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The long-run impact of zoning: Institutional hysteresis and durable capital in Seattle, 1920–2015☆

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ABSTRACT

This paper examines the coevolution of land use and zoning in Seattle from 1920 to 2015. Multiple waves of zoning and land use conversion data at the parcel level allow for a decomposition of the long-run effects of zoning and an exploration of the mechanisms through which zoning influenced future land use. In particular, I disentangle short-run impacts on land use from long-term institutional hysteresis, showing that the latter played a sizable role in shaping future land use. Additionally, data on variances allows me to examine early compliance levels, an underexplored topic with implications for long-run impacts. While much has been written about persistence in urban form due to purely economic forces, relatively little research has explored how institutional forces can entrench or alter this trajectory, and I find that such institutional constraints can have substantial influence.

1. Introduction

How do legal and institutional forces shape the evolution of cities? Research in urban economics has largely focused on the role of purely economic factors, arguing that geography, transportation costs, and durable capital can explain most stylized facts about urban spatial structure. In contrast, some recent work has drawn attention to the role of land use regulations, suggesting that local government policymaking has considerable influence in directing and constraining urban growth (Shertzer et al., 2018; Bunten, 2017). However, little is known about the mechanisms underlying this influence, or how these regulations interact with economic forces to shape cities over time. This study seeks to shed light on these questions by examining the coevolution of zoning and land use over a century in Seattle.

The primary goal of this study is to examine and decompose the impact of early zoning in Seattle on the evolution of land use patterns over the following century. To the extent that the city today reflects the initial plan, I attempt to measure how much of this is driven by changes in land use in the decades immediately following the initial zoning, and how much is attributable to persistence in the form of the zoning law itself. City plans may exhibit hysteresis for any number of reasons: revisions likely began with the previous plan, resulting in an anchoring effect; zoning may be rapidly capitalized into property values,[1] creating a natural constituency for its continuation; planners may desire to impose stability and continuity on zoning to encourage long-horizon investments. If zoning has persistent impacts in the long-run (net of its short-run impact on land use), this suggests that institutional hysteresis may play a large role in shaping land use change.

The data for this paper includes land use surveys from 1920, 1952, and 2015, as well as zoning data from Seattle's first comprehensive ordinance in 1923, variances granted through the following three decades, and the first comprehensive rezoning in 1957. This is matched with newly digitized maps of Seattle's streetcar network and census enumeration districts (EDs), with early demographic data drawn from ED-level 100% decennial census counts provided by Ancestry.com through the Minnesota Population Center. The data assembled overlaps 13 Seattle neighborhoods, including the central business district, several former industrial areas undergoing commercial/residential conversion, and some longstanding residential areas. I use this data to examine the impact of the initial zoning on land

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1 See, e.g., McMillen and McDonald (2002), who documents this for the initial zoning of Chicago.

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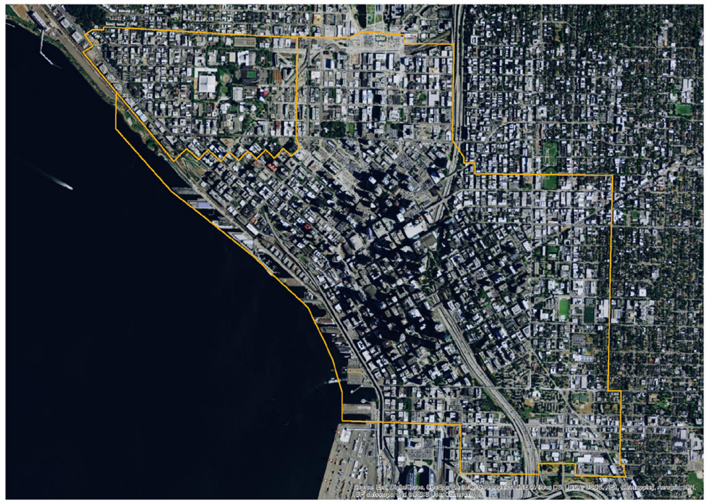


Smaller outline captures coverage of the comprehensive land use sample; larger outline captures extent of the land use change sample for 1920-1952.

Fig. 1. Land use survey extents, 1920–1952.

use conversions over the following three decades as well as its impact on the 1957 comprehensive rezoning. I then estimate the long-run effect of zoning on present-day land use, and examine how this effect attenuates once one accounts for short-run land use and demographic changes in the decades immediately following zoning. If the impact of the initial zoning is only partially mediated through short-run land use and demographic changes, that would indicate a degree of institutional lock-in which has not been documented in the existing literature.

The richness of the data allows me to document a number of other interesting facts. In particular, I estimate the impact of demographics on initial zoning outcomes in 1923, conditional on existing land use; these findings lend external validity to previous work on zoning and discrimination (Shertzer et al., 2016). Multiple surveys show the change in land use patterns over time, quantitatively illustrating the sizable transition of vacant and single-family uses towards multifamily, commercial and industrial use by the early 1950s. Alternating waves of zoning and land use also allow for an estimate of compliance trends in early zoning. I document (1) the extent to which new construction after 1923 followed the prescriptions of the new zoning law, (2) the frequency of variances over the following three decades, (3) the predictability of variances as a function of economic factors, and (4) the extent to which the comprehensive rezoning of 1957 accommodated non-compliers.

Results suggest that the initial 1923 zoning had a strong impact on the city's rapid early development. The initial ordinance also exhibited considerable persistence, playing a major role in shaping the comprehensive rezoning in 1957 even conditional on the evolution of land use up to 1952. This persistence occurred even in places where land use had changed following the initial zoning, providing strong evidence for the legal hysteresis hypothesis. In the longer run, zoning played a major role in determining present-day land use. This occurred despite that fact that early compliance was imperfect, with many parcels converting to land uses incompatible with the initial zoning; while some of these received variances, most did not, and in many cases the zoning/land use mismatch persisted through the comprehensive rezoning in 1957.

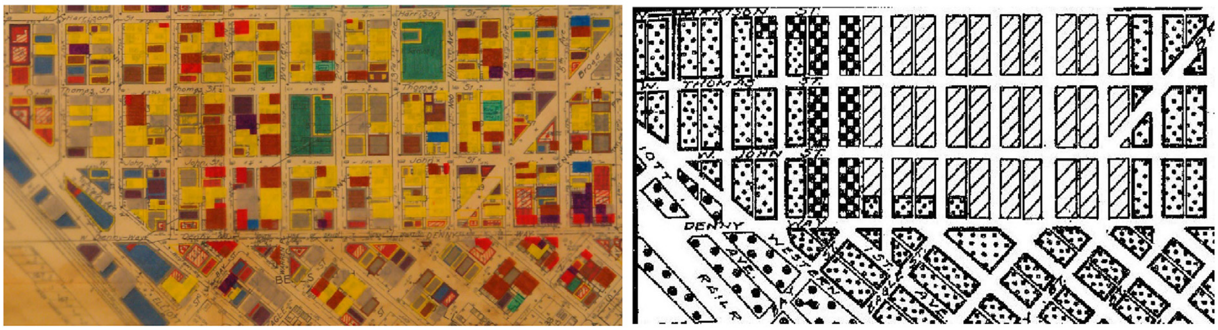
Much previous work on zoning has focused on its impact on land values and its malleability in the face of market forces. The impact of zoning on land values is well documented, suggesting the potential for real effects on land use (McMillen and McDonald, 2002; Ihlanfeldt, 2007; Turner et al., 2014; Koster et al., 2012). Evidence for real effects has been found in Chicago and major cities in Texas (Shertzer et al., 2018). A number of studies have emphasized how persistence in durable capital can influence urban growth, and this is one of the major channels I consider (Redfearn, 2009; Glaeser and Gyourko, 2005). Most dynamic work has examined short-run parcel rezonings, arguing that zoning may often "follow the market" (Wallace, 1988; Munneke, 2005; McMillen and McDonald, 1991). Recent work in Australia suggests that the rezoning process is biased in favor of politically-connected landowners (Murray and Frijters, 2016). This study builds on previous work by examining zoning and land use change over multiple time scales, incorporating both piecemeal and comprehensive rezonings. This is one of few studies able to track land use change over a century, and the first to disentangle the influence of zoning through its immediate effects on land use and its longer-term legal path dependence.

2. Data

This paper focuses on the city of Seattle, with data overlapping 13 neighborhoods in the central district, including the central business district, several former industrial areas undergoing commercial/residential conversion, and some longstanding residential areas. Fig. 1 shows the extent of the sample. The unit of observation is the parcel. Since considerable land assembly and subdivision has taken place, parcel boundaries are not constant over time. To account for this, parcels that were subdivided remain so, while parcels that were consolidated are split along their historic lines. This section describes the land use, zoning, transportation, demographic, and geographic data assembled for the paper.

2.1. Land use

Land use data from 1920–52 is drawn from a series of surveys conducted by the Seattle City Planning Commission which were digitized for this project. The first is a comprehensive survey of land use in 1920 and 1952 at the parcel level for a portion of Lower Queen Anne, north of the central business district; this is the smaller area indicated in Fig. 1. Uses are divided into nine categories: single family or duplex, multifamily, business (such as restaurants and retail stores), service stations, auto parking or sales lots, commercial (such as larger office buildings or light manufacturers), industrial, vacant, and public use. In the analysis, I refer to this as the comprehensive land use sample, as it covers all 882



(A) Land use in Queen Anne, Seattle 1920-1952. (B) 1923 use zoning in Queen Anne, Seattle.

Panel (A) shows a portion of the 1920-52 land use survey of Lower Queen Anne. Yellow denotes single-family or duplex homes, brown denotes multifamily residential use, solid red denotes business use, red bordering with a dot denotes a service station, red hatching denotes auto parking or sales, purple denotes commercial use, blue denotes industrial use, grey denotes vacancy, and green denotes public space. Panel (B) shows the matching portion of the 1923 use zone map. Hatched areas were zoned for multifamily residences, checked areas were zoned for businesses, small dots denote commercial zoning, and large dots denote manufacturing zoning.

Fig. 2. Land use and zoning in Seattle, 1920–1952.

parcels in its extent regardless of whether or not a land use conversion occurred. Fig. 2A depicts a portion of the original survey map.

A larger survey covers all land use changes for 2270 parcels from 1920 to 1952. The extent of the survey is depicted by the larger outline in Fig. 1. While considerably larger than the comprehensive land use sample, it only includes parcels which saw land use conversions between 1920 and 1952. I refer to this portion of the data as the land use change sample. I discuss the advantages and disadvantages of each sample in section 3.

Modern data on land use comes from the King County GIS database and is coded for every parcel in the city. I aggregate parcel classifications to the categories residential (single-family and purely multifamily), mixed use (business and residential), commercial, industrial, and vacant (including parcels under development).

2.2. Zoning and variances

Seattle's first comprehensive zoning ordinance was passed in 1923, and the parcel zoning classifications were digitized from the associated maps. The ordinance regulated uses into six categories: single-family, multifamily, business, commercial, manufacturing, and industrial. Fig. 2B provides a sample of the use zoning map. As was typical at the time, the use districts were hierarchical, with less restrictive zones (such as manufacturing) accommodating uses from more restrictive zones (such as businesses and multifamily dwellings). At the bottom of the use hierarchy, only single-family homes are allowed; at the top, any use, from heavy industry to residential, is permitted. It also established five height districts (40′, 65′, 80′, 100′, and a maximum height district based on street width) and four area districts (A, B, C, and D, with the latter being the least restrictive). As the use restrictions were the most binding and the height/area restrictions were largely collinear with uses, I focus on the use districts in the analysis.

Data on variances over the following three decades comes from a 1953 survey of zoning by the City Planning Commission which covers my entire sample. Positioned immediately after the 1952 land use surveys, it allows me to assess the extent to which uses not conforming to the 1923 ordinance were authorized by the city. The first comprehensive rezoning of Seattle took effect in 1957. This ordinance replaced the early dual-map system with an integrated system of use and density regulations. This divided the city into six single-family zones and two multifamily zones (differentiated by allowed density), three business zones, two commercial zones, a manufacturing zone, and two heavy industrial zones.

2.3. Geography

Since location and geography play a large role in determining land use, data on important geographic factors must be included. For each parcel, I calculated the distance to the central business district, distance to the coast, and distance to KeyArena. The latter is a measure of proximity to the Seattle Center, a public entertainment district developed on the site of the 1962 World's Fair. Since Interstate 5 represents a major division of the central district, I account for a parcel's location west of I-5 in all models.

Another historically important geographic factor is proximity to the former site of Denny Hill. This large hill near downtown was regraded in five phases beginning in 1898 and ending in 1930. Fig. 3 depicts the location of the regrades. This represented a major reshaping of the Seattle landscape and was explicitly intended to ease transportation and encourage the commercial development of the area (Williams, 2015). Thus, parcels located on the regrade site likely experienced a different trajectory of development, which I account for in my analysis.

2.4. Transportation

Since access to major transportation corridors affects development incentives, I calculated for all parcels the distance to the nearest railroad,[2] state highway, and interstate, which is I-5 in most cases. While not completed until the 1960s, I include it in all models to capture anticipatory effects as well as the influence of the state highway it replaced. Additionally, like many cities at the time, Seattle had an extensive streetcar rail network in place in the early 20th century. The network began operation in 1889 (replacing a horse-drawn carriage system) and

[2] Historical railroad data was taken from Atack (2016).

(A) Five phases of the Denny regrade.

(B) Regrading in progress.

Panel (A) shows the former site of Denny Hill and the five phases of the regrade. Regrade 1 (teal) was completed in 1898, regrade 2 (purple) between 1902 and 1906, regrade 3 (green) between 1906 and 1908, regrade 4 (orange) between 1908 and 1911, and regrade 5 (red) between 1929 and 1930 (Williams 2015). Panel (B) shows the regrade in progress circa 1920 (photograph published by O.T. Frasch).

Fig. 3. Denny regrades, 1898–1930.

gradually expanded until it was decommissioned in 1941 (Blanchard, 1968). Using available maps from 1915 to 1941, I digitized the streetcar network and calculated parcels' proximity to the track. A portion of the 1941 map is depicted in Fig. 4. Since access to rail transportation can have significant economic value, it is important to capture this in any analysis of property development; the impact of streetcars can even persist long after the network is dissolved (Brooks and Lutz, 2016).

2.5. Demographics

Demographic data for Seattle in 1920 is drawn from 100% decennial census counts digitized by Ancestry.com and provided through IPUMS. The data includes population density and the percentage of the population that was African-American, Chinese, and Japanese at the enumeration district (ED) level. Parcels are assigned the demographic composition of the ED in which they reside.[3] The typical ED covered an area approximately 0.08 square miles, and parcels from 77 EDs are included in my sample. ED maps were provided by FamilySearch through the Seattle Public Library.

Demographic data for 1950 is recorded at the census tract level and includes measures of population density and the percentage of the

[3] Other ethnic groups were reported but constituted an extremely small fraction of the ED population in my sample; none of the non-white excluded groups exceeded 2% of the population in any ED, so I include them in the omitted category.

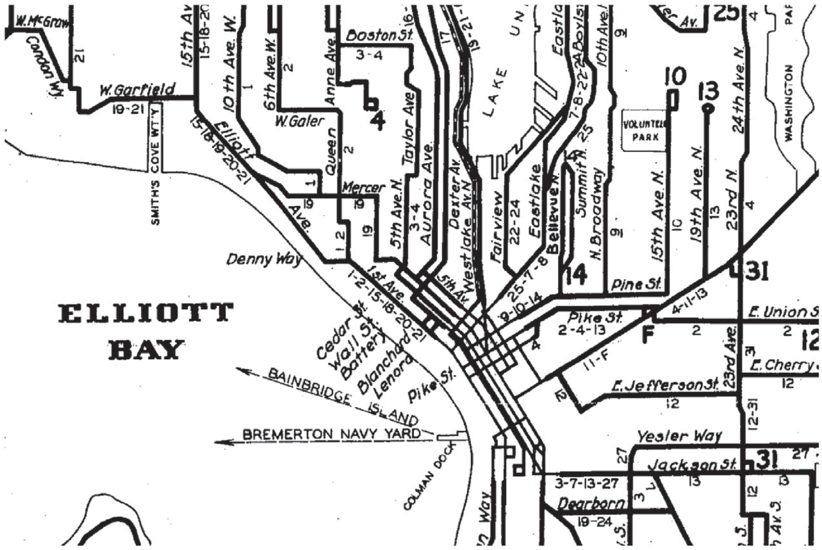


Figure depicts a portion of the Seattle streetcar network circa 1941, shortly before the system was dismantled (Blanchard 1968).

Fig. 4. Seattle streetcar network, 1941.

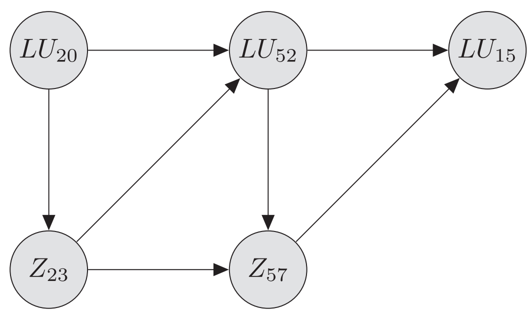


Figure depicts the underlying data generating process as a causal graphical model (Pearl 2009). LU and Z nodes represent land use and zoning, respectively. Subscripts indicate year of observation. Since land use and zoning are the primary focus of this study, transportation and demographic factors are subsumed by the LU nodes.

Fig. 5. Data generating process.

population that was African-American and foreign-born white. It also includes the percentage of housing units that were owner occupied, the average population per occupied housing unit, and median income. As with the 1920 data, parcels were assigned the demographic composition of their associated census tract; the typical tract covered an area approximately 0.3 square miles, and parcels from 15 tracts are included in my sample.

3. Methodology

Fig. 5 depicts the hypothesized data generating process of interest, with land use and zoning coevolving over time. Here I discuss the methods used to examine this process. I first outline the required identifying assumptions, and then move on to the regression specification and variables to be included in each model. There are five distinct sets of analysis conducted below, each requiring a different set of identifying assumptions. I discuss these assumptions informally here; a more formal treatment using Pearl's (2009) causal graph framework is given in the appendix and referenced in footnotes.

The first and simplest analysis examines the determinants of the 1923 zoning classification each parcel received. This requires conditioning on important pre-zoning characteristics, such as land use, transportation access, demographics, and locational factors; the causal effects of these characteristics are identified if there is no unobserved confounder between the pre-zoning predictors and 1923 zoning.[4] While this assumption is unlikely to be perfectly satisfied, the set of pre-zoning covariates (described in detail below) is constructed to account for a wide range of important zoning predictors documented in the literature. Additionally, early zoning ordinances in most US cities strove to impose order on "chaotic" land use patterns; for this reason, they intentionally neglected much existing land use characteristics, following land use patterns broadly rather than tailoring zoning to specific blocks or parcels. This can be observed in Fig. 2, where the relative uniformity of 1923 use zoning contrasts with the high level of use mixing prior

[4] Appendix Fig. A1 repeats Fig. 5 with relevant possible confounders included. The identifying assumption here is that the unobserved confounder U_1 is absent.

Table 1
Descriptive statistics: Land use and zoning.

Variable	Mean Comp. land use sample	Mean Land use change sample
Single-family use, 1920	0.447	0.444
Multifamily use, 1920	0.109	0.038
Business use, 1920	0.062	0.063
Commercial use, 1920	0.068	0.076
Industrial use, 1920	0.019	0.016
Vacant, 1920	0.295	0.363
Single-family use, 1952	0.299	0.093
Multifamily use, 1952	0.192	0.196
Business use, 1952	0.197	0.301
Commercial use, 1952	0.093	0.205
Industrial use, 1952	0.065	0.052
Vacant, 1952	0.154	0.153
Residential use, 2015	0.197	0.198
Mixed use, 2015	0.128	0.101
Commercial use, 2015	0.484	0.393
Industrial use, 2015	0.005	0.02
Vacant, 2015	0.05	0.067
Multifamily zoning, 1923	0.274	0.192
Business zoning, 1923	0.109	0.093
Commercial zoning, 1923	0.584	0.662
Manufacturing zoning, 1923	0.033	0.054
Multifamily zoning, 1957	0.124	0.208
Business zoning, 1957	0.061	0.068
Commercial zoning, 1957	0.688	0.539
Manufacturing zoning, 1957	0.127	0.185
Zoning violation, 1923	0.04	0.033
Zoning violation, pre-1953	0.101	0.08
Variance, 1923-53	0.166	0.065
Zoning violation, 1953	0.067	0.06
Zoning violation, 1957	0.042	0.047
Observations	882	2270

Descriptive statistics for land use and zoning variables used in the analysis.

to zoning. The second analysis examines the impact of 1923 zoning on land use conversions and variances prior to 1957 (conditional on the pre-zoning characteristics). In addition to the previous no-confounding assumption, it must also be the case that there are no unobserved confounders between 1923 zoning and the 1950s land use and variance outcomes.[5]

The third analysis aims to measure the extent to which a parcel's 1923 zoning affected the zoning it received during the comprehensive revision in 1957, conditional on the evolution of land use, demographics, and transportation leading up to the revision. Since 1923 zoning directly affected this evolution, this takes the form of a mediation analysis; I seek to estimate the direct effect of 1923 zoning on 1957 zoning, netting out its indirect effect through induced changes in other important zoning determinants. Conditioning on 1920s and 1950s controls, the analysis requires an absence of confounding between pre-1950s zoning predictors and 1957 zoning as well as between 1923 zoning and 1957 zoning.[6]

The fourth analysis looks at the long-run total effect of 1923 zoning on land use in 2015, conditional on 1920s predictors. To identify this effect, it must be the case that there are no unobserved common causes of 1923 zoning and 2015 land use. Additionally, there must either be no unobserved confounders between 1920s predictors and 2015 land use or between 1920s predictors and 1923 zoning; either condition alone is sufficient.[7] The final analysis aims to estimate the magnitude of the long-run total effect of 1923 zoning that is due to persistence in the institution itself, rather than its short-run impact on real factors leading up to 1957. This requires conditioning on intermediate variables like 1952 land use, 1950s demographics, and the evolution of transportation access. The remaining effect of 1923 zoning can be interpreted as institutional persistence (assuming there are no other unobserved short-run mediators that reflect physical changes due to 1923 zoning). Conditional on 1920s and 50s zoning predictors, identification of the direct effect requires an absence of confounding between (1) 1920s predictors and 1923 zoning, (2) 1920s predictors and 1950s predictors, (3) 1950s variables and 2015 land use, and (4) 1923 zoning and 2015 land use.[8] While these more strenuous assumptions are likely to be violated to some extent, I have included as many variables as possible to mitigate potential bias. Additionally, these conditions do imply that 1920-specific predictors should be conditionally independent of 2015 land use, providing a partial test of the underlying assumptions. I discuss this further below.

The analysis is conducted using linear models of the form

$$y_i = \beta_0 + \beta_1' l_i + \beta_2' z_i + \beta_3' d_i + \beta_4' g_i + \beta_5' t_i + \epsilon_i \tag{3.1}$$

where y_i is an indicator capturing the relevant zoning or land use outcome. l_i is a vector of land use variables coded as indicators; each parcel is coded as single-family, multifamily, business, commercial, industrial, or vacant, with single-family as the omitted category. Depending on the analysis, l_i may contain only 1920 land use or both 1920 and 1952 land use. In all but the first analysis (examining 1923 use zoning determi-

[5] In Appendix Fig. A1, this amounts to the assumption that U_1 and U_5 are absent. Alternatively, the causal impact of 1923 zoning on 1950s land use and variances is still identified in the presence of zoning and pre-zoning confounders U_1 if there is no confounding between the outcomes and pre-zoning variables; this amounts to the assumption that U_2 and U_5 are absent.

[6] In Appendix Fig. A1, this amounts to the absence of U_7 and U_8, conditional on LU_{20} and LU_{52}. Note that the presence of confounding between 1923 zoning and 1950s controls, i.e., U_5, does not affect identification here.

[7] Formally, in Appendix Fig. A1, the first set of identifying assumptions equates to an absence of U_4 and U_6; the second equates to the absence of U_4 and U_1. For both, it is necessary to condition on LU_{20}.

[8] This is equivalent to the absence of U_1, U_2, U_3, and U_4 in Fig. A1.

Table 2
Descriptive statistics: Geography and demographics.

Variable	Mean Comp. land use sample	Mean Land use change sample
West of I-5	1	0.668
Dist. to CBD	0.994	0.483
	(0.25)	(0.331)
Dist. to coast	0.314	0.544
	(0.131)	(0.299)
Dist. to Key Arena	0.191	1.074
	(0.114)	(0.689)
Denny regrade area, 1898–1911	0.012	0.097
Denny regrade area, 1929–1930	0.061	0.087
Dist. to interstate	1.207	0.516
	(0.251)	(0.402)
Dist. to highway	0.495	0.26
	(0.25)	(0.214)
Dist. to railroad	0.272	0.582
	(0.169)	(0.326)
Dist. to 1915 streetcar	0.036	0.047
	(0.033)	(0.046)
Dist. to 1941 streetcar	0.026	0.028
	(0.024)	(0.026)
Pop. density, 1920	12935	23493
	(5674)	(13432)
% black, 1920	0.0009	0.0119
	(0.0013)	(0.0317)
% Chinese, 1920	0.0003	0.008
	(0.0005)	(0.0257)
% Japanese, 1920	0.0052	0.0523
	(0.0066)	(0.1179)
Pop. density, 1950	11629	17591
	(3072)	(9819)
% black, 1950	0.004	0.04
	(0.0031)	(0.072)
% foreign-born, 1950	0.143	0.152
	(0.0279)	(0.037)
% owner-occupied housing, 1950	0.107	0.081
	(0.0623)	(0.0765)
Median income, 1950	2828	2251
	(408)	(537)
Observations	882	2270

Descriptive statistics for demographic, transportation, and geographic variables used in the analysis. Means are presented for all variables; standard deviations are included in parentheses for non-indicator variables. Distances are measured in miles, and population density is persons per square mile.

nants), the models include z_i, a vector of 1923 use zoning indicators. The possible categories include multifamily, business, commercial, or manufacturing, with multifamily as the omitted category.[9] d_i is a vector of demographic control variables; when 1920 is the base year, it includes population density and the fraction of the population that was African-American, Chinese, and Japanese for the enumeration district containing the parcel. In models that also condition on intermediate 1950s variables, d_i also includes population density, percent African-American, percent foreign-born white, percent of housing units that were owner occupied, median income, and population per occupied housing unit for the 1950 census tract containing the parcel.

g_i is a vector of geographic control variables capturing factors which should influence both zoning and land use. In all models, g_i includes the distance to the CBD, coast, and KeyArena. It also includes indicators for parcel location west of I-5 and on the site of one of the first four phases of the Denny regrade (completed by 1911). In models including post-1923 predictors (Tables 12 and 14), it additionally includes an indicator for location on the site of the final phase of the Denny regrade (completed in 1930). The final set of controls, t_i, reflect transportation access factors. It includes the distance to the nearest interstate, state highway, railroad, and 1915 streetcar line.[10] In models including post-1923 predictors (Tables 12 and 14), an additional variable measuring the distance to the expanded 1941 streetcar network is included.

While the set of variables included in g_i and t_i are constant (aside from the inclusion of the final Denny regrade and 1941 streetcar expansion in Tables 12 and 14), the importance of these variables may vary over time. Since the coefficients can change from model to model as other variables are included and other outcomes are considered, the estimated coefficients should reflect the changing values of these locational and transportation factors. To account for correlation of zoning outcomes within blocks, standard errors are clustered at the block level.

I conduct every analysis separately on the comprehensive land use sample and the land use change sample, each of which has its own advantages and drawbacks. The comprehensive sample avoids biases due to selection into early land use change, but its small size may make it less representative of the city as a whole, especially given the changes

[9] No parcels in my sample received single-family zoning or heavier industrial zoning; the latter was concentrated in a small area in the southernmost portion of the city.

[10] The interstate and highway variables are omitted from models estimated on the comprehensive land use sample. The correlation between these two variables in this sample is 0.99, and their correlation with distance to the CBD is 0.92, leading to implausibly large coefficients and standard errors when they are included.

Table 3
Impact of 1920 land use on 1923 use zoning.

Land use, 1920	Multifamily zoning, 1923		Commercial zoning, 1923		Manufacturing zoning, 1923	
	(1)	(2)	(3)	(4)	(5)	(6)
Multifamily housing	0.071	−0.015	−0.055	−0.187***	−0.001	−0.033**
	(0.0589)	(0.0293)	(0.0498)	(0.0591)	(0.0142)	(0.0167)
Business	−0.140**	0.004	−0.177**	−0.005	0.007	−0.026
	(0.0653)	(0.0282)	(0.0717)	(0.0338)	(0.0260)	(0.0173)
Commercial	−0.133***	−0.027	0.002	0.042	−0.007	0.054**
	(0.0384)	(0.0357)	(0.0380)	(0.0297)	(0.0191)	(0.0251)
Industrial	−0.181***	−0.107***	0.052	0.125***	0.247	0.179**
	(0.0530)	(0.0415)	(0.0947)	(0.0442)	(0.1813)	(0.0740)
Vacant	−0.045	0.007	0.049	0.017	0.034	0.024*
	(0.0403)	(0.0182)	(0.0346)	(0.0188)	(0.0340)	(0.0130)
Population density	−0.046	0.042***	−0.219**	−0.090***	0.010	−0.037***
	(0.1043)	(0.0134)	(0.1043)	(0.0190)	(0.0325)	(0.0096)
% black		−0.138***		0.051***		0.026***
		(0.0184)		(0.0144)		(0.0059)
% Chinese		−0.041***		0.034***		0.007
		(0.0137)		(0.0110)		(0.0049)
% Japanese		0.024		0.030		−0.023***
		(0.0266)		(0.0216)		(0.0084)
Estimation	OLS	OLS	OLS	OLS	OLS	OLS
Observations	882	2270	611	1713	882	2270
R^2	0.158	0.367	0.357	0.253	0.189	0.309

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$

Linear regressions of indicators for 1923 zoning outcomes on 1920 land use, demographics, transportation, and geographic covariates. Odd-numbered columns are estimated on the comprehensive land use sample; even-numbered columns are estimated on the land use change sample. Geography and transportation coefficients are omitted to conserve space. Demographic covariates are omitted from odd-numbered columns due to negligible variation on the comprehensive land use sample. The outcome in columns (1)–(2) is an indicator for multifamily zoning in 1923. In columns (3)–(4), the sample is restricted to blocks that received either business or commercial zoning in 1923, and the outcome is an indicator for the more intensive commercial zoning. The outcome in columns (5)–(6) is an indicator for manufacturing zoning in 1923. Standard errors are clustered at the block level.

induced when the neighborhood hosted the 1962 World's Fair.[11] The land use change sample captures a much larger portion of the city, with considerably more variation in land use types, zoning types, and demographics. However, estimates of the long run persistence of zoning could be biased downward if parcels which switched uses early essentially capture all of the zoning effect.

To compare the relative impact of different blocks of covariates (zoning, land use, demographics, transportation, and geography), many of the estimated linear models are accompanied by sheaf coefficients (Whitt, 1986; Heise, 1972). These multiple-partial regression coefficients summarize the impacts of groups of predictors by assuming that each block of variables acts through a single (unobserved) latent variable. The estimated latent variable is standardized, so the coefficients provide a means to compare the relative importance of zoning, land use, demographics, and geography in determining future land use and zoning outcomes.

4. Results

Table 1 presents descriptive statistics for land use and zoning in the comprehensive land use sample and the larger land use change sample; Table 2 reports statistics for geography, transportation, and demographic variables on the two samples. Initially, parcels in both samples were largely vacant or occupied by single-family homes. The two samples are similar in land use mix but differ in other respects; the comprehensive land use sample was less dense and less racially diverse in 1920, and these parcels tended to be farther from the CBD.

4.1. Determinants of 1923 zoning

Table 3 presents results on the determinants of a parcel's use zoning classification in 1923. Columns (1) and (2) examine the likelihood of multifamily zoning relative to business, commercial, and manufacturing zoning in the comprehensive and land use change samples.[12] Parcels hosting business, commercial, and especially industrial uses tended to be less likely to receive multifamily zoning, whereas vacant and multifamily use parcels were no more or less likely to receive such zoning than single-family use parcels (the omitted land use category). In columns (3) and (4), I restrict the sample to include only parcels that received business or commercial zoning and find that the more intensive commercial zoning generally followed industrial uses and was much less likely to be applied to multifamily parcels. Unsurprisingly, columns (5) and (6) report that industrial uses were substantially more likely than any other use to receive manufacturing zoning.

In the broader land use change sample, there is sufficient variation in the concentration of minority populations to effectively measure their impact on zoning outcomes. Consistent with earlier work on Chicago, I find that African-Americans were disproportionately likely to receive manufacturing zoning (Shertzer et al., 2016). They were much less likely to receive multifamily zoning, and when business or commercial zoning was applied it tended to favor the more intensive commercial classification. Chinese-Americans tended to receive less multifamily zoning and more intensive commercial zoning; Japanese-American were somewhat less likely to receive industrial zoning but more likely

[11] For example, while the city had substantial African-, Chinese-, and Japanese-American populations in 1920, none of these groups exceed 2% of the population of the EDs in my comprehensive land use sample. There is considerably more variation in the land use change sample, with African- and Chinese-American populations exceeding 17% of the population in some instances, while the Japanese-American population reached as much as 57% of the population.

[12] No parcels in my sample received zoning for single-family homes or heavier industrial zoning, which was concentrated in a small area in the southernmost portion of the city.

Table 4
Transition matrix: Land use 1920–1952 comprehensive land use sample.

		Land Use, 1952						Total
	SF	MF	B	C	I	V		
Land Use, 1920	SF	217	49	55	17	12	44	394
	MF	1	81	3	0	0	11	96
	B	3	1	47	1	2	1	55
	C	8	4	11	30	5	2	60
	I	1	0	1	2	11	2	17
	V	34	34	57	32	27	76	260
	Total	264	169	174	82	57	136	882

Transition matrix for single-family (SF), multifamily (MF), business (B), commercial (C), industrial (I), and vacant (V) land uses on the comprehensive land use sample.

Table 5
Transition matrix: Land use 1920–1952 land use change sample.

		Land Use, 1952						Total
	SF	MF	B	C	I	V		
Land Use, 1920	SF	0	302	272	157	21	255	1007
	MF	12	0	42	7	0	26	87
	B	27	26	0	46	13	31	143
	C	28	9	82	0	21	33	173
	I	1	3	9	21	0	3	37
	V	143	104	278	235	63	0	823
	Total	211	444	683	466	118	348	2270

Transition matrix for single-family (SF), multifamily (MF), business (B), commercial (C), industrial (I), and vacant (V) land uses on the land use change sample.

Table 6
Transition matrix: Land use 1920–1952 land use change sample - multifamily zoning in 1923.

		Land Use, 1952						Total
	SF	MF	B	C	I	V		
Land Use, 1920	SF	0	120	30	2	1	57	210
	MF	7	0	1	0	0	4	12
	B	10	9	0	0	0	2	21
	C	7	3	2	0	4	2	18
	V	88	56	23	6	1	0	174
	Total	112	188	56	8	6	65	435

Transition matrix for single-family (SF), multifamily (MF), business (B), commercial (C), industrial (I), and vacant (V) land uses on the land use change sample. Sample is further restricted to parcels which received only multifamily zoning in 1923. No parcels hosting industrial uses in 1920 received multifamily zoning in 1923.

to receive commercial zoning rather than zoning for smaller neighborhood businesses.

While the results indicate that pre-existing uses influenced zoning, the predictive power of the models is somewhat weak. This is not surprising given the state of land use prior to zoning - almost half of the parcels in my sample were single-family homes, and none of the parcels received the most restrictive low-density residential zoning. This is indicative of the planning approach of the era, which aimed to accommodate (anticipated) growth in commercial and industrial activity in cities while also creating residential and commercial areas protected from incompatible uses. Similar results have been documented in Chicago (McMillen and McDonald, 2002; Shertzer et al., 2018).

Table 7
Transition matrix: Land use 1920–1952 land use change sample - business/commercial/manufacturing zoning in 1923.

		Land Use, 1952						Total
	SF	MF	B	C	I	V		
Land Use, 1920	SF	0	182	242	155	20	198	797
	MF	5	0	41	7	0	22	75
	B	17	17	0	46	13	29	122
	C	21	6	80	0	17	31	155
	I	1	3	9	21	0	3	37
	V	55	48	255	229	62	0	649
	Total	99	256	627	458	112	283	1835

Transition matrix for single-family (SF), multifamily (MF), business (B), commercial (C), industrial (I), and vacant (V) land uses on the land use change sample. Sample is further restricted to parcels which received business, commercial, or industrial zoning rather than multifamily zoning in 1923.

Table 8
Impact of 1923 zoning on land use conversion, 1920–1952.

	Use change (1)	SF to BCI (2)	V to BCI (3)
Business zoning, 1923	−0.015	0.182**	0.459***
	(0.0822)	(0.0716)	(0.0706)
Commercial zoning, 1923	0.057	0.340***	0.456***
	(0.0568)	(0.0653)	(0.0594)
Manufacturing zoning, 1923	0.160	0.366***	0.710***
	(0.1357)	(0.1315)	(0.0578)
Multifamily use, 1920	−0.289***		
	(0.0434)		
Business use, 1920	−0.334***		
	(0.0684)		
Commercial use, 1920	0.014		
	(0.1070)		
Industrial use, 1920	−0.162		
	(0.1241)		
Vacant use, 1920	0.258***		
	(0.0431)		
	Sheaf coefficients		
Land use, 1920	0.189***		
	(0.0156)		
Zoning, 1923	0.037	0.138***	0.204***
	(0.0252)	(0.0262)	(0.0210)
Geography	0.051**	0.175***	0.132***
	(0.0245)	(0.0642)	(0.0346)
Transportation	0.085***	0.146*	0.095***
	(0.0326)	(0.0825)	(0.0314)
Demographics, 1920	0.047	0.145***	0.033
	(0.0690)	(0.0363)	(0.0205)
Estimation	OLS	OLS	OLS
Observations	882	752	823

***$p<0.01$, **$p<0.05$, *$p<0.1$

Column (1) presents results from a linear regression of an indicator for land use change over 1920–1952 on the full set of 1920 land use, demographics, transportation, and geographic covariates; this model is estimated on the comprehensive land use sample. Column (2) presents results from a linear regression of an indicator for conversion of single-family (SF) use to business (B), commercial (C), or industrial (I) use; only parcels that were SF in 1923 are included, and conversion to MF is the omitted category. Column (3) presents results from a linear regression of an indicator for conversion of vacant parcels to business (B), commercial (C), or industrial (I) use; only parcels that were vacant in 1923 are included, and conversion to SF or MF is the omitted category. All models include 1920 demographics, transportation, and geographic covariates; coefficients are omitted to conserve space. Standard errors are clustered at the block level.

4.2. Land use conversions, 1920–1952

Turning to the response to zoning, I first document land use transitions over 1920–1952, the three decades following the initial zoning, before moving on to regression results. Tables 4 and 5 report transition matrices for land uses. In the comprehensive sample (Table 4), considerable land use conversion took place, with approximately half of the parcels seeing land use changes. Most of these changes involved transitions of single-family uses and vacancies to multifamily, business/commercial, or industrial use. Table 5 reports land use conversions on the sample of all land use changes. As before, most conversions involved a move up the zoning hierarchy, though there is considerable variation.

Tables 6 and 7 repeat the previous analysis while partitioning on zoning; the former restricts to parcels that received multifamily zoning in 1923 while the latter captures the parcels zoned for business, commercial, or manufacturing use. Comparing the transition matrices illustrates the dramatic difference in development patterns between areas zoned more and less restrictively. Less restrictive zoning is associated with substantially more conversion to business, commercial, and industrial use, while multifamily zoning is associated with movements down the use hierarchy for all but single-family homes, which largely converted to multifamily residences.

Table 8 presents regression results for land use conversions on the comprehensive sample. Column (1) shows that the type of zoning had little influence on the probability of a land use change, whereas the pre-existing use had a sizable impact. Multifamily and business uses were much less likely to see a change than single-family uses, while vacant parcels were much more likely to see development. Column (2) shows that business, commercial, and industrial zoning all greatly increased the likelihood that single-family homes were converted to business, commercial, or industrial use (relative to multifamily conversion); column (3) shows very similar results for the conversion of vacant parcels. Sheaf coefficients indicate that zoning was as or more influential than any other group of factors in determining what conversions took place.

Table 9
Transition matrix: Variances 1923–1953.

		Zoning, 1953				Total
	MF	B	C	I		
Zoning, 1923	MF	0	69	55	18	142
	B	1	0	9	0	10
	C	15	8	0	40	63
	Total	16	77	64	58	215

Transition matrix for multifamily (MF), business (B), commercial (C), and industrial (I) zoning on the full sample. No parcels zoned for industrial use in 1923 received variances by 1953.

Table 10
Impact of 1920 land use on variances through 1953.

Land use, 1920	Variance, 1953 (1)	Variance, 1953 (2)
Business zoning, 1923	−0.258***	−0.216***
	(0.0525)	(0.0396)
Commercial zoning, 1923	−0.322***	−0.235***
	(0.0548)	(0.0361)
Manufacturing zoning, 1923	−0.482***	−0.265***
	(0.0971)	(0.0463)
Land use change, 1920-52	0.032	
	(0.0293)	
Multifamily housing	−0.113**	−0.002
	(0.0464)	(0.0256)
Business	0.010	−0.017
	(0.0490)	(0.0127)
Commercial	0.021	0.006
	(0.0472)	(0.0179)
Industrial	−0.087	0.014
	(0.0810)	(0.0302)
Vacant	0.021	0.008
	(0.0266)	(0.0133)
Population density	0.114	0.009
	(0.0934)	(0.0116)
% black		0.007
		(0.0070)
% Japanese		−0.011
		(0.0130)
% Chinese		0.006
		(0.0113)
Estimation	OLS	OLS
Observations	882	2270
R^2	0.276	0.178

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$

Linear regressions of indicators for 1923–53 variances on 1923 zoning, 1920 land use, demographics, transportation, and geographic covariates. Column (1) is estimated on the comprehensive land use sample and column (2) is estimated on the land use change sample. Geography and transportation coefficients are omitted to conserve space. Demographic coefficients are omitted from column (1) due to the negligible variation of those covariates in the comprehensive land use sample. Standard errors are clustered at the block level.

4.3. Compliance levels and variances, 1923–1953

While there is anecdotal evidence of non-compliance in early zoning, there is little formal evidence to back this up. Evidently, the zoning board aimed to accommodate substantial growth and land use change through the original 1923 ordinance. A majority of parcels were "upzoned" in the sense that the zoning allowed uses which were higher on the use hierarchy than existing uses. For example, none of the 1224 single-family homes in my sample received single-family zoning. Nonetheless, 3.4% of parcels were zoned in such a way as to prohibit the existing use.[13] Of these, only 11.6% received a variance by 1953; these variances brought 91% of the parcels into compliance. Overall, 7.7% of parcels had received a zoning variance by 1953.[14]

Table 9 shows how zoning changed for the parcels granted variances. Most of the variances involved the granting of more permissive zoning, with the bulk applied to parcels zoned for multifamily housing in 1923. Only 11.2% of the variances involved downzoning. Table 10 shows that more permissively zoned parcels were less likely to receive a variance. With the exception of multifamily parcels, which were substantially less likely to receive a variance, pre-existing land use and land use conversion appeared to have little impact on variances.

Many parcels were vacant in 1920, and some insight into early compliance can be gleaned by analyzing whether the conversion of these parcels was consistent with the 1923 ordinance and, if not, whether the parcels received a formal variance. Of the 901 parcels in my sample that were vacant in 1920, by 1952 9.8% had been developed into a use incompatible with the 1923 ordinance. Of these, only 25% received a formal variance (by 1953) putting the actual use in compliance with the zoning ordinance. Of the 153 parcels whose use was incompatible with zoning as of 1953, only 38.6% received compatible zoning during the 1957 comprehensive revision of the ordinance. This indicates a nontrivial and persistent level of nonconformity, providing some preliminary evidence that a long-run effect of 1923 zoning on present-day land use would involve a degree of institutional persistence.

4.4. Determinants of 1957 zoning

If the 1923 ordinance were to have long-run effects on land use net of its short-run impact, this should be reflected in its influence on the first comprehensive rezoning of Seattle in 1957. Table 11 shows the relationship between 1923 and 1957 zoning classifications.[15] There were a considerable number of parcels upzoned from multifamily and commercial use, while many business and commercial parcels were

[13] This figure is 4% on the comprehensive sample and 3.3% on the land use change sample.

[14] This figure is 15.9% on the comprehensive sample and 6.2% on the land use change sample.

[15] The 1957 ordinance had additional subclassifications for multifamily, business, commercial, and industrial use; I have consolidated them here for comparability.

Table 11
Transition matrix: Zoning, 1923–1957.

		Zoning, 1957				Total
	MF	B	C	I		
Zoning, 1923	MF	400	34	175	1	610
	B	66	44	167	8	285
	C	104	117	1229	335	1785
	I	0	0	14	120	134
	Total	570	195	1585	464	2814

Transition matrix for multifamily (MF), business (B), commercial (C), and industrial (I) zoning on the full sample.

Table 12
Impact of 1923 zoning on 1957 zoning.

	Business/commercial zoning (1)	Business/commercial zoning (2)	Manufacturing zoning (3)	Manufacturing zoning (4)
Business zoning, 1923	0.211***	0.313***	−0.036	0.021
	(0.0469)	(0.0612)	(0.0309)	(0.0211)
Commercial zoning, 1923	0.213***	0.311***	−0.031	0.124***
	(0.0481)	(0.0902)	(0.0256)	(0.0217)
Manufacturing zoning, 1923	−0.339***	0.001	0.618***	0.455***
	(0.1247)	(0.1132)	(0.0920)	(0.0665)
Multifamily use, 1952	−0.048	−0.034	0.006	−0.006
	(0.0348)	(0.0377)	(0.0213)	(0.0253)
Business use, 1952	0.048	0.151***	0.030	0.005
	(0.0341)	(0.0360)	(0.0405)	(0.0266)
Commercial use, 1952	0.018	0.085**	0.099	0.059*
	(0.0523)	(0.0390)	(0.0692)	(0.0308)
Industrial use, 1952	−0.139*	−0.058	0.243***	0.150***
	(0.0711)	(0.0610)	(0.0678)	(0.0506)
Vacant use, 1952	0.029	0.075*	0.002	0.017
	(0.0346)	(0.0387)	(0.0235)	(0.0275)
	Sheaf coefficients			
Land use, 1920	0.015	0.021**	0.016	0.006
	(0.0129)	(0.0083)	(0.0132)	(0.0060)
Land use, 1952	0.048***	0.074***	0.062***	0.038***
	(0.0132)	(0.0101)	(0.0175)	(0.0095)
Zoning, 1923	0.129***	0.134***	0.115***	0.098***
	(0.0173)	(0.0290)	(0.0151)	(0.0132)
Geography	0.461***	0.442***	0.354***	0.347***
	(0.0436)	(0.0459)	(0.0421)	(0.0286)
Transportation	0.304***	0.375***	0.362***	0.338***
	(0.0526)	(0.0534)	(0.0498)	(0.0389)
Demographics, 1920	0.099*	0.162***	−0.094*	0.176***
	(0.0545)	(0.0288)	(0.0484)	(0.0243)
Demographics, 1950	0.015	0.210***	0.047**	0.157***
	(0.0287)	(0.0334)	(0.0205)	(0.0269)
Estimation	OLS	OLS	OLS	OLS
Observations	882	2270	882	2270
R^2	0.688	0.625	0.595	0.664

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$

Linear regressions of 1957 zoning outcome indicators on 1923 zoning, 1952 land use, 1950 demographics, transportation, and geographic covariates. Outcome in columns (1)–(2) is an indicator for business or commercial zoning in 1957. Outcome in columns (3)–(4) is an indicator for manufacturing zoning in 1957. Columns (1) and (3) are estimated on the comprehensive land use sample and columns (2) and (4) are estimated on the land use change sample. Geography, transportation, and demographic coefficients are omitted from the upper panel to conserve space. Lower panel reports sheaf coefficients for each block of variables. Standard errors are clustered at the block level.

downzoned. However, the majority of multifamily and commercial parcels maintained their original classification, and there was little downzoning of industrial parcels. Table 12 documents the impact of 1923 zoning on 1957 zoning conditional on the evolution of land use, transportation, and demographics following the initial ordinance. The model includes parcel land use as recorded in 1952 and demographics from the 1950 census, as well as the standard transportation and geography controls and an additional variable reflecting expansion of the streetcar line up to 1941.

The results indicate that zoning was highly persistent, even after accounting for land use and demographic change over three decades. Business or commercial zoning in 1923 increased the likelihood of similar zoning in 1957 by as much as 31 percentage points. Manufacturing zoning in 1923 increased the likelihood of similar zoning in 1957 by as much as 62 percentage points, conditional on all other factors. Estimated sheaf coefficients indicate that 1923 zoning had a substantially larger impact on 1957 zoning than 1952 land use; for both outcomes in both samples, zoning was roughly twice as important as land use. Geography and transportation factors tended to dominate all others.

The maintained identifying assumptions imply that 1920 land use should be (conditionally) independent of 1957 zoning in these models, which would suggest that their estimated coefficients should be zero when included in these models. The sheaf coefficients for the 1920 land use variables are very small in all four models, and only reach significance in one, providing some evidence in favor of the identifying assumptions. The same should be true of 1920 demographics; however, these variables tend to still have substantial predictive value even when 1950 demographics are included. The likely explanation for this is that the variables available in the 1920 census differ from those in 1950; population density is measured less precisely in 1950 (since tracts are substantially larger than EDs), and the 1950 census did not separately report the Chinese and Japanese population. Indeed, it is these three variables that lead to the significant coefficients.

4.5. Decomposing the long run impact of zoning, 1923–2015

The results in the previous sections suggest that 1923 zoning could have an impact on modern day land use by influencing both early land use change and later zoning revisions. In this section, I estimate the long-run effect of 1923 zoning conditional on pre-zoning characteristics, and then compare this to the estimate conditional on the post-zoning evolution of land use, transportation, and demographics up to 1952. The difference should capture the extent to which the long-run influence of zoning was due to its short-run effect on land use change, transportation infrastructure, and individual sorting; the residual should indicate the degree of institutional hysteresis.

Table 13 shows the impact of 1923 zoning on land use in 2015. In columns (1)–(2), the samples are restricted to multifamily or mixed-use residences, with an indicator for mixed use as the outcome. The coefficients reflect the extent to which zoning influenced the likelihood that multifamily residential structures include commercial activity as well. Zoning for business or commercial activity appears to have little impact on the comprehensive sample, but commercial zoning has a sizable positive impact on the land use change sample, larger even than pre-existing land use, transportation, and demographics. Table 14 replicates this analysis but conditions on 1952 land use, 1950 demographics, and the expanded streetcar network. The magnitudes of the significant zoning coefficient in column (2) declines somewhat but remains substantial and statistically significant; commercial zoning in 1923 increases the likelihood of mixed use by 19 percentage points relative to multifamily zoning in 1923, even conditional on 1950s variables. The sheaf coefficient for zoning declines by approximately 22% on the land use change sample, indicating that 1923 zoning is slightly less important than 1952 land use and transportation, but still influential.

Columns (3)–(4) of 13 broaden the sample to examine the tradeoff between pure multifamily residential use or mixed/commercial/industrial use; the outcome is an indicator that equals 0 if the parcel is restricted to multifamily residences and 1 if it includes any commercial or industrial activity (possibly in addition to residences). The results indicate a sizable positive impact of less restrictive zoning, larger in magnitude than the influence of pre-existing land use on both subsamples. Turning to the estimates conditional on 1952 land use and 1950 demographics, columns (3)–(4) of Table 14 show that the impact of 1923 zoning declines moderately on both samples, with sheaf coefficients shrinking by 29–43%. Nonetheless, the effects remain large and significant.

Table 13
Impact of 1923 zoning on 2015 land use conditional on 1920s Covariates.

	Mixed use (1)	Mixed use (2)	Mixed/com./ind. (3)	Mixed/com./ind. (4)	Com./ind. (5)	Com./ind. (6)
Business zoning, 1923	0.017	0.086	0.033	0.235***	−0.169	0.197**
	(0.1754)	(0.0819)	(0.0841)	(0.0909)	(0.1188)	(0.0942)
Commercial zoning, 1923	0.069	0.251***	0.114**	0.311***	−0.036	0.177
	(0.0927)	(0.0936)	(0.0449)	(0.1106)	(0.0671)	(0.1227)
Manufacturing zoning, 1923		0.199	0.471***	0.365***	0.495***	0.293**
		(0.1897)	(0.0639)	(0.1211)	(0.0906)	(0.1467)
Multifamily use, 1920	−0.234***	0.141	−0.197***	0.117**	−0.174***	0.046
	(0.0872)	(0.1231)	(0.0650)	(0.0583)	(0.0613)	(0.0830)
Business use, 1920	−0.034	0.051	0.034	0.051	0.046	0.050
	(0.1051)	(0.0788)	(0.0546)	(0.0517)	(0.0716)	(0.0574)
Commercial use, 1920	0.063	0.067	0.043	0.101**	−0.005	0.100*
	(0.1335)	(0.0883)	(0.0517)	(0.0412)	(0.0696)	(0.0546)
Industrial use, 1920	0.369***	0.206*	0.118*	0.079*	0.088	−0.007
	(0.1158)	(0.1093)	(0.0675)	(0.0477)	(0.1115)	(0.0792)
Vacant use, 1920	−0.031	0.019	0.014	0.019	0.039	0.028
	(0.0644)	(0.0400)	(0.0361)	(0.0221)	(0.0431)	(0.0274)
	Sheaf coefficients					
Land use, 1920	0.094***	0.037**	0.069***	0.033***	0.064***	0.027**
	(0.0286)	(0.0179)	(0.0219)	(0.0109)	(0.0202)	(0.0137)
Zoning, 1923	0.031	0.116***	0.089***	0.122***	0.108***	0.077*
	(0.0434)	(0.0433)	(0.0139)	(0.0426)	(0.0219)	(0.0435)
Geography	0.208**	0.150***	0.211***	0.165***	0.182***	0.208***
	(0.0992)	(0.0467)	(0.0260)	(0.0421)	(0.0311)	(0.0569)
Transportation	0.030	0.103***	0.109***	0.067**	0.159***	0.145***
	(0.1199)	(0.0288)	(0.0331)	(0.0282)	(0.0599)	(0.0515)
Demographics, 1920	0.200	0.059**	0.105	0.066***	0.089	0.072***
	(0.2026)	(0.0292)	(0.0829)	(0.0175)	(0.1092)	(0.0251)
Estimation	OLS	OLS	OLS	OLS	OLS	OLS
Observations	287	679	718	1617	718	1617
R^2	0.385	0.289	0.415	0.318	0.279	0.192

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

Linear regressions of 2015 land use outcome indicators on 1923 zoning, 1920 land use, 1920 demographics, transportation, and geographic covariates. Odd-numbered columns are estimated on the comprehensive land use sample; even-numbered columns are estimated on the land use change sample. Outcome in columns (1)–(2) is an indicator for mixed use; sample is restricted to parcels with multifamily or mixed commercial/multifamily use only. Outcome in columns (3)–(4) is an indicator for mixed, commercial, or industrial use; sample is restricted to parcels not vacant in 2015. Outcome in columns (5)–(6) is an indicator for commercial or industrial use; sample is restricted to parcels not vacant in 2015. Geography, transportation, and demographic coefficients are omitted from the upper panel to conserve space. Lower panel reports sheaf coefficients for each block of variables. Standard errors are clustered at the block level.

Table 14
Impact of 1923 zoning on 2015 land use conditional on 1950s Covariates.

	Mixed use (1)	Mixed use (2)	Mixed/com./ind. (3)	Mixed/com./ind. (4)	Com./ind. (5)	Com./ind. (6)
Business zoning, 1923	−0.097	0.050	−0.035	0.135*	−0.179*	0.090
	(0.2060)	(0.0866)	(0.0830)	(0.0748)	(0.1075)	(0.0765)
Commercial zoning, 1923	−0.055	0.191*	0.045	0.178*	−0.089	0.035
	(0.1644)	(0.0972)	(0.0491)	(0.0911)	(0.0711)	(0.0999)
Manufacturing zoning, 1923		0.220	0.332***	0.204*	0.445***	0.123
		(0.2031)	(0.0858)	(0.1101)	(0.1135)	(0.1316)
Multifamily use, 1952	−0.216***	−0.104	−0.135**	−0.112**	−0.117**	−0.118**
	(0.0684)	(0.0680)	(0.0584)	(0.0553)	(0.0569)	(0.0584)
Business use, 1952	0.123	0.155*	0.132***	0.212***	0.143**	0.193***
	(0.1265)	(0.0866)	(0.0413)	(0.0556)	(0.0705)	(0.0577)
Commercial use, 1952	0.051	0.239**	0.119***	0.265***	0.180**	0.269***
	(0.1076)	(0.1010)	(0.0376)	(0.0563)	(0.0696)	(0.0574)
Industrial use, 1952	0.146	0.053	0.106*	0.171**	0.082	0.189**
	(0.1681)	(0.1262)	(0.0592)	(0.0666)	(0.1122)	(0.0815)
Vacant use, 1952	−0.073	0.023	0.052	0.119**	0.162***	0.105*
	(0.0855)	(0.0837)	(0.0417)	(0.0583)	(0.0550)	(0.0611)
	Sheaf coefficients					
Land use, 1920	0.045	0.027	0.027	0.028***	0.029	0.031**
	(0.0276)	(0.0200)	(0.0170)	(0.0102)	(0.0201)	(0.0129)
Land use, 1952	0.128***	0.125***	0.096***	0.138***	0.108***	0.139***
	(0.0361)	(0.0249)	(0.0242)	(0.0160)	(0.0297)	(0.0170)
Zoning, 1923	0.030	0.091**	0.063***	0.070**	0.108***	0.030
	(0.0622)	(0.0457)	(0.0175)	(0.0356)	(0.0124)	(0.0230)
Geography	0.350***	0.244**	0.222***	0.213***	0.177***	0.164**
	(0.1222)	(0.1233)	(0.0281)	(0.0635)	(0.0329)	(0.0703)
Transportation	0.045	0.124**	0.100***	0.068***	0.105*	0.136**
	(0.0321)	(0.0599)	(0.0343)	(0.0182)	(0.0554)	(0.0578)
Demographics, 1920	−0.210	0.050	−0.009	0.057***	0.103	0.059**
	(0.2616)	(0.0342)	(0.0797)	(0.0198)	(0.1049)	(0.0292)
Demographics, 1950	0.118	0.129	0.055*	0.102**	0.096**	0.106***
	(0.0730)	(0.0879)	(0.0311)	(0.0467)	(0.0413)	(0.0342)
Estimation	OLS	OLS	OLS	OLS	OLS	OLS
Observations	287	679	718	1617	718	1617
R^2	0.446	0.343	0.460	0.400	0.343	0.275

***p < 0.01,**p < 0.05,*p < 0.1

Linear regressions of 2015 land use outcome indicators on 1923 zoning, 1920 and 1952 land use, 1920 and 1950 demographics, transportation, and geographic covariates. Odd-numbered columns are estimated on the comprehensive land use sample; even-numbered columns are estimated on the land use change sample. Outcome in columns (1)–(2) is an indicator for mixed use; sample is restricted to parcels with multifamily or mixed commercial/multifamily use only. Outcome in columns (3)–(4) is an indicator for mixed, commercial, or industrial use; sample is restricted to parcels not vacant in 2015. Outcome in columns (5)–(6) is an indicator for commercial or industrial use; sample is restricted to parcels not vacant in 2015. Geography, transportation, and demographic coefficients are omitted from the upper panel to conserve space. Lower panel reports sheaf coefficients for each block of variables. Standard errors are clustered at the block level.

In columns (5)–(6) of 13, the outcome variable is an indicator for the absence of multifamily residential use; this is equivalent in these samples to an indicator for exclusively commercial or industrial use. As in the previous cases, more permissive zoning in 1923 generally increases the likelihood of commercial or industrial use in 2015 relative to mixed or purely residential use, and the impact of zoning comparable to other factors. Conditioning on 1952 land use and demographics, columns (5)–(6) of 14 show that the impact of zoning is approximately the same on the comprehensive land use sample, but substantially diminished on the land use change sample.[16]

Taking an overview of the results, the sheaf coefficients indicate that conditioning on intermediate land use and demographic outcomes has a fairly small effect on the magnitude of the zoning impact on the comprehensive sample; however, the zoning impact is mitigated by 22–61% on the land use change sample. While the impact of zoning through short-run changes in land use is substantial, persistence in zoning itself nonetheless appears to have a sizable impact on present-day land use. This provides strong evidence for the legal hysteresis hypothesis, suggesting that stickiness in the form of the zoning law itself has had a major impact on Seattle's development.

5. Conclusion

Zoning appears to have played a sizable role in the development of Seattle from its inception to the present day. In the decades following the first ordinance in 1923, zoning for commerce or industry greatly increased the likelihood of conversion towards these uses. Moreover, zoning's role was not limited to directing the city's rapid early growth. The spatial form of the ordinance itself persisted for decades and heavily shaped the first comprehensive rezoning in 1957; the legacy of the initial ordinance was roughly twice as important as contemporary land use. This institutional hysteresis is reflected in present-day land use patterns, where the influence of 1923 zoning can be seen even after accounting for three decades of change following the initial plan.

These results are all the more surprising given that compliance was far from perfect in the decades following zoning. Between 1923 and 1952, a sizable number of parcels were developed in a manner expressly forbidden by the initial ordinance. While some of these received variances, most did not, and many of these nonconformities persisted

[16] As before, the maintained identifying assumptions imply conditional independence between 1920 and 2015 land use. The sheaf coefficients for 1920 land use are much smaller than those for 1952 land use and insignificant in four of the six models. Similarly, 1920 demographics are mostly insignificant, with some lingering impact from factors not captured by the 1950 variables.

through the comprehensive rezoning in 1957. Overall, these results suggest that path dependence in zoning emerges through both real and legal channels, and that this path dependence can shape the evolution of land use even after many decades. While much has been written about persistence in urban form due to purely economic forces, relatively little research has explored how institutional forces can entrench or alter this trajectory. This paper shows that such institutional persistence can have substantial influence.

Appendix. This section outlines the maintained identifying assumptions for each analysis. Fig. A1 depicts the assumed data generating process with eight potential sources of confounding.[17] The (conditional) no-confounding requirements for identification are listed below:

(1) Table 3: Total effect of 1920 predictors on 1923 zoning is identified in the absence of U_1.
(2) Table 8: Direct effect of 1920 predictors and 1923 zoning on 1952 land use outcomes is identified in the absence of U_1 and U_5; alternatively, in the absence of U_2 and U_5.
(3) Table 10: Same as above, with the outcome indicating the granting of a variance by 1953.
(4) Table 12: Direct effect of 1923 zoning on 1957 zoning (conditional on 1920s and 1950s predictors) is identified in the absence of U_7 and U_8.
(5) Table 13: Total effect of 1923 zoning on 2015 land use (conditional on 1920s predictors) is identified in the absence of U_4 and either U_1 or U_6.
(6) Table 14: Direct effect of 1923 zoning on 2015 land use (conditional on 1920s and 1950s predictors) is identified in the absence of U_1, U_2, U_3, and U_4.

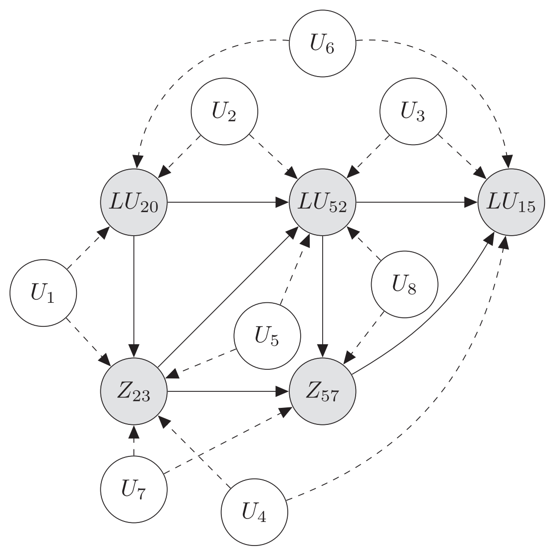


Figure depicts the underlying data generating process as a causal graphical model with eight relevant potential confounders (Pearl 2009). LU and Z nodes represent land use and zoning, respectively. Subscripts indicate year of observation. Since land use and zoning are the primary focus of this study, transportation and demographic factors are subsumed by the LU nodes.

Fig. A1 Data Generating Process with Potential Confounders.

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[17] In Fig. A1, there are 10 possible confounders; it is assumed that common causes linking LU_{20} and Z_{57} or Z_{57} and LU_{15} are not present. Both scenarios seem less plausible than sequential confounding through Z_{23} or LU_{52} (in the first case) or through LU_{52} alone (in the second case). Regardless, this assumption is only relevant for the analysis present in Table 12, since 1957 zoning variables only appear there.