when LUR are present, and recover the price of land and the shadow price of FAR in each block group. Finally, I present some calibration results.

5.1 Market Access and Wages

Given parameters $\{\theta_s, \theta_s, \kappa\}$, data on the skill composition of residential and work block groups ($\{\mathbf{N_{Fu}}, \mathbf{N_{Fs}}, \mathbf{N_{Ru}}, \mathbf{N_{Rs}}\}$) and bilateral commuting times ($\{\boldsymbol{\tau}\}$), commuting market clearing conditions provide a system of equations that can be solved for residential and firm market access for

[21] If amenities and productivities were exogenous, the competitive equilibrium would be efficient, conditional on the zoning ordinance. In the case of endogenous externalities, the competitive equilibrium will not necessarily be efficient and multiple equilibria are possible. Ahlfeldt et al. (2015) show that, given values for parameters and observed data on real estate prices, commuting and residential and workplace population, there exist unique vectors of the unobserved location characteristics that are consistent with the data being an equilibrium of this sort of models.

each skill-type:

$$RMA_{ei} = \sum_{j=1}^{L} \frac{e^{-\kappa\theta_e\tau_{ij}} N_{Fej}}{FMA_{ej}}, \qquad FMA_{ei} = \sum_{j=1}^{L} \frac{e^{-\kappa\theta_e\tau_{ij}} N_{Rej}}{RMA_{ej}}.$$

Using the recovered measures of RMA and FMA, I use equation (11) to recover a measure of skill-specific wages for every location. Since the equilibrium system is only defined to scale, I normalize the geometric mean of wages to one.[22]

5.2 Productivity

Using the firm's first order and zero profit conditions, it is possible to derive an expression that relates block group i's firm productivity to commercial real estate prices and wages:

$$A_{ei} = \left(\frac{r_{Fi}}{1-\alpha}\right)^{1-\alpha} \left(\frac{w_{ei}}{\alpha}\right)^{\alpha} \alpha_e^{\frac{\alpha}{\rho}} \vartheta_{ei}^{\frac{\alpha(1-\rho)}{\rho}} \qquad e \in \{u, s\},$$

where $\vartheta_{ei} = (w_{ei}N_{Fei})/(\sum_{e'} w_{ie'}N_{Fe'i})$ corresponds to the labor expenditure share on type e workers in block group i. Since productivity is assumed to be Hicks-neutral, then $A_{iu} = A_{is}$. For this equality to hold, I assume that the labor share of low- and high-skilled labor also vary across block groups in the city, i.e., α_{uj} and α_{sj} and $\alpha_{uj} + \alpha_{sj} = \alpha$. Normalizing to a geometric mean of 1, the previous equation can be written as:

$$\tilde{A}_i = \tilde{A}_{ei} = \tilde{r}_{Fi}^{1-\alpha} \tilde{w}_{ei}^{\alpha} \tilde{\alpha}_{ei}^{-\alpha/\rho} \tilde{\vartheta}_{ei}^{\alpha(1-\rho)/\rho} \qquad e \in \{u, s\}, \tag{23}$$

where the tilde above a variable denotes that is has been normalized. These equations imply that, given parameters $\{\alpha, \rho\}$, observed data $\{\mathbf{N_{Fu}}, \mathbf{N_{Fs}}, \mathbf{r_F}\}$, and recovered wages $\{\mathbf{w_u}, \mathbf{w_s}\}$, I can determine unique vectors of block group level productivity $\{\mathbf{A}\}$ and measures of the intensity in which different types of workers are used $\{\boldsymbol{\alpha}_u, \boldsymbol{\alpha}_s\}$.

[22] Using the normalized value of wages, I re-scale the measures of RMA and FMA in order to be consistent with this choice of units.

5.3 Real Estate Market

Having recovered block group level measures of productivity, wages and skill-specific labor shares, and given data $\{\mathbf{N_{Fu}}, \mathbf{N_{Fs}}, \mathbf{N_{Ru}}, \mathbf{N_{Rs}}, \mathbf{r_F}, \mathbf{r_R}, \boldsymbol{Z}\}$ and parameters $\{\beta_u, \beta_s, \theta_u, \theta_s, \alpha, \rho, \mu, \tilde{T}_u, \tilde{T}_s\}$, I solve for the real estate market equilibrium $\{\mathbf{p}, \boldsymbol{\nu_R}, \boldsymbol{\nu_F}, \boldsymbol{\chi}, \varphi_u, \varphi_s\}$ using the following procedure:

1. Set $\varphi_u = \varphi_u^0$, $\varphi_s = \varphi_s^0$;

2. Solve for ν_R and ν_F using the floor space market clearing conditions;

3. Find prices $\{\mathbf{p_T}\}$, with $T \in \{R, M, F\}$ using developers' zero profit conditions (equation (21)), and $p_i = \sum_T \omega_{Ti} p_{Ti}$;

4. Find $\bar{\varphi}_u = \frac{\sum_i p_i L_i}{N_{Ru} + x N_{Rs}}$ and $\bar{\varphi}_s = x \bar{\varphi}_u$, where $x = \varphi_s^0 / \varphi_u^0$;

5. If $\bar{\varphi}_u = \varphi_u^0$ and $\bar{\varphi}_s = \varphi_s^0$, continue to 6; else, update $\varphi_e^1 = \zeta \bar{\varphi}_e + (1 - \zeta)\varphi_e^0$ $\forall e$, and repeat 2-5 until convergence;

6. Find Lagrange multipliers $\{\boldsymbol{\chi_T}\}$, $T \in \{R, M, F\}$ (equation (22)), and $\chi_i = \sum_T \omega_{Ti} \chi_{Ti}$.

I set the initial values $\varphi_u^0 = 5.38$ and $\varphi_s^0 = 8.10$, which correspond to the average ratio of housing value plus housing income relative to the total household wage income in Cook County according to the 2015 ACS. The formula in step 4 comes from the fact that total payments to households have to equal total land rents: $\varphi_s N_{Rs} + \varphi_u N_{Ru} = \sum_i p_i L_i$.[23]

5.4 Residential Amenities

For each skill type e, given parameters $\{\theta_e, \beta_e, \eta_e, \tilde{T}_e\}$, observed data $\{\mathbf{N_{Re}}, \mathbf{r_R}\}$ and recovered measures of residential market access and land rents $\{\mathbf{RMA_e}, \varphi_e\}$, I recover block group skill-specific amenities, up to a normalization, using residential choice probabilities from equation (10):

$$\tilde{B}_{ei} = \frac{B_{ei}}{\bar{B}_e} = \tilde{N_{Rei}}^{1/\eta_e} \tilde{r_{Ri}}^{1-\beta_e} \tilde{\tilde{y}}_{ei}^{-1}, \tag{24}$$

[23] I define housing income as the income households obtain from rent plus 1% of the value of their properties.

where y_{ei} is the expected income from equation (8). Note that equations (23) and (24) are similar to those determining the spatial equilibrium in Rosen-Roback type of models (Roback, 1982). That is, amenities and productivity are determined by labor market opportunities and real estate prices in a location.

5.5 Welfare

Finally, given data on $\{\mathbf{r_R}, \tilde{\mathbf{B}}_\mathbf{e}, \mathbf{RMA_e}\}$ and parameters $\{\beta_e, \theta_e, \eta_e, \varphi_e, \tilde{T}_e\}$ for each type of worker, I can recover the average utility of a type e city resident using equation (9):

$$\bar{u}_e = \gamma_{\eta_e}\left[\sum_{m=1}^{L} r_{Rm}^{-\eta_e(1-\beta_e)} B_{em}^{\eta_e}\left(\tilde{T}_e RMA_{em}^{1/\theta_e} + \varphi_e\right)^{\eta_e}\right]^{1/\eta_e}.$$

I can also recover the semi-elasticity of welfare of type e residents with respect to a policy change in a given block group i. Let ξ_i be a specific LUR inside block group i (either zoning or FAR). From the previous equation, I can write the semi-elasticity of welfare to changes in this policy (ε_{u_e,ξ_i}) as:

$$\varepsilon_{u_e,\xi_i} = \sum_m \pi_{Rem}\left[-(1-\beta_e)\varepsilon_{r_{Rm},\xi_i} + \sigma_e\varepsilon_{\pi_{Rsm},\xi_i} + \frac{\tilde{T}_e RMA_{em}^{1/\theta_e}}{\theta_e \bar{y}_{em}}\varepsilon_{RMA_{em},\xi_i} + \frac{\varphi_e}{\bar{y}_{em}}\varepsilon_{\varphi_e,\xi_i}\right] \tag{25}$$

where $\varepsilon_{r_{Ri},\xi_i}$, $\varepsilon_{\pi_{Rsi},\xi_i}$, $\varepsilon_{RMA_{ei},\xi_i}$ and ε_{p_i,ξ_i} correspond to the semi-elasticities of housing prices, high-skilled residential concentration, land prices and residential market access with respect to the change in policy ξ_i. The previous expression suggests that the effect of a policy change on welfare of type e residents can be decomposed into four components: (i) changes in housing prices, (ii) changes in sorting patterns (that affect the skill-specific amenities), (iii) changes in wages (as summarized by residential market access), and (iv) changes in the income coming from the rents of land.

Using the semi-elasticities estimated in equations (2) and (3), together with the calibration method proposed above, I can write the empirical counterpart of equation (25) as:

$$\hat{\varepsilon}_{u_e,\xi_i} = \sum_m \bar{\pi}_{Rem}\left[-(1-\beta_e)\hat{\varepsilon}_{r_{Rm},\xi_i} + \sigma_e\hat{\varepsilon}_{\pi_{Rsm},\xi_i} + \frac{\tilde{T}_e R\bar{M}A_{em}^{1/\theta_e}}{\theta_e \bar{y}_{em}}\hat{\varepsilon}_{RMA_{em},\xi_i} + \frac{\varphi_e}{\bar{y}_{em}}\hat{\varepsilon}_{\varphi_e,\xi_i}\right],$$

where $R\bar{M}A_{em}$, $\bar{y}_{em}$, $\bar{\pi}_{Rem}$ correspond to the average across block groups of RMA, total income of type e residents, and the share of type e residents in block group m relative to their city wide total population, respectively.

5.6 Parameters

In this subsection, I show the origin of the different parameters needed to successfully recover the model's unobservables and quantify the policy counterfactuals. The parameters $\{\kappa, \rho, \alpha, \eta_u, \eta_s\}$ are calibrated to existing values from the literature. First, I set the dis-utility of commuting $\kappa = 0.01$ based on Ahlfeldt et al. (2015). Second, I set the elasticity of substitution between high- and low-skilled workers $\frac{1}{1-\rho} = 1.5$ based on estimates from Ciccone and Peri (2005). Third, I set the cost share of commercial floor space to $1 - \alpha = 0.156$ based on the share of structures in value added found in Greenwood et al. (1997) for the US. Finally, I used the estimates of $\eta_u = 2.959$ and $\eta_s = 3.329$ from Tsivanidis (2019) for the Fréchet shape parameters of the distribution of shocks over residential locations.

Housing expenditure shares $\{1-\beta_u, 1-\beta_s\}$ are calibrated using the 2015 ACS for Cook County as the average share of housing expenditures for all households within skill groups. This share is calculated as the ratio between annual housing costs (owning plus renting costs) and the total household income. These shares correspond to $1 - \beta_u = 0.360$ $1 - \beta_s = 0.268$. The cost share of land in the production of real estate μ is calibrated using data from Davis et al. (2019), who construct estimates of the land share of property value for all census tracts in the US. I take the average across all census tracts in Cook County, resulting in $\mu = 0.256$.

The Fréchet shape parameters from the workers' match-productivity distribution $\{\theta_u, \theta_s\}$ is identified using a gravity approach, given a value for κ. In particular, note that the log version of equation (7) provides a gravity equation relating travel time between locations to commuting flows:

$$\ln \pi_{j|ie} = \zeta_{0,ie} + \zeta_{1,je} - \theta_e \kappa \tau_{ij} + \varepsilon_{ije}$$

where $\zeta_{0,ie}$ and $\zeta_{1,je}$ correspond to origin and destination fixed effects, and ε_{ije} is an unobserved error term. Since the commuting matrix between block groups in Cook County is considerably sparse, I estimate this equation using commuting flows across census tracts.[24] Furthermore, given that the LODES data do not contain commuting flows by skill-level, I estimate this regression using commuting flows for low- and high-wage workers. Table 7 shows the results of these regressions, and indicate that low-wage workers are more sensitive to commutes than high-wage workers, both when travel times or distances are considered.

Table 7: Gravity Regressions

	(1) Low Wage	(2) High Wage	(3) Low Wage	(4) High Wage
Travel Time	-0.050***	-0.035***		
	(0.000)	(0.000)		
Distance			-0.038***	-0.027***
			(0.000)	(0.000)
R-squared	0.396	0.426	0.387	0.421
Observations	1,737,124			

Notes: This table shows the results of OLS regressions on the log conditional commuting shares by income level on travel times and distance between census tracts in 2015-2016 in Cook County. Regressions include tract of origin and of destination fixed effects. Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p. <0.1.

Taking the estimates from Columns (1) and (2), I built skill-specific estimates taking averages using as weights the average share of low- and high-wage residents by skill category across block groups in Cook County.[25] Using $\kappa = 0.01$, I obtain $\theta_u = 4.33$ and $\theta_s = 4.08$, indicating a larger dispersion in the productivity of high-skilled workers. Even though these estimates are not necessarily causal, they lie between the estimates from Tsivanidis (2019)—who finds $\theta_u = 3.30$ and $\theta_s = 2.72$ for Bogotá— and Ahlfeldt et al. (2015)—who find $\theta = 6.83$ for Berlin.

I calibrate the scale parameters of the match-productivity Fréchet distribution using the method proposed by Tsivanidis (2019). In particular, after normalizing $\tilde{T}_u = 1$, I calibrate $\tilde{T}_s$ "so that the aggregate wage skill premium in the model matches that observed in the data" (Tsivanidis, 2019). In particular, from the 2015 ACS I find that the ratio between the average hourly wage of high- and low-skilled workers is 1.92. Using this ratio, I find $\tilde{T}_s = 1.162$ by solving: $1.92 = \frac{\tilde{T}_s \sum_i RMA_{si}^{1/\theta_s} N_{Fsi}/N_{Fi}}{\sum_i RMA_{ui}^{1/\theta_u} N_{Fui}/N_{Fi}}$.

[24] Around 91.6% of block groups pairs have zero commuters. This share decreases to 66% for flows between tracts. Implications of granularity in spatial models are discussed in Dingel and Tintelnot (2021).

[25] Among low-skilled, the share of low-wage workers is 0.577. Among high-skilled, the share is 0.401.

Finally, I estimate the agglomeration parameters using the following log version of equations (14) and (18), using a two-step approach and the first stage described in Section 3.1:

$$\begin{aligned} ln(B_{ei}) &= \sigma_e ln\left(\frac{N_{Rsi}}{L_i}\right) + ln(b_{ei}), \quad e \in \{u, s\} \\ ln(A_i) &= \delta_u ln\left(\frac{N_{Fui}}{L_i}\right) + \delta_s ln\left(\frac{N_{Fsi}}{L_i}\right) + ln(a_i), \end{aligned}$$

where the variables in the left-hand side correspond to the amenities and productivities recovered in Sections 5.2 and 5.4. From these regressions, I can also recover the residential and production agglomeration fundamentals ($\{b_{ui}, b_{si}, a_i\}$) for every block group.

In Table 8, I present the estimated agglomeration parameters. Estimates from Columns (1) and (2) show a similar effect of density on skill-specific amenities: a 1% increase in the density of high-skilled residents leads to an amenity increase of 0.4% for both types of residents. Column (3) shows that high- and low-skilled worker densities have different effects on productivity. While, a 1% increase in the density of high-skilled workers leads to a 0.26% increase in block group productivity, a 1% increase in the density of low-skilled workers seems to cause a reduction of 0.04%. These estimates suggest that the benefits from concentrating high-skilled workers in certain locations in Chicago (e.g., knowledge spillovers) outweigh their costs (e.g., congestion), but the costs are slightly larger for low-skilled workers. However, these estimates should be interpreted carefully as the first stage F-test could suggest a weak instrument problem.

5.7 Calibration Results

In this section, I present a brief description of the variables recovered using the calibration method presented in the previous section. Table A4 in the Appendix presents descriptive statistics of the different variables recovered with the model.

In Figure 5, I present the geographic distribution of land prices (Left Panel) and shadow costs of FAR restrictions (Panel B) in Cook County. The maps show that land is most expensive around the CBD and along the coast of Lake Michigan, particularly north of downtown. Moreover, the shadow costs of FAR restrictions are also relatively high north of downtown, but also in some block

Table 8: Agglomeration Parameters

	(1)	(2)	(3)
	Ln Amenities		Ln Productivity
	Low Sk	High Sk	
Ln.Density High Skilled (Resid.)	0.398***	0.403***	
	(0.000)	(0.000)	
Ln.Density Low Skilled (Work)			-0.036***
			(0.000)
Ln.Density High Skilled (Work)			0.256***
			(0.000)
F-Test	8.20	8.20	0.78
Observations	1,420	1,420	1,336

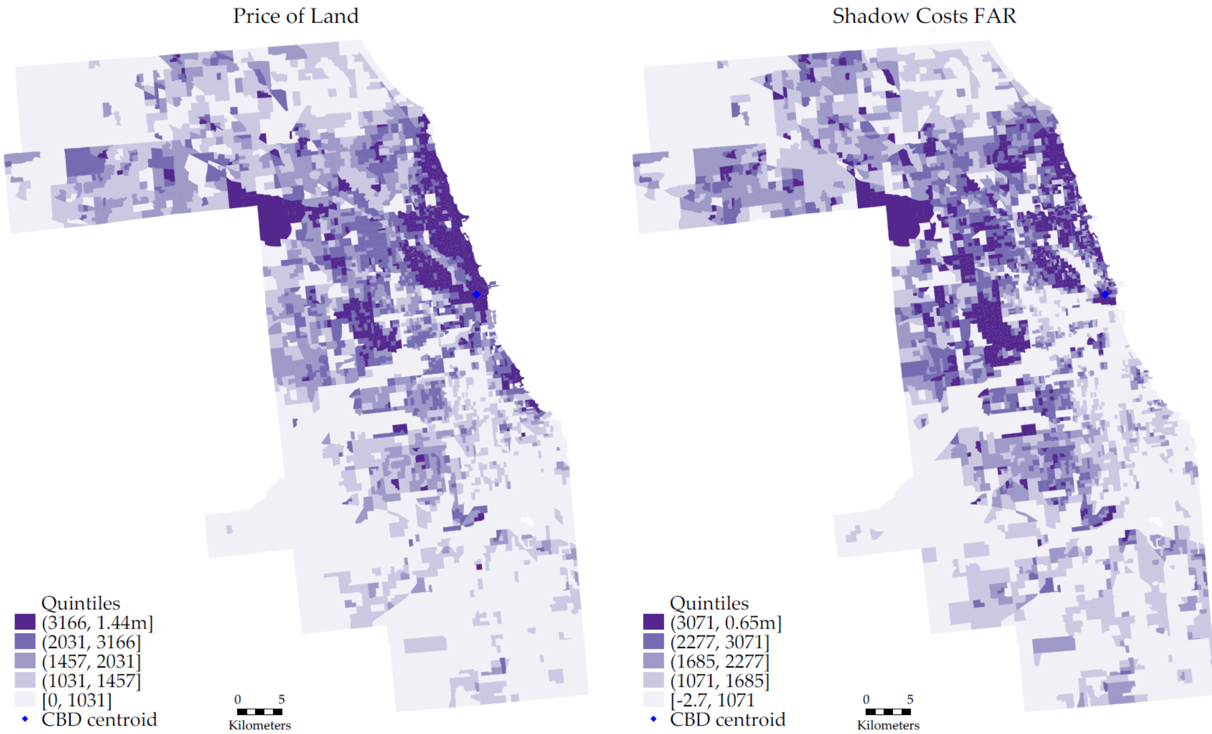
Notes: This table shows the results of 2SLS regressions of the effects of resident and worker density on measures of skill-specific amenities and productivity. The estimations use the 1923 zoning ordinance as instrument and include controls for block group's land area, distance to the CBD and to major waterways, transit access, and historical covariates. The dependent variables were recovered using the quantitative model. Spatial Heteroscedasticity and Autocorrelation Consistent standard errors in parentheses (Conley, 1999); *** p<0.01, ** p<0.05, * p<0.001.

groups in the west, particularly around O'Hare airport. These high values suggest that the city could benefit more from relaxing FAR restrictions in these block groups relative to other locations. From the calibration, I also obtain values for the transfers that residents receive from the rents of land. Recall that these transfers are aggregates that do not vary across space (contrary to wages). In particular, I obtain $\varphi_u = 4.20$ and $\varphi_s = 6.32$.

In Figures A5 and A6 in the Appendix, I show the geographic distribution of amenities and productivities across block groups. The distribution of amenities is quite similar for high- and low-skilled residents, suggesting that both have similar tastes regarding residential amenities. In addition, local productivity is higher around the CBD.[26] Regarding welfare, Table A5 shows the average expected utility for a type e resident in Cook County. I compute this measure with and without the income from land rents. In both cases, welfare is higher for high-skilled relative to low-skilled residents, but the gap between both groups is larger when transfers from land are allowed.

[26] There is also a high and significant correlation between productivity and commercial real estate prices (0.42), and between productivity and the share of commercial land (0.48).

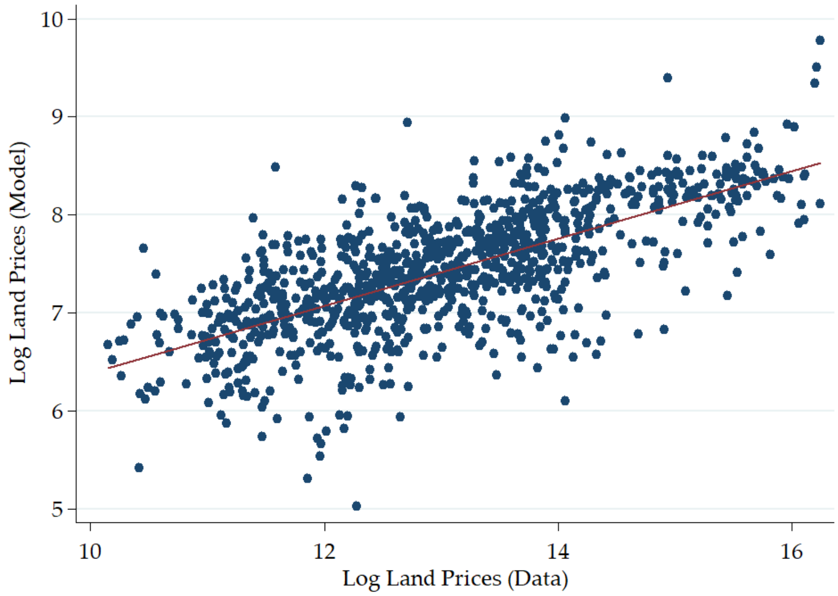
Figure 5: Price of Land and Shadow Cost of Regulations in Cook County, 2015-2016



Notes: This figure shows the land price and the costs of FAR restrictions for every block group in Cook County for the period 2015-2016. Both variables are recovered using the quantitative model. Blue dot represents Chicago's CBD.

Finally, in order to test the fitness of the model, I explore the relationship between the land prices recovered by my model and the land prices estimated by Davis et al. (2019) for Cook County. The latter paper estimates land prices for all Census tracts in the United States using different data, model and methods than the ones I present in this paper. Since prices from Davis et al. (2019) are available at the tract level, I aggregate my model's recovered prices using a weighted sum of the block group prices, where the weights are the block group's area share within its tract. In Figure 6, I present the scatter plot between these two estimated land prices. The figure shows a clear positive relationship between both variables. Moreover, these variables have a coefficient of correlation of 0.70, which is significant at the 99%, suggesting a strong relation between them and a good fit of the model predicting land prices.

Figure 6: Model Fit—Price of Land: Model vs. Davis et al. (2019)



Notes: This figure shows a scatterplot and the regression line between the logarithm of the land prices predicted by the quantitative model and the logarithm of the land prices estimated by Davis et al. (2019). Land prices are at the Census tract level.

6 The Incidence of Land Use Regulations

I now explore the effect of zoning and FAR restrictions on the recovered measures of wages, amenities, productivity and land prices. In particular, I follow the same empirical strategy from Section 3, in which I estimate 2SLS regressions of these outcomes on current zoning and FAR regulations using the 1923 Chicago Zoning Ordinance districts as instrumental variables. Afterward, I perform four different counterfactual exercises to study how welfare and welfare inequality change when there are large changes in LUR.

6.1 LUR and Wages

We start by exploring the relationship between LUR and wages. My 2SLS estimates suggest that a 10pp increase in the share of residential zoning leads to a decrease in the wage of 5.8% for low-skilled workers and of 5.4% for high-skilled workers. However, a similar increase in the share of mixed-use districts leads to a wage increase of 2.6% for both types of workers. Regarding FAR restrictions, an increase of one unit in the allowed FAR in a particular block group, leads to a 19% increase in the wages of both types. I present these estimates in Columns (1) and (2) from Table 9. These results validate earlier results from Table 6: more stringent zoning and FAR restrictions in a location lead to lower wages. Our model suggests that, this result comes as firms respond to higher real estate prices (brought by tighter regulations) by adjusting their wages down.[27]

Table 9: Effects of LUR on Model's Unobservables

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Ln Wages		Ln Amenities		Ln Pro-.	Ln Price	Ln. Shadow
	Low Sk	High Sk	Low Sk	High Sk	ductivity	Land	Price
Panel A							
Sh. Res. Only	-0.60***	-0.56***	0.26***	0.24***	-0.52***	2.64***	4.00***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Sh. Mixed Uses	0.26***	0.26***	-0.09***	-0.11***	0.24***	3.41***	4.31***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
F-Test	12.11	12.21	12.06	12.06	14.62	12.89	12.89
Panel B							
Mean FAR	0.19***	0.19***	-0.03***	-0.03***	0.18***	-0.35***	-0.73***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
F-Test	20.14	20.82	18.48	18.48	20.85	20.42	20.42
Observations	1,389	1,389	1,420	1,420	1,336	1,427	1,427

Notes: This table shows the results of 2SLS regressions of the effects of different LUR measures on measures of wages, amenities, productivity, price of land and the shadow price of FAR restrictions by block group. The estimations use the 1923 zoning ordinance as instrument and include controls for block group's land area, distance to the CBD and to major waterways, transit access, and historical covariates. The dependent variables are in logs and were recovered using the quantitative model from Section 4. Spatial Heteroscedasticity and Autocorrelation Consistent (SHAC) standard errors in parentheses (Conley, 1999); *** p<0.01, ** p<0.05, * p. <0.1.

6.2 LUR, Amenities and Productivity

Results from Table 9 also suggest that more stringent LUR lead to higher residential amenities. In particular, estimates from Columns (3) and (4) from Panel A show that a 10pp increase in the share of residential zoning leads to an increase of around 2.5% in local amenities, relative to block

[27] I also explore the effect of LUR on residential and firm market access. Results show that an increase in the share of mixed-use designations leads to a larger increase in RMA and FMA than a similar increase in any other designation, suggesting that both firms and workers benefit when regulation lets them locate close to each other. These results are available on request.

groups with more commercial zoning. Regarding FAR, a one unit increase in the allowed FAR leads to a decrease in the amenities of 3%. On the other hand, a 10pp increase in the share this type of zoning leads to a decrease in amenities of -1%. These effects are not significantly different for high- and low-skilled residents, suggesting that the amenities generated by LUR are valued similarly by both skill types.[28]

Zoning and FAR restrictions also have sizable effects on local productivity. Specifically, a 10pp increase in the share of residential zoning leads to a decrease of 5.1% in local productivity, relative to block groups with more commercial zoning. A similar increase in mixed-use designations leads to a productivity increase of 2.4%. Moreover, a one unit increase in the allowed FAR results in an 18% increase in local productivity. Two forces are behind these results. First, recall from Table 5 that more mixed-use designations and increases in the allowed FAR lead to higher spatial concentration of workers. As the literature has found, this concentration generates knowledge spillovers, labor market pooling and/or input-out sharing, leading to productivity gains (Rosenthal and Strange, 2004). Second, more mixed-use designations also lead to increases in the spatial concentration of residents, which affects local productivity through increases in wages and firm market access.

6.3 LUR, Price of Land and Stringency

Finally, I estimate the effect of LUR on land prices and the shadow price of FAR limits. Estimates from Column (6) suggest that more stringent regulation leads to increases in local land prices. In particular, a 10pp increase in the share of residential zoning leads to an increase of 30.2% in the price of land, relative to block groups with more commercial zoning. Moreover, a one unit decrease in the allowed FAR, leads to a 35% increase in prices. These results are in line with theories studying the home-voter hypothesis, such as Fischel (2001), who suggest that land and home owners benefit from tighter LUR as they lead to increases in the value of their properties. Nonetheless, and perhaps surprising, a higher share of land zoned for mixed-uses leads to a 40.6% increase in land prices.

Following the framework proposed by Brueckner et al. (2017), I use results from Column (6) to

[28]Recall that in the quantitative model, amenities are generated by the sorting of high-skilled residents into a neighborhood, and that the agglomeration estimates from Table 8 are statistically equal.

study the stringency of FAR. In particular, the authors suggest that if the coefficient accompanying the allowed FAR from a regression on land prices is positive, the existing limit is stringent. Thus, the negative coefficient from Column (6) could suggest that on average, FAR restrictions in Chicago are not too stringent, which lies in line with estimates from Brueckner and Singh (2020). This framework, applied to results from Panel A, suggests that current zoning regulations are quite stringent. An alternative way to study stringency is by analyzing the effect of FAR on their shadow prices recovered from the quantitative model. Recall that these shadow prices represent the profits developers fail to receive due to the FAR restrictions. My estimates, presented in Panel B from Column (7), suggest that relaxing allowed FAR limits by one unit lead to a 73% decrease of the local shadow price of FAR. Hence, they suggest that on average, FAR restrictions in Chicago are quite stringent.[29]

6.4 LUR and Welfare

In this final subsection, I study how welfare of both types of residents and welfare inequality change when there is a large change in LUR. I do this by performing four different counterfactual exercises in which I use the semi-elasticities of real estate prices (from Table 4) and the distribution of skills (from Table 5) with respect to changes in LUR, together with the solution from Section 5. Furthermore, as described in Section 5.5, I decompose the total change in welfare induced by the policies into four mechanisms: changes in housing prices, changes in amenities brought by sorting, changes in residential market access and changes in the land rent income.

First, consider a policy that attempts to eliminate some of the inefficiencies of current zoning designations. In particular, I (i) increase the share of land zoned for residential purposes in those block groups where residential real estate is significantly more expensive, and (ii) increase the share of land zoned for commercial purposes where commercial prices are higher.[30] This policy would affect 68% of block groups. In Panel A from Table 10, I present the change in welfare brought by this policy, with respect to the baseline results from Table A5. Columns (2)-(5) show the changes

[29] Results from Panel A suggest that increasing residential zoning would lead to higher shadow prices, as residential areas tend to have lower FAR.

[30] In particular, in block groups where the gap between residential and commercial prices is more than 1.1, this simulated policy converts up to 10% of commercial-zoned land into residential-zoned land, and viceversa.

when each one of the mechanisms affecting welfare is set to zero. The results suggest welfare gains of around 5.35% for low-skilled residents, a slight decrease of -0.05% for high-skilled residents and a decrease in welfare inequality between both types. The decomposition shows that: (i) most of welfare gains of low-skilled residents come from changes in amenities, while decreases in RMA contribute negatively to it; (ii) high-skilled residents are negatively affected by changes in amenities, but that effect is compensated by lower housing prices and a higher income from the rents of land.

Table 10: Changes in Welfare - Counterfactuals

	(1)	(2)	(3)	(4)	(5)
Panel A: Towards an Optimum Zoning					
	Total Change	ΔPrices=0	ΔSorting=0	ΔRMA=0	ΔLandInc=0
Welfare Low-Skilled	5.35%	5.28%	0.32%	5.61%	5.06%
Welfare High-Skilled	-0.05%	-0.09%	0.29%	0.02%	-0.34%
Relative Welfare	-0.055				
Panel B: ΔFAR = 0.5 if block in top decile of χ_i					
	Total Change	ΔPrices=0	ΔSorting=0	ΔRMA=0	ΔLandInc=0
Welfare Low-Skilled	3.84%	3.82%	-1.15%	6.98%	2.30%
Welfare High-Skilled	-0.31%	-0.32%	-0.19%	1.45%	-1.88%
Relative Welfare	-0.042				
Panel C: Minimum FAR of 1.2					
	Total Change	ΔPrices=0	ΔSorting=0	ΔRMA=0	ΔLandInc=0
Welfare Low-Skilled	5.23%	5.18%	0.09%	5.45%	5.17%
Welfare High-Skilled	-0.20%	-0.24%	0.04%	-0.14%	-0.26%
Relative Welfare	-0.055				
Panel D: At least 25% Mixed-Use Zoning					
	Total Change	ΔPrices=0	ΔSorting=0	ΔRMA=0	ΔLandInc=0
Welfare Low-Skilled	4.87%	3.77%	0.66%	6.47%	4.48%
Welfare High-Skilled	0.02%	-0.80%	0.65%	0.64%	-0.38%
Relative Welfare	-0.050				

Notes: This table shows the changes in the expected utility by skill level in Chicago with respect to the baseline welfare levels from Table A5 and based on the counterfactual exercises described in the text, together with the welfare change when each one of the mechanisms is set to zero. These four mechanisms correspond to (i) changes in housing prices; (ii) changes in amenities brought by changes in sorting; (iii) changes in residential market access; and (iv) changes in the income coming from the rents of land.

In a second exercise, I increase the FAR limit by 0.5 in the block groups from the top decile of the shadow price distribution, that is, in those locations where FAR limits are most constrained. Panel B shows that in this scenario, welfare increases by 3.84% for low-skilled residents, decreases by

0.31% for high-skilled, and welfare inequality between both decreases. For both skill types, changes in housing prices do not affect their welfare, but changes in RMA affect it negatively. Specifically, if RMA did not change due to this policy, welfare would increase by 7% and 1.5% for low- and high-skilled residents, respectively. On the other hand, if it were not for changes in amenities, welfare would decrease. Finally, notice that high-skilled residents are partially compensated with a higher income coming from the rents of land.

Third, I simulate a policy that imposes a minimum allowed FAR of 1.2 everywhere in Chicago. This policy would affect 1022 block groups (47%). In this scenario there would be an increase of around 5.23% in the welfare of low-skilled residents, a decrease of -0.2% for high-skilled residents and a decrease in welfare inequality. Fourth, given the large reductions in housing prices resulting from increases in mixed-use zoning, I simulate a policy that zones for mixed-uses at least 25% of every block group's land area, which would affect 1750 block groups in our data (80%).[31] In Panel D, I present the welfare effects of this policy. In this case, welfare increases by 4.87% for low-skilled and by 0.02% for high-skilled residents, and welfare inequality decreases. For the latter group, changes in sorting and in RMA contribute negatively to their welfare, but this effect is compensated almost perfectly by lower housing prices and larger rents from land. For low-skilled residents, most of their welfare gains comes from changes in sorting.

These results suggest three important conclusions. First, the current zoning ordinance is a regressive policy that benefits high-skilled residents more. Second, LUR can be modified to reduce welfare inequality between types of residents. In particular, the four simulated policies yielded similar welfare changes and a similar reduction in welfare inequality. Third, transfers from the rents of land play an important role determining welfare gains, especially for high-skilled residents. Specifically, they suggest that if home ownership is non-existent, high-skilled residents could be worse off by any change in LUR, but transfers from the rents of lands compensate their welfare losses coming from the other channels.

[31] On average, 78% of the land of these block groups was zoned for residential uses and 11% for commercial uses. In addition, for this simulation, I assume that the share of residential floor space within each block group's mixed use districts remains constant after the policy change.

7 Conclusions

Land use regulations (LUR) shape the daily life of hundreds of millions of urban dwellers around the world. Local governments use different tools, such as zoning restrictions, floor-to-area ratio limits, lot size restrictions, etc., to regulate the use of land. While there is substantial research on the effects of these tools on housing markets, segregation and other outcomes, less empirical work has been done assessing their general equilibrium effects and their impact on the welfare and welfare inequality between different types of residents.

This paper contributes to the literature by investigating the effects of zoning (permitted uses) and FAR restrictions on a wide range of block group level outcomes, on the welfare of high- and low-skilled people and on welfare inequality. Using detailed geographic data for Cook County and the City of Chicago in 2015-2016, I start by studying the effect of current zoning and FAR restrictions on the real estate market and sorting by skill across block groups. For identification, I use the 1923 Zoning Ordinance, which was the first comprehensive zoning ordinance in Chicago. I find that an increase of 10 percentage points in the share of land designated for mixed-uses, leads to a decrease in housing prices of 5.4%, and a decrease in the share of high-skilled residents in that block group.

Afterwards, I build a quantitative model of a city with two types of workers. The inclusion of individual heterogeneity in the model is important, since zoning is often considered a regressive measure. Thus, the inclusion of two types of residents allows me to study the distributional effects of LUR. In the model, I also include microfoundations of a real estate market, in which developers face zoning and FAR restrictions, and supply residential and commercial floor space. The model allows me to decompose the welfare effect of LUR into four components: changes in housing prices, in amenities, in wages and in the income from land rents.

Together with data and parameter values, this model allows me to recover measures of wages, amenities, productivities and land prices for all locations, and study how regulations affect them. Among other results, I find that more residential zoning and lower FAR limits lead to a decrease in local wages and productivity. However, more residential zoning also leads to a significant increase in local amenities through its effect on the sorting of high-skilled residents.

Counterfactual exercises suggest an important welfare enhancing role of large changes in the current regulations, as well as their role in reducing welfare inequality. In particular, I simulated the welfare effects of four policies. First, a policy that allows more residential zoning in block groups displaying an excess relative demand of residential real estate. Second, a policy that increases the FAR limit by 0.5 in those block groups where the constraint binds the most. Third, a policy that sets a minimum FAR of 1.2 everywhere in Chicago. Fourth, a policy that sets a minimum of 25% of land zoned for mixed-uses in each block group. All of these policies lead to similar welfare improvements of low-skilled residents, and to a decrease in the welfare gap between skill types.

Three conclusions arise from these exercises. First, the current zoning ordinance is a regressive policy from which high-skilled residents benefit more. Second, LUR can be modified to reduce welfare inequality between residents. Third, transfers from the rents of land play an important role determining welfare, especially for high-skilled residents. Specifically, my results suggest that if home ownership was non-existent, high-skilled residents would be worse off with any change in LUR, but transfers from the rents of lands compensate their welfare losses coming from other channels.

Lastly, note that this paper excludes other possible forces affecting sorting and urban development that have been studied in the literature. For instance, I do not consider a wide range of fiscal issues, such as Tiebout sorting, in which small jurisdictions set their own policies strategically (Epple and Sieg, 1999; Parkhomenko, 2020). Moreover, I do not take into account dynamic considerations, which are important in the study of real estate markets, both in the demand and supply sides (Bayer et al., 2016; Murphy, 2018). All of these issues are left for future research.

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A Extra Tables and Figures

Table A1: Average and Median Block Group, 2015-2016

		By Block of Residence				
		Total 30+	<HS	HS	Some Coll	>College
County	Mean	416.3	58.0	96.6	123.6	138.2
	Median	373	51.5	87.5	111.5	117
	Total	1.66m	231k	385k	493k	551k
City	Mean	368.1	57.2	86.1	108.6	116.1
	Median	332	50.5	79.5	98	89.5
	Total	806k	125k	189k	238k	254k
		By Block of Work				
		Total 30+	<HS	HS	Some Coll	>College
County	Mean	466.2	60.4	106.1	138.1	161.6
	Median	89.5	14.5	23	27	24.5
	Total	1.86m	241k	423k	551k	645k
City	Mean	463.4	60.2	102.0	135.3	165.9
	Median	66	12	17	19.5	16.5
	Total	1.02m	132k	224k	296k	363k

Notes: This table shows the number of people by education level in the mean and median block group, by both residential and workplace block groups, in both Cook County and the City of Chicago. Educational attainment categories respectively correspond to less than high school, high school or equivalent, some college or associate degree, bachelor's degree or advanced degree.

Table A2: Distribution of Workers by Earnings and Skill, 2015-2016

		Mean Shares, Block of	
Earnings	Education	Residence	Work
Low	Low	23.43%	30.86%
High	Low	15.62%	10.64%
Low	High	23.70%	32.56%
High	High	37.25%	23.59%

Notes: This table shows the distribution of workers by earnings and skills in the average block group of residence and of work in 2015-2016 given by the LODES data for Cook County.

Table A3: OLS Regressions

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	Ln Price	Ln Stock	Ln Price	Ln Stock	Sh. High Skilled (w)	Sh. Low Skilled (a)	Sh. High Skilled (a)	Sh. High Skilled (w)	Sh. Low Skilled (a)	Sh. High Skilled (a)	Sh. Low Wage Low Sk	High Sk
Type	Residential		Commercial			Residence			Work		Work	
Panel A												
Sh. Res. Only	0.15	1.57***	-0.17	-2.90***	0.05*	0.84***	0.97***	-0.07*	-3.24***	-3.23***	0.45***	0.47***
	(0.17)	(0.53)	(0.21)	(0.60)	(0.03)	(0.13)	(0.14)	(0.04)	(0.31)	(0.32)	(0.10)	(0.09)
Sh. Mixed Uses	0.11	1.31***	-0.42	4.56***	-0.01	0.81***	0.79***	-0.08**	-0.10	-0.27	0.50***	0.49***
	(0.20)	(0.49)	(0.31)	(0.88)	(0.03)	(0.14)	(0.16)	(0.04)	(0.38)	(0.38)	(0.13)	(0.10)
R-squared	0.40	0.99	0.32	0.95	0.96	0.99	0.99	0.89	0.95	0.96	0.99	0.99
Panel B												
Mean FAR	-0.03	0.15***	-0.01	-0.04	0.00	-0.04*	-0.04	0.01	0.27***	0.28***	-0.04***	-0.06***
	(0.03)	(0.05)	(0.05)	(0.13)	(0.00)	(0.02)	(0.02)	(0.01)	(0.06)	(0.06)	(0.01)	(0.02)
R-squared	0.40	0.99	0.32	0.94	0.96	0.99	0.98	0.89	0.95	0.95	0.99	0.99
Observations	1,424	1,421	1,376	1,421	1,423	1,427	1,427	1,389	1,427	1,427	1,389	1,389

Notes: This table shows the results of OLS regressions of different zoning measures on prices and stock in the real estate market (Columns 1-4), on different outcomes regarding the spatial distribution of high- and low-skilled workers within and across block groups of residence (Columns 1-3) and work (4-6), on the log share of low wage workers in both skill categories. The regressions include as control variables the block group's land area, distance to the CBD, to major waterways and transit access. Price measures are quality adjusted (hedonic) and are defined in Section 2.1. Dependent variables are in logs; (w) denotes the share within blocks (e.g., high-skilled as proportion to the block's population); (a) denotes the share across blocks (e.g., high-skilled in a block as proportion of city's total high-skilled). Spatial Heteroscedasticity and Autocorrelation Consistent(SHAC) standard errors in parentheses (Conley, 1999); *** p<0.01, ** p<0.05, * p. <0.1.

Table A4: Descriptive Statistics - Recovered Variables

	Skill	Mean	SD	Min	p50	Max
Residential MA	Low	6,319.8	1,134.2	3,017.5	6,354.4	17,141.6
Firm MA	Low	39.35	5.77	20.60	40.41	125.59
Wages	Low	1.05	0.46	0.00	0.99	5.15
Amenities	Low	1.05	0.32	0.00	1.06	2.44
Residential MA	High	8,566.8	1,603.5	4,117.4	8,629.9	21,861.7
Firm MA	High	54.14	7.43	29.60	54.98	178.4
Wages	High	1.08	0.53	0.00	0.99	6.83
Amenities	High	1.05	0.33	0.00	1.06	2.36
Productivity		10.37	4.56	0.00	9.69	56.07
Land Prices		3,152.4	23,652	0.00	1719.4	1.44m
Shadow Price		2,586.4	13,208	-2.68	1960.2	0.65m

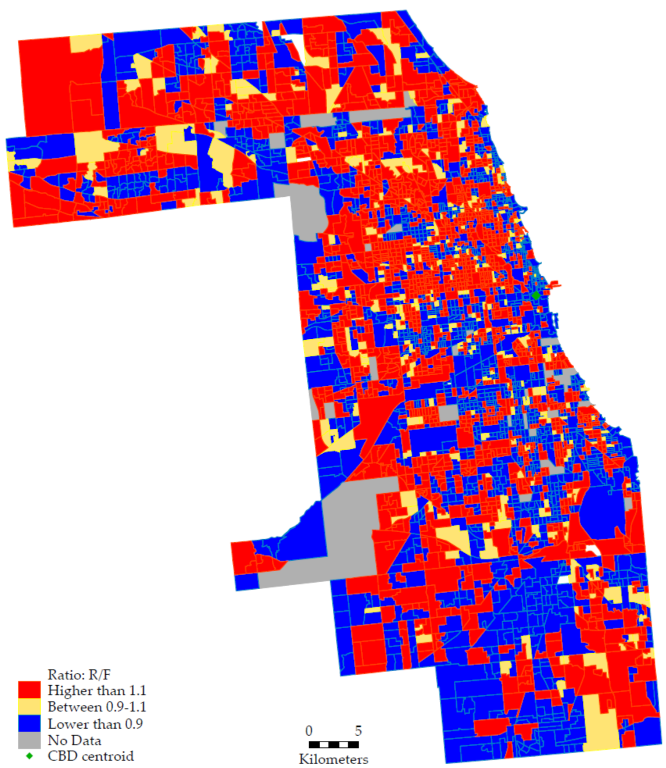
Notes: This table shows descriptive statistics for different variables recovered from the quantitative model using the calibration procedure from Section 5. m indicates millions (1e06).

Table A5: Expected Utility in the City

	(1)	(2)
Welfare Low-Skilled	277.84	178.20
Welfare High-Skilled	290.55	182.41
Relative Welfare	1.046	1.023
Income from Land	YES	NO

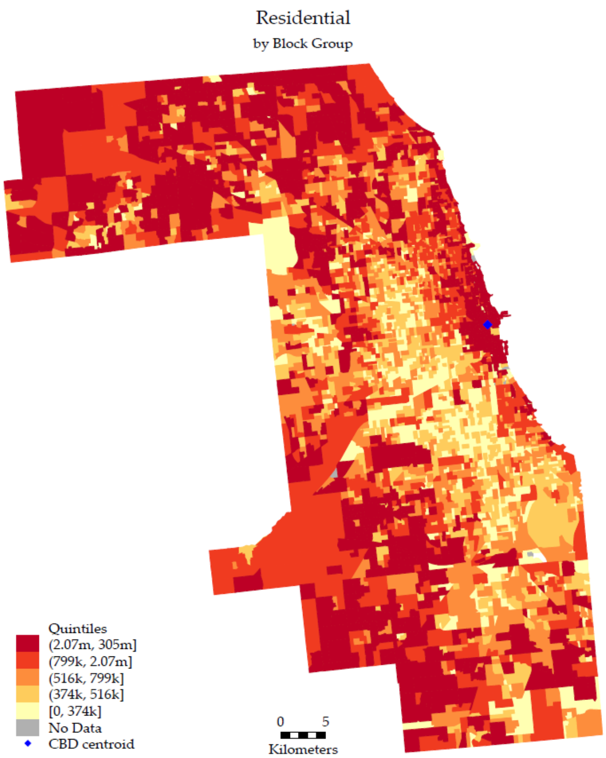
Notes: This table shows the expected utility by skill type in Cook County recovered from the quantitative model from Section 5. Column (1) shows the total expected utility, while Column (2) assumes that residents do not receive any transfer from the rents of land.

Figure A1: Real Estate Price Gap (Residential/Commercial)–Cook County, 2015-2016



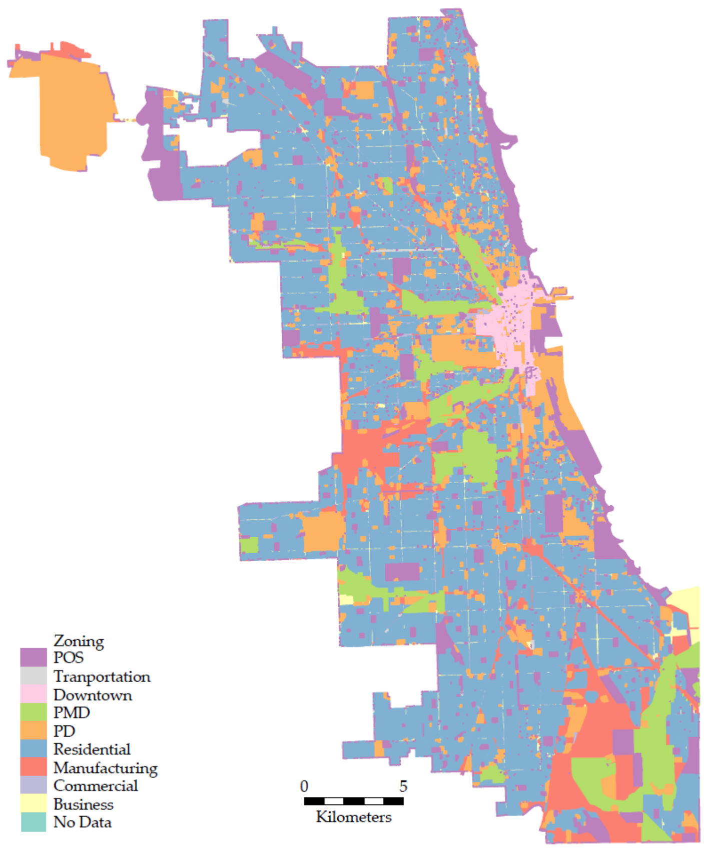
This figure shows the ratio between residential and commercial real estate price indices for every block group in Cook County for the period 2015-2016. These prices are estimated using a hedonic regression approach for both types of properties, separately, and an inverse distance weighted interpolation for those locations without enough observations. Red block groups are those where residential prices are at least 10% higher than commercial prices. Blue block groups are those where commercial prices are at least 10% higher than residential prices. Yellow block groups are those where prices are in the interval between the previous categories. Green dot represents Chicago's CBD.

Figure A2: Total Built Square Footage–Cook County, 2015-2016



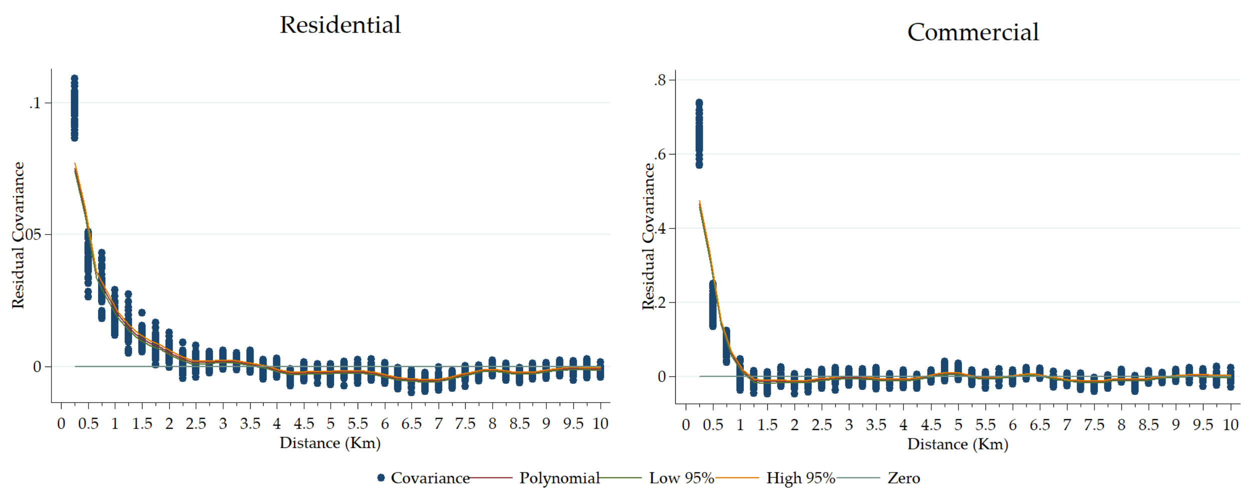
This figure shows the total stock of residential (left) and commercial (right) real estate for every block group in Cook County for the period 2015-2016. The stock is computed as the sum of the built square footage of all properties within type. Blue dot represents Chicago's CBD.

Figure A3: Broad Zoning Designations, 2016



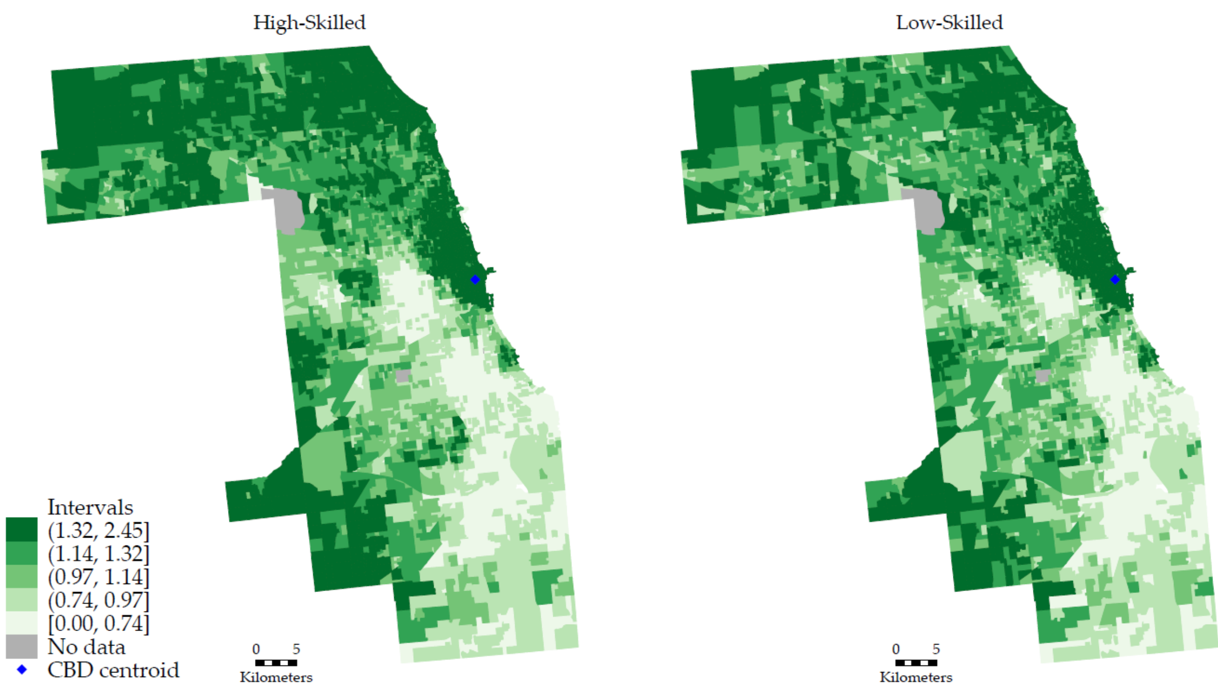
Notes: This figure shows the distribution of the nine zoning classes in the City of Chicago as indicated by the 2016 Zoning Ordinance. POS denotes Parks and Open Spaces. PMD denotes Planned Manufacturing Districts. PD denote Planned Developments.

Figure A4: Spatial Correlation of Real Estate Prices



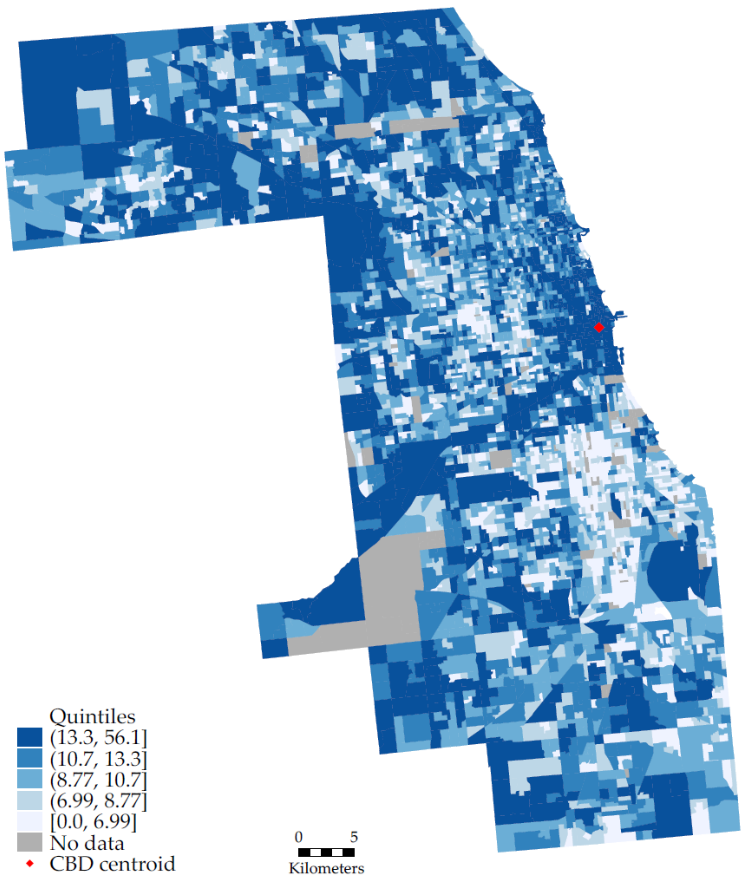
Notes: This figure shows the residual covariance of real estate prices across block groups as a function of their bilateral distance in kilometers. I use residential real estate prices in the left panel and commercial real estate prices in the right panel. This residual covariance is obtained by bootstrapping the spatial correlation between residual real estate prices from regressions of real estate prices on land use regulations, including controls for block group's land area, distance to the CBD and to major waterways, transit access, and historical covariates. Price measures are quality adjusted (hedonic).

Figure A5: Amenities in Cook County, 2015-2016



Notes: This figure shows local residential amenities by skill type for every block group in Cook County for the period 2015-2016. Both variables are recovered using the quantitative model. Blue dot represents Chicago's CBD.

Figure A6: Productivity in Cook County, 2015-2016



Notes: This figure shows local productivity for every block group in Cook County for the period 2015-2016. Productivity is recovered using the quantitative model. Red dot represents Chicago's CBD.