The Incidence of Land Use Regulations

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PRELIMINARY WORK

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 the City of Chicago in 2015-2016, together with a spatial quantitative model with two types of workers and real estate developers who face land use 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% decrease in housing prices, a 15% decrease in wages and a 2.5% increase in amenities. Welfare changes can be decomposed into changes in housing prices, amenities, wages and land rents. I find that more residential and mixed-use zoning lead to welfare improvements for both types of residents, but to an increase in welfare inequality.

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

Keywords: zoning, FAR, skill composition, developers, welfare.

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1 Introduction

Regulations on the use of land are prevalent in almost every city in the modern world,[1] 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. Most of this research follows a reduced form analysis and does not consider the general equilibrium 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. Therefore, it is not possible to study the welfare impacts of LUR without knowing their general equilibrium effects. On the other hand, recent research by Arkolakis et al. (2015) studies general equilibrium and welfare effects of zoning, but does not consider the distributional effects of these policies and do not provide treatment effects.[2]

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% decrease in housing prices, a 14% decrease in high-skilled and a 16% decrease in low-skilled wages and a 2.5% increase in amenities. On the other hand, an equivalent increase in the share of mixed-use designations leads to a lower concentration of high-skilled residents, a larger decrease in housing prices (8.5%), and to increases in wages, particularly for high-skilled workers (8%). Both of these zoning policies lead to increases in welfare, but these gains come from different sources. In particular, most welfare gains brought by residential zoning come from increasing in amenities, while most gains brought by more mixed-use zoning come from reductions in housing prices. These zoning policies also lead to increasing welfare inequality between both types of residents.

These findings highlight the importance of including worker heterogeneity when studying the welfare effects of land use regulations. 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

[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).

[2] Two other papers studying welfare effects of LUR are Cheshire and Sheppard (2002) and Turner et al. (2014). In particular, the latter estimates the effects of LUR on land values and welfare (defined as the sum of land rents and a measure of consumer surplus) using border variation within metropolitan areas across US states.

literature. First, there are significant differences in real wages between high- and low-skilled workers 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 would cause different types of workers to have different location preferences and react differently to changes in LUR.

In order to study these issues, I collect detailed geographic data for the City of Chicago for 2015-2016 from different sources, 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. The real estate data show that residential and commercial prices are significantly different in 95% 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. Furthermore, 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 that control for these characteristics.

Afterward, I present a quantitative model of a city that builds on Ahlfeldt et al. (2015). Contrary to their model and similar to Tsivanidis (2018), I introduce two types of workers: low- and high-skilled, who differ in their income and in the share of it spent in housing. Furthermore, and 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.

Even though the model remains tractable, the effect of LUR on the welfare of both types of workers are not trivial. Therefore, I perform comparative statics that analyze the effects that changes in residential zoning and FAR limits in a particular location have on the welfare of both types of city residents. Total welfare effects of these policies are ambiguous. Specifically, the total effect can be decomposed as the sum of four effects: (i) changes in local housing prices, (ii) changes in local skill-specific amenities, (iii) changes in the income coming from the rents of land, and (iv) changes in wages across nearby locations.

After presenting these theoretical results, I follow the methodology proposed by Ahlfeldt et al. (2015) and Tsivanidis (2018) in order to recover block group measures of wages, amenities and productivity, given observed data and values for the model's parameters. Just as in Ahlfeldt et al. (2015), this mapping is unique regardless of whether the model has a single or multiple equilibria. Afterward, I lay out a solution for the real estate market with land use regulations. The proposed solution lets me recover block group measures of the price of land, the shadow price of FAR regulations and welfare for both types of residents.

Using this calibration strategy, I explore the effect of zoning and FAR restrictions on some recovered unobservables following the instrumental variables approach. With this empirical strategy, 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 16% in the wage of low-skilled workers and of 14% in the wage of high-skilled workers. The effect of a one unit decrease in the FAR allowed limits are 54% and 47%, respectively. These wage decreases are compensated by increases in amenities of around 2.5% and 5% for the respective policies. These policies also have a significantly negative effect on local productivity of 17% and 55%, respectively.

Furthermore, I find positive welfare effects of increasing residential and mixed-use zoning for both types of residents. However, these gains come from different sources. Around 95% of the welfare gains of more residential zoning come from a significant improvement of the amenities associated with this type of zoning, relative to the (dis-)amenities that come with commercial zoning. On the other hand, most welfare gains associated with increases in mixed use zoning come from reduction in housing prices. Finally, increasing FAR limits has a negative impact of welfare due to a decrease in amenities, which more than exceeds the gains from cheaper housing prices and better market access.

Finally, counterfactual exercises suggest an important welfare enhancing role of large changes in the zoning code. 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 more commercial zoning in block groups displaying an excess relative supply of residential real estate. Second, a policy that sets a minimum of land zoned for mixed-uses at 20% in each block group. Third, increasing the FAR limit by one in those blocks where there is a larger social cost of having this restriction. Fourth, setting a minimum FAR of 1.2 everywhere in the city.

All of these policies lead to welfare improvements for both types of people, in particular the second and third counterfactuals. These results suggest an important welfare enhancing role of more mixed-use zoning everywhere in the city and higher density in those neighborhoods with higher demand for housing. However, all of these policies also lead to an increase in welfare inequality between low- and high-skilled workers.

This paper is related to the literature studying the effects of LUR.[3] Theoretically, Helsley and Strange (1995) and Rossi-Hansberg (2004) study some of the welfare effects of different types of land use regulations. Empirically, most of the literature agrees that: i) LUR leads to 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 that ii) it leads to decreases in total welfare, with potentially large distributional impacts (Cheshire and Sheppard, 2002; Turner et al., 2014; Hsieh and Moretti, 2015). Additionally, Saks (2008) shows that places with tighter LUR have larger reductions in long term employment and wages relative to places with more relaxed regulations, when they face a positive housing supply shock. My paper also relates to a series of papers studying zoning in Chicago using 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 in Chicago, zoning has been more important than geography or transportation networks in 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 prices, wages, productivity, amenities and welfare, I study in one single framework the different effects of some of these policies.

This paper is also related to the articles that explore how LUR affects different types of people. In particular, Kahn et al. (2010) and Levine (1999) find that areas with more low density zoning experience more gentrification, which affects mostly minorities and low-income households. On the other hand, Muehlegger and Shoag (2015) suggest that tighter LUR are associated with increases in commuting time, especially for more educated and wealthier individuals. Additionally, Ganong and Shoag (2017) show that stringent LUR in productive cities has caused the returns to living in these cities (net of housing costs) to fall for low-skilled workers but to remain constant for high-skilled workers. These changes have lead to 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, this paper contributes to the debate on whether zoning is a regressive measure, that is, whether it benefits high-skilled people more than low-skilled people.

Furthermore, my paper is part of a recent literature using quantitative models of urban economics such as Ahlfeldt et al. (2015); Arkolakis et al. (2015); Tsivanidis (2018); Baum-Snow and

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

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 (2018), 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. This model allows me to incorporate LUR and study their general equilibrium effects. Third, even though Arkolakis et al. (2015) estimates block specific elasticities of welfare with respect to changes in zoning, they do not analyze the underlying mechanisms leading to such changes. As mentioned earlier, I decompose these welfare effects in changes in rent, wages, amenities and income from land.

Finally, given my analysis of the distribution of jobs and different types of workers within the city, this paper also contributes to the literature on the spatial mismatch hypothesis (Kain, 1968; Gobillon et al., 2007).[4] Recent research has found an inversion in the spatial mismatch patterns: A centralization of jobs but a suburbanization of the low income population (Baum-Snow and Hartley, 2019; Couture and Handbury, 2017; Ehrenhalt, 2012). I contribute to this literature by studying the role of LUR on the spatial mismatch between jobs and residential locations.

The paper proceeds as follows. In Section 2, I describe my data sources. In Section 3, I briefly discuss the 1923 Zoning Ordinance. I this section, I also present facts about the relationship between land use regulations, real estate prices and the distribution of high- and low-skilled workers within Chicago. Section 4 presents the theoretical model and analyze the comparative statics of changing zoning and FAR restrictions. Section 5 exploits the recursive structure of the model in order to show what variables can be recovered, 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 Section 7, I present the effects of LUR on the welfare of both types of people, and the results of the welfare decomposition and the counterfactual exercises. 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 block groups of residence and work, I combine data from four 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 and assessment records for the United States. The LODES and Zillow data are available for any city in the country. However, 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

[4]The spatial mismatch hypothesis refers to the mismatch between the locations of jobs and workers (Kain, 1968).

city boundaries. 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 some descriptive statistics.

2.1 Real Estate Prices

I build measures of real estate prices and stocks for each block group using data from Zillow Economic Research.[5] The Zillow ZTRAX data sets contains real estate transactions for around 3,000 counties in the United States. It is constructed from information in local deed transfers and mortgages for mostly residential properties, but also includes some commercial properties in the more recent years and in larger metropolitan areas.(Zillow, 2017).[6] Among other variables, these data include sales price, transaction date, geographic coordinates and type of property. I merge this dataset with other registers containing the most current and historical assessments for each property. Zillow collects property characteristics, geographic information, current and prior valuations for approximately 150 million parcels in more than 3,000 counties.[7]

I use their ZTRAX transactions and assessment data to build quality-adjusted residential and commercial real estate price indices for each census block group in Cook County in the period 2015-2016. I calculate these indices using a hedonic approach.[8] 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 homes that reported more than 10 transactions between 2009 and 2016, and census block groups with fewer than 5 transactions.

After imposing these restrictions, I run a hedonic regression of the log sales price of a property ($ln(P_{him,T})$) on its characteristics ($X_{him,T}$) and census block group fixed effects ($ln(r_{Ti})$):

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

where h denotes a property of type T (residential R or commercial F) in a census block group i that was sold in month m. I run this regression for residential and commercial transactions separately.

[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.

[6] 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.

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

[8] Alternatively, I could use a repeated sales approach. However, since data for commercial transactions are only available in the latter years (2014 to 2016), it is not possible to compute such an index for commercial real estate.

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). Month of sale fixed effects δ_m account for seasonality in the real-estate market. Block group fixed effect capture the average quality-adjusted log price of a type T properties in the block group. The hedonic residential price index (r_{Ri}) covers around 95% of the all block groups in my sample in the period 2015-2016, while the commercial price index (r_{Fi}) has a coverage of 43%. To overcome this low coverage, for those block groups with a missing commercial price index, I impute the value using the mean within the block group's census tract. This imputation raises the coverage of the commercial price index to 77%.

Since block group fixed effects are identified up to scale, I normalize their geometric mean to 1 in order to be consistent with the normalization that will be imposed in Section 5. Figure 1 presents the distribution of real estate prices across block groups in the City of Chicago. As can be seen in the left panel, the most expensive residential real estate in Chicago 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. On average, commercial real estate prices are higher than residential prices, as well as their dispersion and skewness.

Table 1 presents descriptive statistics for these indices. Note than the mean and standard deviation of commercial prices are higher than for residential prices, but the median is lower. These statistics suggest that the distribution of commercial real estate prices is significantly more skewed, with 5% of the block groups having commercial real estate more expensive than any block group's residential real estate. However, as Column (3) indicates, on average residential real estate is more expensive than commercial real estate in most city blocks (exactly 67%). Moreover, only for 5% of the block groups the gap lies between 0.9 and 1.1, and commercial is more expensive in 29% of them. The existence of these price gaps is interesting from a theoretical perspective since standard 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 of inefficiencies in the real estate market. In particular, they could suggest an excess supply of commercial real estate in some locations relative to residential real estate, and a potential role for land use regulations in allowing the construction of more housing. Figure A1 shows the geographic distribution of such gaps.

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

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

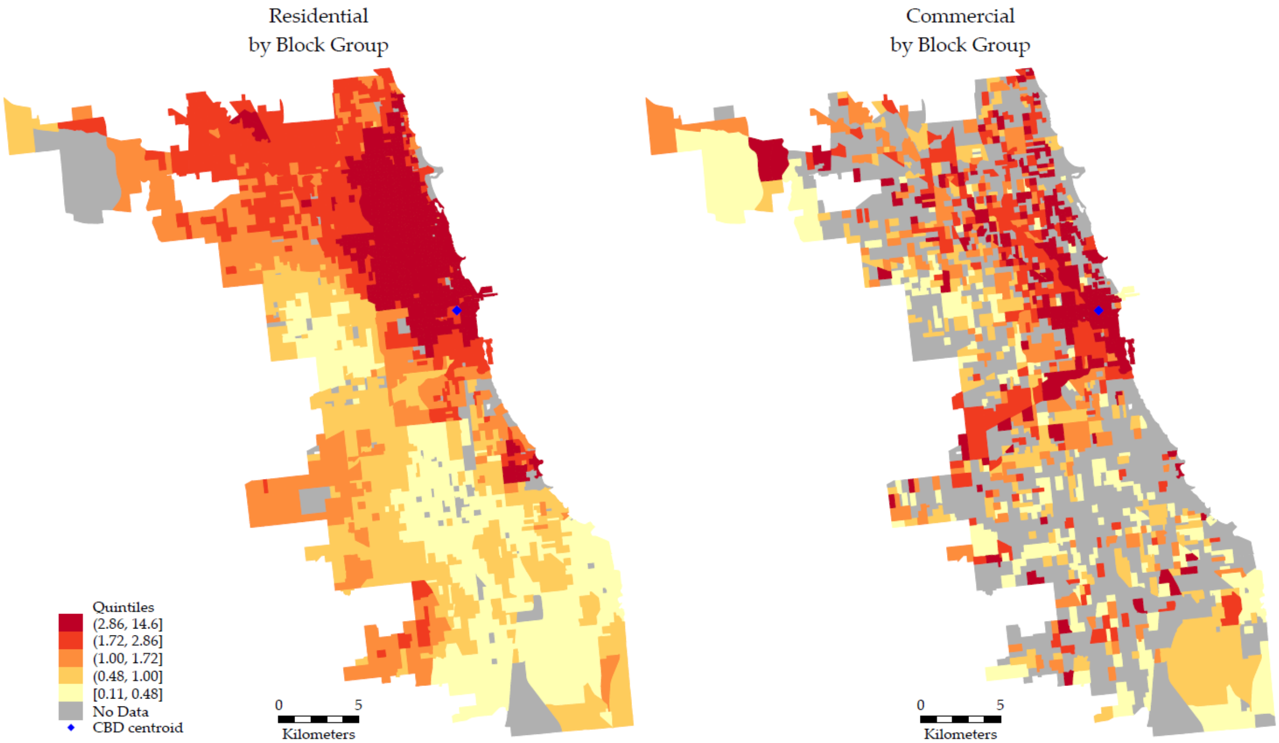


Table 1: Real Estate Hedonic Price Indices, 2015-2016

	(1) Residential	(2) Commercial	(3) Ratio R/C
N. Block Groups	2,067	1,684	1,630
Mean	1.47	2.68	1.84
Std. Dev.	1.28	6.19	3.00
Min	0.09	0.01	0.02
Median	1.14	0.95	1.20
Max	12.16	75.83	58.94
Corr with Res HI	1.0	0.42	
Corr with Com HI	0.42	1.0	

This table shows descriptive statistics for the residential and commercial hedonic price indices and the price ratio between them. Indices have been normalized to have a geometric mean of 1. The table also reports the correlation of these measures with one another and the median price in the block group.

2.2 Land Use Regulations

The Data Portal of the City of Chicago contains a geographic database of all the zoning districts within city boundaries. These data contain coordinates and specific zone class categories for 2012 and 2016. The detailed specifications of each zone class are available in the Chicago Zoning and Land Use Ordinances (City of Chicago, 2019). 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. In total, there are 66 zone classes, 15 Planned Manufacturing Developments (PMD) and more than a thousand Planned Developments (PD) throughout the city.[9]

Out of the total land area in the City, around 52% is currently categorized as residential (R), while manufacturing (M), commercial (C) and business (B) districts take approximately 11%, 3% and 6% of the total area, respectively. Locations categorized as downtown districts (D) take about 1% of the area.[10] PMD and PD cover 6% and 11%, respectively. Assuming that floor area equals land area times the allowed floor-to-area ratio, these shares correspond to 28% of the total floor area for residential, 15% for manufacturing, 4% for commercial, 8% for business, 6% for downtown, 12% for PMD and 24% for PD. The differences between these two sets of shares indicate that every district type has a relatively high allowed density relative to residential districts. I categorize all districts into three categories: those designated for residential purposes only (R and DR), those for commercial only (M, PMD, DS and some C and B) and those with mixed-uses (some B, C, DC and DX), and ignore Parks and Transportation districts. I also categorized each Planned Development into each one of these categories based on their type.[11]

The left panel of Figure 2 presents 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 the areas of mixed use. The right panel of Figure 2 presents the maximum FAR allowed for each zoning district in the city. The map shows a clear sorting pattern of allowed heights: high density (red and pink) is allowed mostly in the downtown area and in some parts along the coast; medium density (greens) is allowed in almost every location along the coast of Lake Michigan and in most of the areas where only firms are allowed; low density (blues) is allowed in the rest of the city. In particular, comparing both maps there seems to be a high correlation between the blocks where only residential uses and low density developments are allowed. Figure A3 presents a map

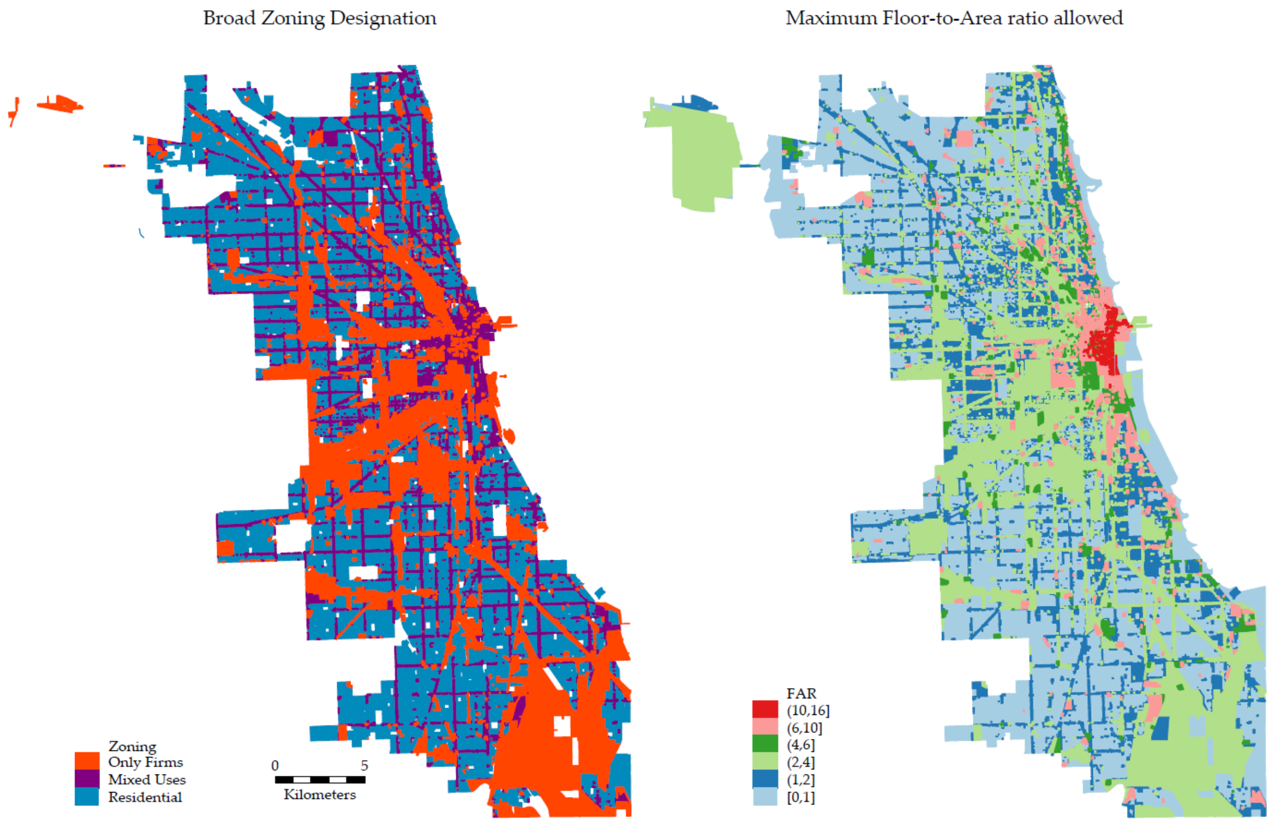
[9] Planned Developments correspond to tall buildings and other large developments in which developers must work with the City to ensure that the project integrates with surrounding neighborhoods (2nd City Zoning, nd).

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

[11] The City of Chicago keeps pdf files for each one of the Planned Developments in https://gisapps.chicago.gov/gisimages/zoning˙pds. PD include uses ranging from Airports (A) and Spectator Sports (S), to mixed used developments (BR) or waterway residential developments (WR). The complete list of types is available on request.

of the distribution of the 9 broad zoning designations.

Figure 2: Zoning in Chicago



Using the information contained in these maps, I build measures of the share of land area and the share of floor space designated for residential, mixed-uses or commercial purposes, and the average allowed floor-to-area ratio in each block group. I also build a measure of the share of residential space allowed in each zoning district using the allowed FAR (as an approximation for the permitted number of floors), together with details inside the Ordinance regarding the number of residential stories allowed in each zoning district. I denote this measure as λ. For example, **B3-3** zoning districts have an allowed FAR ratio 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 $\lambda = 2/3$. This measure will be particularly useful in the calibration of the model in order to capture the share of floor space in mixed-use districts that can be used for residential purposes.[12] I also take the mean of this measure at the block group level. The coefficient of correlation between this measure and (i) the share of land zoned for residential purposes only is 0.70, (ii) the share of land zoned for mixed-uses

[12]For residential-only districts, $\lambda = 1$. For commercial-only districts, $\lambda = 0$. For Planned Developments, I assumed $\lambda = 0.8$ for those categorized as mixed-used (e.g., business residential).

is 0.74, (iii) the allowed FAR is -0.19; these coefficients are significantly different from zero at the 99% confidence level.

In Table 2, I present descriptive statistics of the different measures of zoning across block groups. The table shows that the average block group has 73% of its land zoned for residential purposes only, 10% for commercial purposes only and 17% for mixed-uses. The average allowed floor-to-area ratio is 1.8. Furthermore, out of the 17% of the land that is zoned for mixed-uses, around 77% of it can be used for residential purposes. Compared to the average, the median block group is even more residential and has a lower allowed density. 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	0.73	0.24	0	0.64	0.80	0.90	1
Sh. Mixed Uses	0.17	0.18	0	0.06	0.13	0.23	1
Sh. Firm Only	0.10	0.19	0	0	0	0.10	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

This table shows descriptive statistics for different measures of land use regulations across block groups for Chicago 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 distinct use-districts and the five volume-districts used in this ordinance. I provide further details on 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).[13] 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. In particular, Shertzer et al. (2016a) present evidence showing that neighborhood characteristics such as existing land uses, race and immigrant composition, impacted the design of the initial zoning ordinance. When aggregated to the block group level, this information is available for around 67% of the block groups within Chicago.

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

[13]This material is available at https://www.aeaweb.org/articles?id=10.1257/app.20140430.

(LODES) for 2015 and 2016. The LODES data is built from administrative records, census and survey data. In particular, information about the location of jobs and residences are provided by state unemployment insurance records and federal worker earning records. These data contain counts for the total number of people living and working (stocks) in each census block. This information can be further split by age category, monthly wage categories, economic sector, race, gender and educational attainment. The LODES database also contains the number of commuters between every pair of blocks (flows), but this information can only be separated by age and monthly income categories. Furthermore, I complement this data with bilateral travel times between block group pairs using the routine developed by Huber and Rust (2016).

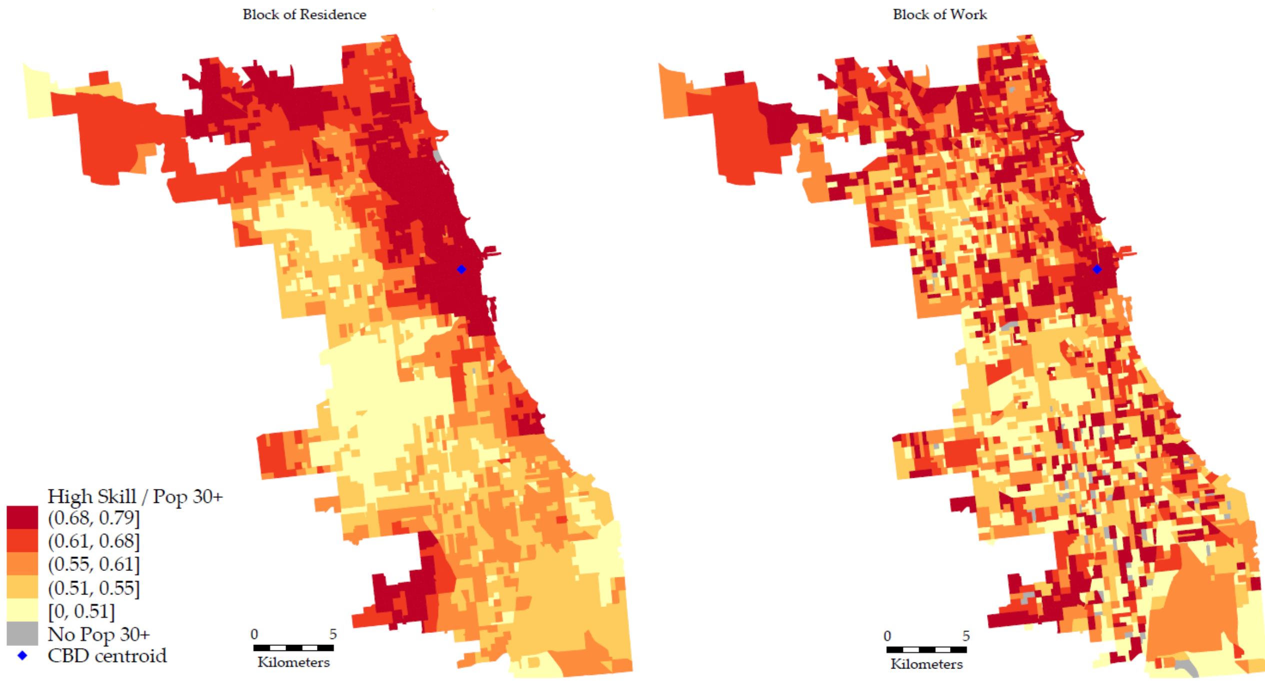
Out of the total working population of age 30 or older in Chicago in 2015-2016, 16% had less than a high school degree, 23% had a high school degree only, 30% had a college or an associate degree, and 32% had a bachelors or an advanced degree. I categorize as low-skilled those workers within the first two categories. Table A1 presents the number of residents and workers by education category in the mean and median block group. The table shows that the average block group of residence in the city has less people than the average block of work, while this pattern changes when looking at the median block. These numbers imply that, even though the distributions of population across block groups of residence and work are both highly skewed, this is particularly true for workplace locations. Moreover, this skweness comes from a relatively high concentration of high-skilled workers into some some block groups (both of work and residence). Figure 3 maps the share of high-skilled workers for every block group in the city by block group of residence (left) and of work (right). The maps show high centralization of high-skilled residents and workers, especially in the downtown area and in the northern part of the city along the coast. On the other hand, low-skilled residents seem to be concentrated in the south and west ends of the city.[14]

The LODES data also contains for each block the number of residents and workers in each educational category for three different earnings categories: $1250/month or less, $1251/month to $3333/month, and greater than $3333/month. I pooled the first two categories as the low wage category.[15] Using these counts, I calculate the share of low-wage workers in each skill category. Approximately one third of residents in Chicago fall into the high-skilled high-wage category, while one fourth lies into the low-skilled low-wage category. Table A2 shows the unconditional distribution of workers by earnings and skills in the average block group of residence and of work. Supplementary regressions show that the share of high-wage residents and workers is higher in block groups closer to the city's CBD relative to those farther away.

[14] This centralization is confirmed with regressions of the share of high-skilled residents or workers as function of the distance of the block group to the CBD. Such regressions indicate that the share of high-skilled residents and workers decreases with the distance of the block group to the CBD.

[15] 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.

Figure 3: Distribution of Skills, 2015-2016



3 Land Use Regulations, Prices and the Distribution of Skills

In this section, I explore the effect of zoning and FAR restrictions on the distribution of real estate prices, wages and people by skill across block groups inside Chicago. Real estate prices and wages are relevant 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 a higher spatial concentration of residents or workers, respectively Bayer et al. (2007); Diamond (2016). Moreover, if each block group is considered to be a small opened economy, the spatial concentration of residents within certain block groups could be a rough measure of local welfare. In order to tackle some of the endogeneity issues present in current zoning regulations, I use the 1923 Chicago Zoning Ordinance. 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 to happen 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). 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 using an instrumental variables approach. In particular, I instrument current zoning measures using the 1923 Chicago zoning ordinance. This ordinance 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 city 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 both allowed uses and building volumes (Shertzer et al., 2018). This ordinance included four use districts: single-family residential, multi-family residential, commercial and manufacturing.[16] It also included five volume districts imposing restrictions on height and lot coverage. Figure 4 shows the location of the four use and the five volume districts. Relevant for this paper, Shertzer et al. (2018) show that zoning in 1923 is a good predictor of current zoning designations.

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

$$Zoning_i = \pi Z_i + \psi X_i + \epsilon_i \tag{1}$$

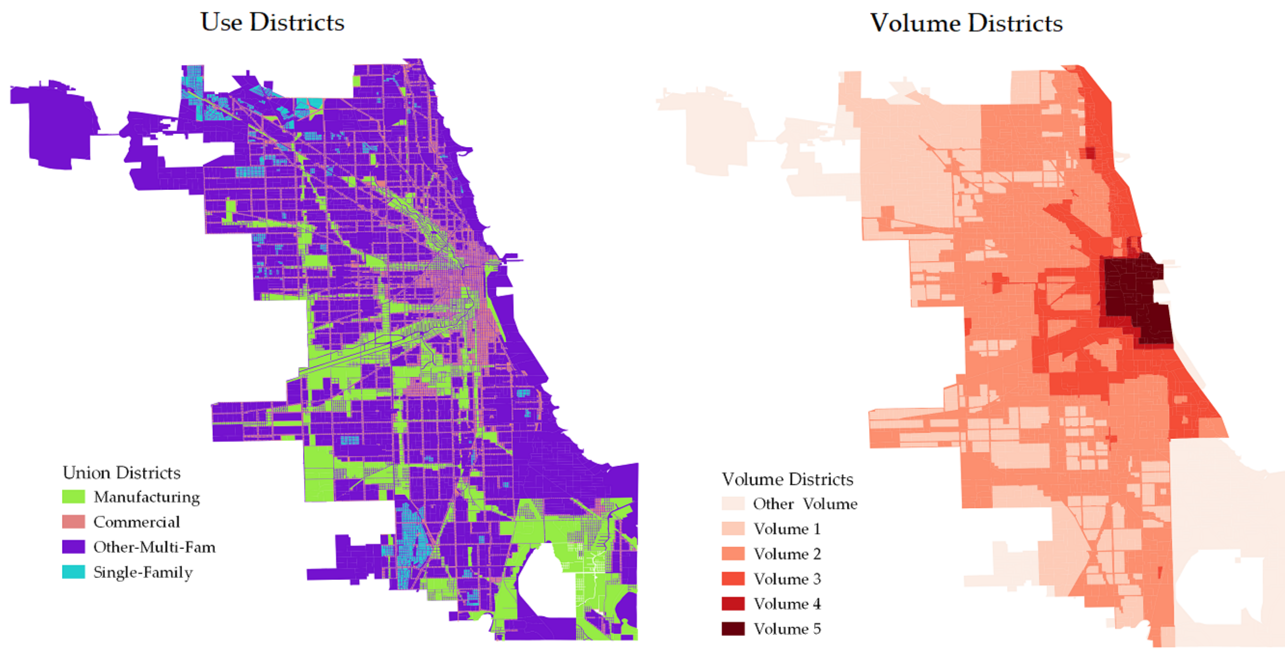
where $Zoning_i$ corresponds to one of our measures of LUR at the block group level in 2016 presented in Table 2; Z_i is a vector that includes the 1923 shares of land designated as manufacturing and commercial (single- and multi-family residential are the omitted categories), and as volume 1, 2 and 3 (volumes 4 and 5 are the omitted categories); X_i is a vector of control variables, which includes total land area in the block group, interactions between distance to the CBD and the closest waterway,[17], 1927-wards fixed effects, and a set of neighboorhood demographic and land use characteristics in 1922.[18] These historical controls also allow me to control for different covariates

[16] These districts were hierarchical, which means that multi-family districts allowed single-family residences, commercial districts allowed multi- and single-family residences, and manufacturing districts allowed any use.

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

[18] I use the same set of controls as Shertzer et al. (2016a) and Shertzer et al. (2018), which are presented in the supplementary material of the former. 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.

Figure 4: 1923 Chicago Zoning Ordinance



affecting the spatial structure in the 1920s. Moreover, this set of controls and fixed effects imply that I am comparing highly similar block groups inside these wards, thus, I am using rather local variation in order to identify the causal effects of zoning. Finally, ϵ_i corresponds to the error term. All of the regressions include spatial heteroscedasticity and autocorrelation consistent (SHAC) standard errors (Conley, 1999).[19]

The results from equation (1) are presented in Table 3. Columns (1)-(2) use the share of land where only residences or mixed uses are allowed, respectively. The share of land where only commercial activity is allowed is the omitted category. Results from these columns are similar to those from Table A.4 in Shertzer et al. (2018): block groups that received more manufacturing and/or commercial zoning in 1923 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 also more likely to have a higher share of land zoned for mixed-uses. Column (5) uses the average allowed FAR ratio as the LUR variable of interest. Results show that block groups that had high share of land area zoned for commercial and manufacturing uses in 1923 are more likely to have high allowed FAR in the present. In terms of volume districts, larger shares of low volume districts in 1923 are positively correlated with lower FAR limits in 2016, relative to blocks with higher-volume districts.

[19]Specifically, I use the Stata routine developed by Hsiang (2010) with a linear Bartlett window and setting the distance cutoff of the spatial kernel to 500m, similar to Ahlfeldt et al. (2015).

Columns (3) and (4) present the results using as dependent variables the share of floor space (calculated as land area times FAR) where only residences or mixed uses are allowed, respectively. Analogous to estimates from Columns (1) and (2), these regressions suggest that block groups that received more manufacturing and/or commercial zoning in 1923 are significantly less likely to have floor space zoned for residential-only purposes in 2016. Finally, Column (6) uses the maximum share of residential space allowed in a block group, as described in Section 2.2. This regression suggests that a larger share of land designated as commercial, manufacturing or in low volume districts (relative to residential and high volume districts, respectively) is correlated with a lower 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 Res. (Land)	(2) Sh. Mixed (Land)	(3) Sh. Only Res. (Floor)	(4) Sh. Mixed (Floor)	(5) Mean FAR	(6) Sh. Res Allowed
Share Comm.	-0.36***	0.41***	-0.44***	0.47***	0.56***	-0.17***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Share Manuf.	-0.46***	0.03***	-0.46***	-0.02***	1.12***	-0.49***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Share Vol. 1	-0.15***	0.09***	-0.22***	0.18***	-1.88***	-0.10***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Share Vol. 2	-0.17***	0.10***	-0.27***	0.20***	-1.62***	-0.13***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Share Vol. 3	-0.15***	0.06***	-0.20***	0.12***	-1.04***	-0.13***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
R-squared	0.96	0.80	0.92	0.79	0.93	0.97

This table shows the results of regressions of 2016 measures of land use regulations as function of the share of allowed uses given by the 1923 Chicago Zoning Ordinance in each block group. 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. (3)-(4) correspond to the share of floor space in districts where only residences or mixed uses are allowed, respectively. (5) corresponds to the mean FAR. (6) 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 1,435. 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

I now explore the effects of current zoning regulations on the real estate market. I investigate these effects using two different measures of zoning: (i) the share of land area in residential-only, mixed uses and firm-only designations (Columns 1-2 from Table 3), and (ii) the mean floor-to-area ratio

(Column 5). In particular, I run the following regressions:

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

where $ln(r_{Ti})$ corresponds to the quality-adjusted price indices for type T properties (residential or commercial) in block group i, from equation (1); $Zoning_i$ 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.

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 residential space or lower densities in order to keep their housing values up (Fischel, 2001; Ortalo-Magné and Prat, 2014). This intuition is confirmed in Table A3, where I run the OLS regressions without using the instrumental variables or the historical controls. These regressions show a positive but non-significant relationship between zoning and FAR and real estate prices. Therefore, I estimate equation (2) using two-stage least squares (2SLS), where the first stages are given by equation (1) and Table 3. Identification under this strategy requires that historical zoning regulations can only affect real estate prices through their impact on current zoning regulations, once controlling for this large set of historical controls and ward fixed effects. These 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 geographic characteristics, but that differed in 2016 zoning characteristics.

Table 4 presents the results of these regressions. Panel A uses the share of land designated for residential, mixed- and firm uses (as the omitted category) as the measures of LUR. Estimates suggest that block groups with a larger share of area designated as residential-only, relative to block groups with more commercial-only area, have lower residential prices and less built area. In particular, an increase of 10 percentage points in the share of residential only area (e.g., going from the median to the 75th percentile block group) leads to a small but significant decrease of around 1% in the average price of both residential and commercial properties, relative to block groups with more commercial zoning. For a similar increase in the share of mixed-uses zoning, the reduction of housing prices would be of around 8.5%. Additionally, this higher share of mixed-use designations has a positive effect on commercial real estate prices of 6%.[20]

Panel B shows that an increase of one unit in the mean allowed FAR would lead to a decrease of 1% in the average price for residential real estate, but could lead to a 19% increase in the price for commercial real estate. The weak effect of a higher FAR on housing prices can be driven by the sum of two effects. On one hand, higher buildings provide more space (as indicated by Column 2), thus pushing prices down. On the other hand, taller buildings lead to higher densities, which could lead to a larger provision of amenities and a higher price for residential units. The positive

[20]These marginal effects are computed as $e^{\hat{\beta}} - 1$.

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	-0.08***	-0.02***	-0.10***	-3.93***
	(0.00)	(0.00)	(0.00)	(0.00)
Sh. Mixed Uses	-0.89***	-0.12***	0.59***	2.33***
	(0.00)	(0.00)	(0.00)	(0.00)
F-Test	15.09	13.67	11.34	11.78
Panel B				
Mean FAR	-0.01***	0.25***	0.19***	1.17***
	(0.00)	(0.00)	(0.00)	(0.00)
F-Test	18.55	19.13	16.39	15.87
Observations	1,346	1,423	1,114	1,329

This table shows the results of 2SLS regressions of the effects of different zoning measures on prices and stock in the real estate market, using the 1923 zoning ordinance as instrument and controlling for block group's land area, distance to the CBD and to major waterways, 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.

effect for commercial properties could be driven by an increase in agglomeration economies that are brought by a higher density of workers and businesses.

3.3 LUR and the Spatial Distribution of Skills

I explore the effects of current land use regulations on the distribution of high- and low-skilled workers–within and across block groups–by running the following regressions:

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

where $Skills_i$ denotes one of the measures of skill composition of a block group i (either of residence or work): (i) the share of high-skilled people inside the block group ($h_i/(h_i + l_i)$), (ii) the number of high-skilled people in the block group relative to every other block group in the city ($h_i/\sum_j h_j$), and (iii) the number of low-skilled people in a block group relative to every other block group in the city ($l_i/\sum_j l_j$). The first measure captures the skill composition of a given block group, while the latter two capture the spatial concentration of a particular skill inside a block group.

Table 5 presents the results of these regressions using block groups of residence in Columns (1)-(3) and block groups of work in Columns (4)-(6). Notice from Column (1) in Panel A that a higher share of residential-only zoning leads to a a higher share of high-skilled residents, relative to those block groups with more firm-only designations. The effect is small but significant: 0.1% for a 10pp increase in the share of residential zoning. Columns (2) and (3) suggest that more residential zoning also leads to a higher concentration of high- and low-skilled 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, leads to a decrease of 0.9% in the share of high-skilled residents. Column (2) suggests that this change in skill composition is coming from an increase of 2% in the spatial concentration of low-skilled residents inside the block group. Regarding workplaces, Column (4) shows that increases in mixed-use zoning lead to increases in the relative 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 an increase of 1% in the concentration of high-skilled residents in the block group. However, it also leads to a spatial decentralization of residents. This puzzling result could come from the fact that higher allowed FAR could be associated with more mixed-use or commercial zoning, relative to residential. This can be seen in Columns (5) and (6) which show that, a higher allowed FAR leads to an increase in the spatial concentration of workers of both types of skill. In particular, a one unit increase of the allowed FAR leads to an increase in the relative spatial concentration of high-skilled workers of 76%, and an increase of 83% for low-skilled workers.

Not controlling for the endogeneity of land use regulations could also lead to biased coefficients in this relationship. For example, blocks with a higher share of high-skilled and high-income residents could lobby for more residential space. On the other hand, the high demand for residential and commercial space in some parts of the city, could result in a higher share of mixed-use districts and allowed FAR. These forces could be biasing upward the coefficients. Columns (5)-(10) from Table A3 confirms this intuition.

3.4 LUR and the Spatial Distribution of Wages

Finally, I investigate the effects of current LUR on the distribution of wages for both high- and low-skilled workers with the following regressions:

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

where $ShLowWage_{e,i}$ denotes the share of low wage workers in a given skill group e in a block group i. These regressions are from a workplace perspective since it gives a more direct relationship between zoning and the wages payed by firms. Table 6 presents the results of these regressions for low-skilled (Column 1) and high-skilled workers (Column 2).

Results from Panel A suggest that block groups with a higher share of area zoned for residential

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	0.01***	0.53***	0.56***	0.08***	-2.62***	-2.27***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Sh. Mixed Uses	-0.09***	0.21***	0.01***	-0.01***	1.30***	1.26***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
F-Test	12.14	12.14	12.14	12.42	12.30	12.42
Panel B						
Mean FAR	0.01***	-0.08***	-0.06***	-0.03***	0.83***	0.76***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
F-Test	19.14	19.14	19.14	21.08	20.50	21.08
Observations	1,431	1,431	1,431	1,397	1,397	1,397

This table shows the results of 2SLS regressions of the effects of different zoning measures 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), using the 1923 zoning ordinance as instrument and controlling for block group's land area, distance to the CBD and to major waterways, 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 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.

or for mixed-uses have a higher share of low-wage workers in those block groups for both skill types. In particular, a 10pp increase in the share of residential zoning leads to an increase in the share of low-wage workers of 3.8% for low-skilled, and 5.2% for high-skilled. For a 10pp increase in the share of mixed-uses, the increase are of 3.9% and 2.1%, respectively. Recall from Table 4 that a higher share of mixed-use designations also leads to higher commercial real estate prices. These results could suggest that since firms face higher floor state prices as the result of less commercial zoning, they adjust by offering lower wages. Similarly, results from Panel B suggests that tighter FAR limits lead to a higher share of low-wage workers, regardless of their skill level: 9% increase for low-skilled and 18% increase for high-skilled after a one unit decrease in the allowed FAR. Alternatively, firms that offer lower wages (e.g., less productive firms) could be more likely to locate in more residential areas, while firms that offer higher wages more likely to locate in places where taller buildings are allowed. Further analysis of the effect of LUR on wages is done in Section 6 using a model-recovered measure of wages.

Table 6: Effects of LUR on Wages

	(1)	(2)
	Sh. Low Wage	
Skill Cat.	Low	High
Panel A		
Sh. Res. Only	0.37***	0.51***
	(0.00)	(0.00)
Sh. Mixed Uses	0.38***	0.21***
	(0.00)	(0.00)
F-Test	12.30	12.42
Panel B		
Mean FAR	-0.09***	-0.18***
	(0.00)	(0.00)
F-Test	20.50	21.08
Observations	1,397	1,397

This table shows the results of 2SLS regressions of the effects of different zoning measures on the log share of low wage workers in both skill categories, using the 1923 zoning ordinance as instruments and controlling for the block group's land area, distance to the CBD and major waterways, and historical covariates. Spatial Heteroscedasticity and Autocorrelation Consistent (SHAC) standard errors in parentheses (Conley, 1999); *** p<0.01, ** p<0.05, * p. <0.1.

4 A Quantitative Model of a City

The empirical results presented in Section 3 suggest that block groups with more residential and higher FAR limits tend to have lower housing prices and a higher share of high-skilled residents. On the other hand, block groups with a relatively higher share of land zoned for mixed-uses will also have cheaper housing prices, but a higher share and spatial concentration of low-skilled workers. Furthermore, more residential zoning and lower FAR limits seem to have a significant negative effect on wages in a given location. 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 to study the effect of zoning in other unobserved outcomes such as amenities, productivities and land prices. Furthermore, it will show how to combine these effects in order to study the incidence of LUR on the welfare of high- and low-skilled people.

In this model, individuals choose where to live and work and how much goods and floor space to consume. Workers are either high- or low-skilled. Both types differ in the fraction of their income spent on housing and their total income (wages plus transfers received from land rents). Firms choose the number of each type of workers and amount of floor space for production. This part of the model builds mainly on the model developed by Ahlfeldt et al. (2015), but also draws some elements from Diamond (2016) and Tsivanidis (2018). As a contribution to the literature, I add microfoundations for the real estate market. In particular, I model real estate developers who face land use regulations and, subject to them, use land and capital to provide floor space.

Start by considering 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 and residential amenities. I assume that these characteristics are exogenous, but I discuss what happens when there are endogenous agglomeration economies. Block groups also differ in terms of their access to the rest of the city. Finally, 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), which have a fixed total population of N_s and N_u, respectively. Both types receive income from their labor and from land rents 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:

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

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

where B_{ei} denotes skilled-specific amenities at the place of residence and reflects the average preference of living in i by type e residents; h_{Rio} and c_{io} represent the amount of residential floor space (housing) and final good demanded by worker o living in block i. Commuting costs act as a dispersion force, reducing the productivity 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.

Note that the Cobb-Douglas parameter is indexed by skill type. In particular, 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 workers (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; 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) representing the payments received by households from the rents of land. These transfers are aggregates that do not vary across space (contrary to wages), and are the same for all residents, conditional on their skill type. In particular, I assume that these payments are larger for high-skilled residents ($\varphi_s > \varphi_u$).[21] The sum of these payments across all workers must equal the 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 of this problem 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. Solving the problem by backward induction, consider first the workplace location problem for type e residents from a location i, who 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 implying a lower degree of unobserved heterogeneity. With these draws, workers 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 worker of working in location j conditional on living in i:

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

Since there is a continuum of agents, by the law of large numbers this probability also corresponds to the number of type e individuals residing in location i and working in location j (N_{eij}) relative to the total type-e workers living in location i (N_{Rei}). Intuitively, this probability depends positively on the wage firms offer in that location net of commuting costs, relative to all other locations. Differences in the dispersion parameter θ_e between high- and low-skilled workers determine the difference in the incidence of commuting costs across skill groups. In addition, RMA_{ei} denotes the residential market access of block i by 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, and is described in greater detail in Tsivanidis (2018).

Before productivity shocks are revealed, the expected income $\bar{y}_{ei}$ associated with living in i is:

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

[21] 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, high-skilled residents also received a larger amount of rent income.

where $\tilde{T}_e = T_e^{1/\theta_e}\gamma_{\theta_e}$ and γ_{θ_e} is the gamma constant evaluated at $1-\frac{1}{\theta_e}$. The previous equation suggests that workers receive a higher labor 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 equation 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 places of residence.

Similarly, the probability that a type e worker chooses to live in i out of all possible block groups within the city 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 choosing to commute to j:

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

where FMA_{ej} denotes firm market access, which measures the access to type e workers by firms located 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:

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

These two variables can be jointly calculated using our block group level data on employment, population and bilateral commuting times. Finally, total demand for residential floor space by type

e workers is given by:

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

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

4.2 Firms

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

$$\begin{aligned} Y_j &= A_j \tilde{N}_{Fj}^{\alpha} H_{Fj}^{1-\alpha}, \\ \text{where } \tilde{N}_{Fj} &= \left[\alpha_u N_{Fju}^{\rho} + \alpha_s N_{Fjs}^{\rho}\right]^{\frac{1}{\rho}} \end{aligned}$$

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 a constant 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; $\alpha = \alpha_u + \alpha_s$ corresponds to the total labor share, and α_e to the intensity in the use of type e labor in total 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}) in that location as given. From the first order conditions, I obtain an expression to see how firms substitute between both types of labor and an expression for the demand of total effective labor:

$$\begin{aligned} \frac{w_{ju} N_{Fju}^{1-\rho}}{\alpha_u} &= \frac{w_{js} N_{Fjs}^{1-\rho}}{\alpha_s}, \\ \tilde{N}_{Fj} &= (\alpha A_j)^{\frac{1}{1-\alpha}} \left[\alpha_u^{\frac{1}{1-\rho}} w_{ju}^{\frac{-\rho}{1-\rho}} + \alpha_s^{\frac{1}{1-\rho}} w_{js}^{\frac{-\rho}{1-\rho}}\right]^{\frac{1-\rho}{\rho(1-\alpha)}} H_{Fj}. \end{aligned} \tag{14}$$

Note that effective employment in block j increases when local productivity increases, wages paid to either type of worker decrease or available floor space in that block increases. Using the zero profit condition, I obtain an expression for the equilibrium price of office floor space in location j:

$$r_{Fj} = \alpha^{\frac{\alpha}{1-\alpha}}(1-\alpha) A_j^{\frac{1}{1-\alpha}} \left[\alpha_u^{\frac{1}{1-\rho}} w_{ju}^{\frac{-\rho}{1-\rho}} + \alpha_s^{\frac{1}{1-\rho}} w_{js}^{\frac{-\rho}{1-\rho}}\right]^{\frac{\alpha(1-\rho)}{\rho(1-\alpha)}}. \tag{15}$$

This equation states that firms are able to pay higher rents for commercial floor space in blocks with higher productivity and/or lower wages. Equivalently, firms are able to pay higher wages in locations with higher productivity and/or lower rents.

4.3 Real Estate Market with Zoning Restrictions

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 building restrictions. Assume that the production of floor space takes place in a competitive market.[22] Furthermore, assume that floor space demanded by households and firms have the same characteristics. In order to produce floor space, developers use capital and land with a production technology that exhibits constant returns to scale. Finally, assume that the owners of capital do not live in the city and the price of capital is the same at every location and is determined in a national market. I normalize this price to one.

Total demand for residential and commercial floor space in every location is given by the respective solutions of the workers' and firms' maximization problems. Given these assumptions, in a world with no zoning restrictions, developers would build floor space for the group of agents (workers or firms) with the highest willingness to pay, until the price of commercial and residential floor space equalize. This is the standard assumption in recent models, including Ahlfeldt et al. (2015) and Tsivanidis (2018). This rent equalization leads to an optimal distribution of land between residential and commercial uses.

However, when city authorities regulate the use of land in a given location, the price of both types of floor space could differ in equilibrium. Consider a Zoning Ordinance given by the matrix $\mathbb{Z} = \{\omega_R, \omega_M, \omega_F, \lambda\}$, 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 in the city, with $\omega_{Ri}+\omega_{Mi}+\omega_{Fi} = 1$, and λ corresponds to the maximum allowed share of residential space within each block group's mixed-use districts. Assuming that land in a block is fixed and can be divided between districts, a representative developer chooses the level of capital that maximizes his profits given the price of land in block i (p_i). In residential and commercial districts, his problem is given by:

$$\max_{K_i} r_{Ti} H_T(\omega_{Ti} L_i, K_i) - p_i \omega_{Ti} L_i - K_i,$$

where $T \in \{R, F\}$, $H_T(\omega_{Ti} L_i, K_i) = \nu_{Ti} \left(\omega_{Ti} L_i\right)^{\mu} K_i^{1-\mu}$ 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 types of regulations) affecting construction of either residential or commercial floor

[22] Gyourko and Molloy (2015) state that there is no evidence of market power in the residential construction market as there are over 100,000 companies in the single family construction business. Combes et al. (2019) show similar numbers for France.

space in a particular location. In mixed-use districts, the developer solves:

$$\max_{K_i} r_{Ri}\lambda_i H_R(\omega_{Mi}L_i, K_i) + r_{Fi}(1-\lambda_i)H_F(\omega_{Mi}L_i, K_i) - p_i\omega_{Mi}L_i - K_i.$$

The solutions from these problems, together with the zero profit conditions, yield the total supply of residential and commercial floor space in a given block i and the price of land in block i:

$$H_{Ri}^S = \nu_{Ri}L_i(1-\mu)^{\frac{1-\mu}{\mu}}\left\{\omega_{Ri}(\nu_{Ri}r_{Ri})^{\frac{1-\mu}{\mu}} + \omega_{Mi}\lambda_i\left[\lambda_i\nu_{Ri}r_{Ri} + (1-\lambda_i)\nu_{Fi}r_{Fi}\right]^{\frac{1-\mu}{\mu}}\right\}, \tag{16}$$

$$H_{Fi}^S = \nu_{Fi}L_i(1-\mu)^{\frac{1-\mu}{\mu}}\left\{\omega_{Fi}(\nu_{Fi}r_{Fi})^{\frac{1-\mu}{\mu}} + \omega_{Mi}(1-\lambda_i)\left[\lambda_i\nu_{Ri}r_{Ri} + (1-\lambda_i)\nu_{Fi}r_{Fi}\right]^{\frac{1-\mu}{\mu}}\right\}, \tag{17}$$

$$p_i = \sum_T \omega_{Ti}p_{Ti} \quad \text{with} \quad p_{Ti} = \mu(1-\mu)^{\frac{1-\mu}{\mu}}\left[\lambda_i r_{Ri}\nu_{Ri} + (1-\lambda_i)r_{Fi}\nu_{Fi}\right] \tag{18}$$

and $T \in \{R, M, F\}$, $\lambda_i = 1$ when $T = R$ and $\lambda_i = 0$ when $T = F$. 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:

$$H_{Ri}^D = \frac{1}{r_{Ri}}\left[\sum_e (1-\beta_e)N_{Rei}\left(\tilde{T}_e RMA_{ei}^{1/\theta_e} + \varphi_e\right)\right] = H_{Ri}^S \tag{19}$$

$$H_{Fi}^D = \left[\frac{(1-\alpha)A_i}{r_{Fi}}\right]^{\frac{1}{\alpha}}\left[\sum_e \alpha_e N_{Fei}\right]^{\frac{1}{\rho}} = H_{Fi}^S. \tag{20}$$

These conditions determine the equilibrium price of residential and commercial floor space in every block. In particular, prices for residential real estate depend positively on the population density of residents of each type and their total income, and negatively on the share of area zoned for residential uses. On the other hand, prices for commercial real estate depends positively on the density of workers of each type and the block's productivity, and negatively on the share of area zoned for commercial uses.

4.3.1 Equilibrium with Zoning

Given the model's parameters $\{\{\beta_e, \theta_e, \eta_e, \tilde{T}_e\}_{e\in\{u,s\}}, \kappa, \alpha, \rho, \alpha_s, \mu\}$, exogenous location-specific characteristics $\{\mathbf{B_u}, \mathbf{B_s}, \mathbf{A}, \boldsymbol{\tau}, \boldsymbol{L}, \boldsymbol{\nu_R}, \boldsymbol{\nu_F}\}$ and the city total population of each type $\{N_u, N_s\}$, the general equilibrium of the model with zoning $\mathbb{Z} = \{\omega_R, \omega_M, \omega_F, \lambda\}$ is given by the city wide expected utility for both types of people $\{\bar{u}_u, \bar{u}_s\}$, vectors $\{\{\mathbf{N_{Re}}, \mathbf{N_{Fe}}, \mathbf{w_e}\}_{e\in\{u,s\}}, \mathbf{r_R}, \mathbf{r_F}, \mathbf{p_R}, \mathbf{p_F}, \mathbf{p_M}\}$ and transfers from the rents of land $\{\varphi_u, \varphi_s\}$, such that both types maximize their utility given their budget constraint, firms maximize their profits, developers maximize their profits subject to the zoning restrictions, there is zero profits in the good and real estate markets, markets clear, and block group level working and residential population adds 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 types of workers (14), zero profits in the market for final goods (15), residential floor space market clearing (19), commercial floor space market clearing (20), and zero profits in real estate markets (18). By the First Welfare Theorem, this competitive solution is efficient, conditional on the existing Zoning ordinance.

When amenities and productivity are endogenous and depend on local population density as presented in Appendix B, the vector of parameters also includes the elasticities of amenities and productivity with respect to skill-specific population densities. In this case, the competitive equilibrium will not necessarily be efficient and multiple equilibria are possible. Nonetheless, 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 the model.

4.4 Real Estate Market with Zoning and FAR Restrictions

Consider now 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 $\bar{h}_T$ denotes the vector of maximum allowed FAR for type T construction in every block group. The profit maximization problem of the developers is now a constrained optimization consisting of the problem described in Section 4.3, subject to a floor-to-area ratio constraint given by

$$\left(\frac{K_i}{\omega_{Ti} L_i}\right)^{1-\mu} \leq \bar{h}_{Ti},$$

where $T \in \{R, M, F\}$ and $\left(\frac{K_i}{\omega_{Ti} L_i}\right)^{1-\mu}$ approximates the unconstrained FAR. The solutions from these problems yields the total supply of residential and commercial floor space and the price of land in location i. In particular, when the restriction does not bind, the solution is given by equations (16)-(23). When the constraint is binding, it is given by:

$$\begin{aligned}
H^S_{Ri} &= \nu_{Ri} L_i \left[\omega_{Ri} \bar{h}_{Ri} + \omega_{Mi} \lambda_i \bar{h}_{Mi}\right], && (21)\\
H^S_{Fi} &= \nu_{Fi} L_i \left[\omega_{Fi} \bar{h}_{Fi} + \omega_{Mi} (1-\lambda_i) \bar{h}_{Mi}\right], && (22)\\
p_i &= \sum_T \omega_{Ti} p_{Ti} \quad \text{with} \quad p_{Ti} = \bar{h}_{Ti} \left[\lambda_i r_{Ri} \nu_{Ri} + (1-\lambda_i) r_{Fi} \nu_{Fi} - \bar{h}_{Ti}^{\frac{\mu}{1-\mu}}\right], && (23)\\
\chi_{Ti} &= \lambda_i r_{Ri} \nu_{Ri} + (1-\lambda_i) r_{Fi} \nu_{Fi} - \frac{1}{1-\mu} \bar{h}_{Ti}^{\frac{\mu}{1-\mu}}, && (24)
\end{aligned}$$

where $T \in \{R, M, F\}$ and χ_{Ti} represents the Lagrangian multiplier of this problem. This multiplier can be interpreted as the shadow costs of the FAR restrictions, or the marginal profits of relaxing them, and its solution comes from the first order and the complementary slackness conditions. Moreover, if the FAR restriction does not bind for type T properties in location i, $\chi_{Ti} = 0$.

4.4.1 Equilibrium with Zoning and FAR restrictions

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

4.5 Comparative Statics and Welfare

In this subsection, I analyze the effects of zoning and FAR restrictions on the welfare of both types of workers. Define ξ_i as a specific land use regulation inside block group i. Taking logs from equation (9) and deriving with respect to ξ_i, I can write the semi-elasticity of welfare to changes in this policy (ε_{u_e,ξ_i}) as:

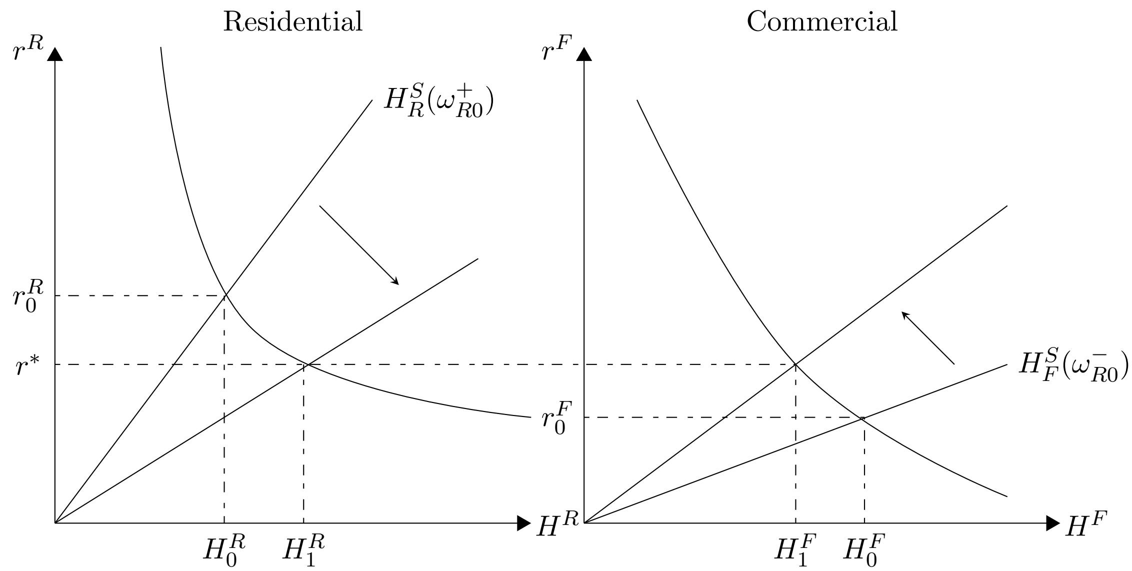
$$\varepsilon_{u_e,\xi_i} = \sum_m \pi_{Rem} \left[-(1-\beta_e)\varepsilon_{r_{Rm},\xi_i} + \varepsilon_{B_{em},\xi_i} + \frac{\tilde{T}_e RMA_{em}^{1/\theta_e}}{\theta_e \bar{y}_{em}} \varepsilon_{RMA_{em},\xi_i} + \frac{\varphi_e}{\bar{y}_{em}} \varepsilon_{\varphi_e,\xi_i} \right]. \tag{25}$$

The previous expression suggests that the effect of a marginal change of policy ξ_i on aggregate welfare of type e residents can be decomposed into four components: (i) changes in housing prices, (ii) changes in local 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 this expression, I now analyze each of these components for changes in zoning and changes in FAR limits. First, in order to analyze the effect of a change in zoning policy, assume that there are no mixed-use districts and that the City decides to make block i more residential, i.e., to increase ω_{Ri}, until residential and commercial rents equalize. Figure 5 shows the effect of this increase in the share of the area zoned for residential purposes on block i's real estate market:

Notice first that when residential real estate prices are higher than commercial prices, which is the case for 67% of the block-groups in Chicago, a proper increase in residential zoning can lead to rent equalization in that block. In particular, residential rents in block i decrease ($\frac{\partial r_{Ri}}{\partial \omega_{Ri}} \leq 0$) because there is more space that can be use for housing purposes, while commercial rents increase ($\frac{\partial r_{Fi}}{\partial \omega_{Ri}} \geq 0$). Moreover, equation (15) indicates that since there is free entry in the final goods market, wages for both types of workers adjust downward in order to drive profits back to zero, $\frac{\partial w_{ei}}{\partial \omega_{Ri}} \leq 0$, for $e \in \{u, s\}$. The magnitude of the relative wage reduction between both groups

Figure 5: Effects of More Residential Zoning on the Real Estate Market



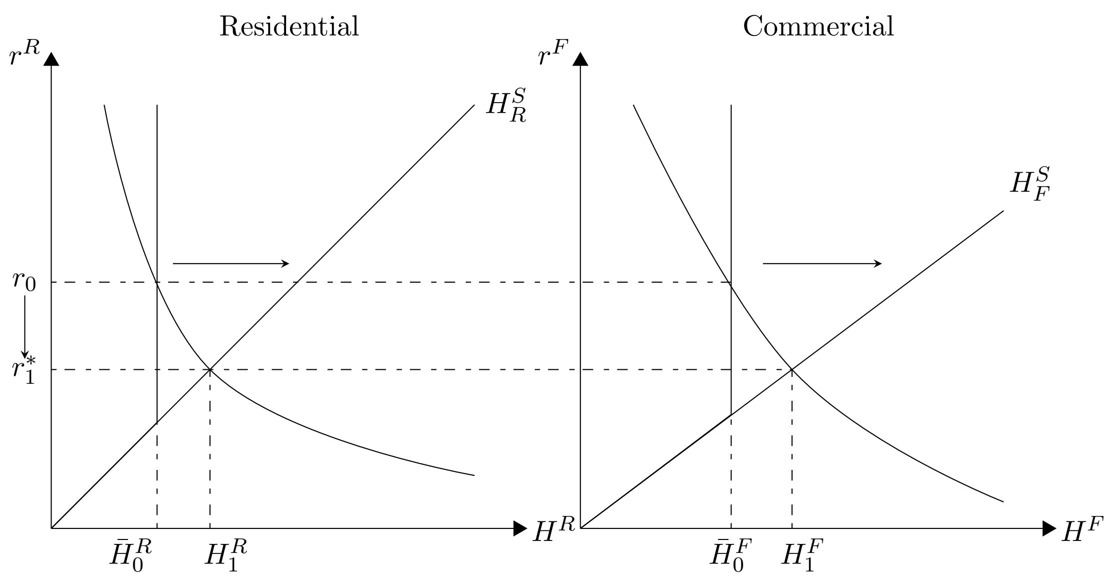
depends on the skill composition of the block group, the elasticity of substitution between skill types and their use shares.

Changes in zoning in a given block can also affect rents and wages in other blocks. Given that more residential space and residents are allowed in block i, the demand for housing in nearby blocks decreases, as well as residential rents. The opposite effect takes place in the commercial real estate market, leading to an increase in commercial rents. This implies that wages in nearby blocks decrease. The magnitude of these effects depends on the distance of each block group to block group i. Summarizing, the effects for a particular block group j of an increase in residential zoning in block i would be $\frac{\partial r_{Rj}}{\partial \omega_{Ri}} \leq 0$, $\frac{\partial r_{Fj}}{\partial \omega_{Ri}} \geq 0$ and $\frac{\partial w_{ej}}{\partial \omega_{Ri}} \leq 0$. Since wages decrease in block group i and in surrounding blocks, an increase in residential zoning also leads to a decrease in i's residential market access.

Another force affecting changes in welfare are changes in amenities induced by more residential zoning. I would expect this effect to be positive since more residential zoning tend to attract more high-skilled and high-income people, as suggested by Table 5. This higher concentration could mean higher property taxes and a better provision of local public goods, such as public schools and parks. Finally, since residential real estate prices decrease, but commercial prices increase, it is not clear *ex-ante* whether total income from land rents increases or decreases. Summarizing, decreases in housing prices and increases in amenities caused by more residential zoning would affect welfare positively, while the generalized decrease in wages negatively.

Second, in order to analyze the effect of loosening FAR restrictions, assume that the city decides to eliminate (a binding) FAR restriction for all properties in block i, and that zoning is such that equilibrium rents are equal. Figure 6 shows the effect of this policy on block i's residential and commercial real estate markets. Notice that equilibrium rents decrease for both residential and commercial floor space ($\frac{\partial r_i^*}{\partial \bar{h}_i} < 0$). Moreover, since rents paid by firms are lower, wages would increase to satisfy the good's zero profit condition: $\frac{\partial w_{ei}^*}{\partial \bar{h}_i} > 0$.

Figure 6: Effects of Loosening FAR Restriction on the Real Estate Market



The loosening of this height restriction also causes less competition for space in nearby blocks, leading to lower rents and higher wages in every block. Hence, an increase in block i's residential market access. Since rents decrease in block group i and in its vicinity, it must be that total rents in the city decrease, leading to lower transfers coming from the rents of land. Although it is not clear from the model how amenities would react, results from Section 6 will show that amenities decrease when FAR restrictions are less stringent. In conclusion, when a FAR restriction is loosen, welfare would increase if the increase in wages and decrease in housing prices compensate the decrease in amenities and land income.

5 Calibration

In this section, I show how to recover the model's unobservables using my data on real estate prices, land use regulations and skill-composition by block groups, and given values for the different parameters. I build on the methodology from Ahlfeldt et al. (2015) and Tsivanidis (2018) and recover unobserved wages, amenities and productivities using the model and the available data. Afterward, I solve for the real estate market when land use regulations are present, which lets me recover the price of land across blocks and the shadow prices of the regulations. Finally, after showing the source of the model's parameters, I present some results from the calibration exercises.

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 for residential and firm market access for each types of worker:

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

Using the recovered measures of RMA and FMA, I use equation (11) to recover a measure of wages for each type of workers in location i. Since the equilibrium system is only defined to scale (it is homogenous of degree zero), I normalize the geometric mean of wages to one. Using the normalized value of wages, I rescale the measures of RMA and FMA in order to be consistent with this choice of units.

5.2 Productivity

Using the firm zero profit condition (equation (15)) and the optimal substitution between high- and low- skilled labor (equation (14)), it is possible to derive an expression that relates block group i's firm productivity to commercial real estate prices and wages:

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

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 inside a block group is assumed to be Hicks-neutral, it must be that $A_{iu} = A_{is}$. Therefore, I have an extra parameter that needs to adjust for this equality to hold. In particular, assume that the labor share parameters of low- and high-skilled labor vary across blocks 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:

$$\tilde{A}_i = \tilde{A}_{ei} = \tilde{r}_{Fi}^{1-\alpha} \tilde{w}_{ei}^{\alpha} \tilde{\alpha}_{ei}^{-\alpha/\rho} \tilde{\vartheta}_{ei}^{\alpha(1-\rho)/\rho} \quad e \in \{u, s\}, \tag{26}$$

The previous 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 $\{\boldsymbol{\alpha}_u, \boldsymbol{\alpha}_s\}$.

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 $\{\mathbf{p}, \boldsymbol{\nu_R}, \boldsymbol{\nu_F}, \boldsymbol{\chi}, \varphi_u, \varphi_s\}$ 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 $\{\mathbf{p_T}\}_{T \in R,M,F}$ using developers' zero profit conditions (equation 23), and find $p_i = \sum_T \omega_{Ti} p_{Ti}$;
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 run 2-5 until convergence;
6. Find Lagrange multipliers $\{\boldsymbol{\chi_T}\}_{T \in R,M,F}$ (equation 24), and find $\chi_i = \sum_T \omega_{Ti}\chi_{Ti}$.

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 to the total household wage income. The formula in step 4 is given by (i) the fact that total payments to households have to equal total land rents: $\varphi_s N_{Rs} + \varphi_u N_{Ru} = \sum_i p_i L_i$, and (ii) $x = 2.817$ corresponds to the ratio of housing income between high-skilled and low-skilled workers, given by the 2015 ACS for Cook County.[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):

$$\tilde{B}_{ei} = \frac{B_{ei}}{\bar{B}_e} = \left(\frac{N_{Rei}}{\bar{N}_{Ru}}\right)^{1/\eta_e} \left(\frac{r_{Ri}}{\bar{r}_R}\right)^{1-\beta_e} \left(\frac{\bar{y}_{ei}}{\bar{y}_e}\right)^{-1}, \tag{27}$$

where the bar above a variable denotes its geometric mean, and y_{ei} is the expected income derived in equation (8). Note that equations (27) and (26) 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 (summarized by wages and RMA) and real estate prices in a location.

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

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):

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

In order to recover the average semi-elasticity of welfare of type e residents with respect to a policy change in block group i, ε_{u_e,ξ_i} (either zoning or FAR), I use equation (25) under the assumption that the change in policy from block group i does not affect any other block group j. Using the semi-elasticities of housing prices, amenities, land prices and residential market access with respect to the change in this policy, obtained from Table 4, 9 and A5, I recover the semi-elasticity of welfare as:

$$\varepsilon_{u_e,\xi_i} = \bar{\pi}_{Rei} \left[-(1-\beta_e)\hat{\varepsilon}_{r_{Ri},\xi_i} + \hat{\varepsilon}_{B_{ei},\xi_i} + \frac{\tilde{T}_e R\bar{M}A_{ei}^{1/\theta_e}}{\theta_e \bar{y}_{ei}} \hat{\varepsilon}_{RMA_{ei},\xi_i} + \frac{\varphi_e}{\bar{y}_{ei}} \frac{p_i \bar{L}_i}{\sum_j p_j L_j} \hat{\varepsilon}_{p_i,\xi_i} \right],$$

where $\hat{\varepsilon}_{r_{Ri},\xi_i}$, $\hat{\varepsilon}_{B_{ei},\xi_i}$, $\hat{\varepsilon}_{RMA_{ei},\xi_i}$ and $\hat{\varepsilon}_{p_i,\xi_i}$ correspond to the respective semi-elasticities. Finally, $R\bar{M}A_{ei}$, $\bar{y}_{ei}$, $\bar{\pi}_{Rei}$ corresponds to the average across block groups of the recovered measures of RMA and total income for type e residents and the share of type e residents in block group i relative to their city wide total population, respectively.

5.6 Parameters

With the exception of φ_u and φ_s, which are calibrated following the procedure outlined in Section 5.3, all the parameters have been taken as given. In the rest of this subsection, I show the calibration of the remaining parameters needed to successfully recover the model's unobservables.

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 the results obtained by 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 for the US found in Greenwood et al. (1997). Finally, I used the estimates of $\eta_u = 2.959$ and $\eta_s = 3.329$ from Tsivanidis (2018) for the Fréchet shape parameters of the distribution of shock over residential locations.

Housing expenditure shares $\{1-\beta_u, 1-\beta_s\}$ are calibrated using the 2015 ACS for Cook County. In particular, I calculate the mean across skill groups of each household's share of housing expenditures, calculated as the ratio between annual housing costs (owning plus renting costs) and the total household income. The skill-level of a household corresponds to the household's highest educated member. 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 Chicago, resulting in $\mu = 0.27$.

The Fréchet shape parameters from the workers' match-productivity distribution $\{\theta_u, \theta_s\}$ can be identified using a gravity equation, given a value for κ . In particular, the log version of equation (7) provides a gravity equation connecting travel time between block groups 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 LODES data does no contain commuting flows by skill-level, I estimate this regression using commuting flows for low- and high-wage workers. Results from these regressions are presented in Table 7 and indicate that high-wage workers are more sensitive to commute than low-wage workers, both when travel times or distances are taken into account.

Table 7: Gravity Regression

	(1) Low Wage	(2) High Wage	(3) Low Wage	(4) High Wage
Travel Time	-0.016***	-0.020***		
	(0.000)	(0.000)		
Distance			-0.013***	-0.017***
			(0.000)	(0.000)
R-squared	0.774	0.824	0.772	0.824
Observations	205,709	125,332	205,709	125,332

This table shows the results of OLS regressions on the log conditional commute shares by income level on travel times and distance between block group levels with non-zero commuting in 2016 in the City of Chicago. Regressions include block group of origin and of destination fixed effects. Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p. <0.1.

Even though these estimates are far from being causal, they are consistent with traditional models in urban economics that suggest that high-income workers have a higher opportunity cost of commuting time (Wheaton, 1977). Taking the estimates from Columns (1) and (2), I built skill-specific estimates taking the average using as weights the average share of low- and high-wage workers in each skill category across block groups.[24] Using $\kappa = 0.01$, I obtain $\theta_u = 1.74$ and $\theta_s = 1.83$, indicating a larger dispersion in the productivity of low-skilled workers. These numbers are in line with recent estimates from the literature such as Severen (2018) and Hsieh et al. (2019).

[24] Among low-skilled, the share of low-wage workers is 0.59203. Among high-skilled, the share is 0.36503.

Finally, I use the method proposed by Tsivanidis (2018) to calibrate the scale parameters of the match-productivity Fréchet distribution. In particular, 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, 2018). 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 wage gap, $\tilde{T}_s = 1.643$ is found by solving: $1.92 = \frac{\tilde{T}_s \sum_i RMA_{si}^{1/\theta_s} N_{Fsi}/N_{Fi}}{\sum_i RMA_{ui}^{1/\theta_u} N_{Fui}/N_{Fi}}$.

5.7 Calibration Results

In this subsection, I present descriptive maps of the different variables that were recovered using the calibration described previously. Figure 7 shows the geographic distribution of skilled-specific amenities across block groups. Note that the distribution is quite similar for both types of workers, suggesting that both high- and low-skilled residents have similar tastes regarding residential amenities. Nonetheless, note that high-skilled specific amenities are more concentrated in the north and northwestern part of the city. On the other hand, some block groups in the west and south parts of the city seem to provide some amenities that are more valued by low-skilled residents.

Figure 7: Amenities

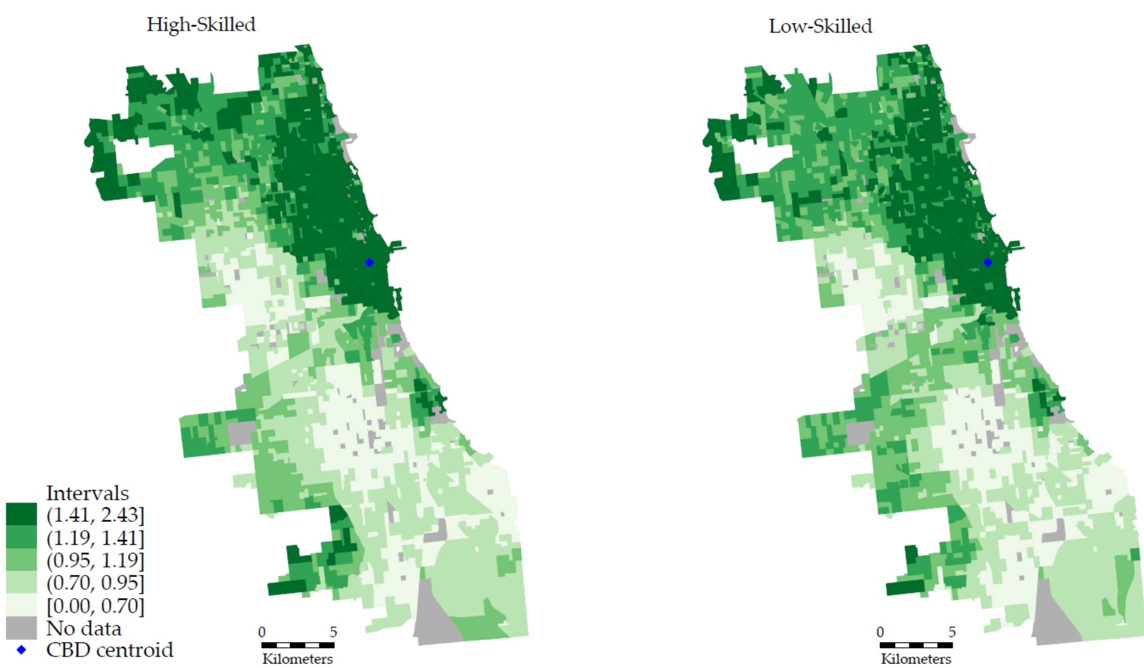
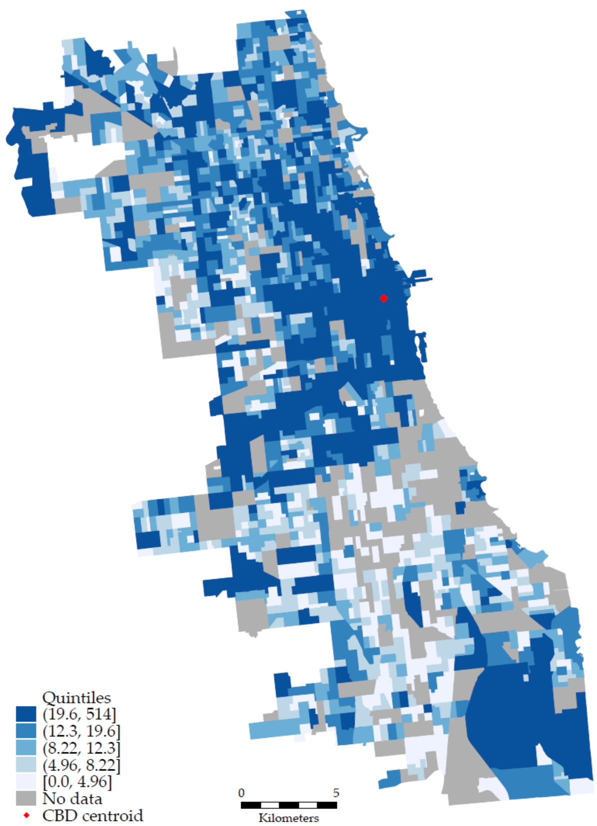


Figure 8 shows the geographic distribution of productivities. Note that it is higher around the CBD. In particular, note that there seems to be a positive correlation between places with high final good productivity and places with high commercial real estate prices (Figure 1) and places with a high share of commercial land (Figure 2). In fact, these correlations are of 0.31 and

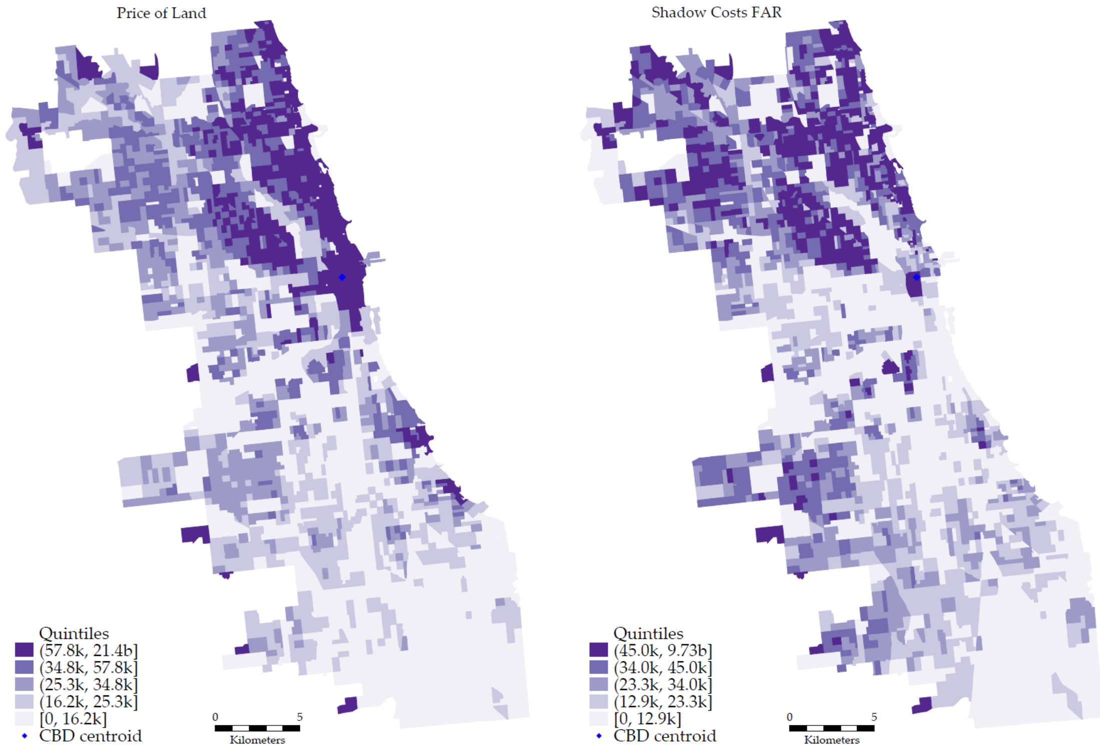
0.34, respectively. Finally, Figure 9 presents the distribution of land prices (Left Panel) and of the shadow costs of FAR restrictions (Panel B). According to my measure for the price of land, land is most expensive around the CBD and along the coast of Lake Michigan, particularly north of downtown. Finally, the shadow costs of FAR restrictions are higher north and northwest from downtown, but also in some block groups southwest. These high values suggest that the city could benefit more from relaxing FAR restrictions in these block groups relative to other locations with a lower value of these shadow costs. From the model solution, 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), and are the same for all residents, conditional on their skill type. In particular, I obtain $\varphi_u = 50.39$ and $\varphi_s = 141.93$.

Figure 8: Productivity



Regarding welfare, Table 8 shows the average expected utility for a type e worker living in the city. I compute this measure with and without the income from land rents. Recall from equation (9) that this utility is formed by other three components: housing prices, skill-specific amenities and residential market access. In both cases, welfare is higher for high-skilled relative to low-skilled workers, but the gap between both groups is larger when transfers from land are allowed. In the following section, I study how welfare changes when land use regulations change. Finally, Table A4 in the Appendix presents more descriptive statistics for the different variables recovered with the

Figure 9: Price of Land and Shadow Cost of Regulations



model.

Table 8: Expected Utility in the City

	(1)	(2)
Welfare Low-Skilled	4268.6	3308.4
Welfare High-Skilled	6062.0	3983.7
Relative Welfare	1.420	1.204
Income from Land	YES	NO

This table shows the expected utility by skill level in Chicago recovered from the model based on Equation (9).

6 Other Effects of Land Use Regulations

I now explore the effect of zoning and FAR restrictions on the recovered wages, amenities, productivity and land prices. In particular, I follow the same empirical strategy from Section 3, in which I run 2SLS regressions of these outcomes on current zoning and FAR regulations using the 1923

Chicago Zoning Ordinance districts as instrumental variables.

6.1 LUR and Wages

Columns (1) and (2) from Table 9 present the results of regressions of the effects of zoning and FAR restrictions on wages. In particular, a 10pp increase in the share of residential zoning leads to a decrease in the wage of 16% for low-skilled workers and of 14% for high-skilled workers. However, a similar increase in the share of mixed-use districts leads to increases in wages of 7% and 8%, respectively. Regarding FAR restrictions, an increase of one unit in the allowed FAR in a particular block group, leads to increases of 54% and 47% in the wages of low- and high-skilled workers. Note that the semi-elasticities of the wages with respect to residential zoning or FAR limits are higher for low-skilled people, while the semi-elasticity with respect to mixed-use zoning is higher for high-skilled workers. The results from these regressions validate the earlier results from Table 6: more stringent zoning and FAR restrictions in a particular location lead to lower wages. In light of our model, this result comes as firms respond to higher real estate prices (brought by tighter regulations) by adjusting their wages downward.

Related to these results, Table A5 presents the results of these regressions using Residential and Firm Market Access as dependent variables. Recall that RMA_{ei} summarizes the access to employment opportunities of type e workers from residential block i, while FMA_{ei} is a measure of the access to type e workers by firms located in j. Results show that an increase in the share of mixed-use designations or in the allowed FAR leads to a small but significant increase in both type's residential market access. All of these results imply that firms and workers benefit when they are closed from each other. Results also suggest that when regulations are tighter, firms find it more difficult to access workers and vice versa. Results for FMA are analogous.

6.2 LUR, Amenities and Productivity

Columns (3) and (4) from Table 9 show the effects of zoning and FAR restrictions on the block group skill-specific amenities. Results 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 groups with more commercial zoning. Note that this effect is not significantly different for high- and low-skilled residents, suggesting that the type of amenities generated by residential zoning are valued similarly by both types of residents. This is also the case for mixed-use zoning, for which a 10pp increase in the share this type of zoning leads to a decrease in amenities of -1.3%. Regarding FAR, a one unit increase in the allowed FAR leads to a decrease in the amenities of 5% and 4% for low- and high-skilled residents, respectively. These effects imply that, depending on the specific policy, the impact of LUR on amenities could be either strengthening or softening the negative effect that less stringent LUR has on housing prices.

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	-1.76***	-1.47***	0.25***	0.22***	-1.86***	3.89***	4.61***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Sh. Mixed Uses	0.66***	0.79***	-0.13***	-0.13***	1.25***	2.86***	2.69***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
F-Test	13.13	13.13	15.09	15.09	11.70	13.13	13.13
Panel B							
Mean FAR	0.54***	0.47***	-0.05***	-0.04***	0.55***	-0.57***	-0.85***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
F-Test	20.72	20.72	18.55	18.55	17.07	20.72	20.72
Observations	1,435	1,435	1,346	1,346	1,116	1,435	1,435

This table shows the results of 2SLS regressions of the effects of different zoning measures on measures of skill-specific wages, amenities, productivity, price of land and the shadow price of FAR restrictions by block group, using the 1923 zoning ordinance as instruments and controlling for the block group's land area, distance to the CBD and to major waterways, 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.

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 17% in the block group's productivity, relative to block groups with more commercial zoning. A similar increase in mixed-use designations leads to a productivity increase of 13.3%. Moreover, a one unit increase in the allowed FAR leads to an increase of 55% in local productivity. Two forces could be behind these results. First, recall from Table 5 that a higher share of mixed-use designations or allowed FAR leads to a higher spatial concentration of workers. Behind this high-concentration of workers there could be a higher concentration of firms that could benefit from knowledge spillovers, labor market pooling or input-out sharing, leading to higher agglomeration economies (Rosenthal and Strange, 2004). Second, more mixed-uses and higher FAR also lead to an increase in the spatial concentration of residents, allowing firms and workers to locate closer from each other, which could affect local productivity through increases in wages and firm market access.

6.3 LUR, Price of Land and Stringency

Table 9 also shows the effect of zoning and FAR restrictions on the price of land and the shadow price of FAR restrictions. Results from Column (6) suggest that a 10pp increase in the share of residential zoning leads to an increase of 47.6% in the local price of land, relative to block groups with more commercial zoning. A higher share of land zoned for mixed-uses also leads to increases in the price of land, but its effect is two-thirds lower (33%). Finally, a one unit decrease in the allowed FAR limit, leads to a 57% increase in the local price of land. These results are in line with theories studying the home-voter hypothesis, such as Fischel (2001), who suggest that land owners benefit from tighter land use regulations as they lead to an increase in the value of their properties.

Following the framework proposed by Brueckner et al. (2017), I use results from Column (6) to study the stringency of regulations. In particular, Brueckner et al. (2017) suggest that if the coefficient accompanying the allowed FAR from a regression with land prices (as dependent variable) is positive, the existing limit is stringent. The negative coefficient in Panel B from Column (6) suggests that, on average FAR restrictions in Chicago are not too stringent. This lies in line with estimates from Brueckner and Singh (2020), who find that FAR stringency is close to zero in Chicago. This framework, applied to results from Panel A, suggests that current zoning regulations are quite stringent, even if FAR limits are not. Another way to study stringency is to analyze the effect of LUR on the shadow price of FAR restrictions using results from Column (7). Recall that the shadow price represents the profits developers fail to receive due to the FAR restrictions. Panel B suggests that relaxing allowed FAR limits by one unit leads to a reduction of the local shadow price of 85%. Results also suggest that increasing residential zoning lead to an increase in this shadow price, which could be driven by the low densities associated with residential districts.

7 The Incidence of Land Use Regulations

I now explore the effects of zoning and FAR restrictions on aggregate welfare of both types of residents by performing two quantitative exercises. First, using equation (25) as described in Section 5.5, I decompose the total change in skill-specific welfare induced by a change in LUR in block group i into four mechanisms: changes in housing prices, changes in amenities, changes in residential market access and changes in the income coming from land rents. Second, I perform four counterfactual exercises in which I find the total change in welfare for both types of residents given by changes in different zoning or FAR restrictions in different block groups.

Table 10 presents results for the welfare decomposition. Although these semi-elasticities seem small in magnitude, recall that they represent the average change in welfare (given a change in regulation) across 2185 block groups. Results from Panel A suggest that a 10pp increase in the share of residential zoning, compared to block groups with more commercial zoning, leads to an increase in welfare of 0.0013% for the low-skilled and 0.0011% for the high-skilled population. Notice that most of the welfare gains brought by more residential zoning come from increases in amenities (around 91%), followed by reductions in housing prices (9.8% for low- and 8.3% for high-skilled workers). Decreases in residential market access contribute negatively to the total change, but by less than 0.5% of the total. Finally, increases in the rents from land contributes by 0.18% and 0.31% of the total change for low-skilled and high-skilled residents, respectively. The assumption that changes in the value of land are distributed among all of the city residents could be behind the low contribution of land rents to total welfare. Notice that, without taking into account the effect that this zoning policy has on other city block groups, increases in residential zoning seem to benefit low-skilled residents more, since they benefit more from the reduction in housing prices and the increase in amenities.

Table 10: Welfare Decomposition

	Total Change	H. Prices	Amenities	RMA	Land Rents
Panel A: 10pp increase in Residential Only Share					
Low-Skilled	0.0013%	9.76%	90.54%	-0.47%	0.18%
High-Skilled	0.0011%	8.32%	91.72%	-0.35%	0.31%
Panel B: 10pp increase in Mixed-use Share					
Low-Skilled	0.0008%	171.16%	-74.31%	2.96%	0.19%
High-Skilled	0.0005%	227.66%	-131.92%	3.74%	0.52%
Panel C: one unit increase in FAR limits					
Low-Skilled	-0.0020%	-11.44%	115.92%	-4.62%	0.14%
High-Skilled	-0.0014%	-11.84%	117.91%	-6.36%	0.29%

This table shows decomposition of the average change in total welfare, given by a change in policy in a particular block group, as the sum of the four different mechanisms suggested by the theory and using estimates from Tables 4, 9 and A5.

Panel B suggest that a 10pp increase in the share of mixed-use designations would lead to an increase in welfare of 0.0008% for low-skilled and 0.0005% for high-skilled residents. Unlike Panel A, most of the welfare gains from more mixed-use zoning come from the reductions in housing prices (171.2% for low- and 227.7% for high-skilled workers), with these reductions benefiting low-skilled workers more. Increases in residential market access also benefit both types of workers, but its effects are modest: 3% and 3.7%, respectively. On the other hand, the decrease in amenities associated with an increase in mixed-use zoning offsets a large part of the gains brought by cheaper housing; a contribution of -74.3% for low-skilled residents and -132% for high-skilled residents. Similar to Panel A, increases in the rents from land contributes by 0.19% and 0.52% of the total change for low-skilled and high-skilled residents, respectively. Finally, Panel C shows that an increase of one unit in the allowed FAR would lead to a decrease in welfare of -0.0020% for low-skilled and -0.0014% for high-skilled residents, thus increasing the welfare gap between both types of residents. Even though reductions in housing prices and increases in residential market access are benefiting both types of residents–by around 11% and 5.5%–, these contributions are overshadowed by the large reduction in amenities associated with increasing FAR limits (more than 115%).

In general notice that, all of the changes in zoning or FAR limits considered so far, lead to decreases in housing prices. These effects are potentially linked to the large price gaps between residential and commercial real estate prices documented in Section 2.1. As I discussed then, residential real estate is significantly more expensive than commercial real estate in 67% of block groups. These gaps could indicate that current regulations are not optimal, since they can be caused by an excess supply of commercial real estate in these locations, relative to residential real estate. Therefore, large changes in LUR that provide more residential space in the city are potentially welfare improving.

In order to see how welfare of both types of residents changes when there is a larger change in land use regulations, I perform four different counterfactual exercises. In these exercises, I use the semi-elasticities of residential and commercial real estate prices (from Table 4) and the distribution of skills (from Table 5) with respect to changes in the different LUR, together with the solution discussed in Section 5. First, consider a policy that increases residential zoning in those block groups where residential real estate is significantly more expensive, and vice versa. Thus, this policy attempts to eliminate some of the inefficiencies of current zoning designations. In particular, in those block groups where the gap between residential and commercial real estate prices is more than 10%, I simulate a policy that converts up to 10% of commercial-zoned land into residential-zoned land. Conversely, in those block groups where the ratio between residential and commercial real estate prices is less than 0.9, I assume that up to 10% of the land zoned for residential purposes will now be zoned as commercial-only. In total, this policy affects 445 (20%) and 616 block groups (28%), respectively. The affected block groups are shown in Figure A1 in red (price ratio larger than 1.1) and blue (price ratio less than 0.9).

Panel A from Table 11 presents the change in welfare brought by this policy. The changes are computed with respect to the baseline results from Table 8. Columns 1 and 2 show the results for the case in which residents receive transfers from the value of land, while Columns 3 and 4 assume absentee landlords. In the case when residents receive transfers from the rents of land, results suggest welfare gains of around 0.4% for high-skilled residents and 0.04% for low-skilled residents, and an increase in the relative welfare between both types of residents. Recall that welfare gains in this case come mainly from the improvement in amenities brought by residential zoning, relative to commercial zoning, with decreases in housing prices playing a secondary (but still important) role.

Given the large reductions in housing prices that result from increases in mixed-use zoning, in a second exercise, I simulate the effect of a policy that zones at least 20% of every block group's land area for mixed uses, keeping constant the distribution between commercial and residential shares within existing mixed-uses within the block group. In Chicago in 2016, 1520 block groups (70%) had less than 20% of mixed-used designations. Within these block groups, on average 80% of the land was zoned for residential and 11.5% for commercial purposes. I assume that the increase in mixed-use zoning comes from whatever land is zoned for commercial uses within the block group, and the remaining from residential land. Panel B presents the welfare effects under this policy.

Table 11: Changes in Welfare - Counterfactuals

Panel A: Towards an Optimum Zoning				
	Level	Change	Level	Change
Welfare Low-Skilled	4,270.4	0.042%	3,307.8	-0.020%
Welfare High-Skilled	6,085.0	0.378%	4,001.4	0.443%
Relative Welfare	1.425	0.005	1.210	0.006
Panel B: At least 20% Mixed-Use Zoning				
	Level	Change	Level	Change
Welfare Low-Skilled	4,278.4	0.229%	3,304.2	-0.128%
Welfare High-Skilled	6,120.4	0.959%	4,011.6	0.700%
Relative Welfare	1.431	0.010	1.214	0.010
Panel C: ΔFAR = 1 if block in top quartile of χ_i				
	Level	Change	Level	Change
Welfare Low-Skilled	4,274.4	0.136%	3,305.0	-0.104%
Welfare High-Skilled	6,149.8	1.438%	4,051.5	1.687%
Relative Welfare	1.439	0.019	1.226	0.022
Panel D: Minimum FAR of 1.2				
	Level	Change	Level	Change
Welfare Low-Skilled	4,270.0	0.033%	3,305.7	-0.082%
Welfare High-Skilled	6,119.5	0.944%	4,032.3	1.214%
Relative Welfare	1.433	0.013	1.220	0.016
Income from Land	YES		NO	

This table shows the expected utility by skill level in Chicago based on the counterfactual exercises described above, and its changes with respect to the baseline welfare levels from Table 8.

When residents receive transfers from the value of land, welfare increases by 0.23% for low-skilled residents and by around 1% for high-skilled residents. Moreover, the welfare gap between these two groups increases by 0.01 units.

In a third exercise, I increase the FAR limit by 1 in all of those block groups in the top quartile of the distribution of shadow costs recovered from the model and presented in Figure 9. Recall that these shadow costs are a measure of how stringent are FAR restrictions in a given block group. Therefore, relaxing FAR in these block groups could imply large welfare gains. Panel C shows the results of this simulation. In this scenario, welfare increases by around 0.14% for low-skilled residents and by around 1.44% for high-skilled residents. Moreover, the welfare ratio between both types of workers increases by 0.02 units. Notice that most of the block groups affected by this policy are located in the northern part of the city. These block groups have relatively more amenities and experience relatively more demand for housing than other areas in the city, in particular from high-skilled residents. Thus, it is natural that high-skilled residents benefit more from this policy.

Finally, I simulate a policy that sets a minimum FAR of 1.2 everywhere in the city, keeping zoning designations fixed. This policy would affect 1505 block groups (69%) and would lead to large increases in welfare for high-skilled residents (0.94%), but modest increases for low-skilled residents (0.03%). Therefore, the welfare ratio between both types would increase by 0.013 units.

These for policies suggest that, even though zoning can be a welfare-enhancing policy for both types of residents, it is a regressive policy that benefits high-skilled residents more. Moreover, for the cases with absentee landlords in all of the four counterfactual exercises, high-skilled residents experience a similar improvement in welfare compared with the case with transfers, but there is a reduction in welfare for low-skilled residents. The comparison between these two set of results suggest an important role of transfers from the rent of land in determining welfare gains, especially for low-skilled residents. In particular, they suggest that if home ownership is non-existent, low-skilled residents could be worse off by any change in land use regulations that attempts to increase the supply of residential housing.

8 Conclusions

Land use regulations shape the daily life of hundreds of millions of urban dwellers around the world. In order to regulate the use of land, local governments use different tools such as zoning restrictions (permitted uses), floor-to-area (height) limits, lot size restrictions, among others. While there is substantial research on the effects of these different 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 of different type of workers.

This paper contributes to the literature by investigating the effects of zoning and FAR restrictions on a wide range of block group level outcomes and, ultimately, on the welfare of high- and low-skilled people. Using detailed geographic data for the City of Chicago in 2015-2016, I start by studying the effect of current zoning and floor-to-area restrictions on the real estate market and skill-composition across block groups within the city. For identification, I use the 1923 Zoning Ordinance, which was the first comprehensive zoning ordinance in Chicago. In particular, 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 8.5% and a decrease in the spatial concentration of high-skilled residents.

Afterwards, I build a quantitative model of a city with two types of workers. The inclusion of worker heterogeneity in the model is important, as zoning is often considered a regressive measure. Thus, the inclusion of two types of workers allows me to study the distributional effects of land use regulations. 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 effect of land use regulations on welfare into four components:

changes in housing prices, in amenities, in wages and in the income from land rents.

Given data and values of parameters, this model allows me to recover measures of wages, amenities, productivities, price of land across block groups within the city and study how regulations affect these variables. In particular, I find that more residential zoning and tighter FAR limits lead to a decrease in local wages, in particular for low-skilled workers, and to a decrease in local productivity. However, tighter regulations also have a significant effect improving neighborhood amenities.

My results also suggest that increasing residential zoning would lead to increases in welfare for both types of residents. These welfare gains seem to be driven mostly by improvement of the amenities associated with residential zoning, relative to the (dis-)amenities that come with commercial zoning. In addition, most welfare gains associated with increases in mixed use zoning come from reduction in housing prices. Finally, increasing FAR limits has a negative impact of welfare due to a decrease in amenities, which more than exceeds the gains from cheaper housing prices and better market access.

Finally, counterfactual exercises suggest an important welfare enhancing role of large changes in the zoning code. 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 more commercial zoning in block groups displaying an excess relative supply of residential real estate. Second, a policy that sets a minimum of land zoned for mixed-uses at 20% in each block group. Third, increasing the FAR limit by one in those blocks where there is a larger social cost of having this restriction. Fourth, setting a minimum FAR of 1.2 everywhere in the city. All of these policies lead to welfare improvements for both types of residents, and to an increase in the welfare gap between them. These results imply that more residential and mixed-use zoning and higher allowed densities play an important role increasing the welfare of the population, but can also increase welfare inequality across groups of residents.

Lastly, I would like to highlight that this paper excludes other possible forces affecting sorting and urban development widely studied in the literature. For instance, I am not taking into account a wide range of fiscal issues such as Tiebout sorting, in which small jurisdictions set their own fiscal policy strategically in order to provide local public goods (Epple and Sieg, 1999). These forces are important because, as Fischel (2015) suggests, zoning is closely integrated with these local government functions. I also exclude from my analysis dynamic problems that important in the study of real estate markets, both in the demand (Bayer et al., 2016) and in the supply side (Murphy, 2018). All of these issues are left for future research.

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A Extra Tables and Figures

Figure A1: Real Estate Price Gap: Residential/Commercial, 2015-2016

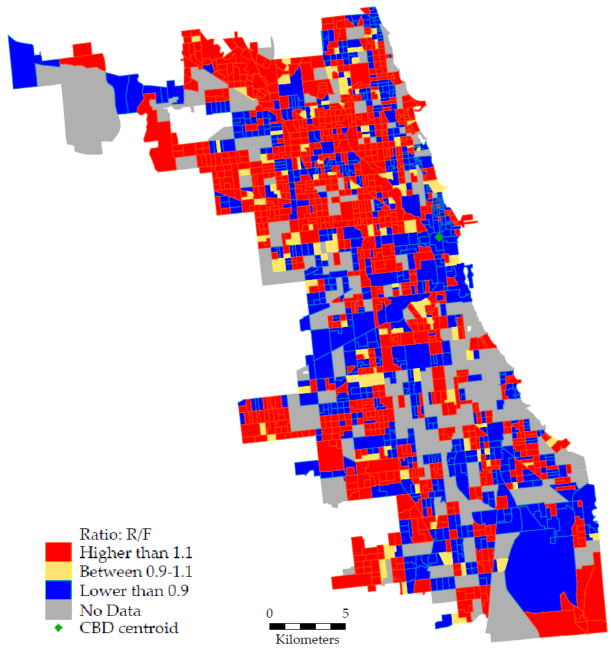

Figure A2: Real Estate in Chicago - Total Built Square Footage, 2015-2016

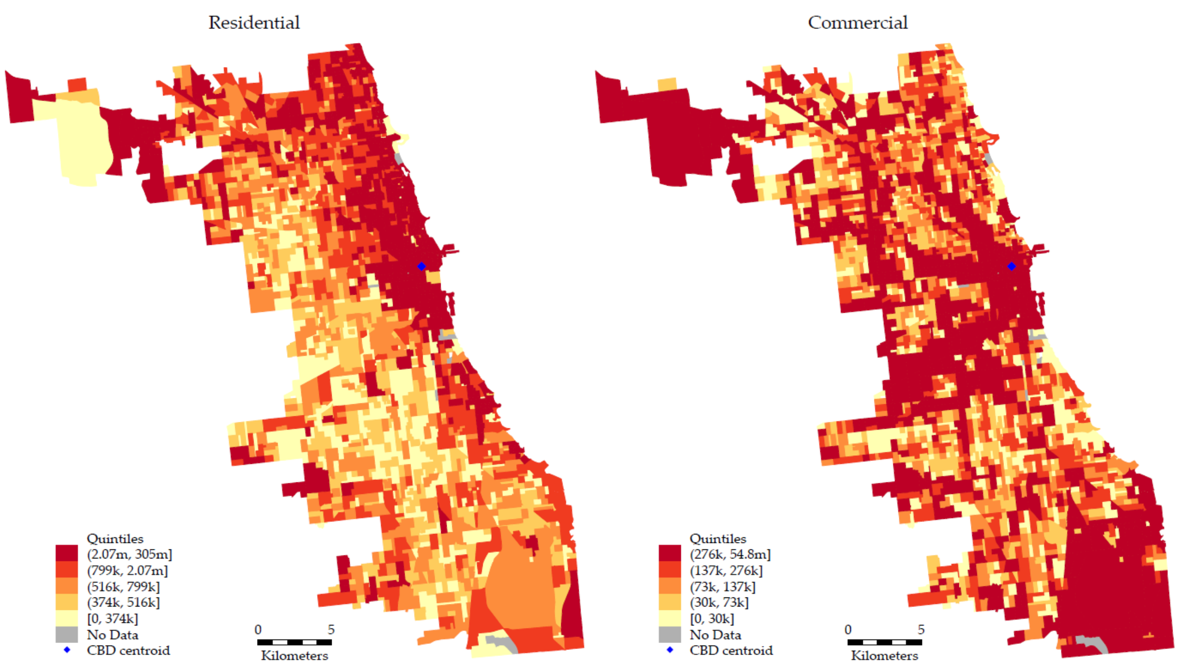

Figure A3: Broad Zoning Designations, 2016

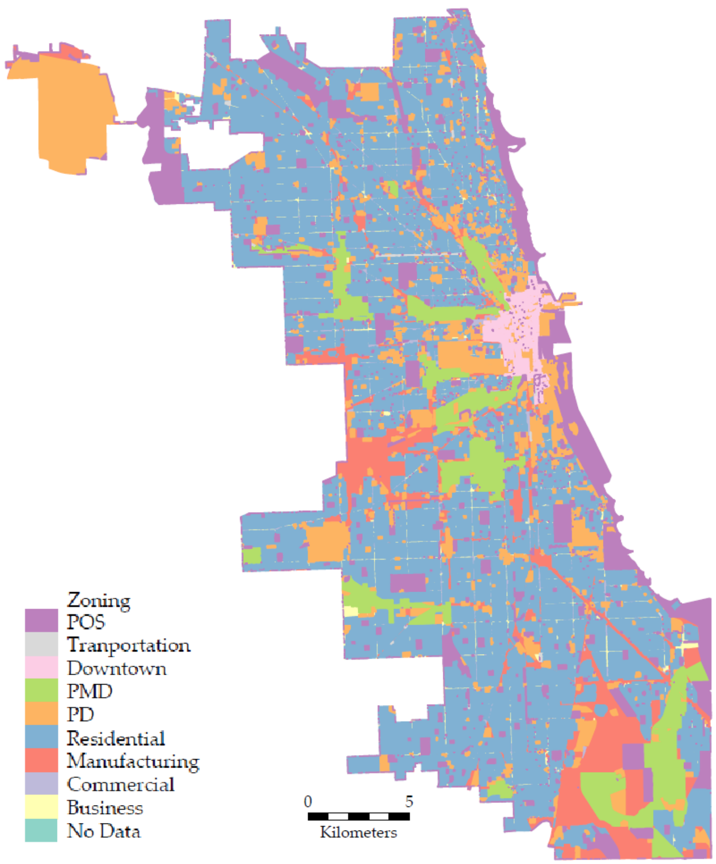

Table A1: Average and Median Block Group, 2015-2016

		Total 30+	<HS	HS	Some Coll	>College
By Block of Residence						
County	Mean	416.2	58.0	96.5	123.5	138.2
	Median	373	51.5	87.5	111.5	117
	Total	1.66m	231k	385k	493k	551k
City	Mean	367.6	57.1	86.0	108.5	116.0
	Median	331.5	50.5	79.5	98	89.5
	Total	803k	125k	188k	237k	253k
By Block of Work		Total 30+	<HS	HS	Some Coll	>College
County	Mean	466.1	60.4	106.1	138.0	161.6
	Median	89.5	14.5	23	27	24.5
	Total	1.86m	241k	423k	551k	645k
City	Mean	435.7	56.7	95.3	126.6	157.1
	Median	65.5	12	17	19.5	16.5
	Total	952k	124k	208k	277k	343k

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	25.82%	33.92%
High	Low	15.37%	11.07%
Low	High	23.94%	33.43%
High	High	34.87%	21.58%

This table shows the distribution of workers by earnings and skills in the average block group of residence and of work in 2015-2016.

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	0.07	0.67***	0.04	-3.54***	0.06***	0.53***	0.66***	-0.06*	-3.31***	-3.31***	0.41***	0.44***
	(0.14)	(0.23)	(0.22)	(0.36)	(0.02)	(0.16)	(0.15)	(0.03)	(0.28)	(0.29)	(0.10)	(0.09)
Sh. Mixed Uses	0.14	1.10***	0.23	-0.03	0.06**	0.50***	0.64***	-0.01	-0.25	-0.26	0.44***	0.42***
	(0.17)	(0.34)	(0.33)	(0.44)	(0.03)	(0.18)	(0.17)	(0.04)	(0.31)	(0.32)	(0.12)	(0.10)
R-squared	0.40	0.99	0.29	0.99	0.95	0.98	0.98	0.89	0.94	0.94	0.99	0.99
Panel B												
Mean FAR	0.01	0.23***	0.05	0.24***	0.01***	-0.02	0.02	0.02***	0.29***	0.32***	-0.04***	-0.06***
	(0.02)	(0.04)	(0.05)	(0.04)	(0.00)	(0.02)	(0.02)	(0.01)	(0.04)	(0.05)	(0.01)	(0.02)
R-squared	0.40	1.00	0.29	0.99	0.95	0.98	0.98	0.89	0.93	0.93	0.99	0.99
Observations	1,346	1,423	1,114	1,329	1,431	1,431	1,431	1,397	1,397	1,397	1,397	1,397

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, and controlling for block group's land area, distance to the CBD and to major waterways. 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	7,915.6	557.4	6,106.4	7,944.1	9,074.3
Firm MA	Low	31.18	1.51	25.01	31.42	33.94
Wages	Low	1.53	2.52	0.00	0.98	71.36
Amenities	Low	1.08	0.37	0.29	1.10	2.28
Residential MA	High	11,616.9	924.4	8,766.1	11,655.7	13,710.3
Firm MA	High	38.51	2.29	29.94	38.72	42.93
Wages	High	1.56	2.96	0.00	0.97	90.35
Amenities	High	1.08	0.38	0.31	1.06	2.42
Productivity		15.19	22.33	0.00	10.16	513.38
Land Prices		9.87m	458m	0.00	29.93k	21,400m
Shadow Price		4.53m	208m	-0.02	28.96k	9,740m

This table shows descriptive statistics for different variables recovered from the model using the calibration procedure from Section 5. k indicates thousands (1e03) and m indicates millions (1e06).

Table A5: Effects of LUR on Market Access

	(1)	(2)	(3)	(4)
	Residential M.A.		Firm M.A.	
Skill Cat.	Low	High	Low	High
Panel A				
Sh. Res. Only	-0.003***	-0.002***	-0.003***	-0.001***
	(0.000)	(0.000)	(0.000)	(0.000)
Sh. Mixed Uses	0.012***	0.010***	0.018***	0.014***
	(0.000)	(0.000)	(0.000)	(0.000)
R-squared	1.000	1.000	1.000	1.000
F-Test	13.13	13.13	13.13	13.13
Panel B				
Mean FAR	0.004***	0.005***	0.002***	0.003***
	(0.000)	(0.000)	(0.000)	(0.000)
R-squared	1.000	1.000	1.000	1.000
F-Test	20.72	20.72	20.72	20.72
Observations	1,435	1,435	1,435	1,435

This table shows the results of 2SLS regressions of the effects of different zoning measures on measures of residential and firm market access using the 1923 zoning ordinance as instruments and controlling for the block group's land area, distance to the CBD and to major waterways, and historical covariates. These measures were recover using the quantitative model from Section 4. Spatial Heteroscedasticity and Autocorrelation Consistent standard errors in parentheses (SHAC) (Conley, 1999); ***p<0.01, **p<0.05, *p. <0.1.

B Endogenous Agglomeration

B.1 Endogenous Amenities

Throughout the paper, I treated block group - skill specific residential amenities B_{ei} as exogenous. However, amenities are an important factor when people determine their place of residence. For instance, Bayer et al. (2007) show that households have higher willingness to pay to live in a location densely populated by high-skilled workers. On the other hand, people living in locations with parks, lakes or historical buildings, might experience a dis-utility from high population density. Moreover, different types of workers have different valuation for different types of amenities (Albouy, 2016; Couture and Handbury, 2017).

Similar to Tsivanidis (2018), I assume that amenities in a block 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 a location of type-e workers. The latter, represents how population density of high-skilled workers affect this willingness to live. In particular, amenities in location i are given by:

$$B_{ei} = b_{ei} \left(\frac{N_{Rsi}}{L_i} \right)^{\sigma_e}, \tag{28}$$

where L_i denotes land area in location i; σ_e controls the relative importance of the externalities in overall residential amenities by type e individuals. Notice that in contrast to Ahlfeldt et al. (2015), I assume that there are not spillovers of these amenities across locations.

B.2 Endogenous Productivity

Equivalently, I assume that productivity in a location j depends on two components. First, an exogenous component a_j that represents production fundamentals from location j. Second, a term summarizing production externalities of both types of workers in that location. Specifically,

$$A_j = a_j \left(\frac{N_{Fuj}}{L_j} \right)^{\delta_u} \left(\frac{N_{Fsj}}{L_j} \right)^{\delta_s}, \tag{29}$$

where N^F_{uj}/L_j and N^F_{sj}/L_j correspond to the workplace employment density per unit of land area L_j of low- and high-skilled workers in location j, respectively. The standard interpretation of these externalities is that density facilitates knowledge spillovers, input sharing or market pooling (Rosenthal and Strange, 2004). I allow for the density of both types of workers to have a different impact on the productivity. In these expressions, δ_u and δ_s control the relative importance of externalities on determining productivity.

B.3 Equilibrium with Endogenous Agglomeration

Given the model's parameters $\{\{\beta_e, \theta_e, \eta_e, \tilde{T}_e, \sigma_e, \delta_e\}_{e\in\{u,s\}}, \kappa, \alpha, \rho, \alpha_s, \mu\}$, exogenous location-specific characteristics $\{\mathbf{b_u}, \mathbf{b_s}, \mathbf{a}, \boldsymbol{\tau}, \boldsymbol{L}, \boldsymbol{\nu_R}, \boldsymbol{\nu_F}\}$ and the city-type total population $\{N_u, N_s\}$, the general equilibrium of the model with zoning $\mathbb{Z} = \{\omega_R, \omega_M, \omega_F, \lambda\}$ and agglomeration externalities is given by the city-wide expected utility for both types of workers $\{\bar{U}_u, \bar{U}_s\}$, the vectors $\{\{\mathbf{N_{Re}}, \mathbf{N_{Fe}}, \mathbf{w_e}\}_{e\in\{u,s\}}, \mathbf{r_R}, \mathbf{r_F}, \mathbf{p_R}, \mathbf{p_F}, \mathbf{p_M}\}$ 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 and developers maximize their profits, there is zero profits in the good and real estate market, 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 (14), zero profits in the market for final goods (15), residential floor space market clearing (19), commercial floor space market clearing (20), and zero profits in real estate markets (18).

B.4 How do Agglomeration Externalities impact Comparative Statics

Because density generates agglomeration externalities, in the presence of endogenous productivity and amenities the effect could depend heavily on how firms and both type of workers value density. Even though I expect firms to always value density positively (because it increases their productivity), it is not clear how households should value it. For instance, households might value density positively if it generates more consumption amenities, but they might value it negatively if it causes congestion of roads or natural amenities, or higher crime rates.

In the production sector, I always expect firms to value externalities positively. Therefore, if firms are not being allowed in one specific block, causing people to leave some workplace locations, the total effect of a zoning policy would be stronger than what I predicted in Section 4.3. This is, there would be a stronger contraction in the demand for commercial real estate since there would be less benefits from agglomeration economies.

This is also the case if LUR causes people to leave certain residence locations and households consider higher density to be a good externality. In this case, the demand curve for housing will shift inwards causing a further reduction in residential rents, and reinforcing the effects derived in Sections 4.3 and/or 4.4. However, if households value density negatively, the demand curve for residential floor space would shift outwards after the policy, leading to increases in the residential rents, softening the effects Sections 4.3 and/or 4.4. Depending on the size of these externalities, the effect could more than compensate the initial effect and lead to higher residential prices.