You Only Lend Twice: Corporate Borrowing and Land Values in Real Estate Cycles *

Cameron LaPoint†

Columbia University

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Abstract

This paper uses a natural experiment in Japan to provide evidence of the feedback loop between corporate borrowing and commercial real estate investment emphasized in macro-finance models with collateral constraints. Japan enacted a series of reforms in the early 1980s which relaxed national regulatory constraints on the height and size of buildings. Combining originally-constructed local commercial land price indices for over 400 localities with geocoded firm balance sheets, I show that these land use deregulations generated a boom-bust cycle in corporate real estate values, borrowing, and real estate investment. Firms located in more *ex ante* land use constrained areas both issued more debt and invested more heavily in real estate, thus amplifying the initial positive shock to commercial real estate prices. I develop a multi-city spatial sorting model with production externalities and real estate collateral which uses the estimated reduced form effects of my local regulatory instruments on firm outcomes to assess aggregate effects of the reform. I find that the deregulatory shock to commercial real estate markets and corporate borrowing environment amplified the real estate cycle in the 1980s and led to an increased incidence of zombie lending in the 1990s.

Keywords: corporate borrowing, collateral, feedback loop, investment, real estate cycles, land use regulation, spatial sorting, regional heterogeneity, commercial real estate prices

JEL classifications: E22, G11, G32, R31, R52

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†Department of Economics, Columbia University, 1022 International Affairs Building, 420 W 118th Street, New York, NY 10027. Email: cameron.lapoint@columbia.edu; Web: http://cameronlapoint.com

1 Introduction

In capital markets favoring private bankruptcy arbitration, a company's ability to borrow increases with the liquidation value of assets such as land which may be used as collateral. Many theoretical papers in the macro-finance literature have emphasized the role of these institutional features in generating a feedback loop between corporate borrowing capacity and capital values (Shleifer & Vishny 1992; Hart & Moore 1994; Kiyotaki & Moore 1997). This lending environment gives rise to a collateral channel through which firms in good times borrow against physical assets to make capital investments. Such investments raise the market value of firms' collateral, allowing firms to borrow more. The dynamic nature of this feedback loop amplifies real estate boom-bust cycles relative to environments where firms do not face collateral constraints.

Yet, while there is a large empirical corporate finance literature exploring the link between real estate values and firms' borrowing behavior (Benmelech et al. 2005; Almeida & Campello 2007; Campello & Larrain 2015; Lin 2016; Lian & Ma 2019; Drechsel 2019) or investment behavior (Chaney et al. 2012; Campello & Giambona 2013; Bahaj et al. 2018, 2019), there is little direct evidence of the existence of this feedback loop during real estate boom-bust cycles. If firms do not reinvest in assets directly tied to borrowing limits, collateralized lending will have only a static effect on asset cycles, as there will be no feedback of the initial shock into asset prices. Decomposing investment responses to real estate price shocks across different types of capital is thus critical to assess the importance of collateral constraints for asset price cycles.

This paper uses a natural experiment in Japan to provide new evidence of the feedback loop between corporate borrowing and commercial real estate investment. Japan enacted a series of national-level reforms to land use regulations in the early 1980s which relaxed restrictions on the height and size of buildings. These reforms raised local real estate prices to a greater extent in areas that were more constrained by national land use regulations prior to the reforms. In the more constrained areas, the liberalization of land use restrictions increased the productivity of land, raising the market value of local real estate. Using *ex ante* measures of regulatory constraints on land use as instruments for firm real estate values, I show that these land use deregulations induced boom-bust dynamics in firm real estate values, borrowing, and real estate and non-real estate investment. Firms which were subsequently delisted or were recipients of zombie loans in the 1990s account for the bulk of this real estate investment response, suggesting that the land use reforms contributed to long-run financial distress in the corporate sector.

Japan's experience during the 1980s offers a useful setting for studying the link between corporate borrowing and local real estate boom-bust cycles for three reasons. One reason is that the institutional environment closely corresponds to models with collateral constraints, since the vast majority of corporate debt in Japan is secured by physical assets such as land. Over 99% of firms in my sample held real estate during the 1980s, compared to roughly half of large U.S. firms during the 1990s (Chaney et al. 2012; Cvijanović 2014). Second, the relaxation of land use regulations began in

1983, prior to the rapid rise in real estate prices, and during a period of relative economic tranquility. Cities' exposure to the reforms is thus unlikely to be contaminated by macroeconomic factors that would be correlated with firm borrowing and investment decisions. Third, Japan experienced one of the largest real estate cycles in recent economic history; land prices grew by 56% in aggregate between 1985 and 1990, and by 155% in the six most populous cities.

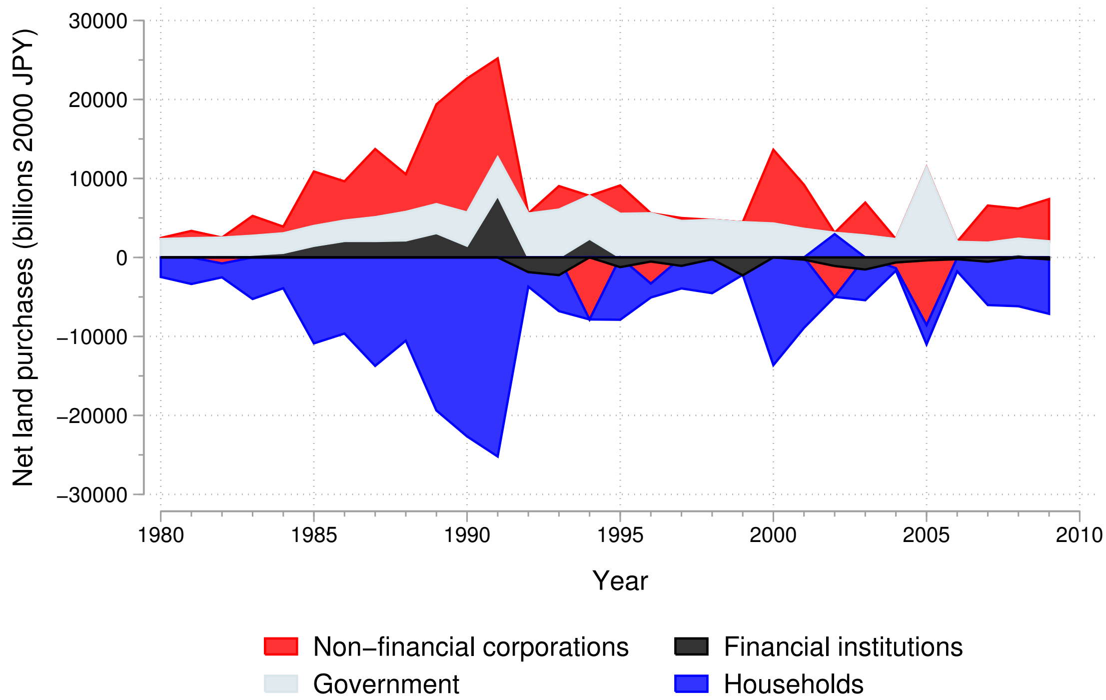
I document the importance of firms' collateral for corporate borrowing in Japan using a novel dataset that features three key components: one is local commercial land price indices covering over 400 cities going back to 1975. Creating these indices is a necessary first step because there are no publicly available local real estate price indices that cover the 1980s boom-bust cycle. Second, I use urban planning maps to determine how limits on building height and size imposed by land use laws vary in commercial areas across cities. The final critical feature of my dataset is a list of corporate headquarters and facility locations that I hand collected from annual financial disclosure documents. The resulting dataset combining these three features allows me to match firms to their creditors, and match firms to the location and market value of their real estate holdings.

I establish two main facts about real estate prices during the Japanese boom-bust cycle. These facts build on contemporary anecdotes (Cutts 1990) and on previous papers which only used prefecture-level variation in prices to document a relationship between Japanese real estate prices and bank-firm outcomes (Gan 2007a,b; Mora 2008). First, there was substantial heterogeneity in city-level price growth between 1985 and 1990 that cannot be explained by population and per capita income. For instance, in Fukuoka, the 8th largest city, land prices grew by 74% over this five-year period, but in neighboring Kita-Kyushu, the 11th largest city, prices grew by a modest 11%. Second, in all cities with population greater than 300,000, commercial and industrial land values together increased by far more than residential land values, indicating within-city heterogeneity.

The larger cycle in commercial relative to residential real estate supports the notion that firms' real estate investment and land values were intimately related during this episode. Figure 1 confirms the aggregate pattern of large net purchases of land from households by non-financial corporations during the 1980s cycle and the international Lehman boom in the 2000s. I show using my facility level data that over 90% of corporate real estate held in the 1980s was for commercial and industrial use, indicating that these transactions were concentrated in the non-residential real estate market.

I exploit these facts about local real estate markets in the 1980s to estimate the effects of changes in real estate values on corporate borrowing and investment. My results are consistent with a closed feedback loop between real estate values, corporate borrowing, and real estate investment. Firms which actively issued debt borrowed an additional 3.1% of every 1 JPY increase in the market value of their real estate holdings over the period. Firms invested an extra 1.5% of every 1 JPY increase in real estate assets, with 1% going towards further real estate investment and 0.5% allocated to investment in machinery. This real estate investment response was concentrated among firms which were eventually delisted. The fact that firms responded to the shock by investing in both real estate and non-real estate physical capital is consistent with input complementarity, and suggests that

FIGURE 1. Net Land Purchases by Institutional Sector



Notes: 10,000 billion JPY corresponds to approximately 100 billion USD in 2000 dollars, or 3% of 1990 Japanese GDP. Data source: Cabinet Office, Government of Japan, SNA Capital Finance Accounts.

most real estate investment during this episode was productive rather than speculative.

These effects are economically large. A one-standard deviation increase in firm market real estate value increases real estate investment by 0.3 standard deviations and net debt issues by 0.3 standard deviations along the intensive margin. My estimates of firms' borrowing responses are large relative to estimates ranging from 0.04 to 0.08 standard deviations in the U.S. (Chaney et al. 2012; Cvijanović 2014; Lian & Ma 2019) for two reasons. One reason is that in my setting the response is entirely on the intensive margin of real estate ownership, as 99% of listed firms own real estate. Another reason is that I analyze a setting in which firms are less likely to face earnings-based borrowing constraints which are prevalent among large U.S. firms (Lian & Ma 2019; Drechsel 2019; Greenwald 2019). For the firms in my sample, point estimates from regressions of net debt issues on earnings measures are 75% lower than regressions estimated for similar samples of U.S. firms.

Establishing a causal link between real estate values and firm outcomes is challenging due to potential reverse causality and unobserved local demand shocks that affect both land prices and firms' financial decisions. To overcome these concerns, I construct instruments for real estate values using measures of city-level exposure to two waves of national land use deregulation enacted in 1983 and 1987. In doing so, my paper relates to a large body of recent work which attempts to explain spatial variation in housing price growth in the U.S. 2000s using either topography (Burchfield et al. 2006; Hilber & Mayer 2009; Saiz 2010) or regulation of new housing supply (Glaeser & Gyouko 2003; Gyourko et al. 2008; Hilber & Vermeulen 2016; Gyourko et al. 2019).

My measures for local exposure to the national reforms are the share of land parcels in 1980 for which the statutory maximum floor-to-area ratio (FAR) is binding and median road width in 1980. These variables reflect key policy parameters which determine land use restrictions. In Japan national regulatory limits on the height and size of buildings are increasing functions of the width of the front-facing road adjacent to a land plot. This means that the marginal value to landowners of the 1980s liberalization of land use constraints was higher in areas with predominantly narrow roads. Consistent with this idea, cities with *ex ante* smaller roads and a larger share of land plots for which the statutory maximum FAR was binding experienced more construction and a larger boom-bust cycle after the 1983 reform introduced higher limits on building size.

My proposed instruments for estimating the causal relationship between the value of corporate real estate and borrowing and investment address some of the issues raised with other types of instruments for real estate prices widely used in the literature. Several recent papers have used the Saiz (2010) geography-based measures of local housing supply inelasticity as instruments for real estate values (e.g. Mian & Sufi 2011; Chaney et al. 2012; Mian et al. 2013; Aladangady 2017). This type of instrument is inappropriate in my research setting, as I show a Saiz-style measure for Japan is highly negatively correlated with local land values during the boom period. As noted in Mian & Sufi (2014) and Davidoff (2016), this suggests geography-based measures are correlated with drivers of local demand, thereby violating the exclusion restriction for firm-level outcomes.

I conduct three checks on the validity of the exclusion restriction that my land use reform exposure instruments are uncorrelated with unobserved determinants of firm borrowing and investment outcomes. First, I find no differential pre-trend between firms in my sample which are more or less exposed to the 1980s land use deregulations. Moreover, my sample of firms which are above vs. below the median value of exposure to the land use reform is balanced in the pre-reform period on a large set of balance sheet characteristics. Lastly, I show that my instruments do not predict empirical proxies for Tobin's Q or corporate forecasts of business conditions. These results suggest the land use deregulations did not influence firm investment opportunities or beliefs about future economic conditions through channels external to local real estate prices.

I then use my instruments to establish links between firms' investment behavior during the boom and their long-run financial health. Many authors have documented the prevalence of "zombie lending," or evergreening loans, in 1990s Japan (Ahearne & Shinada 2005; Peek & Rosengren 2005; Caballero et al. 2008; Giannetti & Simonov 2013) and in the EU following the 2000s real estate boom (Schivardi et al. 2017; Acharya et al. 2019; Blattner et al. 2019). My results add to this literature by providing direct evidence of a financial accelerator arising from corporate investment during real estate booms. I identify zombie loans using the firm-level measure introduced in Caballero et al. (2008) and find that the incidence of zombie lending during the 1990s was 20% higher among firms which were the most exposed to the land use reform based on 1980 facility locations.

In the final part of the paper, I develop a multi-city spatial sorting model with real estate collateral to microfound the land use reform instruments and assess aggregate effects of the deregulations on real estate prices, investment, and output. In this environment, land use deregulation constitutes a positive shock to the elasticity of the local real estate supply curve, allowing more people to sort into cities than under the previous regime. Following a large literature on agglomeration and congestion, I introduce local production externalities into the model by assuming local productivity is a concave function of the number of employees working in an area (Glaeser & Gottlieb 2008; Greenstone et al. 2010; Kline & Moretti 2014; Allen & Arkolakis 2014; Herkenhoff et al. 2018).

Accounting for the effects of agglomeration forces on local property demand delivers the observed positive correlation between post-reform real estate prices and the extent to which *ex ante* land use restrictions are binding. This positive relationship between prices and deregulation runs counter to findings of recent papers in the urban economics literature. Favilukis et al. (2019) build a dynamic spatial equilibrium model calibrated to NYC and estimate that housing prices modestly fall in response to a relaxation of building size constraints. Lin & Wachter (2019) use the regulatory index of Gyourko et al. (2008) for cities in California to estimate a general equilibrium sorting model and also find that prices fall in response to more lax regulations. Both models find that endogenous amenities play a limited role in mitigating the supply effects of land use deregulation.

My model builds on the framework of Hsieh & Moretti (2019), who do not consider the implications of production externalities or corporate borrowing decisions for the effects of local housing supply constraints on prices. In my model, the flattening of the local supply curve due to a relaxation of building restrictions has a direct negative effect on prices, but an indirect positive effect due to workers sorting into the city beyond the initial limits specified by land use law. When I calibrate the model to Japanese data the supply channel is relatively weak, and local prices rise in response to land use deregulation. Firms' real estate investment, financed by new debt issues, amplifies the impact of this deregulatory shock on prices.

With my instrument based on floor-to-area ratio limits as the shock to local supply inelasticity, the model generates 20% of the growth in aggregate non-residential prices during the 1980s. Versions of the model in which collateral constraints bind for only a fraction of firms exhibit the fat right tail of the empirical price growth distribution. This indicates that heterogeneity in the slackness of corporate borrowing limits is important for explaining geographic dispersion in real estate values.

The remainder of the paper is organized as follows: Section 2 discusses the construction of the new dataset linking matched bank-firm balance sheets to local land values. Section 3 describes the reforms to land use regulation. Section 4 outlines my empirical strategy for estimating causal relationships between land values and corporate borrowing and investment. Section 5 presents the main firm-level evidence in favor of the feedback loop. Section 6 provides evidence of links between exposure to the real estate cycle and a firm's long-run financial health. Section 7 introduces collateral into a spatial sorting model to illustrate the instruments and assess aggregate effects of the land use reforms. Section 8 concludes.

2 Data and Heterogeneity in Local Land Values

This section describes my construction of an original dataset of local land values and matched bank-firm balance sheet data covering over 400 Japanese cities going back to 1975. I provide additional details on the price index construction in Appendix A and on the corporate balance sheet data in Appendix B.

2.1 Government Land Appraisal Surveys

I start by merging two publicly available annual land appraisal datasets from the Ministry of Land, Infrastructure, Transport, and Tourism (MLIT). The first of these datasets consists of the Official Land Price Announcements collected by real estate appraisers hired by the national government. The other dataset consists of a collection of prefectural land price surveys administered by real estate appraisers hired by each individual prefectural government. Supplementing the national appraisal reports with the prefectural surveys vastly improves geographic coverage, as the national reports exclude roughly one-third of municipalities.

Merging the national and prefectural datasets results in a panel of over 200,000 land plots with information on the price, address, adjacent roads, size, and physical characteristics of the land plot and any buildings on top of the land. Appraisers collect these details because the purpose of the surveys is to provide policymakers with reliable land values in order to calibrate national and local property tax levies.[1] My full dataset begins in 1970 and by 1975 covers all 1,741 of Japan's municipalities and includes approximately 40,000 land plots in each annual wave. In my empirical analysis, I exclude data from years 1970-1974, since the prefectural surveys only begin in 1975.

The national and prefectural governments select land plots for appraisal that are representative of a land use category (i.e. residential, commercial, or industrial) at the township level. The data have a panel structure, because as long as the MLIT Land Appraisal Committee deems a plot to be representative of its region and land use category, it remains in the survey. Given this selection criterion, there are two main reasons that MLIT highlights for why a land plot might be considered unrepresentative and removed from the survey: (i) the legally designated use of the land changes substantially (e.g. factories relocate to a previously residential district), or (ii) the government gives the municipality a new city-size designation due to large changes in population or mergers of smaller townships into a new city. I observe a land plot in the data for an average of 17 years (median 15 years).[2]

[1] While the survey name suggests that the land plot is being valued independently of the building that sits on top of it, documentation from MLIT indicates that appraisers are instructed to value the land and building as a bundle. This corresponds to the IRS guidelines of "Highest and Best Use" for real property valuation. I describe the appraisal procedures in more detail in Appendix A.5.

[2] Survey entry and exit does not affect my measurement of prices. I obtain virtually identical prices (cross-sectional correlation of 0.99) when in computing my indices I restrict to a balanced panel of plots over my sample time period.

2.2 Constructing Local Land Price Indices

I aggregate the appraisal data on individual properties to create local land price indices covering over 400 Japanese cities during the 1980s real estate boom-bust cycle. My estimation approach leverages the fact that plots in my dataset are appraised each year to adjust for differences in the quality of land plots across and within geographic areas. In the rest of the paper, an "area" refers to a city attached to a modern Census geocode, or to a neighborhood within a city defined by either a use or zoning classification (e.g. residential, commercial, or industrial).

In particular, for each area c I subset to land plots located in that area and compute a land price index by estimating the following plot-level regression:

$$\log p^c_{i,t} = \delta^c_t + \eta^c_i + \epsilon^c_{i,t} \tag{2.1}$$

$$P^c_t = \exp(\delta^c_t) \tag{2.2}$$

where i indexes an individual land plot. As is standard when computing hedonic price indices, I form my indices by transforming the estimated time dummies $\hat{\delta}^c_t$ and normalizing the coefficients to a base year. The individual plot fixed effects η^c_i control for all time-invariant observed or unobserved characteristics of the land plot and any structures existing on the land.

The key advantage of this plot-level fixed effects approach is that I do not have to take a stance on the set of characteristics to include as independent variables to capture the quality of the property. I show in Appendix A.3 that the cross-sectional patterns in my indices estimated via (2.1) are qualitatively and quantitatively similar when I replace the plot fixed effects with a vector of potentially time-varying characteristics $X_{i,t}$ and interactions among those characteristics on the right-hand side. Including these time-varying characteristics provides only small additional quality adjustments because very few properties in my dataset experience construction and demolition, and thus in many instances these elements of $X_{i,t}$ would be absorbed by the plot fixed effects.[3]

My index construction has several elements in common with other frequently used real estate price indices. With identified plot fixed effects my indices are a hybrid of repeat sales methods and standard hedonic methods which instead only control for a vector of observables $X_{i,t}$.[4] The repeat sales methodology pioneered by Case & Shiller (1987, 1989) restricts analysis to properties that transact more than once during the sample period and regresses log first differences in prices on a full set of indicators for whether a property is transacted in year t. The estimated coefficients yield an index that differences out time-invariant features that determine quality while using only information on property sale dates, prices, and location. My indices obtained from equation (2.1)

[3] Augmenting equation (2.1) with a geospatial weighting matrix on the error term, which captures spillover effects of prices of nearby plots, also delivers similar results.

[4] Early examples of hybrids of repeat sales and hedonic methods include Case & Quigley (1991) and Quigley (1995), who combine samples of single and repeat-sales dwellings to estimate price indices using weighted least squares. My approach is also similar to that of Fang et al. (2015) who use Chinese transactions data but include housing development fixed effects rather than individual fixed effects to perform a quality adjustment.

use the same set of variables as a repeat sales index, but since I observe the same plot every year, I do not need to throw away any observations to produce quality-adjusted local prices. In this sense, I consider my index to be a *repeat appraisal*, or quasi-hedonic index.[5]

While the individual land values I use are obtained from repeated real estate appraisals, information provided by MLIT on the appraisal methodology suggests that reported land values are comparable to transaction prices on similar bundles of land and buildings. This distinction between appraisal and transaction prices is potentially important to my research design for two reasons. One possible issue is that because appraisals are backward looking my price indices might be smoothed, meaning that I will underestimate the magnitude of price changes in periods of dramatic volatility like the late 1980s (Guren et al. 2018). Another concern is that measurement error in land values might vary systematically across regions, leading to biased estimates of firms' borrowing and investment responses to land value changes. This will be the case if, for instance, real estate transaction volume in an area where a firm locates is correlated with determinants of local demand for that firm's goods and services.

To address these concerns about the validity of appraisal prices, I construct a separate dataset of repeat sales indices based on publicly available records starting in 2005 for over three million transactions. I find 2008-2016 growth rates for local repeat sales and repeat appraisal prices have a cross-sectional correlation of 0.7 among cities with 2000 Census population over 400,000. This comovement across the transaction-based and appraisal-based indices suggests any measurement error associated with using appraisals is negligible. I describe these transaction records and compare the two types of indices in more detail in Appendix A.2.

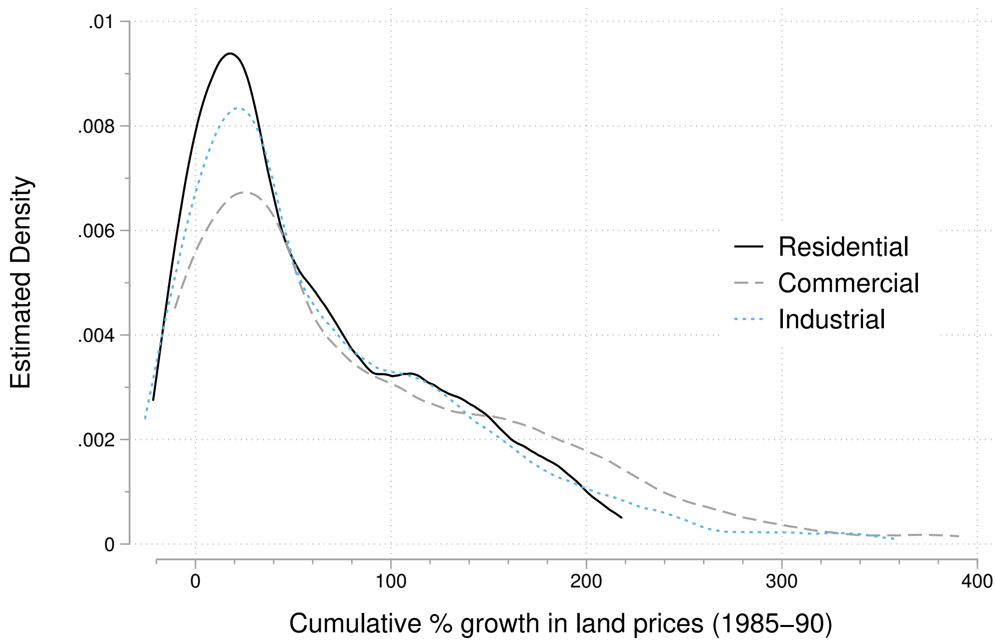
I also show robustness of my results to constructing expenditure-based indices that consider individual properties to be a distinct variety of the same type of good. Expenditure-based indices involve taking a weighted average of year-on-year price changes where the weights are functions of value shares in adjacent years. Implicitly, my repeat appraisal index weights the price changes of all properties equally.[6] While assigning the correct weights is important for putting bounds on the magnitude of aggregate price changes, it turns out to be largely irrelevant for differences in land price growth across geographical areas during the 1980s.[7] I provide formulas for these indices and describe their taxonomy in more detail in Appendix A.3.

[5]For a balanced panel of plots, the repeat appraisal method is a regression analog of the Jevons index, which takes a geometric average of year-on-year price changes among plots observed in each pair of adjacent years.

[6]Although official national-level indices for Japan are constructed by taking a simple geometric average of individual price changes, this equal-weighting method has been shown to understate the degree of aggregate price changes during the boom suggested by national accounts data (Nakamura & Saita 2007). Appendix A.4 compares price indices constructed from prefectural land stocks in national accounts data to indices constructed using my repeat appraisal method.

[7]For instance, a Törnqvist index which weights price changes by the property's arithmetic average of value shares, generates on average 10 percentage points more cumulative growth in 1985-1990 land values relative to my index, but the cross-sectional correlation between growth rates for my index and the Törnqvist index is 0.95.

FIGURE 2. Distribution of Growth Rates in Land Values



2.3 New Stylized Facts About Land Values in Japan

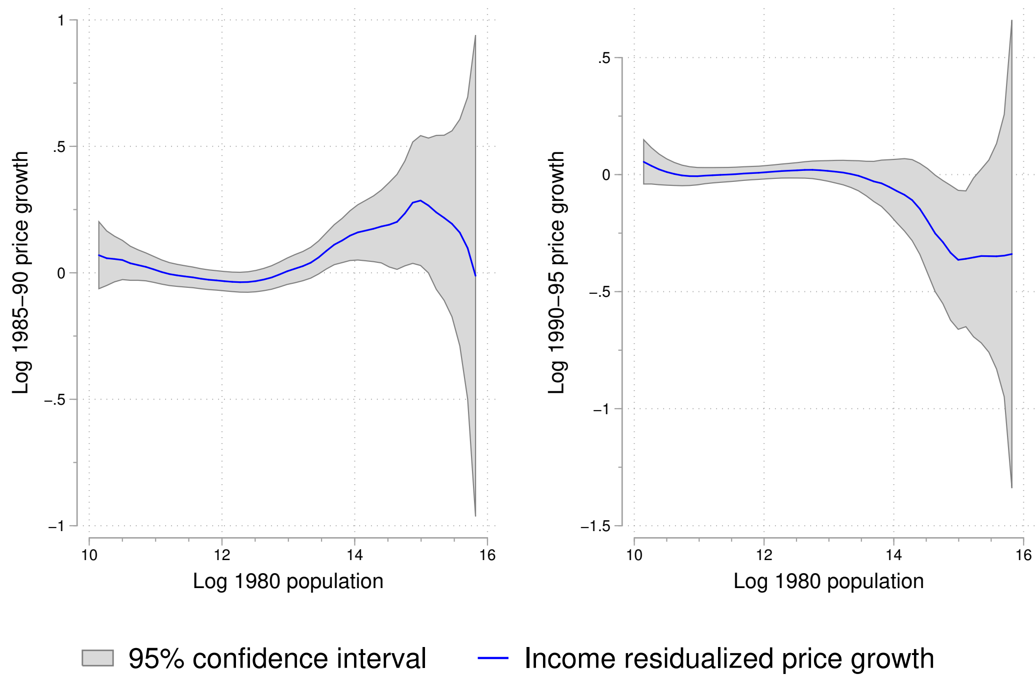
I use my repeat appraisal indices to present two main facts about land values in Japan during the 1980s cycle. First, there was substantial heterogeneity in city-level price growth between 1985 and 1990 that cannot be explained by population and distance from Tokyo. Second, in all cities with 1980 population greater than 300,000, commercial and industrial land values together increased by far more than residential land values.

Figure 2 plots the estimated kernel density of cumulative growth in land prices during the height of the boom period (from 1985 to 1990) for all 425 municipalities in my sample. Each line in the figure corresponds to the distribution of growth rates organized by broad use classification (residential, commercial, and industrial).[8] The figure shows that while some areas of Japan experienced annualized growth rates as high as 80% in commercial and industrial land values, roughly a quarter of cities in my sample experienced less than 10% growth in residential and commercial land prices over this five-year period.

To what extent can this geographical heterogeneity be explained by factors such as city size or per capita income? Figure 3 plots the local smoothed mean of the city-level relationship between log non-residential (commercial and industrial) price growth during the boom-bust cycle and log

[8]These use classifications are ascribed to each individual land plot by the real estate appraiser assigned to survey the plot. While this use classification is a distinct concept from zoning, the use categories and zoning are highly correlated. Among plots assigned to a city planning area, 99% of residential use plots are located in a residential zone, and 95% of commercial use plots are located in a commercial zone.

FIGURE 3. Non-residential Land Price Growth as a Function of 1980 Population



1980 population residualized on per capita income. After controlling for differences in income across localities, there is a positive relationship between the magnitude of price movements and city size among cities ranked in the top 25 by 1980 population, but no clear relationship in the rest of the distribution. This points to other factors driving a large portion of the variation in non-residential real estate prices during this episode. I show in Section 3 how differential exposure of areas to 1980s land use deregulation explains 15% of the cross-regional variation in non-residential prices.

2.4 Bank-Firm Balance Sheet Data

The final step in my data construction is to match firms to the location of their physical assets. I do so by hand-collecting a new dataset of corporate facility locations in the 1980s for firms required to submit annual financial disclosure documents to the Financial Services Agency (FSA). Colloquially known as *yuhō*, these documents are similar in structure and scope to Form 10-K filings required by the SEC for public companies in the U.S. In Japan all companies which offer shares or bonds in public offerings, or which offered securities in the recent past, are required to file statements with the FSA. While some unlisted companies are required to file *yuhō*, the firms in my sample consist of publicly listed non-financial firms.[9]

[9] The Financial Instruments and Exchange Act (FIEA) of 2006 replaced a 1948 version of an earlier law of the same name which defines disclosure requirements on the basis of publicly traded securities. During my sample time period, disclosure requirements were dictated by the 1948 version of the FIEA and its amendments.

A distinguishing feature of the *yuhō* is a section in which firms provide a list of facility names, city-level locations for each facility including the corporate headquarters, and the net book value of these facilities. Sites listed on these forms include industrial plants, sales branches, research facilities, administrative offices, and in some cases residential real estate holdings. Firms provide the number of employees and the net book value of the types of physical capital located on-site, including land, buildings, industrial structures (e.g. a loading dock), construction in progress, transportation (vehicles + vessels), and other tools and machines.

I match these geocoded items from corporate financial disclosure reports with the non-consolidated firm-level balance sheet totals compiled by the Development Bank of Japan (DBJ). The DBJ data are compiled from the *yuhō* filed for each firm-year, but provide only the reported totals for balance sheet items without any information about the location of the firm's assets. Aggregated balance sheet data begin in 1956, and for the 1980 calendar year include 1,570 firms which can be matched to a local land price index on the basis of facility locations. I use these detailed balance sheet data to construct investment and debt variables and to convert real estate assets from book to market values.[10] I describe the sample restrictions and provide summary statistics for my final estimation sample of 1,489 firms in Appendix B.4.

Finally, to assess the extent to which banks may alter their lending behavior in response to shocks to the real estate assets of their clients, I merge bank balance sheet data from the Nikkei NEEDS Financial Quest database with the DBJ firm-level data.

3 Land Use Reforms and Real Estate Values

In this section I construct measures of local exposure to the relaxation of land use regulations beginning in 1983. I show that these measures help explain the cross-city and within-city variation in real estate values documented in the previous section.

3.1 Background on Land Use Law in Japan

I start by describing the structure and history of land use law in Japan.[11] There are two national statutes originally enacted in 1919 which encapsulate all regulatory requirements that buildings in Japan must satisfy: the City Planning Law and the Building Standard Law. Crucially for my empirical strategy of identifying exogenous shocks to firm real estate values, these laws apply nationally, and prior to 1999 local governments did not have the legal authority to enact ordinances

[10] I outline this book to market conversion in Section 4 and further accounting definitions in Appendix E.

[11] The majority of the content in this subsection is based on English translations of older versions of the Building Standard Law (Ministry of Construction 1990; 1994) and narrative accounts of the 1980s reforms from the urban planning literature (Hayakawa & Hirayama 1991; Sorensen et al. 2010).

to expand or constrict the provisions of either the City Planning Law or Building Standards Law.[12]

The City Planning Law (CPL) defines zoning categories and stipulates how individual land parcels are sorted into those zones.[13] For the 1980s period which is the focus of this paper, there were eight distinct zone classifications, plus a category, "outside city planning area," for which no restrictions on use or building apply.[14] Such plots are generally located on the outskirts of a municipality and account for 23% of my sample of appraisals. In what follows, I construct price indices using only the subsample of plots that are subject to national land use laws.[15]

The other national statute, and the one that features prominently in the 1980s land use deregulations, is the Building Standard Law (BSL) which imposes restrictions on what type of building features are allowed within each zoning category.[16] Pre-1990 versions of the BSL assigned limits along three dimensions within each zone: (i) floor-to-area ratios (FAR), defined as the total floor area divided by the total plot area; (ii) building coverage ratios (BCR), defined as the area of the building base divided by the total plot area; and (iii) slant-plane restrictions which provide maximum height limits that are increasing in the width of the road adjoining the land plot.[17]

A series of reforms to the land use laws in 1983 and 1987 explicitly targeted FAR limits as a way to increase building capacity in urban areas. The first wave of these reforms was announced in March 1983 and implemented in July 1983 when Prime Minister Nakasone delivered recommendations to the Ministry of Construction to unilaterally increase FAR allowances in city planning areas. This first wave of reforms was also accompanied by an amendment to the City Planning Law (CPL) which rezoned residential areas to commercial areas. Since commercial zoned land is subject to higher limits on the FAR, BCR, and height, this revision of the CPL effectively lifted building restrictions in many areas which were previously zoned as residential.

[12]Starting in 1999 Cabinet officials were given the authority to define special districts wherein landowners can propose zoning changes by two-thirds majority, conditional on local municipal governments ratifying the proposed changes. Additionally, a 2003 reform to the Building Standard Law gave local governments the power to lift floor-to-area ratio limits without petitioning higher levels of government to approve special zoning.

[13]The use of the property within each zone is not tightly regulated. For instance, houses and shopping malls can both be built within a commercial zone, but factories must be built within an industrial zone. Similarly, stores are permitted within many of the residential zones. In my appraisal data the recorded use of the building and the major zoning category are highly correlated, as 95% of commercial use plots (e.g. office space, stores) are located in a commercial zone. In this sense, the CPL provides a set of definitions rather than imposing building restrictions.

[14]The eight classifications consisted of three separate classes of residential zones, three classes of industrial zones, and two classes of commercial zones.

[15]This reduces the number of cities with enough land plots to create a price index to 281. However, my results are virtually unchanged when I instead construct the price indices using the full sample of appraised plots. My results are also unchanged if I use the same set of 281 cities but include parcels outside city planning areas. There is minimal variation across cities in the share of land parcels within a city planning area.

[16]Although the current version of the BSL reflects many new building parameters which were introduced in the 1990s and 2000s, I focus here on restrictions which were in force during the 1980s.

[17]The slant-plane refers to the hypotenuse of the triangle created by connecting the base of a building to the opposite end of the adjoining road. The basic idea of these restrictions is that height limits are equal to the distance between the building base and the opposite end of the adjoining road, multiplied by a scale factor which varies by zone classification.

The second wave of reforms was implemented in early 1987 via amendments to the BSL, although many of the provisions were announced by the Prime Minister following the first wave of reforms in 1983. The reform to the BSL included codified increases in FAR allowances across all zones, increased absolute height limits in the most restrictively zoned residential areas, and more relaxed slant-plane restrictions. The stated purpose of these deregulations was to make development of large buildings easier in Tokyo to help the city compete with other global cities like New York. Yet, while the objectives of the amendments may have focused on easing development in the most urbanized areas, the laws themselves could not target any particular cities because the land use laws and any amendments apply nationally.

In the rest of the paper, I focus on the provisions of the 1983 and 1987 reforms which relaxed FAR limits and lifted height restrictions. I do this for several reasons. First, my data do not allow me to exploit variation arising from revisions to the CPL which reclassified residential land as commercial. This is because plots which are rezoned from one broad use class to another are purged from the panel of appraised land parcels. Second, while I observe the number of building stories, I do not observe the actual height of a building. I am therefore unable to isolate pre-reform measures of exposure based directly on the slant-plane restrictions. Lastly, FAR limits influence both the height and size of buildings, and both waves of reforms involved an increase in these limits. Differences across cities in the elasticity of local real estate supply are thus more likely to be reflected in measures of regulatory constraints based on FAR limits than height restrictions or building coverage ratios alone.

3.2 Constructing Measures of Land Use Constraints

I now introduce two city-level measures of exposure to the land use reforms: median road width and the share of land plots eligible for an increase in floor-to-area ratios as a result of the reforms to the BSL beginning in 1983. Since statutory limits on the height and size of buildings are all (weakly) increasing functions of the adjacent road width, all else equal, land use statutes are more likely to be binding for cities with narrower roads. Similarly, the share of land plots eligible for an increase in floor-to-area ratio (FAR) limits is inversely related to the extent to which national land use statutes place binding restrictions on building capacity. This is because increases in FAR limits during the reform period are more likely to pass through to land parcels on relatively wide roads.

I exploit two features of the BSL limits on floor-to-area ratios. The law imposes different criteria depending on whether the land parcel is located on a road with width above or below 12 meters:

(i) For plots with front road width $\geq$ 12m, the floor-to-area ratio limit is determined by a statutory maximum y which depends on the boundaries of the zoning map drawn by the Ministry of Construction.

(ii) If road width < 12m, the FAR limit is instead $maxFAR = \min\{x, y\}$ where x is:

$$x = 100 \times \begin{cases} 0.4 \cdot roadwidth & \text{if residential} \\ 0.6 \cdot roadwidth & \text{if commercial or industrial} \end{cases} \tag{3.1}$$

For each of the land plots in my appraisal data, I observe road width, $maxFAR$ (the statutory maximum), and the zoning classification. This means that for plots on a road with width under 12 meters, I can compute x but do not observe the zoning parameter y. The two phases of land use reforms in 1983 and 1987 unilaterally increased y across all zones. Therefore, a plot exposed to the reform is one for which y rather than road width was the binding parameter.

Using this observation, I classify land plots as exposed to the land reform if they (i) are adjacent to a road wider than 12 meters, or if (ii) $x > maxFAR$. In the latter scenario, a plot is on a road that is relatively wide but faces restrictive zoning. Hence, both of these cases capture plots which are relatively unconstrained *ex ante*. This leads to a natural measure of reform exposure at the city level which takes into account both cases (i) and (ii):

$$T_j^{Pre} = \frac{\text{\# plots satsifying (i) or (ii)}}{\text{total \# of plots in city planning area}} \tag{3.2}$$

where by construction $0 \leq T_j^{Pre} \leq 1$, and $1 - T_j^{Pre}$ instead captures the share of plots constrained by FAR limits prior to the reform. I compute T_j^{Pre} using 1980 data for each city j to capture the regulatory environment in a baseline year prior to the first wave of reforms in 1983.

For the remainder of the paper I pool together commercial and industrial plots in my analysis of local land prices. I do this for two reasons. First, the parameters determining binding FAR limits and height restrictions are the same across commercial and industrial zoned plots, as shown in equation (3.1). The variation across cities in exposure to the land use reforms I exploit to identify shocks to firm real estate holdings is therefore unlikely to vary within cities between commercial and industrial zoned neighborhoods. Second, while companies in my dataset provide a brief description of the use of facilities related to their business activities, I do not observe the zoning categories of their real estate holdings. Attempting to classify facilities into zoning categories on the basis of these descriptions would introduce noise into my valuation of corporate real estate assets.[18]

My measures of *ex ante* local exposure to the land use reforms together explain 15% of the cross-sectional variation in land value growth during this episode. Figure 4 plots cumulative land growth during the height of the boom (1985-1990) against each of the exposure measures computed using 1980 as a pre-reform benchmark year. For both measures the cross-sectional correlation

[18] This will produce conservative estimates of firm responses to fluctuations in real estate values to the extent that (i) there is more cross-city variation in commercial land values during this time period, and (ii) the majority of firm real estate assets are either office buildings or factories, and thus likely fall into commercial/industrial zoning categories.

is highly negative, and the R^2 is approximately 0.10 for each individual exposure measure.[19] In particular, for median road width (Panel A), a one meter increase in 1980 median road width in a city is associated with 8.5% lower cumulative growth in land values during the real estate boom. In Panel B, a 10 percentage point increase in the 1980 share of land plots eligible for relaxed FAR limits is associated with 20.1% lower cumulative growth in land values during the real estate boom.

Figure 4 provides compelling evidence that areas which were more constrained by land use law prior to the 1980s reforms experienced larger swings in real estate values during the boom. The figure shows that the exposure measures are not simply picking up differences in city size. Each point in the figure is proportional in size to 1980 Census population. For both measures there is no clear pattern of high or low population cities being more or less constrained.

One might argue that my land use constraint measures are only two of many possible proxies for local real estate supply elasticity. Recent papers in the U.S. have proposed using the Saiz (2010) geography-based measures of local housing supply inelasticity as instruments for local real estate values (e.g. Mian & Sufi 2011; Chaney et al. 2012; Mian et al. 2013; Aladangady 2017). For research designs where the outcome variables are at the firm level, much of the criticism of the Saiz-based instruments has focused on violations of the exclusion restriction arising from the fact that local land unavailability is highly correlated with local demand for non-tradable goods (Mian & Sufi 2014; Davidoff 2016).

Moreover, little research has addressed whether the Saiz measures are good proxies for local supply constraints beyond the context of the 2000s U.S. real estate boom. An exception is Guren et al. (2018), who find that IV estimates of the housing wealth effect using the Saiz elasticity are much larger and far more imprecise prior to 2000 in the U.S. This raises the concern that geography-based measures, even when interacted with a time-varying demand shock such as 10-year Treasury rates, may not sufficiently capture whether local land constraints are currently binding.

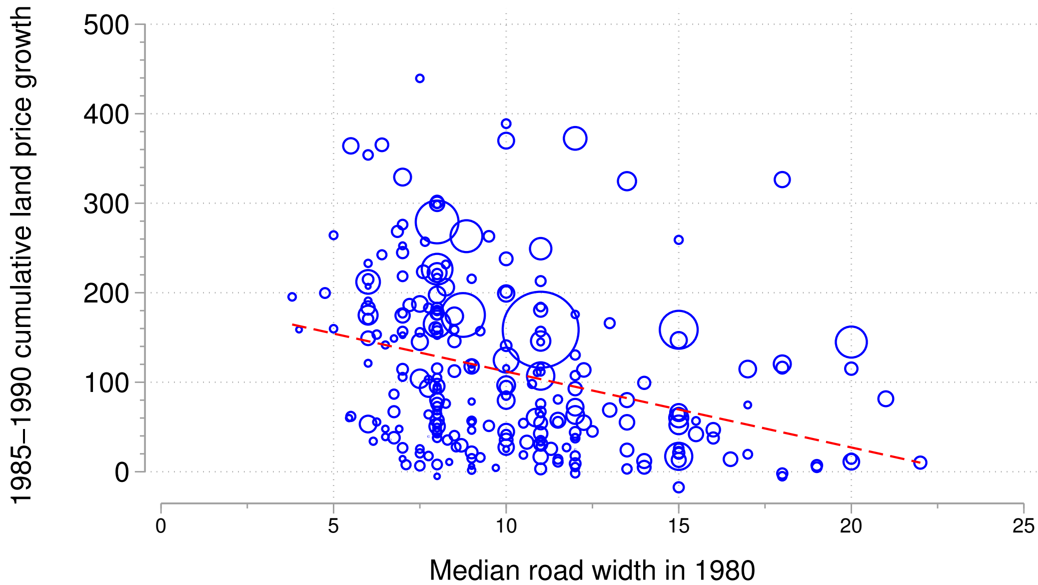
To further motivate my use of local exposure to the national land use reforms of 1983 and 1987 as instruments for firm real estate values, I show in Appendix C that the supply inelasticity and unavailable land share measures first proposed in Saiz (2010) are poor proxies for local supply constraints in Japan. In particular, the share of land deemed unavailable for development using the Saiz methodology is highly *negatively* correlated with growth in local land values from 1985 to 1990. This correlation has the opposite sign for growth in residential real estate values in the U.S. during the height of the 2000s boom. This indicates that geography-based measures are only useful proxies for supply constraints to the extent that they are highly negatively correlated with the stringency of existing land use regulation.[20]

[19] I provide additional results from difference-in-differences regressions of price levels on these exposure measures interacted with a post-reform dummy in Appendix G.1.

[20] For the share of non-residential land plots exposed to the lifting of FAR limits, the correlation with the unavailable land share is -0.08 in the cross-section of 108 municipalities with Saiz-style measures made available by Hosono et al. (2018). Similarly, the correlation of available land share with median road width in commercial and industrial areas is only -0.06.

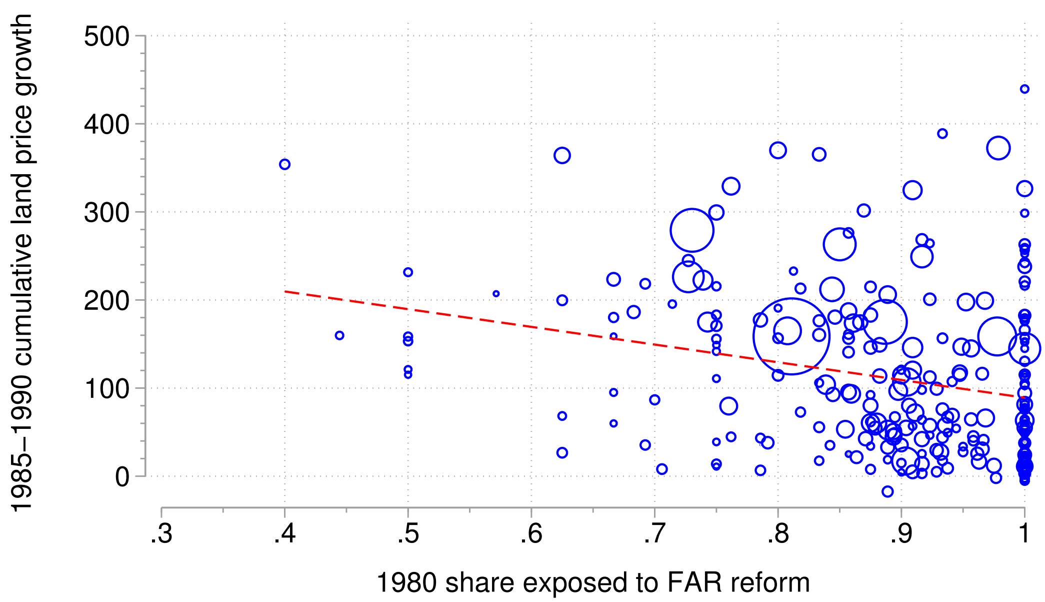
FIGURE 4. City-level Land Price Growth and Land Use Reform Exposure

A. Median Road Width and Commercial/Industrial Land Price Growth



β = −8.48
N = 250
R–squared = 0.1031

B. FAR Limit Share and Commercial/Industrial Land Price Growth



β = −200.98
N = 249
R–squared = 0.0701

4 Empirical Strategy

This section describes my empirical strategy for identifying the effect of shocks to firms' real estate asset values on borrowing and investment behaviors. My strategy is motivated by the evidence presented in Section 3 that areas which were more *ex ante* constrained by land use regulations experienced larger growth in real estate values after the land use reform in 1983.

Consider first the following regression equation that relates firm outcomes to market values of real estate listed on the balance sheet:

$$Y_{i,t}^{j} = \alpha_i + \delta_t + \beta \cdot RE_{i,t}^{j} + \epsilon_{i,t}^{j} \tag{4.1}$$

where $Y_{i,t}^{j}$ is the ratio of a measure of net debt issues or investment to lagged assets, and $RE_{i,t}^{j}$ is the ratio of the market value of real estate assets in year t relative to lagged assets for firm i with corporate headquarters located in city j.[21] Since firm real estate asset values reported in the balance sheet data are measured at acquisition cost, I first convert these values to market value by assigning a local non-residential land price index for city j and estimating the average age of real estate assuming a linear depreciation rate of 2%.[22]

This version of the model implicitly assumes all firm real estate holdings are located in an area around the headquarters, an assumption I relax later in Section 5.3. To establish that assigning real estate assets to the corporate HQ location is not a placebo shock, I hand collected information on facility ownership for all firms in my sample. Table 1 presents tabulations of the percentage of firms which own their HQ facility or other real estate assets located within the same Census city code as the HQ. Roughly 84% of firms in both the full sample and my estimation sample own their HQ facility, and 91% own either their HQ facility or other real estate assets in the vicinity of the HQ. Under a less stringent definition of real estate ownership which includes capital improvements (e.g. furnishings or renovations) to buildings, 95% of firms own real estate in the HQ city.[23]

Estimating equation (4.1) by OLS is likely to result in a biased estimate of the causal effect of firm real estate asset values on investment and borrowing. Common factors such as expectations about future productivity may result in increased demand for a firm's goods and services and simultaneously drive up real estate prices. If firms respond to such local demand shocks by increasing their borrowing and investment, it may appear that appreciation in firms' real estate holdings are

[21] Normalizing accounting variables by a measure of lagged book assets is standard practice in the corporate finance literature (e.g. Kaplan & Zingales 1997; Almeida et al. 2004). I show in Appendix G.8 the robustness of my results to instead normalizing by book assets in a benchmark year prior to the reform.

[22] These procedures follow the methods used in Chaney et al. (2012) and Lian & Ma (2019), with a few adaptations to the Japanese data. I provide full details on the book to market conversion in Appendix E.1 and procedures for estimating building depreciation rates in Appendix F.

[23] To the extent that some firms do not hold much, if any, real estate in the HQ city, the assumption in equation (4.1) that all real estate assets are located in the HQ city will produce conservative estimates by overestimating the extent to which real estate values comove with prices in the HQ city.

TABLE 1. Real Estate Ownership in the Corporate HQ City

	HQ facility ownership	RE ownership in HQ city	RE improvements in HQ city	Total
Full sample	1,312 (83.6%)	1,427 (90.9%)	1,495 (95.2%)	1,570
Estimation sample	1,249 (83.9%)	1,354 (91.0%)	1,416 (95.2%)	1,489
Excluding non-standard reports	1,235 (86.9%)	1,318 (92.8%)	1,373 (96.6%)	1,421

Notes: This table shows the tabulation of HQ ownership status among firms in the DBJ sample which can be matched to a local price index on the basis of their corporate HQ location. HQ ownership is determined by whether the firm reports a strictly positive amount of either building or land assets in their 1980 filings. "RE improvements in HQ city" refers to whether the firm owns RE in the HQ city or lists any positive amount of capital improvements to buildings in the HQ city. "Excluding non-standard reports" refers to the estimation sample excluding firms in the water transport, railway, and utilities (electricity/gas) sectors which are not required to report land and building assets by location. I describe my procedures for assigning ownership status in more detail in Appendix B.

driving these responses when in reality no causal link is present. Further, there may be a reverse causality problem, whereby increased firm borrowing may facilitate real estate acquisitions within the same year. Reverse causality may also run through investment, as large firms' physical capital investment could increase the value of real estate on the firm's balance sheet through general equilibrium effects operating on local property markets.

I address these sources of endogeneity by instrumenting the market value of firms' real estate assets using two measures of city-level exposure to the land use reform, median road width and the share of land plots unaffected by an increase in floor-to-area ratio limits via the land use reform in 1983, or $1 - T_j^{Pre}$ from equation (3.2), interacted with an indicator variable equal to one for years after and including 1983. These instruments extract an exogenous shock to real estate supply using the post-reform dummy as a common demand shock. In doing so, the effect of corporate real estate values on borrowing and investment behaviors is identified off the differential exposure of firms' headquarter locations to the land use reforms enacted in 1983 and 1987.

The full model can be described by the following equations and exclusion restrictions:

$$Y_{i,t}^j = \alpha_i + \delta_t + \beta \cdot RE_{i,t}^j + \epsilon_{i,t}^j$$

$$RE_{i,t}^j = \alpha_i + \delta_t + \psi' \cdot \left(\mathbf{T_j^{Pre}} \times Post_t\right) + \eta_{i,t}^j \tag{4.2}$$

$$\text{cov}\left(\mathbf{T_j^{Pre}} \times Post_t, \epsilon_{i,t}^j\right) = 0 \tag{4.3}$$

where the vector $\mathbf{T_j^{Pre}}$ includes the two proxies for local exposure to the national land use reform, and $Post_t$ is a dummy equal to unity in the post-reform period. The excluded instruments $\mathbf{T_j^{Pre}} \times Post_t$ are a difference-in-differences interaction, where the first difference compares cities with different levels of median road width and shares of land plots constrained by FAR limits, and the second difference is between the pre-reform period with more stringent building restrictions and the post-reform period with more relaxed restrictions on building height and size.[24]

Due to the difference-in-differences flavor of this IV strategy, I can investigate the validity of the exclusion restriction in (4.3) by examining whether firms located in areas with different levels of exposure to the land use reforms follow parallel trends in real estate values prior to the reforms. To do so, I estimate the following event study version of the first stage:

$$RE^j_{i,t} = \alpha_i + \delta_t + \sum_{k=-12}^{+6} \psi'_k \cdot \left(\mathbf{T^{Pre}_j} \times Post_{t-k}\right) + \eta^j_{i,t} \tag{4.4}$$

where $\psi'_k = (\beta_{1k} \quad \beta_{2k})$ is the vector of average partial effects of each instrument on firm real estate values. To obtain the total magnitude of the first stage effect of the excluded instruments, I add the average partial effects of each pre-reform constraint measure to obtain $\gamma_k = \beta_{1k} + \beta_{2k}$. The γ_k capture the total derivatives at horizon k of firm-level real estate values, allowing each of the individual pre-reform constraint measures to vary simultaneously. Given that changes in road width influence the share of plots in an area at the FAR limit, the total derivative of the first stage captures how relaxing building constraints along one dimension may result in a mechanical change in constraints along the other dimension.[25]

The evidence in Figure 5 supports the validity of the parallel trends assumption or exclusion restriction. The estimated total derivatives $\hat{\gamma}_k$ are not statistically different from zero before 1983, suggesting that there is no clear pre-trend. The y-axis in this figure represents the effect on the market value of firm real estate assets relative to lagged book assets of a one-standard deviation shock to land use exposure at the HQ city (i.e. increasing both instruments by one standard deviation). The vertical lines in this figure at 1983 and 1987 indicate years when the government enacted substantial revisions to the national land use codes.

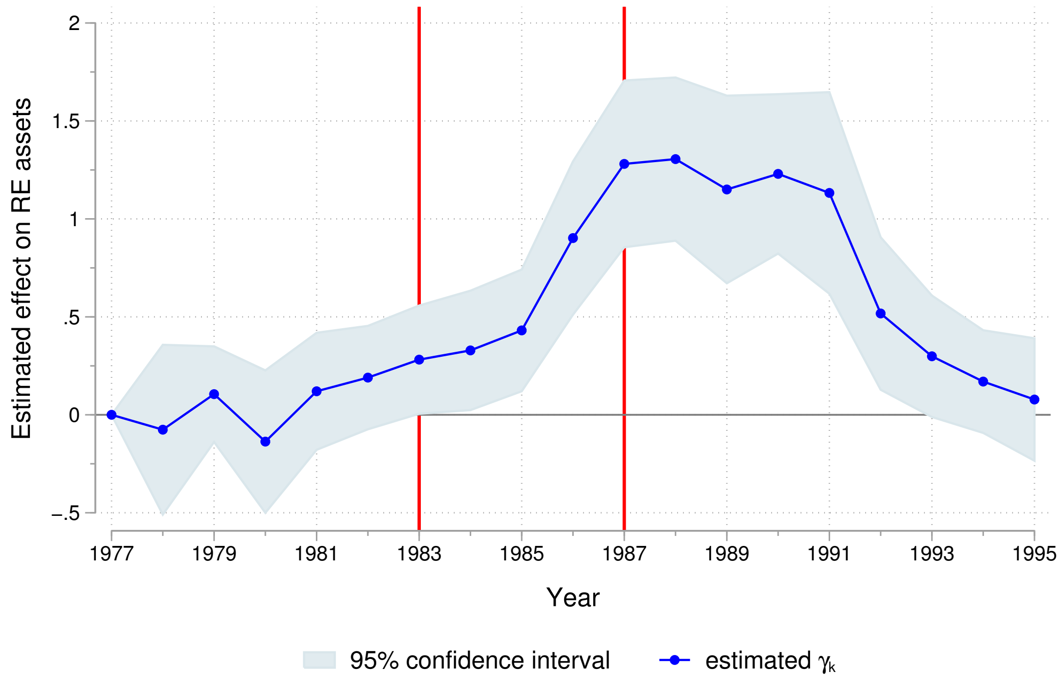
Table 2 provides estimates from the first stage regression of equation (4.2) to show that my research design does not face a weak IV problem. For my preferred estimates in column (2) which use city-level median road width as an excluded instrument and 1977-1995 as the sample period, the Montiel Olea-Pflueger F-test for the excluded instruments, which is robust to clustering by city code and to heteroskedasticity, exceeds the thresholds for 5% worst case bias relative to OLS at the 5% confidence level.[26] The fact that road width is a positive predictor of real estate values in the post-reform period, conditional on the share of plots constrained by FAR limits, suggests that within the cross-section of cities with similar shares of plots that are *ex ante* constrained by land use regulation, the positive contribution of constrained plots on wide roads ($>$ 12m in length) to

[24]I cluster standard errors at the HQ city code level in specifications where treatment is assigned at the HQ location. This produces conservative standard errors relative to two-way clustering at the city code $\times$ year level.

[25]I provide event study results for the just-identified first stage using my FAR-based instrument in Appendix G.2.

[26]With the exception of the estimates in column (3) which use the average road width measure as an excluded instrument in the 1977-1990 period, the Montiel Olea-Pflueger F-test exceeds the thresholds for 10% worst case bias relative to OLS at the 5% confidence level.

FIGURE 5. First Stage Regression (Land Use Reform Exposure)



Notes: This figure is based on equation (4.4), which estimates an event study version of the first-stage effect of the land use reform exposure instruments (in standard deviations) on the ratio of firm market real estate values to lagged book assets. Each point on the graph is the sum of the partial derivatives with respect to each instrument interacted with a time dummy: $\hat{\gamma}_k = \hat{\beta}_{1k} + \hat{\beta}_{2k}$. 95% confidence intervals were computed using the formula $\sqrt{\sigma^2(\hat{\beta}_{1k}) + \sigma^2(\hat{\beta}_{2k})}$ for standard errors. Standard errors for partial effect estimates were obtained from clustering by city code. The regression includes firm and year fixed effects and a full set of year $\times$ industry code and year $\times$ Census region code dummies. Vertical red lines indicate the two years when provisions of the land use reforms were officially codified.

real estate values predominates.[27]

The first stage estimates also show that the land use reform exposure measures capture cross-sectional differences in firm real estate assets during both the boom and the bust. Indeed, the event study coefficients in Figure 4 display the same hump-shaped patterns as in the aggregate time series for land values presented in Appendix A.1. This suggests that firms located in areas more *ex ante* constrained by building restrictions were in general more exposed to fluctuations in real estate values. The ability of the instruments to explain cross-sectional differences in real estate values over the entire episode explains why restricting the sample period to the boom period 1977 to 1990 lowers the strength of the first stage in Table 2.

[27] Recall that the measure of constrainedness using FAR limits constructed in Section 3.2 includes both plots on relatively wide roads ($>$ 12m in length) and plots on narrower roads which happen to be subject to urban planning maps with more stringent FAR limits. Consistent with the idea that measures of road width help predict real estate values, even conditional on other land use reform exposure statistics, Sargan-Hansen tests fail to reject the null hypothesis that the overidentifying restrictions are valid in all specifications listed in Table 2.

TABLE 2. First Stage Effect of Instruments on Firm Real Estate Assets

	1977 – 1995		1977 – 1990	
	(1)	(2)	(3)	(4)
Average road width × Post	0.149***		0.199***	
	(3.69)		(3.48)	
Median road width × Post		0.210***		0.291***
		(4.57)		(4.47)
FAR limit share × Post	8.87***	12.39***	10.46***	15.36***
	(4.86)	(7.66)	(3.76)	(6.55)
Montiel Olea & Pflueger F-test	17.89	32.25	12.13	24.24
First stage F-test (cluster-robust)	12.26	31.78	7.60	21.73
First stage F-test (Cragg-Donald)	270.60	311.86	339.37	416.86
Sargan-Hansen J-test (p-value)	0.96	0.59	0.56	0.37
N	27,925	27,925	20,590	20,590
# Firms	1,488	1,488	1,488	1,488
# Cities	160	160	160	160
Adj. R^2	0.36	0.36	0.38	0.38

Notes: The dependent variable in each regression is the ratio of firm market real estate to lagged book assets. In the IV estimations, excluded instruments are 1980 average road width or 1980 median road width, and the 1980 share of plots constrained by FAR limits, each interacted with a post-reform dummy equal to unity in years after 1983. All regressions include firm and year fixed effects. t-statistics in parentheses obtained by clustering standard errors by city code. $^{***}p < 0.01, ^{**}p < 0.05, ^{*}p < 0.1$

My identification strategy relies on the assumption that there are no unobserved differences between firms operating in areas more or less exposed to land use deregulation. I conduct several additional checks on the validity of the exclusion restriction in Appendix G.3. I show that my sample of firms which are above vs. below the median value of HQ-level exposure to the land use reform is balanced on a large set of pre-reform characteristics including size, book, real estate assets, ROA, interest coverage, and outstanding debt. Further, my instruments do not predict empirical proxies for Tobin's Q and corporate forecasts of business conditions. This suggests the land use deregulations did not influence firm investment opportunities or beliefs about future economic conditions through alternative channels to local real estate prices.

5 Firm Borrowing and Investment Responses

My IV empirical strategy yields evidence of a feedback loop between corporate borrowing and real estate investments during the 1980s Japanese cycle that is consistent with the intuition of standard models with collateralized firm borrowing. In this section, I estimate that firms which actively issue debt borrow an additional 3.1% of every 1 JPY increase in the market value of their real estate holdings over the period 1977-1995. Firms invested an extra 1.5% of every 1 JPY increase in real estate assets, with 1% going towards real estate and 0.5% allocated to investment in machines.

5.1 Results for Corporate Borrowing

Table 3 provides the baseline results with net total debt issues as the outcome variable from estimating equation (4.1) by OLS and by using the reform exposure measures to instrument for firm-level market real estate, as in equation (4.2).[28] I include results from specifications where I add year fixed effects interacted with indicators for the firm's main bank, three-digit industry code, Census region, and quintiles of size (by total assets) and age.[29] Specifications including the full set of controls therefore compare firms more exposed to the land use reform to those less exposed but who operate within the same industry and Census region, are in the same part of the size and age distribution, and receive the majority of their loans from the same creditor.

For total debt issues, the IV estimate in column (4) in Table 3 is 0.010, and significant at the 5% level. However, while the point estimates remain stable across the OLS and IV specifications with the inclusion of controls interacted with year fixed effects the IV estimates lose statistical significance. Importantly, new debt issuance is less common in Japan during this time period than among U.S. COMPUSTAT firms in the 1990s and 2000s. Indeed, 9% of firm-years in my sample record zero net debt issues, suggesting that much of the borrowing response captured by the estimates in Table 3 is due to an intensive margin response among firms who actively issue new debt through banks or corporate bond markets.

To confirm this, in Table 4 I estimate an intensive margin borrowing response to real estate values by restricting to observations where firms issue a strictly positive amount of debt during the year. The IV estimates in Table 4 are between two and three times as large and more precisely estimated than the corresponding IV estimates in Table 3. In standard deviation terms, a 1 s.d. increase in firm real estate values increases firm net debt issues by 0.3 s.d. along the intensive margin.[30]

Figure 6 highlights how the land use reform exposure instruments particularly affect the debt

[28] I define net debt issues as the sum of the yearly change in outstanding long-term debt and the yearly change in bonds payable. I restrict attention to long-term bank debt and bond issuance, as there are a large number of missing values for short-term debt issues and lines of credit in the firm balance sheet data.

[29] Following a large literature on firm-bank interactions in Japan (e.g. Giannnetti & Simonov 2013; Balloch 2018), I define the main bank as the bank accounting for the largest share of the firm's long-term loans. I obtain similar results when I include insurance companies and public lending institutions in the set of creditors and instead create a main creditor fixed effect.

[30] To assess the role of selection in the intensive margin estimates in Table 4, I estimated Tobit specifications left-censored for values of total debt issuance below zero. While the OLS Tobit model delivers the same point estimate as the intensive margin OLS estimate (0.014 with a p-value of 0.000), the IV Tobit model delivers a much lower and statistically insignificant estimate (0.006 with a p-value of 0.514). Since the Tobit estimates are a weighted average of the intensive margin effect of changes in real estate values on debt issuance and the selection effect on the probability of issuing strictly positive new debt, attenuation towards zero indicates that the land use reform shock reduced the probability of issuing new debt for some firms. The intensive margin estimates in Table 4 are thus likely driven by firms which were particularly credit constrained prior to the reform.

TABLE 3. Total Debt Issuance Response to Increase in RE Values

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Market RE	0.007***	0.008***	0.008***	0.010**	0.009	0.010	0.010
	(0.001)	(0.001)	(0.001)	(0.004)	(0.006)	(0.008)	(0.008)
Effect in standard deviations	0.10	0.11	0.11	0.14	0.12	0.14	0.14
Estimation	OLS	OLS	OLS	IV	IV	IV	IV
Main bank × year		✓	✓		✓	✓	✓
Industry & region × year		✓	✓			✓	✓
Size & age bin × year			✓				✓
First stage F-test (cluster-robust)	–	–	–	33.08	38.78	21.25	20.07
First stage F-test (Cragg-Donald)	–	–	–	294.67	233.62	96.36	92.60
N	27,744	27,218	27,206	27,687	27,292	27,176	27,164
# Firms	1489	1,481	1,480	1,486	1,486	1,479	1,478
# Cities	160	159	159	158	158	158	158

Notes: The dependent variable in each regression is net debt issues relative to lagged book assets. All regressions include firm and year fixed effects. In the IV estimations, the excluded instruments are 1980 median road width, and the 1980 share of plots constrained by FAR limits, each interacted with a post-reform dummy equal to unity in years after 1983. Industry fixed effects refer to three-digit DBJ industry codes, and region fixed effects refer to the 8 Census regions. Size bin refers to quintiles of total book assets. Age bin refers to quintiles of firm age, measured from 1980 using public listing dates. For each firm, the main bank is the creditor issuing the largest share of outstanding loans to the firm. Standard errors in parentheses and F-stats are clustered by city code. $^{***}p < 0.01, ^{**}p < 0.05, ^{*}p < 0.1$

issuance of firms which actively issue new debt. Panel A of Figure 6 plots the estimated total reduced form effect of the instruments on the total response of net debt, while Panel B restricts attention to firm-years with strictly positive net debt issues. The total reduced form effect of increasing *ex ante* land use constraints in the HQ city is 50% larger along the intensive margin than the total response following the second wave of land use deregulation in 1987. The intensive margin response of debt issuance also remains elevated after the crash of aggregate land prices and the stock market in 1990, which suggests that firms which borrowed heavily during the boom may have contributed to the zombie lending phenomenon of the 1990s. I return to this point in Section 6, where I show delisted firms account for the bulk of the zombie lending and real estate investment responses to the land use reforms.

My yen-for-yen estimates of the corporate borrowing response along the intensive margin are similar in magnitude to those for the total borrowing response of U.S. firms in Chaney et al. (2012). Yet in standard deviation terms, my estimates for the total response of corporate borrowing are larger than comparable estimates reported by Chaney et al. (2012) and Cvijanović (2014). In particular, my estimates imply that a one-standard deviation increase in firm real estate assets results in a 0.14 s.d. increase in net debt issues, compared to a 0.08 s.d. response estimated by

TABLE 4. Intensive Margin Debt Issuance Response to Increase in RE Values

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Market RE	0.014***	0.016***	0.016***	0.023***	0.023***	0.031***	0.035***
	(0.001)	(0.001)	(0.001)	(0.008)	(0.008)	(0.012)	(0.012)
Effect in standard deviations	0.19	0.22	0.22	0.31	0.31	0.42	0.47
Estimation	OLS	OLS	OLS	IV	IV	IV	IV
Main bank × year		✓	✓		✓	✓	✓
Industry & region × year		✓	✓			✓	✓
Size & age bin × year			✓				✓
First stage F-test (cluster-robust)	–	–	–	25.38	24.95	15.10	15.10
First stage F-test (Cragg-Donald)	–	–	–	125.15	100.06	42.99	39.74
N	12,474	11,971	11,966	12,403	12,033	11,954	11,949
# Firms	1,459	1,411	1,410	1,417	1,416	1,408	1,407
# Cities	157	155	155	154	154	154	154

Notes: The dependent variable in each regression is net debt issues relative to lagged book assets, conditional on positive net long-term debt issues. All regressions include firm and year fixed effects. In the IV estimations, the excluded instruments are 1980 median road width, and the 1980 share of plots constrained by FAR limits, each interacted with a post-reform dummy equal to unity in years after 1983. Industry fixed effects refer to three-digit DBJ industry codes, and region fixed effects refer to the 8 Census regions. Size bin refers to quintiles of total book assets. Age bin refers to quintiles of firm age, measured from 1980 using public listing dates. For each firm, the main bank is the creditor issuing the largest share of outstanding loans to the firm. Standard errors in parentheses and F-stats are clustered by city code. $^{***}p < 0.01, ^{**}p < 0.05, ^{*}p < 0.1$

Chaney et al. (2012) and 0.04 s.d. response estimated by Cvijanović (2014).[31]

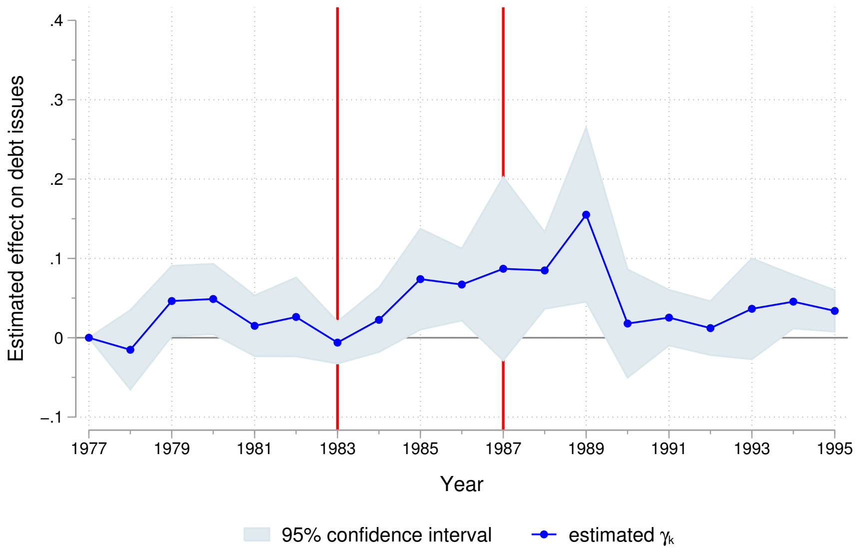
There are two key differences between my sample of Japanese firms and U.S. firms which help explain why my estimates are larger in standard deviation terms than those obtained in related studies. Firms in my sample are relatively old; the median firm was 40 years old in 1980, as measured by the public listing date.[32] This may partially account for why 99% of the firms in my sample have acquired real estate compared to approximately 50% among the sample of younger firms (median age 11 to 12 years) used by Chaney et al. (2012) and Cvijanović (2014). Second, loan covenants in Japan have historically emphasized the importance of liquidation value of physical assets such as land and buildings. As Lian & Ma (2019) and Bahaj et al. (2018; 2019) document, real estate collateral is more important among SMEs which comprise a small portion of the sample of firms used in most empirical studies of the collateral channel. Hence, my sample likely includes a much larger fraction of firms which can enter into a debt contract secured by real estate as collateral.

[31] Chaney et al. (2012) provide an OLS estimate of the dollar-for-dollar response of net long-term debt issues equal to 0.032. In their sample, increasing real estate value by one standard deviation (1.36) increases net debt issues by $0.032 \times 1.36 = 0.041$, which is about 8% of the standard deviation of net debt issues (0.50). Similarly, Cvijanović (2014) reports a dollar-for-dollar response of net long-term debt issues equal to 0.049, which implies a 1 s.d. effect of $0.049 \times 0.72 = 0.035$, or 4% of the standard deviation of net long-term debt issues (0.88).

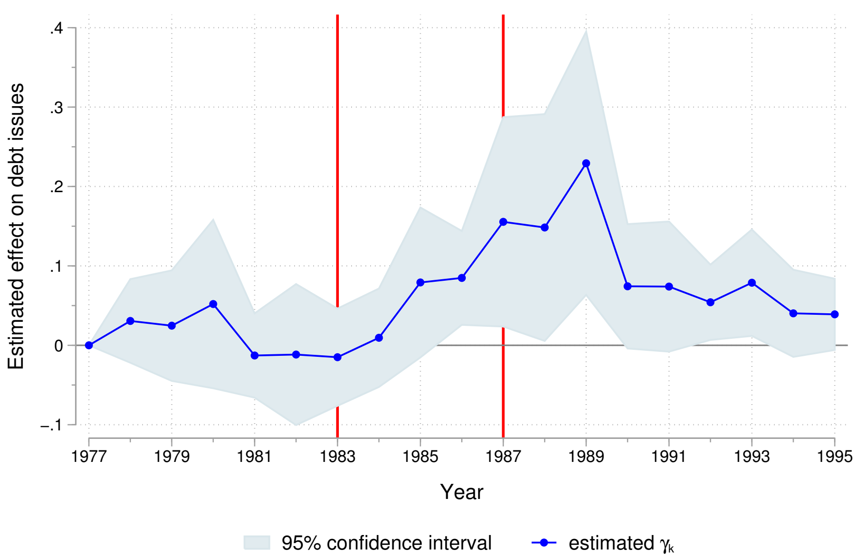
[32] The median firm was 47 years old in 1980 if I instead measure age by the incorporation date hand-collected from the history section of each firm's corporate filings.

FIGURE 6. Reduced Form Regression: Debt Issuance Response to Land Use Reform Exposure

A. Total Response



B. Intensive Margin Response



Notes: This figure provides estimates of the reduced form effect of the land use reform exposure instruments (in standard deviations) on the ratio of firm net debt issues to lagged book assets. Each point on the graph is the sum of the partial derivatives with respect to each instrument interacted with a time dummy: $\hat{\gamma}_k = \hat{\beta}_{1k} + \hat{\beta}_{2k}$. 95% confidence intervals were computed using the formula $\sqrt{\sigma^2(\hat{\beta}_{1k}) + \sigma^2(\hat{\beta}_{2k})}$ for standard errors. Standard errors for partial effect estimates were obtained from clustering by HQ city code. The regression includes firm and year fixed effects and year $\times$ industry code and a full set of year $\times$ Census region code dummies. Vertical red lines indicate the two years when provisions of the land use reforms were officially codified.

5.1.1 Real Estate Collateral or Cash Flows?

An emerging corporate finance literature argues that the vast majority of large U.S. non-financial firms face borrowing constraints that are a function of cash flows based on current operating earnings (Sufi 2007; Lian & Ma 2019; Drechsel 2019; Greenwald 2019). Two main provisions in the legal code incentivize Japanese creditors to rely instead on collateralized debt contracts. First, an insolvent debtor is not required to file a court petition for bankruptcy or restructuring. Second, while Japan has an extensive code governing bankruptcy court filings and proceedings, the law allows for private liquidation initiated by the creditor in the event that a debtor does declare bankruptcy, which offers creditors a quick and cost-effective alternative to applying for arbitration in court (Schumm 1988). Packer & Ryser (1992) examine credit registry data in Japan during the 1980s and find that over 90% of bankruptcies resulted in a combination of suspension of bank transactions and private liquidation.[33] Additionally, over half of bankruptcy court proceedings concluded in 1989 lasted more than 3 years, with 24% lasting more than 5 years. Hence, lending on collateral helps the creditor reclaim at least some of the principal from an insolvent client while avoiding large legal fees and time costs associated with arbitration in bankruptcy court.

I confirm the importance of real estate assets relative to earnings and cash flow for firm borrowing by adding controls for EBITDA, net cash receipts (OCF), lagged cash, and Q to the baseline specification in equation (4.1).[34] The results in Table 5 indicate that even conditional on earnings and contemporaneous and lagged cash flows, shocks to firm real estate cause new debt issues.[35] The IV estimate in column (3) is unchanged by the inclusion of EBITDA in column (4) and OCF in column (5). EBITDA also predicts borrowing to a far lesser extent than the 27% of every dollar estimate of Lian & Ma (2019) for large U.S. firms with earnings-based borrowing constraints.[36]

5.1.2 Are Other Physical Assets Used as Collateral?

In this subsection I show the importance of real estate for corporate borrowing remains after controlling for changes in the market value of non-real estate physical capital assets. To do so, I convert the book values of machines, tools, and transportation vehicles using inflation from the historical Bank of Japan (BOJ) wholesale price indices for domestic and imported corporate goods. I estimate the average age of these categories of physical assets by comparing the acquisition cost to

[33] Interestingly, Packer & Ryser (1992) also find that of the 185 bankruptcies among firms with over 3 billion yen in liabilities at the height of the boom (1988-1990), 27% were real estate firms, and 56% engaged in private liquidation. Among all real estate firms which declared bankruptcy, more than 80% were privately liquidated.

[34] See Appendix E.6 for details on how these variables are computed.

[35] Along the intensive margin, for the full specification with controls interacted with year fixed effects, EBITDA ceases to have any statistically significant effect.

[36] Estimates on the coefficients of EBITDA and OCF in these regressions do not have a direct economic interpretation because borrowing reverse causes cash flows, and cash flows are mechanically correlated with real estate assets to the extent that such assets generate income for the firm.

TABLE 5. Debt Issuance and RE Values Conditional on Cash Flows

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Market RE	0.007^{***}	0.004^{***}	0.010^{**}	0.010^{**}	0.008^{**}	0.014^{*}	0.013
	(0.001)	(0.001)	(0.004)	(0.004)	(0.004)	(0.008)	(0.009)
EBITDA		0.044^{***}		0.059^{***}	0.087^{***}	0.076^{***}	0.045^{***}
		(0.008)		(0.008)	(0.010)	(0.014)	(0.010)
OCF		-0.094^{***}			-0.092^{***}	-0.092^{***}	-0.095^{***}
		(0.006)			(0.007)	(0.008)	(0.007)
Lagged cash		-0.005^{***}					-0.006^{***}
		(0.001)					(0.001)
Q		0.007^{***}					0.006^{***}
		(0.001)					(0.001)
Estimation	OLS	OLS	IV	IV	IV	IV	IV
Controls × year FEs		✓				✓	✓
First stage F-test (cluster-robust)	–	–	33.08	30.99	31.46	23.19	24.07
First stage F-test (Cragg-Donald)	–	–	294.67	298.00	299.81	94.36	80.87
N	27,744	26,330	27,687	27,687	27,687	26,829	25,458

Notes: The dependent variable in each regression is net debt issues relative to lagged book assets. EBITDA is operating income plus depreciation and amortization. Accounting definitions for OCF, cash, and Q are given in Appendix E.6. Controls × year FEs includes controls for main bank, industry codes, region fixed effects, size, and age bin dummies interacted with year fixed effects. Standard errors in parentheses and F-stats are clustered by city code. $^{***}p < 0.01, ^{**}p < 0.05, ^{*}p < 0.1$

annual accounting depreciation for each asset type to compute depreciable life and then assuming the linear rate of depreciation consistent with that depreciable life.[37]

Table 6 shows that the response of debt issuance to a shock to firm real estate assets remains economically and statistically significant even after controlling for the total market value of other fixed assets such as machines, tools,and vehicles. The point estimates for the coefficient on $RE^{j}_{i,t}$ are virtually identical to the baseline results in Table 3 and Table 4, while the coefficient on other fixed assets is small and marginally significant for total debt issues and statistically insignificant, and even negative, for some specifications with intensive margin debt issuance as the outcome. These results suggest that other physical production inputs are imperfect substitutes for real estate in providing collateral to creditors.[38]

[37]See Appendix E.2 for full details on the book to market conversion for non-real estate fixed assets.

[38]One potential concern is that these borrowing response estimates do not take into account the relative importance of different components of the physical capital stock to firms' production. In Appendix E.5, I use a sufficient statistics approach based on Q-theory to construct capital stock aggregates which weight individual capital components by their share in the firm's production.

TABLE 6. Debt Issuance and RE Values Conditional on Other Fixed Assets

	Total debt issues				Intensive margin			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Market RE	0.008***	0.008*	0.014*	0.013	0.015***	0.021***	0.028***	0.028**
	(0.001)	(0.004)	(0.008)	(0.008)	(0.001)	(0.008)	(0.011)	(0.011)
Other fixed assets	0.004*	0.004*	0.003	0.003	0.000	0.000	−0.006	−0.007
	(0.002)	(0.002)	(0.002)	(0.003)	(0.005)	(0.005)	(0.004)	(0.005)
Estimation	OLS	IV	IV	IV	OLS	IV	IV	IV
Main bank × year			✓	✓			✓	✓
Industry & region × year			✓	✓			✓	✓
Size & age bin × year				✓				✓
First stage F-test (cluster-robust)	–	28.26	21.52	21.40	–	26.75	14.76	15.08
First stage F-test (Cragg-Donald)	–	294.76	99.18	95.66	–	120.32	53.37	50.39
N	25,547	25,486	24,652	24,641	11,459	11,385	10,922	10,917
# Firms	1,402	1,395	1,349	1,348	1,370	1,325	1,292	1,291
# Cities	158	156	152	152	152	152	149	149

Notes: The dependent variable in each regression is net debt issues relative to lagged book assets. All regressions include firm and year fixed effects. For other fixed assets, the book to market conversion is conducted using the historical corporate goods price indices for tools, general machines, and transport from Bank of Japan. Standard errors in parentheses and F-stats are clustered by city code. $^{***}p < 0.01, ^{**}p < 0.05, ^{*}p < 0.1$

5.2 Results for Firm Investment

Next, I document the responsiveness of firms' investment behaviors to changes in the value of real estate. To do so, I estimate OLS and IV versions of equation (4.1) using various measures of physical capital investment as the outcome variable. Relative to other papers which empirically document a collateral channel, one critical distinction is that I observe disaggregated categories of physical capital investment. I define real estate investment as the year-on-year change in the total net book value of buildings, land, and construction in progress plus accounting depreciation for buildings.

My ability to separate these categories of investment is important for interpreting the empirical results of regressions of net debt and investment on real estate values through the lens of the Kiyotaki-Moore model. A key feature in this class of models is a feedback loop whereby firms borrow against a physical asset and then subsequently reinvest in the same physical capital asset, further raising the value of collateral. If firms were to instead use the proceeds of increased borrowing to only invest in non-collateralized physical assets, then there may not be the dynamic feedback loop between asset values and borrowing and investment opportunities that has been shown theoretically to amplify boom-bust cycles in asset prices.

Table 7 displays an economically large response of real estate investment to firm market real estate values. The OLS estimates imply firms invest 1.5% of every 1 JPY increase in firm real

TABLE 7. Real Estate Investment Responses to Increase in RE Values

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Market RE	0.013***	0.015***	0.015***	0.007**	0.008**	0.009**	0.008**
	(0.000)	(0.000)	(0.000)	(0.003)	(0.004)	(0.004)	(0.004)
Effect in standard deviations	0.41	0.48	0.48	0.24	0.27	0.30	0.27
Estimation	OLS	OLS	OLS	IV	IV	IV	IV
Industry & region × year		✓	✓		✓	✓	✓
Size bin × year			✓			✓	✓
Age bin × year			✓				✓
First stage F-test (cluster-robust)	–	–	–	31.78	21.07	18.85	18.25
First stage F-test (Cragg-Donald)	–	–	–	311.86	110.29	98.28	97.49
N	27,944	27,884	27,872	27,925	27,868	27,868	27,856
# Firms	1,489	1,486	1,485	1,488	1,485	1,485	1,484
# Cities	160	159	159	158	158	158	158

Notes: The dependent variable in each regression is real estate investment relative to lagged book assets. Real estate investment is defined as the yearly change in the net book value of real estate (buildings + land + construction in progress) plus accounting depreciation for buildings. All regressions include firm and year fixed effects. Standard errors in parentheses and F-stats are clustered by city code. $^{***}p < 0.01, ^{**}p < 0.05, ^{*}p < 0.1$

estate values in real estate. For the IV estimate in column (7), the implied response with a full set of controls is 0.8% of every 1 JPY increase in real estate values. This implies a 1 s.d. increase in firm real estate values leads to a 0.27 s.d. increase in real estate investment. Further, in all specifications the point estimates remain significant at the 5% level, even with the inclusion of a rich set of firm controls for size, age, and industry and region interacted with year dummies.[39]

Do firms also increase investment in non-real estate assets in response to shocks to the value of their real estate assets? One possibility is that real estate and other physical components of the capital stock are complements to firm production, in which case investment in both types of assets should simultaneously increase when property values increase. Yet the evidence in Section 5.1 suggests that real estate is the predominant form of collateral used to secure corporate debt. This means that firms may face incentives to reinvest in real estate but not other physical assets to gain access to more credit. Hence, whether other capital investment increases in response to a shock to real estate assets depends on which of these two channels dominates.

[39] I show in Appendix G.6 that land and new construction account for the bulk of the real estate investment response. Since land and construction are non-depreciable components of real estate, the real estate investment response I document is not driven by building maintenance or changes in corporate tax incentives for claiming building depreciation.

TABLE 8. Response of Investment in Machines

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Market RE	0.007***	0.008***	0.008***	0.005***	0.006*	0.006*	0.005*
	(0.001)	(0.001)	(0.001)	(0.002)	(0.003)	(0.003)	(0.003)
Effect in standard deviations	0.31	0.35	0.35	0.22	0.27	0.27	0.22
Estimation	OLS	OLS	OLS	IV	IV	IV	IV
Industry & region × year		✓	✓		✓	✓	✓
Size bin × year			✓			✓	✓
Age bin × year			✓				✓
First stage F-test (cluster-robust)	–	–	–	31.29	19.56	17.44	17.41
First stage F-test (Cragg-Donald)	–	–	–	264.73	95.50	85.14	84.93
N	27,947	27,809	27,797	27,890	27,771	27,771	27,759
# Firms	1,489	1,481	1480	1,486	1,479	1,479	1,478
# Cities	160	159	159	158	158	158	158

Notes: The dependent variable in each regression is investment in machines relative to lagged book assets. This measure is defined as the yearly change in the net book value of machines plus accounting depreciation. All regressions include firm and year fixed effects. In the IV estimations, the excluded instruments are 1980 median road width, and the 1980 share of plots constrained by FAR limits, each interacted with a post-reform dummy equal to unity in years after 1983. Standard errors in parentheses and F-stats are clustered by city code. $^{***}p < 0.01, ^{**}p < 0.05, ^{*}p < 0.1$

Table 8 examines the response of investment in machines to firm real estate values.[40] The IV estimate in column (4) indicates a highly significant and robust response of investment in machines of 0.5% of every 1 JPY increase in real estate assets. I show the results for measures of overall physical capital investment in Appendix G.6. I find no investment response in other disaggregated components of the physical capital stock (i.e. vehicles and tools).

The overall physical capital investment response I find is somewhat higher than the 0.21 s.d. response reported in Chaney et al. (2012) using Saiz's (2010) supply inelasticity measures as an instrument for local real estate prices. While I also use a cross-sectional estimation approach to identify firms' capital investment response, Chaney et al. (2012) compare corporate real estate owners to non-owners. Their estimates are thus a composite of the fraction of real estate assets pledgable as collateral (intensive margin ownership) and firms' real estate ownership decisions (extensive margin ownership). In contrast, in my research design investment and borrowing responses are identified by comparing real estate-owning firms within the same industry, region, and age and size quintile which receive different dosages of exposure to land use deregulation.

The estimates in this section provide strong evidence that firms located in areas more *ex ante* constrained by building regulations reinvested the windfall they received from the land use reform

[40] I provide analogous results in Appendix G.6 using measures of aggregate non-real estate physical capital investment as the outcome variable. I construct physical capital aggregates using the methods of Appendix E.5. In general, I find a more muted response of non-real estate investment computed as the sum of the yearly change in the net book value of machines, vehicles, and tools, plus accounting depreciation.

in real estate assets and machines. Combined with the observations in Section 5.1 that real estate is the preferred form of collateral for securing corporate debt, these results suggest that firms reinvest in assets directly tied to borrowing limits during asset price booms and, to a lesser extent, invest in complementary inputs to production. This increase in both real estate and non-real estate investment widens the scope for amplification of real business cycles through aggregate investment.

5.3 Spatial Distribution of Real Estate Assets

In this subsection, I leverage hand-collected information on the location of facilities owned by firms in my dataset to show that corporate resources tend to be highly concentrated at the HQ location. In the results presented so far I follow previous studies (Chaney et al. 2012; Cvijanović 2014; Lian & Ma 2019) in imputing the location of firm real estate assets using the registered HQ address. I use the facility-level data to check robustness of my results to using instruments which take weighted averages of land use reform exposure across all locations where the firm operates.

I hand-collected information from each firm's securities filings on the name and general purpose of corporate facilities, on-site employment, and the size and net book values of real estate assets located at each facility. Due to the time-consuming nature of this process, I did this for a single year, selecting 1980 because more firms have filings available in this year than in other years prior to the land use deregulations. I focus on facilities for which the firm has at least a partial ownership stake; that is, the site is not fully rented from some third party.[41]

Table 9 displays tabulations for firms in my sample which itemized their facilities in 1980.[42] On average, firms hold 39% of the net book value of domestic real estate assets within the HQ city. In terms of quantities of production inputs, 43% of employment and 34% of owned land area is located in the same city as the HQ.[43] This is a strikingly high degree of resource concentration given that firms in my sample tend to span many locations, with the median firm owning six facilities across five distinct municipalities. These statistics suggest assigning all corporate real estate assets to the HQ location is a reasonable first pass at estimating the strength of the collateral channel.

Still, for most firms the majority of real estate assets and employees are outside the HQ location. If my instruments have a causal interpretation, then using a more general definition of firm location should strengthen the first stage effect on real estate values. To test this, I compute an exposure index $\overline{T}_i$ for each firm i by taking a weighted average of the share of floor-to-area ratio (FAR)

[41] Appendix B provides detailed examples of the facility itemizations and describes how I match facilities to locations. I refer to locations as facilities rather than establishments because many facilities have zero onsite employees, and multiple facilities may fall under the same tax entity.

[42] These tabulations exclude firms which have non-standard reporting formats (e.g. railway companies) for which it is not possible to assign a location to real estate holdings.

[43] Conditional on HQ ownership, the real estate and employment shares in the HQ city are 41% and 46%, respectively.

TABLE 9. Summary Statistics for 1980 Corporate Facilities

	Mean	Median	SD	10th pct.	90th pct.	N
RE asset share at HQ city	0.39	0.32	0.32	0.01	0.93	1,446
Employment share at HQ city	0.43	0.37	0.33	0.00	0.97	1,446
Land area share at HQ city	0.34	0.22	0.34	0.00	0.97	1,446
Non-residential RE share	0.94	1.00	0.12	0.80	1.00	1,446
# owned facilities	7.2	6.0	5.3	2.0	14.0	1,446
# unique cities	5.5	4.0	4.0	2.0	11.0	1,446

Notes: Using the facility-level data, this table shows the share of the net book value of real estate assets, employment, and land (measured in m^2), located in the same city as the corporate HQ. Non-residential RE share refers to the share of real estate assets which are identified as non-residential sites (e.g. offices or factories). I also report tabulations for the number of owned facilities listed separately in the 1980 filings and the number of unique cities that these facilities span. See Appendix B for more details on the data construction.

constrained plots $1 - T_j^{Pre}$ across cities j where the firm owns a facility:

$$\overline{T}_i = \sum_{j=1}^{n_i} \omega_{i,j} \cdot \left(1 - T_j^{Pre}\right) \tag{5.1}$$

$$\omega_{i,j} = \frac{N_{i,j}}{\sum_{k=1}^{n_i} N_{i,k}} \tag{5.2}$$

where n_i refers to the number of distinct locations at which the firm lists facilities in its securities filing.[44] I construct the weights $\omega_{i,j}$ for each firm-location according to the net book value of real estate assets or employment, represented by $N_{i,j}$. The median weighted share of constrained plots is 0.12 compared to 0.19 for the unweighted version. The weighting procedure compresses the range of exposure intensity but creates a more continuous measure of reform exposure across firms. My results are quantitatively similar regardless of whether I use weights based on employment or book real estate shares, so I present results in this section using employment shares.[45]

Abandoning the assumption that all corporate real estate assets are located in the HQ city requires a new method for converting from book to market values. To this end, I create a firm-level non-residential price index which is a weighted average across the local price indices P_j at each location where the firm operates, with the weights $\omega_{i,j}$ defined above in equation (5.2). I then inflate up total real estate assets in each firm-year to market value using this index and the methods described in Section 4 and Appendix E.1. This valuation method incorporates the distribution of

[44]Refer back to Section 3.2 for details on how I construct the city-level measure of exposure T_j^{Pre}.

[45]The exclusion restriction is more likely to hold for the measure of firm-level exposure constructed using employment shares. The evidence in Giroud & Mueller (2017) suggests firms are far less likely to compensate for shocks to real estate values during booms relative to busts by shifting employment across locations.

TABLE 10. Responses to Real Estate Values at Firm-level vs. HQ-level

	Total debt issues				Real estate investment			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Market RE	0.008***	0.007***	0.009**	0.006***	0.014***	0.013***	0.006**	0.003**
	(0.001)	(0.001)	(0.004)	(0.002)	(0.001)	(0.001)	(0.003)	(0.001)
Effect in standard deviations	0.11	0.15	0.12	0.13	0.44	0.66	0.19	0.15
Estimation	OLS	OLS	IV	IV	OLS	OLS	IV	IV
RE valuation	HQ	Firm	HQ	Firm	HQ	Firm	HQ	Firm
Montiel Olea & Pflueger F-test	–	–	23.46	104.94	–	–	21.72	120.36
First stage F-test (cluster-robust)	–	–	24.27	127.03	–	–	20.22	174.29
First stage F-test (Cragg-Donald)	–	–	257.94	633.62	–	–	264.00	485.78
N	24,998	24,998	24,998	24,998	25,182	25,182	25,182	25,182
# Firms	1,341	1,341	1,341	1,341	1,341	1,341	1,341	1,341
# Cities	151	151	151	151	151	151	151	151

Notes: The dependent variables are total net debt issues or real estate investment. Even columns use market real estate valuations obtained from a firm-level average price index, where the weights are the share of full-time employment at each location. In columns (3) and (7), the excluded instrument is the 1980 share of plots constrained by FAR limits interacted with a post-reform dummy. Columns (4) and (8) use the weighted average of the FAR limit shares defined by equations (5.1) and (5.2). All regressions include firm and year fixed effects. Standard errors in parentheses and F-stats are clustered by HQ city code. $^{***}p < 0.01, ^{**}p < 0.05, ^{*}p < 0.1$

the firm's resources without imposing assumptions about the age of assets at individual locations.[46]

Table 10 shows similar corporate borrowing and investment responses to my baseline results when I use these firm-level prices to value corporate real estate assets.[47] Using firm-level measures of prices and exposure to the land use reform tightens the link between the reform and market real estate values, with the Montiel Olea-Pflueger first stage F-stat almost quadrupling relative to the HQ-level IV estimations in columns (3) and (7). Across the two methods for assigning firm locations, the point estimates in standard deviation terms remain stable for both debt issuance and real estate investment.[48] These facts demonstrate a high degree of geographic concentration among Japanese firms during this time period and add further support to my research design based on corporate exposure to non-residential land use deregulation.

[46] An alternative method would be to inflate real estate assets at each location using the corresponding local price index, add up these market values in the benchmark year (1980), and then iterate forward and backwards by adding in depreciation and changes in the gross book value of real estate. This method requires the strong assumption that all acquisitions outside the benchmark period consist of new buildings or vacant land. I show robustness of my analysis to this type of book to market conversion in Appendix G.4.

[47] Real estate, utilities, and transportation firms are not subject to the same reporting requirements for fixed assets, and so coverage of the facility-level data for these sectors is incomplete. See Appendix B for more details.

[48] The lower estimates for the real estate investment response in this table relative to the baseline results in Table 7 also reflect the absence of real estate and transportation firms which rely heavily on land as production inputs. Unfortunately, these firms do not systematically itemize their real estate assets by location.

6 Long-run Consequences: Zombie Lending

In this section I use long-run measures of firms' financial health to demonstrate that firms' borrowing and investment responses to commercial land use deregulation resulted in severe consequences for the corporate sector into the late 1990s and early 2000s. This finding is consistent with financial accelerator models (e.g. Kiyotaki & Moore 1997; Bernanke et al. 1999) where borrowing frictions such as collateral constraints exacerbate macroeconomic downturns.

6.1 Heterogeneity by Survivorship

I start by using a very simple measure of long-run financial health: whether the firm was delisted in the post-boom period for reasons other than a merger. Table 11 reports results from estimating the baseline specification in equation (4.1) separately for the roughly one-third of firms in my sample which were eventually delisted and the remaining two-thirds which remain publicly listed. For net debt issues as the outcome variable, the IV estimate in column (3) indicates no statistically significant response to real estate values for delisted firms. The IV estimate in column (4) for surviving firms is marginally significant, suggesting the land use reform shocks induced a larger borrowing response among firms that survived the financial crises of the 1990s and early 2000s.

But delisted firms are more likely to invest in real estate in response to the land use reform shocks. In particular, the IV estimate in column (7) for delisted firms is statistically significant at the 1% level, but the IV estimate in column (8) for surviving firms is statistically zero. Moreover, the IV estimate of the real estate investment response for delisted firms is 0.01 compared to 0.007 in the baseline results pooling all firms in Table 7. The bulk of the real estate investment response observed in the full cross-section of firms is thus due to firms that ultimately did not survive the post-boom crises.

Standard macro-finance models with representative firms show that an initial positive shock to the value of collateral induces both more borrowing and more investment in the collateralizable asset. The results here suggest that the average borrowing response of firms in the economy is generated by a distinct subset of firms than the firms which drive the increase in investment. One explanation for this finding is that survivorship is an *ex post* proxy for access to credit, in which case delisted firms do not borrow because they have limited access to corporate bond markets or bank lending. Yet, whether a firm is delisted in the post-boom period is virtually uncorrelated with commonly used measures of corporate external financing constraints.[49] This suggests that a firm's long-run performance, as measured by delisted status during the bust period, is unrelated to their credit access in the pre-boom period.

[49] I describe these measures of financing constraints in Appendix E.3 and show more *ex ante* credit constrained firms account for the bulk of new debt issues during the boom-bust cycle in Appendix G.9. The correlation between delisted status and *ex ante* borrowing constraints ranges from 0.03 for the Kaplan-Zingales index to 0.16 for the Whited-Wu index.

TABLE 11. Heterogeneous Responses by Firm Survivorship

	Total debt issues				Real estate investment			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Market RE	0.005***	0.009***	0.005	0.011*	0.012***	0.014***	0.010***	0.004
	(0.002)	(0.001)	(0.007)	(0.006)	(0.001)	(0.000)	(0.004)	(0.004)
Effect in standard deviations	0.07	0.12	0.07	0.15	0.38	0.45	0.31	0.13
Delisted	Yes	No	Yes	No	Yes	No	Yes	No
Estimation	OLS	OLS	IV	IV	OLS	OLS	IV	IV
First stage F-test (cluster-robust)	–	–	20.92	23.78	–	–	22.08	22.60
First stage F-test (Cragg-Donald)	–	–	71.87	237.97	–	–	77.96	254.60
N	9,802	18,070	9,783	18,070	9,826	18,118	9,807	18,118
# Firms	526	963	525	963	526	963	525	963
# Cities	92	129	91	129	92	129	91	129

Notes: The dependent variables are total net debt issues or real estate investment. In the IV estimations, the excluded instruments are 1980 median road width, and the 1980 share of plots constrained by FAR limits, each interacted with a post-reform dummy equal to unity in years after 1983. Delisted refers to whether the subsample restricts to firms which are no longer listed because they do not meet the requirements to be listed on the stock exchange. Standard errors in parentheses and F-stats are clustered by city code. $^{***}p < 0.01, ^{**}p < 0.05, ^{*}p < 0.1$

6.2 Land Use Reform Exposure and Zombie Lending

The fact that delisted firms account for the bulk of the real estate investment response during the boom years provides suggestive evidence of a financial accelerator during the 1990s. To shed further light on this hypothesis, I assess whether firms which were more exposed to the national land use deregulations in the early 1980s were also more likely to be recipients of loans in forbearance during the 1990s. Several papers have documented the prevalence of "zombie lending," or evergreening loans, in 1990s Japan (Hoshi & Kashyap 2004; Ahearne & Shinada 2005; Peek & Rosengren 2005; Caballero et al. 2008). While most of these papers are concerned with identifying zombie firms using *ex post* measures of firm productivity, Peek & Rosengren (2005) provide direct evidence that firms in dire financial condition during the 1990s were more likely to be granted additional credit.[50]

I adopt the zombie index of Caballero et al. (2008) to identify financial struggling firms in the 1990s.[51] The logic of this index is that a firm is the recipient of an (undeclared) non-performing loan if in a given year its reported interest payments are below some minimum threshold required to service total debt. Given that evergreening is often in violation of original loan contract terms, bank employees have an incentive to hide their clients' insolvency. An advantage to this notion of

[50] A newer literature on credit misallocation in the EU in the wake of the 2008 global financial crisis instead identifies zombies from the bank's balance sheet, arguing that undercapitalized banks have incentives to delay writing off non-performing loans (Schivardi et al. 2017; Acharya et al. 2019; Blattner et al. 2019).

[51] I thank Takeo Hoshi for sharing the corporate bond interest rate series used in this section.

zombie lending is that it is based directly on interest rates, which are forecast with uncertainty, rather than accounting measures which are readily observable.[52]

I use this zombie index to document differential trends in the incidence of 1990s zombie lending based on a firm's *ex ante* exposure to the land use reform in the early 1980s. Rather than imputing exposure entirely at the HQ location, I use the facility-level data to take into account the distribution of a firm's real estate assets and employment across locations with potentially heterogeneous land use constraints. Since my snapshot of pre-reform exposure is taken in 1980, but the zombie lending phenomenon occurs up to 20 years later, it is possible that over such a long horizon a firm may have drastically shifted the allocation of resources across geographic locations or changed its HQ location altogether.[53]

To account for geographic shifts in firm resources over a longer time horizon, I focus on the measure of firm exposure $\overline{T}_i$ introduced in Section 5.3 that takes a weighted average of land use reform exposure across facility locations. Figure 7 plots the time series of asset-weighted zombie percentages for all delisted firms, classifying firms as "more constrained" if they are within the top 30% of firms by $\overline{T}_i$. Panel A compares the results of this exercise using employment shares vs. real estate asset shares as weights using a dummy version of the zombie index, while Panel B makes the same comparison using a fuzzy version of the index which varies continuously on the interval [0,1].

The figure shows that firms which were more exposed to the land use reform using 1980 data were more likely to become zombies. Under the crisp zombie index, zombie incidence was on average 0.7 percentage points or 20% higher among constrained firms in the 1990s; for the fuzzy zombie index, zombie incidence was on average 0.8 percentage points or 21% higher among constrained firms. Although the choice between employment and real estate asset weights to create the exposure measure affects the timing of the divergence, the magnitude of the difference in zombie incidence across the two groups of firms is left intact.

7 Aggregate Implications of the Land Use Reform

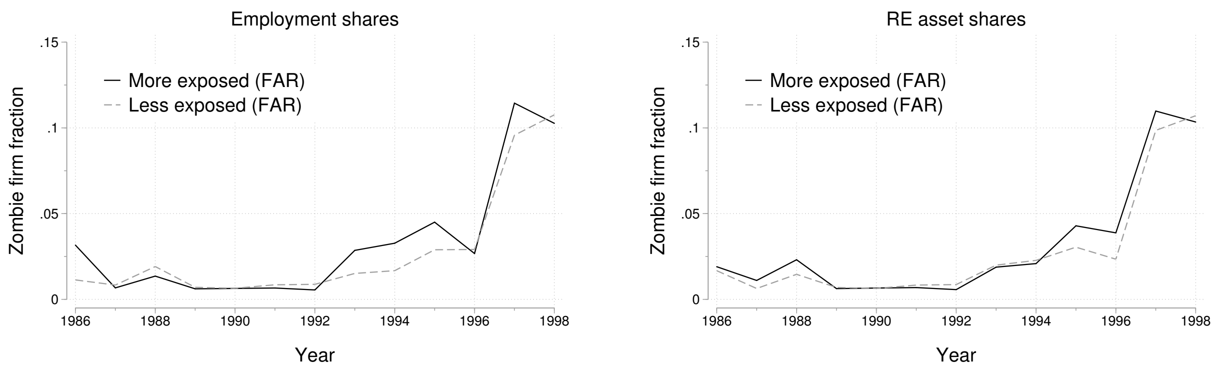
In this section, I propose a spatial sorting model with real estate collateral, land use law, and local production externalities which microfounds the use of *ex ante* land use constraint measures as instruments for local market real estate values. I calibrate separate versions of the model where collateral constraints always or sometimes bind in the cross-section of firms. The land use reforms explain 20% of the aggregate fluctuations in non-residential land prices, and a version of the model with sometimes binding collateral constraints generates the fat right tail in the cross-sectional distribution of non-residential price growth observed in the data during the 1980s boom.

[52] I provide formulas and describe the interest rate series in Appendix E.4.

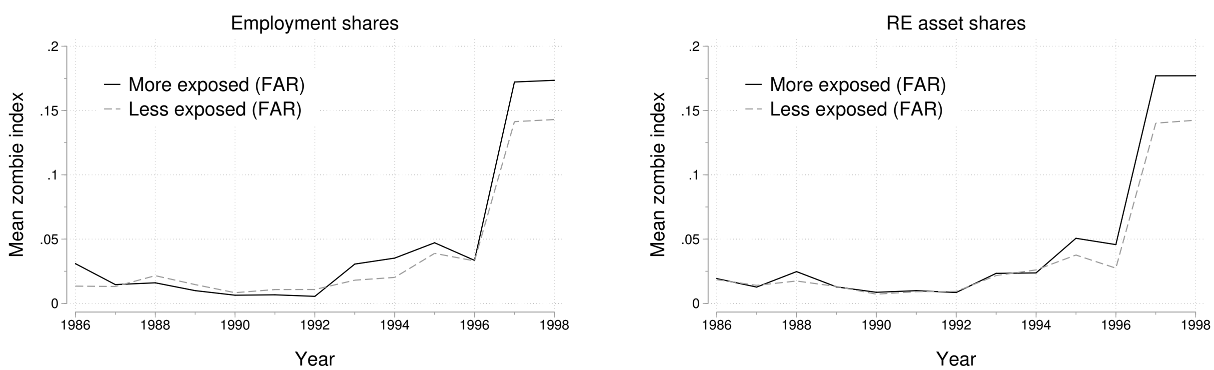
[53] Indeed, I find no statistically significant difference in the incidence of zombie lending across constrained and unconstrained firms using a measure of land use exposure determined purely at the HQ level.

FIGURE 7. Zombie Incidence and Land Use Reform Exposure

A. Crisp Zombie Index



B. Fuzzy Zombie Index



Notes: This figure plots the time series of asset-weighted zombie percentages using the index measures of Cabellero et al. (2008). Panel A refers to a binary version of the index, and Panel B refers to fuzzy version of the index which varies continuously over the interval (d_1, d_2) = (-25 bps, 75 bps). More constrained refers to the zombie index constructed for firms in the top 30% of the weighted exposure index $\overline{T}$ defined by equation (5.1), while less constrained refers to the same index construction for the bottom 70% of firms by $\overline{T}$. See Appendix E.4 for more details on the zombie index construction.

7.1 Spatial Sorting Model with Collateral

I start by introducing a static version of the model with no collateral or firm investment decision to describe how the spatial sorting mechanism delivers the positive correlation between prices and the magnitude of local exposure to the land use reforms. I then build on the static version of the model to decompose the dynamic effects arising from the feedback loop and the static effects of the productivity shock to land induced by the land reform.

7.1.1 Static Version of the Model

Each city j produces a homogeneous good according to a Cobb-Douglas production function taking labor L, physical capital K, and land T available for development as inputs:

$$Y_j = A(N_j) \cdot L_j^{\alpha} K_j^{\eta} T_j^{1-\alpha-\eta} \tag{7.1}$$

The production shares α and η are assumed to be the same across all cities. The supply of land is assumed to be fixed in each city, which guarantees that no city has infinite population. The endogenous productivity element is captured by $A(N_j)$, which is a function of the number of people N_j residing in a city. This means that labor demand in each city does not take into account the productivity gains from migration that occur through hiring more workers.

I endogenize local productivity by assuming local TFP is a concave function of the number of employees working in an area. My choice of modeling the productivity shock to land arising from the land use reform via positive spillover effects from worker migration is also empirically motivated. I show in Appendix D.1 that employed population flows and land price growth have a correlation of 0.5 in the cross-section of cities during the boom years. This indicates that there was both a high degree of worker mobility during this time period and that the predictions of the agglomeration channel are consistent with the data.

Following Glaeser & Gottlieb (2008) I assume the productivity spillover takes the same concave form across cities: $A(N_j) = N_j^{\omega}$, where $\omega \in [0, 1]$ captures the strength of the agglomeration ($A'(\cdot) \geq 0$) and congestion effects ($A''(\cdot) \leq 0$). When $\omega = 0$ the model collapses to the case with exogenous productivity considered in Hsieh & Moretti (2019). The assumption that the parameter ω is constant across cities follows the conclusions of Albouy (2008) and Kline & Moretti (2014) that the elasticity of endogenous agglomeration to city size is the same in large and small cities.

I assume perfect mobility, homogeneous local goods, absentee landlords, and fixed land endowments. As in Hsieh & Moretti (2019), it is straightforward to show that this model is isomorphic to one with differentiated goods, and the main conclusions obtain when workers instead of landlords own shares in the aggregate stock of real estate. Allowing for imperfect mobility weakens the agglomeration channel and thus theoretically reduces the strength of the land use reform instrument used in this paper. I discuss how my results change with the extent of labor market mobility in Appendix D.4.

There are perfect labor markets in each city, and perfect (national) capital markets with an exogenous interest rate R. Firms' profit maximization therefore sets the marginal products of labor and capital in a city equal to the local wage and interest rate, respectively. Workers are assumed to be freely mobile and in equilibrium move to the city that maximizes their utility. The local nominal wage is thus pinned down by

$$W_j = \frac{V P_j^{\beta}}{Z_j} \tag{7.2}$$

where V is the worker's indirect utility, β is the expenditure share spent on real estate, and Z_j is the exogenous local amenity value. The price P_j is the local real estate price. Each worker pays the same per-unit price for real estate.[54]

Real estate supply is determined by a developer owned by foreign shareholders. This developer uses labor from a segmented labor market consisting of immobile workers L_j^D who earn exogenous wages W_j^D.[55] Following Favilukis et al. (2019), this real estate developer must abide by building restrictions $\overline{H}$ stipulated by the FAR limits in each city, resulting in the profit function:

$$\pi_j = \max_{L_j^D} \left\{ P_j \cdot \left(1 - \frac{H_j}{\overline{H}_j}\right) \left(L_j^D\right)^{\rho} - W_j^D L_j^D \right\} \tag{7.3}$$

where $\rho < 1$, so developers face decreasing returns to scale. The FAR limits function like a tax on developer profits, where the distortion per dollar of revenue is equal to the ratio of the existing building stock to the maximum allowed building stock, measured as m^2 of total floor area.

The developer's problem results in a straightforward mapping between supply inelasticity and the FAR limits which are the main source of identifying variation in my empirical setting:

$$\gamma_j \propto \frac{\overline{H}_j}{\overline{H}_j - H_j} \tag{7.4}$$

where H_j is the current stock of real estate, and $\overline{H}_j$ is the maximum stock of real estate that is permissible under current FAR limits. The supply inelasticity in each city is the limit on building supply relative to the slack in the limit based on current building stock. As the current building stock approaches the statutory limit $\overline{H}_j$, the real estate supply curve becomes perfectly inelastic.[56]

[54] This assumption conforms to the empirical strategy in Section 4, where I use the same local commercial land price index, P_j based on the location j of the corporate HQ to convert real estate assets from book to market value.

[55] If instead the deveoper hired workers from the same pool as the goods-producing firm, combined with the production externality this would mean the developer could easily prop up revenue by bringing in new workers, which would result in lower supply inelasticities.

[56] Defining the supply inelasticity in this way is consistent with the approach taken in Brueckner et al. (2017) and Brueckner & Singh (2019), who argue that land use regulations are more stringent in areas where land value per square foot is more strongly positively related to FAR limits.

Suppose now local property prices can be summarized by

$$P_j = \overline{P}_j \cdot \Big[A(N_j)\Big]^{\xi} \cdot L_j^{\gamma_j} \tag{7.5}$$

where $\overline{P}_j$ is a function of the exogenous objects of the model, which include parameters from the developer's problem. The responsiveness of prices to labor supply is decreasing in the limits on building constraints imposed by FAR limits in a city. The model thus reflects the evidence in Section 3.2 that prices vary substantially across Japanese cities depending on the extent to which constraints imposed by national land use regulation bind at the local level.

The parameter ξ captures the extent to which the production externality from an increased workforce gets capitalized into higher real estate prices. I set $\xi = \frac{1}{\beta\cdot(1-\eta)}$ so that equilibrium labor does not depend on the agglomeration elasticity parameter ω. A higher share of housing expenditures β lowers worker utility from moving to more populated cities. With a fixed world interest rate R, a higher capital share η in production implies that the labor demand curve is more elastic, so wages fall less from migration.

In spatial equilibrium there is full employment, so the employed population is equal to the population in each city: $L_j = N_j$. Setting labor demand equal to labor supply and imposing $L_j = N_j$ yields equilibrium employment:

$$L_j = \left(\frac{\alpha^{1-\eta}\eta^{\eta}}{R^{\eta}V^{1-\eta}} T_j^{1-\alpha-\eta} Z_j^{1-\eta} \cdot \overline{P}_j^{-\beta(1-\eta)}\right)^{\frac{1}{1-\alpha-\eta+\beta\gamma_j(1-\eta)}} \tag{7.6}$$

Local equilibrium employment is higher in cities with a greater land endowment, higher quality amenities, and lower real estate supply inelasticity γ_j.

Against this backdrop, relaxing national land use regulations represents a one-time permanently negative shock to γ_j. Such a shock translates to a fall in the average slope of the real estate supply curve. Taking log differences on both sides of the equilibrium property pricing relationship in equation (7.5) reveals the competing effects of this shock on prices:

$$\Delta \log P_j = \underbrace{\Delta\Big(\gamma_j \cdot \log L_j\Big)}_{<0} + \underbrace{\frac{\omega}{\beta(1-\eta)} \cdot \Delta \log L_j}_{>0} \tag{7.7}$$

The first term captures the traditional channel of a reduction in local real estate prices from a flattening of the supply curve. In the absence of an agglomeration channel this would be the sole effect of a negative shock to γ_j on real estate prices, and prices would unequivocally fall. The second term captures the local productivity gains from the relaxation of land use restrictions. After deregulation flattens the supply curve, local labor demand increases, driving up wages and leading more workers to sort into the city. This increased migration generates a productivity spillover through $A(N_j)$.[57] Under perfect mobility the positive effect on prices from a negative shock to γ_j dominates whenever the elasticity of agglomeration with respect to local employment is greater than the share of land in production: $\omega > 1 - \alpha - \eta$.[58]

7.1.2 Dynamic Version of the Model

I add several features to the static version of the model: firm investment, collateral constraints on firm borrowing tied to real estate prices, and non-real estate capital. These additions are needed to generate the feedback loop between prices and real economic outcomes emphasized in the empirical results. I retain the same labor block of the model, so that the worker's optimality condition (7.2) holds for each city in each period t. In what follows, I suppress the j subscript since firms face the same problem in each city.

Firms have Cobb-Douglas production as before, but now physical capital K_t is an aggregator function $f(\cdot)$ of two types of capital: real estate K_t^R and other physical capital K_t^N (e.g. machines, tools, vehicles). The physical capital aggregate depreciates at rate δ and follows the standard investment law of motion:

$$K_{t+1} = \Big(\Phi(i_t) + (1-\delta)\Big) \cdot K_t \tag{7.8}$$

where $i_t = I_t/K_t$ and $\Phi(\cdot)$ is a convex adjustment cost function. In my baseline estimation, I assume no adjustment costs, or $\Phi'(i_t) = 1$. Therefore Tobin's q is $q_t = 1/\Phi'(i_t) = 1$. I argue this is a reasonable assumption for my purposes on two grounds. First, I show in Appendix G.3 that my land use deregulation instruments do not predict empirical proxies for q at the firm level. Second, while adjustment costs are typically introduced to mitigate explosive capital dynamics in response to a shock, the goal of this paper is to analyze an episode during which capital grew substantially over a short period of roughly five years.

Firms face a collateral constraint whereby they can borrow D_{t+1} up to a fraction ψ of their physical capital stock, valued at the prevailing price in the real estate market:

$$D_{t+1} \leq \psi P_t \cdot K_{t+1}^R \tag{7.9}$$

where P_t represents the local real estate price. This is an incentive compatibility constraint in the sense that ψ represents the fraction of assets creditors could seize from a firm in the event of default. I retain the small open economy assumption of a national interest rate R_t for debt.

Firms choose sequences of L_t, K_{t+1}^R, K_{t+1}^N, D_{t+1} to maximize the present discounted sum of all future earnings subject to the law of motion in (7.8) and the collateral constraint in (7.9). The

[57] Figure D.2 in the Appendix provides a graphical depiction of how the land use reform operates on local real estate markets in this model.

[58] See Appendix D.3 for the derivation and a discussion of the empirical relevance of this case.

Lagrangian associated with this optimization problem is

$$\mathcal{L} = \sum_{t=0}^{\infty} \theta_j^t \Bigg\{ A(N_t) \cdot L_t^{\alpha} K_t^{\eta} T^{1-\alpha-\eta} - W_t L_t - \Big(K_{t+1} - (1-\delta) \cdot K_t\Big)$$

$$- r_t D_t + \Delta D_{t+1} + \mu_t \cdot \Big[\psi P_t K_{t+1}^R - D_{t+1}\Big] \Bigg\} \tag{7.10}$$

where θ_j^t is the discount factor, and μ_t is the Lagrange multiplier on the collateral constraint.

The set of optimality conditions associated with the firm's problem are:

$$A(N_t) \cdot F'_{L_t} = W_t \tag{7.11}$$

$$\mu_t \cdot \psi P_t = \Big[1 - \theta_j(1-\delta)\Big] \cdot f'_R - \theta_j A(N_{t+1}) \cdot F'_{K_{t+1}^R} \tag{7.12}$$

$$\theta_j A(N_{t+1}) \cdot F'_{K_{t+1}^N} = \Big[1 - \theta_j(1-\delta)\Big] \cdot f'_N \tag{7.13}$$

$$1 - \mu_t = \theta_j R_t \tag{7.14}$$

$$\mu_t \geq 0; \qquad \mu_t \cdot \Big(\psi P_t K_{t+1}^R - D_{t+1}\Big) = 0 \tag{7.15}$$

where $F(K, L, T) = L_j^{\alpha} K_j^{\eta} T_j^{1-\alpha-\eta}$ for shorthand. The final conditions in (7.15) are the Kuhn-Tucker non-negativity and slackness conditions. Since I am interested in the difference between steady states before vs. after a negative shock to γ_j, I focus on the steady state of the model where all variables are constant. With a constant national interest rate in the steady state, conditions (7.14) and (7.15) together say that the collateral constraint will bind whenever $\theta_j R < 1$, and will be slack if $\theta_j R = 1$. This is because when $\theta_j R < 1$ the firm's discount factor is less than the discount factor for debt, so firms will issue debt until they reach their borrowing limit.

Accounting for the fact that both workers and firms demand real estate in this version of the model, equilibrium prices are now:

$$P_{j,t} = \overline{P}_j \cdot \Big[A(N_{j,t})\Big]^{\xi} \cdot L_{j,t}^{\gamma_j} \cdot \Big(K_{j,t}^R\Big)^{\sigma} \tag{7.16}$$

where γ_j is the supply inelasticity determined by the real estate developer's profit-maximization problem. The new term in the pricing equation $\Big(K_{j,t}^R\Big)^{\sigma}$ indicates that a firm's investment in physical capital also pushes up prices. With this pricing function, consider the same experiment of a one-time permanent and unexpected negative shock to the supply inelasticity parameter γ_j. Taking log differences of (7.16), where the difference is taken between the post-reform and pre-reform steady states of the model, I obtain the following decomposition:

$$\Delta \log P_j = \underbrace{\Delta\Big(\gamma_j \cdot \log L_j\Big) + \omega\xi \cdot \Delta \log L_j}_{\text{static}} + \underbrace{\sigma \cdot \Delta \log K_j^R}_{\text{dynamic}} \tag{7.17}$$

The first term captures the static effect of the γ_j shock explored in the static version of the model, while the second term captures the effect of firm investment in physical capital on real estate prices. In this model, the shock induces workers to sort into a city, increasing prices and thus the value of firm collateral.[59] This increase in borrowing limits induces firms which were previously borrowing constrained to use more capital inputs, thus further driving up real estate prices.[60] I list the full set of local equilibrium conditions in Appendix D.3.

7.2 Model Parameterization

This section describes the parametric forms used in the implementation of the model as well as the calibration of parameters and the mapping between the instruments used in the empirical part of the paper and local real estate supply inelasticity.

Functional forms. I set the investment adjustment cost function such that $\Phi'(i_t) = 1$. The production externality takes the form $A(N_{j,t}) = N_{j,t}^{\omega}$ with $\omega \in (0,1)$ for each city j. I assume the capital aggregate takes the following functional form over real estate and non-real estate physical capital:

$$f(K^R, K^N) = (K^R)^s \cdot (K^N)^{1-s} \tag{7.18}$$

where s denotes the production share of each type of physical capital in the aggregate capital input. For this capital aggregator, real estate and non-real estate inputs are complements, which is consistent with the evidence on investment responses in Section 5.2. Finally, to nest the static version of the model in Section 7.1.1 into the full dynamic version, I set $\xi = 1/\beta(1-\eta)$, so that the production externality gets priced into local real estate prices via the term $[A(N_{j,t})]^{\xi} = N_{j,t}^{\omega/\beta(1-\eta)}$ in equation (7.16).

Parameters. Since my objective is to quantify the aggregate effect of the land use deregulation between a pre-reform and post-reform steady state, I calibrate the model to 1980 and 1990 data for the set of 214 cities with data available from those two years. Table 12 summarizes the full set of parameter values.[61] Global parameters refer to those that are common across all cities, while local parameters refer to parameters that are specific to each city.

[59] This mechanism implies the exclusion restriction underlying the land use reform as an IV in (4.3) is valid, *conditional on employment growth*. My reduced form estimates of firm borrowing and investment responses are virtually unchanged when I include firm-level year-on-year employment growth as an additional control. As in the spatial sorting model, higher employment growth is positively correlated with both debt issuance and real estate investment in the empirical cross-section.

[60] Another important feature of this pricing function is that it nests both the static version of the model ($\sigma = 0, \xi = \frac{1}{\beta(1-\eta)}$) and the model of Hsieh & Moretti (2019) in which land use deregulations unequivocally result in lower real estate prices ($\sigma = \omega = 0$).

[61] I describe the data sources for these parameters in more detail in Appendix D.5 and Appendix E.5.

TABLE 12. Parameter Values: Baseline Calibration

Parameter	Notation	Value	Target/Source
Panel A: Global parameters			
Agglomeration elasticity	ω	0.30	reduced form evidence
Price elasticity of RE inv.	σ	0.60	reduced form evidence
Borrowing limit	ψ	0.45	Debt/RE = median
Overall depreciation rate	δ	0.05	Input share-weighted depreciation
Net interest rate	r	0.05	BOJ LT prime rate
Firm discount factor	θ	0.95	Standard; $\theta R < 1$
Capital share	η	0.30	Karabarbounis & Neiman (2014)
Labor share	α	0.55	Karabarbounis & Neiman (2014)
RE share in capital	s	0.39	Perpetual inventory share
Housing expense share	β	0.15	Family Income and Expenditure Survey
Panel B: Local parameters			
RE supply inelasticity	γ_j	Varies	Statutory FAR limits
Land endowment	T_j	Varies	Unavailable land share
Amenities	Z_j	Varies	Income residual: P_j^{β}/W_j

To start, I set the parameter ψ so that in the version of the model where the collateral constraint always binds ($\theta R < 1$) the value of debt to real estate is equal to the median ratio observed in the data for firms in the 1980s. The net interest rate $r = 0.05$ matches the average long-term prime rate from the Bank of Japan (BOJ). I set the firm's discount factor based on the firm's weighted average cost of capital (WACC). In the baseline calibration, I set $\theta = 0.95$ to match the median WACC, which yields $\theta R < 1$ for all firms in the baseline calibration.[62]

I set the overall capital depreciation rate to $\delta = 0.05$ by taking an input share-weighted average over the 2% rate I assume for real estate in the rest of the paper and the accounting depreciation rates for non-real estate physical capital components. I use an input share of $s = 0.39$ for real estate computed using the sufficient statistics method of Hayashi & Inoue (1991) in Appendix E.5. I set the capital and labor share to match the values reported in Karabarbounis & Neiman (2014) for Japan. I calibrate the housing expense share, which determines disposable income and thus how attractive any particular city is to a worker, by setting $\beta = 0.15$ to match the average ratio of housing expenses (rent + mortgage payments + repairs) relative to total expenditures in the Family Income and Expenditure Survey (FIES) data.[63]

[62] See Appendix E.5 and Appendix E.6 for details on how I compute the WACC for each firm.

[63] While I could define β_j as a local parameter, there is minimal variation in the expenditure survey data both across cities and over time. For instance, over the 1980s, the standard deviation of the housing share of household expenditures is 0.05 with a median of 0.14.

The final two global parameters are elasticities informed by the reduced form moments identified in Section 5. The agglomeration elasticity ω captures how production externalities vary with city size, and this is pinned down by the reduced form effect of the land use shock on the value of real estate assets fixed from a baseline period. Conversely, the price elasticity of real estate investment σ is informed by the reduced form effect of the land use shock on real estate investment. In this sense, ω corresponds to the "static" effect of the reform which operates through population flows, whereas σ corresponds to the "dynamic" effect of the reform which operates through firm investment in real estate after the land use regime changes.[64]

I use two methods to map these parameters to the data. First, I run the regression implied by the log-differences equation in (7.17) on city-level data for commercial and industrial prices, population flows, and real estate investment. This yields baseline estimates of $\omega = 0.3$ and $\sigma = 0.6$ when I compute growth rates between 1980 and 1990.[65] Second, I use minimum distance estimation to compute parameter values for ω and σ that allow the model to match the empirical moments.

Next, I turn to the set of local parameters. I take the worker's sorting condition in equation (7.2) and normalize indirect utility to $V = 1$ so that amenities Z_j are the residual between the housing cost and wages in city j.[66] I calibrate the fixed land endowment for each city using one minus the unavailable land share reported in Hosono et al. (2018), who adopt the methodology of Saiz (2010). This share measures the fraction of land that is not located on a steep incline or a body of water, and thus captures the share available for development.[67]

The final and most crucial parameter is the land use shock itself, parameterized by the local real estate supply inelasticity γ_j. I use the cross-sectional differences in the deregulation of floor-to-area ratio (FAR) limits described in Section 3 and the existing stock of real estate (measured by floor space) to construct an elasticity estimate for each city in each year. According to equation (7.4), this yields average local supply inelasticities of 2.73 in 1980 and 2.70 in 1990. This masks substantial heterogeneity in the pass-through of the national reform to local building supply. The shock to FAR limits implies local supply inelasticity falls by more than 10% for a quarter of cities in my sample.

7.3 Aggregate Effects on Prices and Real Outcomes

I use the calibrated model to conduct a simple aggregation exercise. I compute the steady state equilibrium for each city in 1980 and 1990. For each period, I then add up output, debt, and capital inputs across all cities and compute growth rates between 1980 and 1990. To aggregate

[64] An alternative interpretation of these parameters is that they assign relative roles to the demand for real estate arising from workers and firms in determining equilibrium prices. Since one unit of real estate capital K^R may not be the unit of real estate demanded by a single worker, these weights offer a conversion between real estate as capital investment and real estate as housing.

[65] I present the full regression results from this exercise in Appendix D.5.

[66] This is standard practice in the urban economics literature. See, for instance, Albouy (2008).

[67] I summarize the construction of land availability in Appendix C.

TABLE 13. Aggregate Effects of the Reform (1980-1990)

	Full CC	Partial CC	No CC	Data
ΔP_{80-90}	19%	20%	26%	90%
ΔY_{80-90}	197%	399%	-34%	82%
ΔK^R_{80-90}	84%	55%	44%	87%
ΔK^N_{80-90}	422%	198%	6%	98%
ΔK_{80-90}	185%	55%	29%	87%
ΔD_{80-90}	2%	19%	0%	150%

Notes: In the data column, I computed percentage changes in prices using an aggregate index for non-residential properties estimated via equation (2.1). Changes in output, real estate and non-real estate capital stock, and outstanding debt were computed from System of National Accounts (SNA) data for non-financial private corporations.

city-level prices, I take an employment share-weighted average of the price levels. This method for aggregating prices reflects the way aggregate price indices are constructed in practice, since the number of appraisals and transactions occurring within an area is proportional to population.

Table 13 compares aggregate growth rates implied by the model to those in the data for non-residential prices constructed from my repeat appraisal index, and production-based output, corporate capital stock, and outstanding corporate debt from national accounts data.[68] I consider three versions of the model: one where the collateral constraint is always slack for all cities ("No CC"), one where the constraint binds for cities in my sample where firms have $\theta_j R < 1$ ("Partial CC"), and a final version where the collateral constraint always binds for each city ("Full CC").[69]

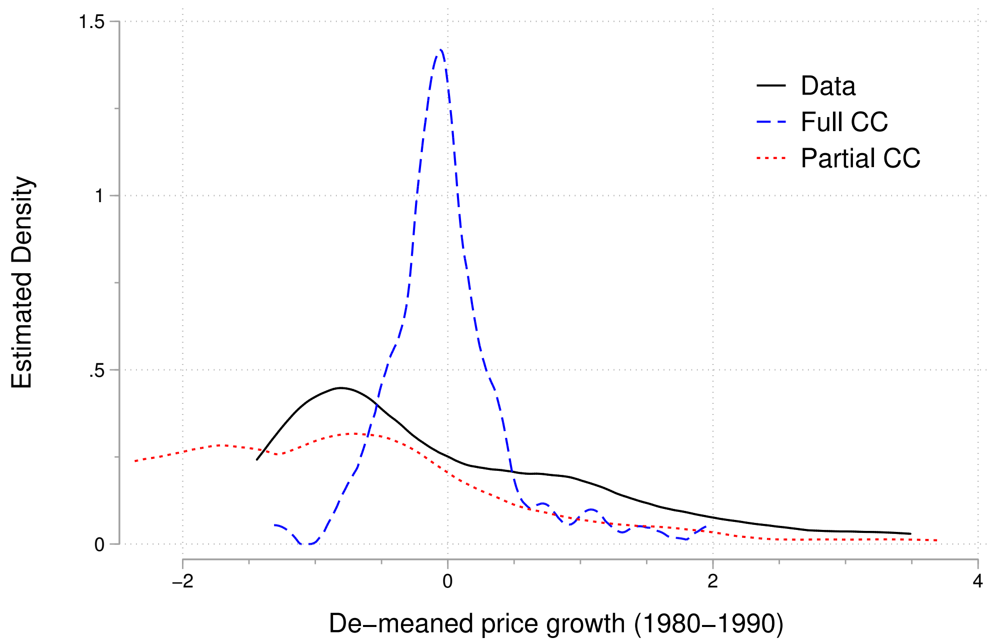
The model with financial frictions explains roughly 22% of the aggregate growth in non-residential real estate values, or 30% of overall real estate price growth, during the 1980s. The presence of borrowing frictions generates large booms in output and investment in both real estate and non-real estate inputs, consistent with the input complementarity documented empirically in Section 5.2. The model with always-binding collateral constraints generates a mild increase in debt, as cities which experience negative price growth face reduced borrowing capacity.[70] The larger boom in corporate debt in the sometimes-binding version of the model indicates a positive correlation in the cross-section between price growth and the incidence of binding borrowing constraints.

[68] I discuss the aggregate welfare implications of the land use reform in Appendix D.6.

[69] When I allow for cross-sectional heterogeneity in collateral constraints, I right-censor the firm's discount rate at $\theta_j = 1/R$ so that the slackness condition guaranteeing a non-negative Lagrange multiplier is satisfied. Each θ_j is computed as the asset-weighted average of discount factors across firms with an HQ in city j.

[70] In the version of the model where the collateral constraint is always non-binding, steady state debt is completely determined by the initial value, which I normalize to be zero for all firms.

FIGURE 8. Spatial Distribution of Price Growth: Model vs. Data



Several key forces in the model generate these results. First, the model generates large effects of the land use deregulation on output because in this setting pre-reform land use restrictions (captured by γ_j) and collateral constraints generate a high degree of spatial misallocation of labor. The lifting of land use limits mitigates misallocation by allowing more people to sort into previously building-constrained cities. The land use reform also relaxes borrowing limits in cities through the effects of worker inflows on collateral values. In contrast, output contracts in the version of the model with no borrowing limits. With no borrowing limits, the feedback loop between prices and investment creates a winner-take-all scenario where cities either experience large inflows of workers or become ghost towns with a near-zero population share. The concavity of the production externality $A(N_{j,t})$ magnifies the effect on output, as workers generate large marginal productivity spillovers in ghost towns, while superstar cities realize infinitesimal gains from one more worker.

Spatial sorting also dampens the effect of the reform on aggregate prices through this "beggar thy neighbor" general equilibrium effect, since increased demand for real estate in one city is offset by worker flows away from other cities. Although aggregate price growth is roughly constant across the three versions of the model, the implied geographic distributions of price growth are quite different. Figure 8 plots the distribution of de-meaned growth rates for non-residential real estate prices between 1980 and 1990 for the data and the always and sometimes-binding collateral constraint versions of the model.[71] When all firms are up against their borrowing limit, all variation in price

[71]In the non-binding constraint version of the model the distribution is virtually bimodal, with ghost towns experiencing large price drops and superstar cities experiencing outsized price gains.

growth arises from the spatial sorting induced by the shock to real estate supply inelasticity. The sometimes-binding version of the model instead produces a mass of firms which are up against their borrowing limit and which also receive a large windfall gain in the value of their collateral. The existence of such firms allows the model to generate the fat right tail in non-residential price growth observed in the data for the 1980s. Heterogeneity in corporate borrowing constraints thus appears important for explaining geographic dispersion in prices during real estate boom-bust cycles.

8 Conclusion

This paper uses a natural experiment in 1980s Japan to provide new evidence of a feedback loop between corporate borrowing and investment in real estate assets used to secure debt. I demonstrate that firms owning real estate in areas where national land use deregulations were more strongly capitalized into local property markets both borrowed more and invested more in real estate and in complementary inputs such as machines. This increase in both real estate and non-real estate investment widens the scope for amplification of real business cycles through aggregate investment and is consistent with the predictions of standard macro-finance models with financing frictions.

The source of variation I use in this paper helps explain both the boom and the bust in real estate prices. Firms more exposed to the land use reforms borrowed more and invested more in real estate during the boom years, but were also more likely to deleverage and divest from real estate during the bust years even though the land use reform was a permanent shock to the productivity of land. Exposure to the 1980s land use deregulation also predicts the high incidence of zombie lending beginning in the mid-1990s. This suggests relaxing land use restrictions can have a long-lasting and destabilizing influence on the real economy through interactions with corporate borrowing limits.

The narrative I propose for 1980s Japan accords with observations in the literature on historical asset price cycles that episodes colloquially known as "bubbles" are preceded by the introduction of a new type of asset, and propagated by institutional constraints on efficient trading (Garber 1990, 2000). In the context of 1980s Japan the new asset was a plot of land under newly implemented regulatory constraints. At the same time, bankruptcy laws encouraging private liquidation in the event of insolvency gave rise to corporate reliance on real estate assets for obtaining long-term credit. The interaction of these features created local real estate cycles that were based on fundamentals, as the corporate sector attempted to price newly introduced varieties of real estate assets.

More generally, I document new stylized facts about the dynamics of commercial real estate markets during a boom-bust cycle which featured a large volume of land transactions from the household to the corporate sector. The prominent role of commercial relative to residential real estate in this episode suggests that the strength of the feedback loop between asset values and real aggregate outcomes may depend crucially on the pass through of shocks to different segments of local real estate markets. Unpacking how firms choose new locations for their physical operations and relating such decisions to this feedback loop is a worthwhile path for future research.

References

Acharya, V.V. C. Eisert, C. Eufinger, & C. Hirsch (2019): "Whatever It Takes: The Real Effects of Unconventional Monetary Policy," forthcoming *Review of Financial Studies*.

Ahearne, A.G. & N. Shinada (2005): "Zombie Firms and Economic Stagnation in Japan," *International Economics and Economic Policy*, 2(4): 363-381.

Aladangady, A. (2017): "Housing Wealth and Consumption: Evidence from Geographically Linked Microdata," *American Economic Review*, 107(11): 3415-3446.

Albouy, D. (2008): "Are Big Cities Bad Places to Live? Estimating Quality of Life Across Metropolitan Areas," NBER Working Paper, No. 14472.

Allen, T. & C. Arkolakis (2014): "Trade and the Topography of the Spatial Economy," *Quarterly Journal of Economics*, 3(1): 1085-1140.

Almeida, H., M. Campello, & M.S. Weisbach (2004): "The Cash Flow Sensitivity of Cash," *Journal of Finance*, 59(4): 1777-1804.

Almeida, H. & M. Campello (2007): "Financial Constraints, Asset Tangibility, and Corporate Investment," *Review of Financial Studies*, 20(5): 1429-1460.

Amiti, M. & D. Weinstein (2018): "How Much Do Idiosyncratic Bank Shocks Affect Investment? Evidence from Matched Bank-Firm Loan Data," *Journal of Political Economy*, 126(2): 525-587.

Bahaj, S., A. Foulis, G. Pinter, & P. Surico (2018): "Employment and the Collateral Channel of Monetary Policy," Discussion Paper No. 1832, Centre for Macroeconomics (CFM).

Bahaj, S., A. Foulis, G. Pinter (2019): "Home Values and Firm Behaviour," Bank of England Working Paper.

Balloch, C.M. (2018): "Inflows and Spillovers: "Tracing the Impact of Bond Market Liberalization," *mimeo*, Columbia University.

Barsky, R. (2011): "The Japanese Asset Price Bubble: A Heterogeneous Approach," in Hamada, K., A. Kashyap, and D. Weinstein, eds., *Japan's Bubble, Deflation, and Long-term Stagnation*, MIT Press.

Basu, S. & J.G. Fernald (1997): "Returns to Scale in U.S. Production: Estimates and Implications," *Journal of Political Economy*, 105(2): 249-283.

Benmelech, E., M.J. Garmaise, & T.J. Moskowitz (2005): "Do Liquidation Values Affect Financial Contracts? Evidence from Commercial Loan Contracts and Zoning Regulation," *Quarterly Journal of Economics*, 120(3): 1121-1154.

Bernanke, B.S., M. Gertler, & S. Gilchrist (1999): "The Financial Accelerator in a Quantitative Business Cycle Framework," *Handbook of Macroeconomics*, 1: 1341-1393.

Blattner, L., L. Farinha, & F. Rebelo (2019): "When Losses Turn into Loans: the Cost of Undercapitalized Banks," ECB Working Paper Series, No. 2228.

Brueckner, J.K., S. Fu, Y. Gu, & J. Zhang (2017): "Measuring the Stringency of Land-use Regulation and its Determinants: The Case of China's Building-height Limits," *Review of Economics and Statistics*, 99(4): 663-677.

Brueckner, J.K. & R. Singh (2019): "Stringency of Land Use Regulation: Building Heights in U.S. Cities," *mimeo*, UC Irvine.

Burchfield, M., H.G. Overman, D. Puga, M.A. Turner (2006): "Causes of Sprawl: A Portrait from Space," *Quarterly Journal of Economics*, 121(2): 587-633.

Caballero, R.J., T. Hoshi, & A.K. Kashyap (2008): "Zombie Lending and Depressed Restructuring in Japan," 98(5): 1943-1977.

Campello, M. & E. Giambona (2013): "Real Assets and Capital Structure," *Journal of Financial and Quantitative Analysis*, 48(5): 1333-1370.

Campello, M. & M. Larrain (2015): "Enlarging the Contracting Space: Collateral Menus, Access to Credit, and Economic Activity," *Review of Financial Studies*, 29(2): 349-383.

Case, B. & J.M. Quigley (1991): "The Dynamics of Real Estate Prices," *Review of Economics and Statistics*, 73(1): 50-58.

Case, K.E. & R.J. Shiller (1987): "Prices of Single Family Homes Since 1970: New Indices for Four Cities," NBER Working Paper, No. 2393.

Case, K.E. & R.J. Shiller (1989): "The Efficiency of the Market for Single-Family Homes," *American Economic Review*, 79(1): 125-137.

Chaney, T., D. Sraer, & D. Thesmar (2012): "The Collateral Channel: How Real Estate Shocks Affect Corporate Investment," *American Economic Review*, 102(6): 2381-2409.

Chernozhukov, V., I. Fernández-Val, & A.E. Kowalski (2015): "Quantile Regression with Censoring and Endogeneity," *Journal of Econometrics*, 186(1): 201-221.

Cleary, S. (1999): "The Relationship between Firm Investment and Financial Status," *Journal of Finance*, 54(2): 673-692.

Cloyne, J., C. Ferreira, M. Froemel, & P. Surico (2018): "Monetary Policy, Corporate Finance and Investment," NBER Working Paper, No. 25366.

Cordoba, J. & M. Ripoll (2004): “Credit Cycles Redux,” *International Economic Review*, 45(4): 1011-1046.

Cutts, R.L. (1990): “Power from the Ground Up: Japan’s Land Bubble,” *Harvard Business Review*, 68: 164-172.

Cvijanović, D. (2014): “Real Estate Prices and Firm Capital Structure,” *Review of Financial Studies*, 27: 2690-2735.

Davidoff, T. (2016): “Supply Constraints Are Not Valid Instrumental Variables for Home Prices Because They Are Correlated with Many Demand Factors,” *Critical Finance Review*, 5(2): 177-206.

Davis, M.A. & J. Heathcote (2007): “The Price and Quantity of Residential Land in the United States,” *Journal of Monetary Economics*, 54: 2595-2620.

Diewert, W.E. (1978): “Superlative Index Numbers and Consistency in Aggregation,” *Econometrica*, 46(4): 883-900.

Drechsel, T. (2019): “Earnings-Based Borrowing Constraints and Macroeconomic Fluctuations,” *mimeo*, LSE.

Dumagan, J.C. (2002): “Comparing the Superlative Törnqvist and Fisher Ideal Indices,” *Economics Letters*, 76(2): 251-258.

Epple, D., B. Gordon, & H. Sieg (2010): “A New Approach to Estimating the Production Function for Housing,” *American Economic Review*, 100(3): 905-924.

Fang, H., Q. Gu, W. Xiong, & L. Zhou (2015): “Demystifying the Chinese Housing Boom,” NBER Macroeconomics Annual, 30: 105-166.

Favilukis, J., P. Mabille, & S.V. Nieuwerburgh (2019): “Affordable Housing and City Welfare,” *mimeo*, Columbia Business School.

Gan, J. (2007a): “Collateral, Debt Capacity, and Corporate Investment: Evidence from a Natural Experiment,” *Journal of Financial Economics*, 85: 709-734.

Gan, J. (2007b): “The Real Effects of Asset Market Bubbles: Loan- and Firm-Level Evidence of a Lending Channel,” *Review of Financial Studies*, 20(6): 1941-1973.

Garber, P.M (1990): “Famous First Bubbles,” *Journal of Economic Perspectives*, 4(2): 35-54.

Garber, P.M (2000): *Famous First Bubbles*, MIT Press.

Giannetti, M. & A. Simonov (2013): “On the Real Effects of Bank Bailouts: Micro Evidence from Japan,” *American Economic Journal: Macroeconomics*, 5(1): 135-167.

Giroud, X. & H.M. Mueller (2017): Firms Internal Networks and Local Economic Shocks, forthcoming *American Economic Review*.

Glaeser, E.L. & J.D. Gottlieb (2008): "The Economics of Place-Making Policies," NBER Working Paper, No. 14373.

Glaeser, E.L. & J. Gyourko (2003): "The Impact of Building Restrictions on Housing Affordability," *FRB New York Economic Policy Review*, 9(2): 21-39.

Glaeser, E.L. & J. Gyourko (2018): "The Economic Implications of Housing Supply," *Journal of Economic Perspectives*, 32(1): 3-30.

Glaeser, E.L. & C.G. Nathanson (2014): "Housing Bubbles," NBER Working Paper, No. 20426.

Greenstone, M., R. Hornbeck, & E. Moretti (2010): "Identifying Agglomeration Spillovers: Evidence from Winners and Losers of Large Plant Openings," *Journal of Political Economy*, 118(3): 536-598.

Greenwald, D.L. (2019): "Firm Debt Covenants and the Macroeconomy: The Interest Coverage Channel," *mimeo*, MIT Sloan.

Guren, A.M., A. McKay, E. Nakamura, & J. Steinsson (2018): "Housing Wealth Effects: The Long View," *mimeo*, UC Berkeley.

Gyourko, J. & R. Molloy (2015): "Regulation and Housing Supply," *Handbook of Regional and Urban Economics*, 5: 1289-1337.

Gyourko, J., A. Saiz, & A. Summers (2008): "A New Measure of the Local Regulatory Environment for Housing Markets: The Wharton Residential Land Use Regulatory Index," *Urban Studies*, 45(3): 693-721.

Gyourko, J., J. Hartley, & J.A. Krimmel (2019): "The Local Residential Land Use Regulatory Environment across U.S. Housing Markets: Evidence from a New Wharton Index," NBER Working Paper, No. 26573.

Hadlock, C.J. & J.R. Pierce (2010): "New Evidence on Measuring Financial Constraints: Moving Beyond the KZ Index," *Review of Financial Studies*, 23(5): 1909-1940.

Hagino, S., T. Hiroki, F. Inadachi, C. Sakuraba, & Y. Sato (2011): "Enhancing Household Data on the Flow of Funds Accounts in Japan," *IMF/OECD Conference on "Strengthening Sectoral Position and Flow Data in the Macroeconomic Accounts"*.

Hart, O. & J. Moore (1994): "A Theory of Debt Based on the Inalienability of Human Capital," *Quarterly Journal of Economics*, 109(4): 841-879.

Hayakawa, K. & Y. Hirayama (1991): "The Impact of the *Minkatsu* Policy on Japanese Housing and Land Use," *Environment and Planning D: Society and Space*, 9(2): 151-164.

Hayashi, F. (1990): "Taxes and Corporate Investment in Japanese Manufacturing," in *Productivity Growth in Japan and the United States*, ed. by C. Hulten, Chicago: University of Chicago Press.

Hayashi, F. & T. Inoue (1991): "The Relation Between Firm Growth and Q with Multiple Capital Goods: Theory and Evidence from Panel Data on Japanese Firms," *Quarterly Journal of Economics*, 59(3): 731-753.

Hennessy, C.A. & T.M. Whited (2007): "How Costly is External Financing? Evidence from a Structural Estimation," *Journal of Finance*, 62(4): 1705-1745.

Herkenhoff, K.F., L.E. Ohanian, & E.C. Prescott (2018): "Tarnishing the Golden and Empire States: Land-use Restrictions and the U.S. Economic Slowdown," *Journal of Monetary Economics*, 93: 89-109.

Hilber, C.A.L. & C. Mayer (2009): "Why Do Households without Children Support Local Public Schools? Linking House Price Capitalization to School Spending," *Journal of Urban Economics*, 65: 74-90.

Hilber, C.A.L. & W. Vermeulen (2016): "The Impact of Supply Constraints on House Prices in England," *The Economic Journal*, 126: 358-405.

Hornbeck, R. & E. Moretti (2018): "Who Benefits from Productivity Growth? Direct and Indirect Effects of Local TFP Growth on Wages, Rents, and Inequality," NBER Working Paper, No. 24661.

Hoshi, T. & A.K. Kashyap (2004): "Japan's Financial Crisis and Economic Stagnation," *Journal of Economic Perspectives*, 18(1): 3-26.

Hosono, K., T. Mizuta, K. Nakajima, & I. Uesugi (2018): "Supply Elasticity of Housing Market in Japan," *mimeo*, Hitotsubashi University.

Hsieh, C. & E. Moretti (2019): "Housing Constraints and Spatial Misallocation," *American Economic Journal: Macroeconomics*, 11(2): 1-39.

Kaplan, S.N. & L. Zingales (1997): "Do Investment-Cash Flow Sensitivities Provide Useful Measures of Financing Constraints?" *Quarterly Journal of Economics*, 112(1): 169-215.

Karabarbounis, L. & B. Neiman (2014): "The Global Decline of the Labor Share," *Quarterly Journal of Economics*, 129(1): 61-103.

Kashyap, A., D. Scharfstein, & D. Weil (1990): "The High Price of Land and the Low Cost of Capital: Theory and Evidence from Japan," *mimeo*, Harvard Business School.

Kindleberger, C.P. (1996): *Manias, Panics and Crashes: A History of Financial Crises*, Wiley: New York, NY. .

Kiyotaki, N. & J. Moore (1997): "Credit Cycles," *Journal of Political Economy*, 105(2): 211-248.

Kline, P. & E. Moretti (2014): "Local Economic Development, Agglomeration Economies, and the Big Push: 100 Years of Evidence from the Tennessee Valley Authority," *Quarterly Journal of Economics*, 129: 275-331.

Knoll, K., M. Schularick, & T. Steger (2017): "No Price Like Home: Global House Prices, 1870-2012," *American Economic Review*, 107(2): 331-353.

Kocherlakota, N.R. (2000): "Creating Business Cycles Through Credit Constraints," *Federal Reserve Bank of Minneapolis Quarterly Review*, 24.

Lamont, O., C. Polk, & J. Saaá-Requejo (2001): "Financial Constraints and Stock Returns," *Review of Financial Studies*, 14(2): 529-554.

Lian, C. & Y. Ma (2019): "Anatomy of Corporate Borrowing Constraints," *mimeo*, Chicago Booth.

Lin, L. (2016): "Collateral and the Choice Between Bank Debt and Public Debt," *Management Science*, 62(1): 111-127.

Lin, D. & S. Wachter (2019): "The Effect of Land Use Regulation on Housing Prices: Theory and Evidence from California," *mimeo*, Wharton.

Mendoza, E.G. (2010): "Sudden Stops, Financial Crises, and Leverage," *American Economic Review*, 100(5): 1941-1966.

Mian, A., K. Rao, & A. Sufi (2013): "Household Balance Sheets, Consumption, and the Economic Slump," *Quarterly Journal of Economics*, 128: 1687-1726.

Mian, A. & A. Sufi (2011): "House Prices, Home Equity-Based Borrowing, and the U.S. Household Leverage Crisis," *American Economic Review*, 101(5): 2132-2156.

Mian, A. & A. Sufi (2014): "What Explains the 2007-2009 Drop in Employment?" *Econometrica*, 82: 2197-2223.

Ministry of Construction (1990): *The Building Standard Law of Japan*, Building Guidance Division & Urban Building Division, ed., Tokyo: Building Center of Japan.

Ministry of Construction (1994): *The Building Standard Law of Japan*, Building Guidance Division & Urban Building Division, ed., Tokyo: Building Center of Japan.

Mora, N. (2008): "The Effect of Bank Credit on Asset Prices: Evidence from the Japanese Real Estate Boom during the 1980s," *Journal of Money, Credit and Banking*, 40(1): 57-87.

Morinobu, S. (2006): "The Rise and Fall of the Land Myth in Japan – Some Implications for Chinese Land Taxation," Policy Research Institute, Ministry of Finance Working Paper Series No. 06A-08.

Nagaraja, C.H., L.D. Brown, & S.M. Wachter (2017): "Repeat Sales House Price Index Methodology," *mimeo*, Wharton.

Nakamura, K. & Y. Saita (2007): "Land Prices and Fundamentals," Bank of Japan Working Paper Series No. 07-E-8.

Nathanson, C.G. & E. Zwick (2017): "Arrested Development: Theory and Evidence of Supply-Side Speculation in the Housing Market," NBER Working Paper, No. 23030.

Okina, K., M. Shirakawa, & S. Shiratsuka (2001): "The Asset Price Bubble and Monetary Policy: Japan's Experience in the Late 1980s and the Lessons," *Monetary and Economic Studies, Institute for Monetary and Economic Studies, Bank of Japan*, 19(S1): 395-450.

Packer, F. & M. Ryser (1992): "The Governance of Failure: An Anatomy of Corporate Bankruptcy in Japan," Columbia Graduate School of Business, Center on Japanese Economy and Business, Working Paper, No. 62.

on Real Activity in the United States," *American Economic Review*, 90(1): 3045.

Peek, J. & E.S. Rosengren (2005): "Unnatural Selection: Perverse Incentives and the Misallocation of Credit in Japan," *American Economic Review*, 95(4): 1144-1166.

Piketty, T. (2014): *Capital in the Twenty-First Century*, Harvard University Press.

Quigley, J. (1995): "A Simple Hybrid Model for Estimating Real Estate Price Indexes," *Journal of Housing Economics*, 4(1): 1-12.

Saiz, A. (2010): "The Geographic Determinants of Housing Supply," *Quarterly Journal of Economics*, 125(3): 1253-1296.

Schivardi, F., E. Sette, & G. Tabellini (2017): "Credit Misallocation during the European Financial Crisis," BIS Working Paper, No. 669.

Schumm, B. (1988): "Comparison of Japanese and American Bankruptcy Law," *Michigan Yearbook of International Legal Studies*, 9: 291-331.

Shimizu, C. & T. Watanabe (2010): "Housing Bubble in Japan and the United States," Japanese Society for the Promotion of Science (JSPS) Working Paper, No. 50.

Shleifer, A. & R.W. Vishny (1992): "Liquidation Values and Debt Capacity: A Market Equilibrium Approach," *Journal of Finance*, 47(4): 1343-1366.

Sorensen, A., J. Okata, & S. Fujii (2010): "Urban Renaissance as Intensification: Building Regulation and the Rescaling of Place Governance in Tokyo's High-rise *Manshon* Boom," *Urban Studies*, 47(3): 556-583.

Sufi, A. (2007): "Bank Lines of Credit in Corporate Finance: An Empirical Analysis," *Review of Financial Studies*, 22(3): 1057-1088.

Whited, T.M. & G. Wu (2006): "Financial Constraints Risk," *Review of Financial Studies*, 19(2): 531-559.

Yoshida, J. (2016): "Structure Depreciation and the Production of Real Estate Services," *mimeo*, Penn State.

Appendix to

You Only Lend Twice: Corporate Borrowing and Land Values in Real Estate Cycles

by Cameron LaPoint (Columbia)

Contents

A Land Price Index Construction

This appendix provides additional details regarding the construction of historical local land price indices covering the 1980s real estate cycle in Japan.

A.1 Aggregate and Regional Time Series

Figure A.1 plots indices for aggregate land values over the forty-year period 1975 to 2016 for all of Japan and the six historically largest cities.[72] In the figure, I compare my repeat appraisal indices to the corresponding official Urban Land Price Indices compiled by the Japan Real Estate Institute (JREI) and published by the Statistics Bureau.[73] Including all types of land, prices grew by 56% in aggregate between 1985 and 1990, with land prices growing by 155% in the six major cities. Restricting to commercial land, prices grew by 67% in aggregate and by 185% in the six major cities. For comparison, from 2002 to the peak of the recent U.S. real estate cycle in 2007, housing prices grew by only 40% in aggregate and 57% on average among the six most populous MSAs.[74]

The hump shape of the aggregate time series displays three common empirical characteristics of historical real estate price cycles: large price volatility, short-term price change momentum, and long-run mean reversion (Kindleberger 1996; Glaeser & Nathanson 2014). Land prices bottomed out in 2004 before rebounding in the major cities in the late 2000s due to the transmission of the "Lehman" credit shock through increased demand from foreign investors for Japanese real estate. However, even during the late 2000s episode, land values failed to attain levels seen directly before the onset of the 1980s boom.

Figure A.1 also shows that my repeat appraisal indices closely track the official JREI indices, which are computed by chaining geometric averages of year-on-year price changes. However there are a few differences between the two sets of indices due to differences in the underlying data sources. One observation is that the JREI indices appear to be lagged by one year relative to my indices, which is due to different effective valuation dates. This is notable because of an apparent one-year timing mismatch between the 1991 peak in the JREI Urban Land Price Index and the December 1989 peak in the Nikkei 225 stock average index, as is commonly observed among researchers of this period (e.g. Okina et al. 2001; Morinobu 2006; Barsky 2011). The JREI indices are constructed from appraisals with valuation dates of March 31 in each year. Hence, the index value in year t may consist almost entirely of appraisals conducted in $t-1$, leading to an artificial one-year lag in

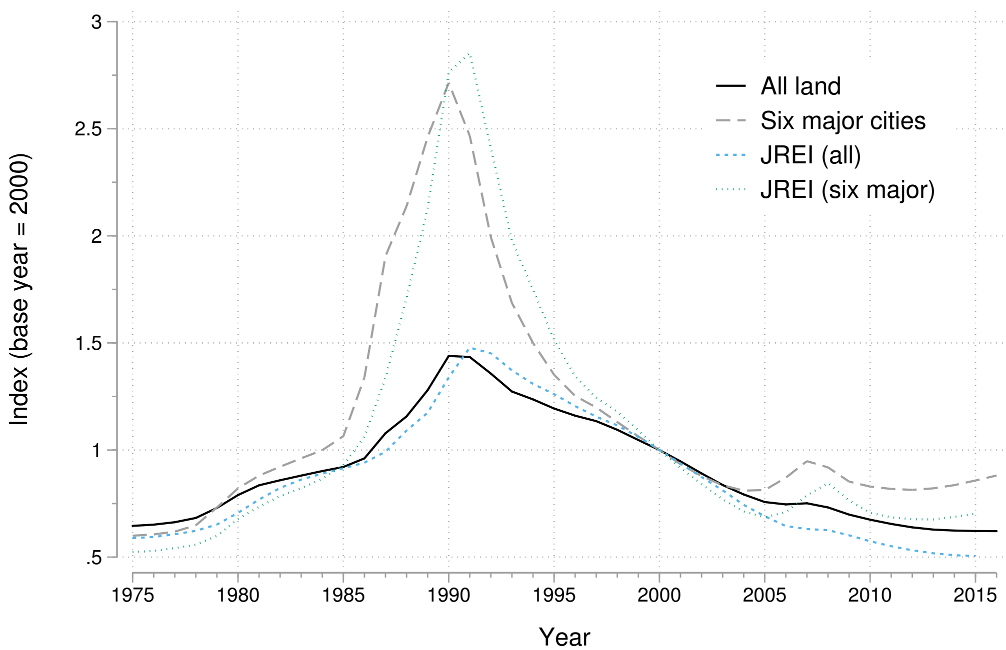
[72] The six cities are the 23 central wards of Tokyo, Yokohama, Nagoya, Kyoto, Osaka, and Kobe. These cities currently rank within the top 10 largest by population.

[73] I refer to the JREI Urban Land Price Index as the "official" land price index because it is the only continuously published index available online through the Statistics Bureau. While MLIT does maintain a Published Land Price Index computed from the same appraisal data I use here, as of writing this index is only available for a subset of years starting in 1985.

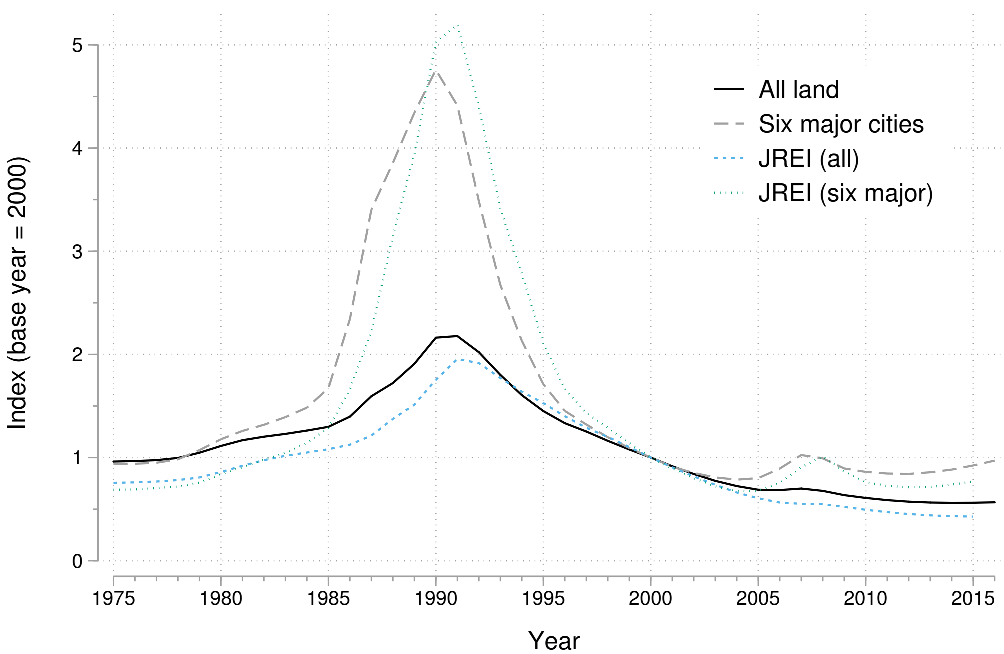
[74] I calculated these statistics for the U.S. by taking annual averages of the quarterly Federal Housing Finance Agency (FHFA) all-transactions housing price index for each MSA and normalizing the index to be equal to unity in 2000. The six most populous MSAs according to the 2000 U.S. Census were New York-Northern New Jersey-Long Island, Los Angeles-Long Beach-Santa Ana, Chicago-Naperville-Joliet, Philadelphia-Camden-Wilmington, Dallas-Forth Worth-Arlington, and Miami-Fort Lauderdale-Miami Beach.

FIGURE A.1. Aggregate Land Price Indices: 1975 – 2016

A. Land Price Indices for All Land



B. Commercial Land Price Indices



price movements.[75]

The time series behavior of land values differs substantially even among cities within the same Census region, which suggests that geographic differences in land values stem from a highly localized source. Figure A.2 plots the price indices for all land types for the largest cities in each Census region. While the timing of the momentum change around 1990 is highly correlated across cities within the same region, price levels differ dramatically during the boom-bust cycle. There are also notable differences across regions in the timing of the bust. Outside of the Kanto (Tokyo) and Kansai (Osaka) regions, many cities either experience a gradual drop in land values or continue to experience increases in land values after the initial stock market crash in 1990.[76]

A.2 Transaction vs. Appraisal Price Indices

This subsection assesses the extent to which price series constructed from property tax appraisal records might differ from price series based on transactions. Both methods show prices fell substantially following the post-Lehman boom. I find 2008-2016 growth rates for repeat sales and repeat appraisal prices have a correlation of 0.5 in the cross-section, with a cross-sectional correlation of 0.7 among cities with population over 400,000.

Unfortunately there are no publicly available microdata for Japanese property transactions prior to 2005, when the Ministry of Land, Infrastructure, Transport, and Tourism (MLIT) introduced the Real Estate Transaction-price Information (RETI) database. These data are structured in a very similar fashion to the appraisal data used in this paper, which are also provided by MLIT. Municipalities began providing quarterly data in waves, with 1,715 out of 1,741 modern municipalities providing data as of 2017. To maximize the amount of temporal and geographic overlap between appraisal and transaction records, I restrict to the 214 cities that began providing data as of the start of 2007, which covers all firm HQ cities in my corporate balance sheet data.

Besides time and geographic coverage, there are other differences between the datasets which affect my ability to compare appraisal and transaction prices.[77] First, the transaction data include several variables not in the appraisal data, including the exact floor space of the building and build year.[78] Further, values for non-price variables in the transactions data are censored, and for many properties usage is not precisely catalogued into residential, commercial, and industrial categories. Lastly, for privacy concerns, locations are only defined up to a neighborhood level (i.e. a collection of city blocks). Since there is no panel id, this means individual properties in RETI can only be tracked over time by matching on immutable characteristics observed across separate transactions.

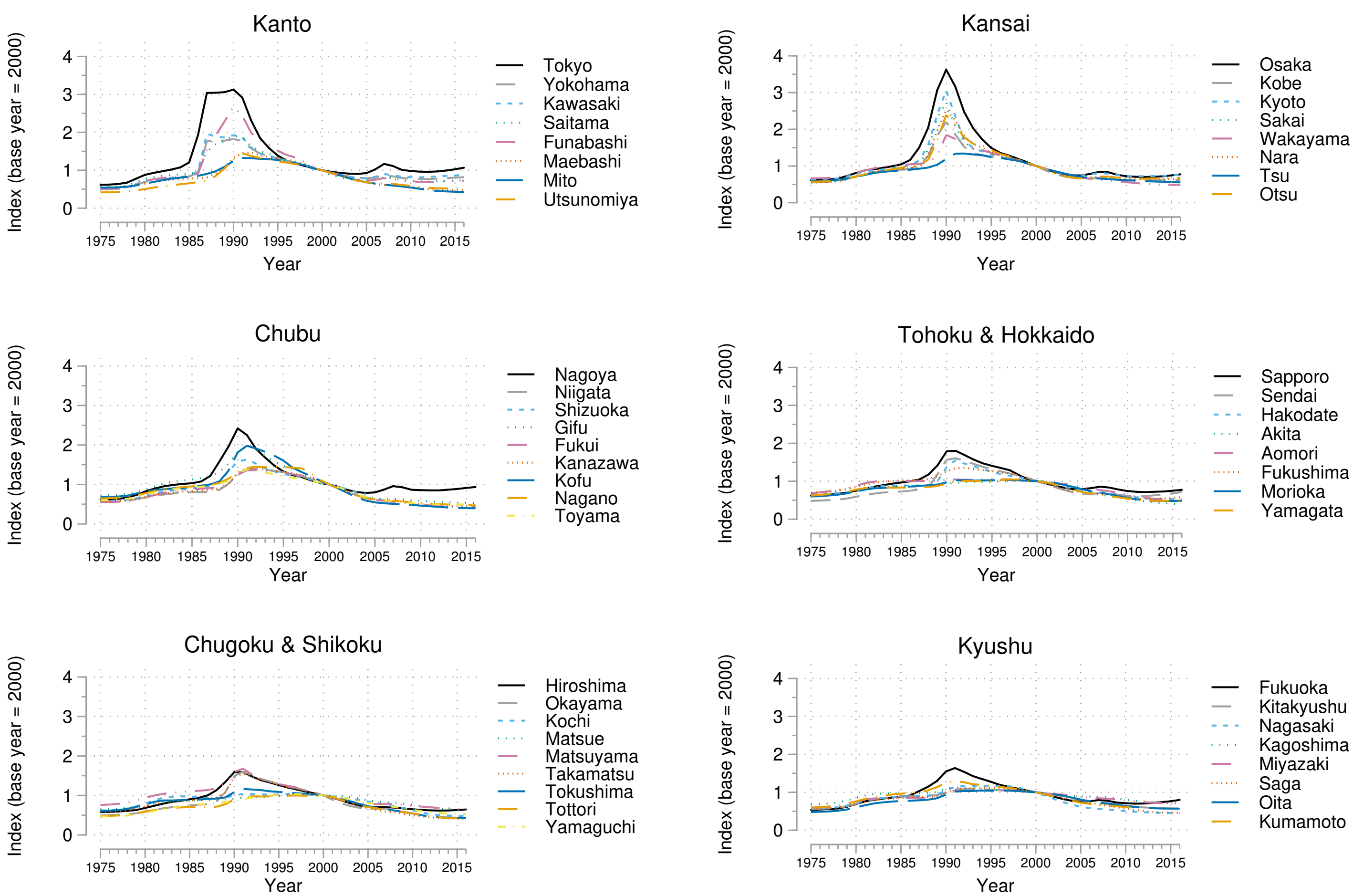
[75] After accounting for such timing differences between the repeat appraisal and JREI indices, small differences in levels between the two sets of indices remain. For example, comparing the JREI with a one-year lead to the repeat appraisal index, for all land the repeat appraisal index is on average 1% lower than the JREI in the 1980s, but 6% higher than the JREI for the six major cities and 16% higher for all commercial land. These deviations are due to differences in the sampling frame for my data versus for the data underlying the Urban Land Price Index.

[76] These findings offer a caveat to a closely related paper by Gan (2007a), who argues that regional variation in the collapse of local real estate prices is minor relative to the drop in aggregate prices, and that prefectural-level prices are an adequate proxy for the exposure of the firm to price drops.

[77] See the online codebook at http://www.land.mlit.go.jp/webland_english/note.html for more details on how the government selects individual transactions to be included in the RETI database. In general, a transaction is recorded as long as the property does not have sufficiently unique features that researchers can use to identify the exact address and owners.

[78] I use these variables to estimate depreciation rates based on the transactions data in Appendix F.

FIGURE A.2. City-level Land Price Indices, By Region



Given the differences in variable definitions across the datasets, I apply a repeat sales approach to the transactions data. I run regressions of individual prices on a full set of time (year and quarter) and individual property fixed effects, as in equation (2.1). For the transactions data, additional assumptions are required to identify repeat sales.[79] I assign two transactions to the same property if they satisfy the following two criteria:

- The property being transacted is exactly the same according to a set of observables which includes: city name, neighborhood name, name of the nearest station, plot area, cardinal direction and width of the adjacent front-facing road, frontage, and an indicator for whether the property is a unit in an apartment complex. I select these variables because they are relatively invariant to alterations owners might make to the property before reselling, such as adding a new bedroom or demolishing the building completely.

- I assume that a property which can be matched across two transactions according to the above set of criteria is not "flipped" within the same quarter. Hence, I assign two transactions which feature an otherwise identical property to distinct panel ids if the two transactions occur within the same quarter.

Using these criteria, I identify 29% of transactions as repeat sales, meaning a property transacts at least twice during the sample period.[80] I pool residential and commercial use property transactions due to the small number of commercial repeat sales taking place in cities outside Tokyo.

Figure A.3 compares growth rates in repeat sales and repeat appraisal prices during the mini-bust period following the Lehman shock in 2008. There is an S-shaped relationship between the two sets of growth rates; while the two sets of prices have a cross-sectional correlation of 0.5, the indices diverge for cities which experienced large swings in sales prices over the period. However, as Panel B indicates, for the largest cities the two indices are much more strongly related, with appraisal-based growth rates moving almost one for one with transaction-based growth rates and a cross-sectional correlation of 0.7. Since over 90% of corporate headquarters are located in these 53 large cities, these results point to appraisal-based prices being a valid substitute for sale prices in my setting.

A.3 Alternative Appraisal Price Indices

In this appendix subsection I present formulas and results on the cross-sectional distribution of land values obtained under alternative indexing approaches. For simplicity, I suppress the c subscript indicating that the index is computed for land located in a particular area.

Regression-based indices

A standard hedonic index would replace the individual plot fixed effects in the regression specification in (2.1) with a vector of potentially time-varying plot characteristics $X_{i,t}$.

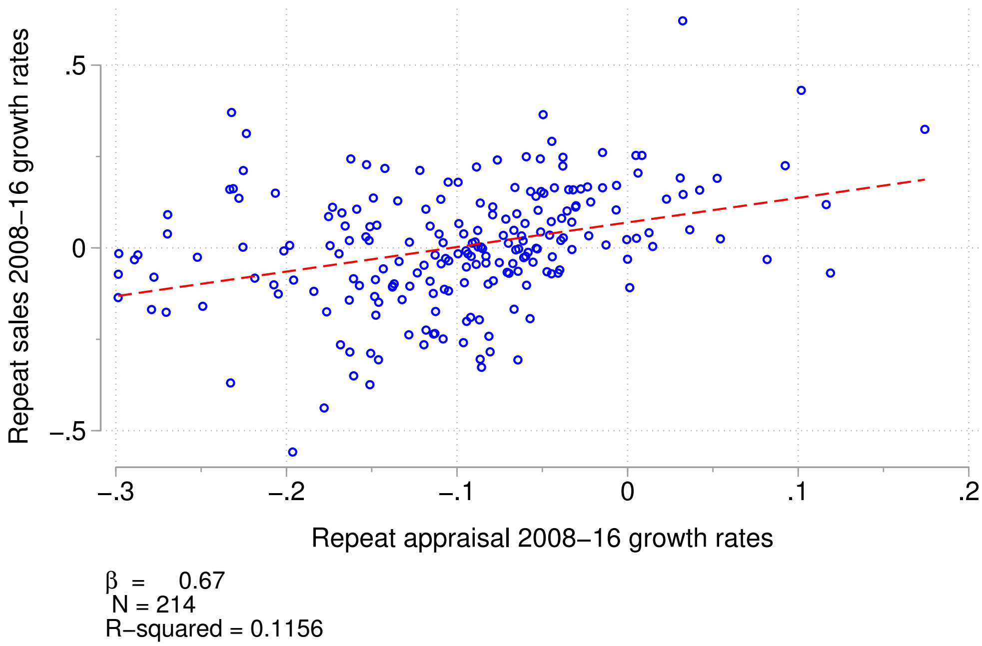
$$\log p_{i,t} = \delta_t + \beta \cdot X_{i,t} + \epsilon_{i,t} \tag{A.1}$$

[79] Following Case & Shiller (1987;1989), I drop recently renovated properties from the sample.

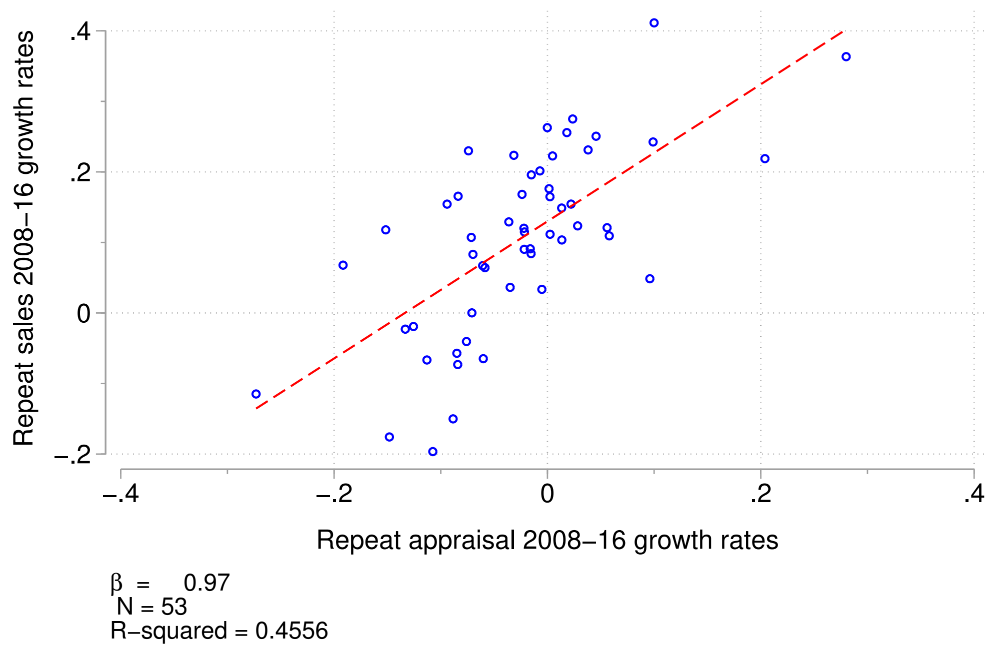
[80] Nagaraja et al. (2017) report a 53% incidence of repeat sales in their transactions data covering 20 large MSAs in the U.S. over two decades. This is comparable to the 48% incidence of repeat sales I obtain when I drop the "no flipping" condition and restrict to cities of population greater than 400,000. To the extent that my procedures might only identify very similar properties located within the same neighborhood, the fixed effect in the repeat sales regression is akin to the housing development fixed effect approach used in Fang et al. (2015).

FIGURE A.3. Repeat Appraisal vs. Repeat Sales Prices in the Cross-Section

A. Growth Rates across All Cities



B. Growth Rates across Large Cities (2000 Population > 400,000)



As in the repeat appraisal method, the hedonic index is formed by transforming the estimated time dummies $P_t = \exp(\hat{\delta}_t)$ and normalizing to a base year. The conditioning set $X_{i,t}$ controls for differences in quality across individual plots to isolate aggregate fluctuations in market real estate values. I include the following variables in $X_{i,t}$: location fixed effects, a quadratic in plot area, a cubic in distance to the nearest station, dummies for current use of the property (e.g. office, bank, rental housing, etc.), a station distance and area interaction term, city planning zone classification, an indicator for whether the plot is on a private road, building material, and statutory maximum floor-to-area and building coverage ratios.[81]

Plots appearing in the appraisal records are selected to be representative of a land use category and geographic area combination. As discussed in Section 2.1 plots will be removed from the survey in instances where the designated use of the land changes substantially. There may also be selection of price observations into the survey due to the match between appraisers and the properties they are assigned to appraise. To account for these sources of unobserved heterogeneity due to selection, I estimate versions of my repeat appraisal specification in equation (2.1) where the individual plot fixed effects η_i are treated as random variables. I report results using both the maximum likelihood (MLE) and generalized least squares (GLS) estimators to isolate the random effects (RE).

Expenditure-based indices

I consider price indices which take a weighted geometric average of year-on-year price changes in land plots i in an area:

$$P_t = \prod_{i \in \mathcal{I}} \left(\frac{p_{i,t}}{p_{i,t-1}} \right)^{\omega_{i,t}} \tag{A.2}$$

where $\mathcal{I} := \mathrm{I}_t \cap \mathrm{I}_{t-1}$ is the set of all land plots observed in periods t and $t-1$. In the simplest case, which is sometimes called a Jevons index, $\omega = 1/|\mathcal{I}|$ and all plots observed in adjacent periods receive equal weight in determining the index value in period t. The chained version of this equal-weighted index corresponds to the method employed in the construction of the official index maintained by the Japan Real Estate Institute (JREI).

An alternative to equally weighting all adjacent price relatives is to instead weight them in proportion to their value relative to the aggregate value of land in an area. These value shares can be computed as:

$$s_{i,t} = \frac{p_{i,t} \cdot x_{i,t}}{\sum_{i \in \mathcal{I}} p_{i,t} \cdot x_{i,t}} \tag{A.3}$$

where $p_{i,t}$ is the per-unit (i.e. square meter) price, and $x_{i,t}$ is the size of the plot in square meters. Plots in the appraisal data used in this paper rarely change size, and such changes generally result in the plot being retired from the survey soon after the change occurs. Therefore almost all changes in the value share of a land plot are due to changes in the per-unit price of the land. The value shares for land correspond to the expenditure shares computed in a CPI context where the i would instead refer to individual goods, and x would refer to the purchased quantities of the good.

[81] Results are quantitatively robust to estimating different versions of equation (A.1) which include a larger set of variables and higher-order polynomials of station distance. I report results here for a more parsimonious conditioning set due to missing observations for many building-specific variables.

Using these value shares, one can define the Sato-Vartia index which computes a geometric average of price relatives as in equation (A.2), where the weights are the log mean of the value shares for a plot over t and $t-1$:

$$\omega_{i,t}^{SV} = \frac{(s_{i,t} - s_{i,t-1})/(\log s_{i,t} - \log s_{i,t-1})}{\sum_i \left[(s_{i,t} - s_{i,t-1})/(\log s_{i,t} - \log s_{i,t-1})\right]} \tag{A.4}$$

Another commonly used price index is the Törnqvist index which instead weights adjacent price relatives by the arithmetic average of value shares in t and $t-1$:

$$\omega_{i,t}^{T} = \frac{s_{i,t} + s_{i,t-1}}{2} \tag{A.5}$$

It is also possible to compute versions of the Laspeyres and Paasche indices commonly used by government statistical bureaus to construct official CPI measures. The Laspeyres index asks how much does the price of the same basket of land cost using the previous year plot sizes

$$P_t^L = \frac{\sum_i p_{i,t} \cdot x_{i,t-1}}{\sum_i p_{i,t-1} \cdot x_{i,t-1}} \tag{A.6}$$

Whereas the Paasche index asks how much does the price of the same basket of land cost using current year sizes:

$$P_t^P = \frac{\sum_i p_{i,t} \cdot x_{i,t}}{\sum_i p_{i,t-1} \cdot x_{i,t}} \tag{A.7}$$

Given that plot size rarely changes within the panel, the Laspeyres and Paasche indices for local land values are virtually identical in my application.[82] Finally, I compute the Fisher index by taking the geometric average of the Laspeyres and Paasche index:

$$P_t^F = \left(P_t^L \cdot P_t^P\right)^{1/2} \tag{A.8}$$

It is well established in index theory that the Fisher and Törnqvist indices numerically approximate each other (Diewert 1978; Dumagan 2002). For this reason, a Fisher land price index can also be considered a weighted geometric average of price relatives where the weights are proportional to the value share of each individual land plot.

Comparing Indexing Methods

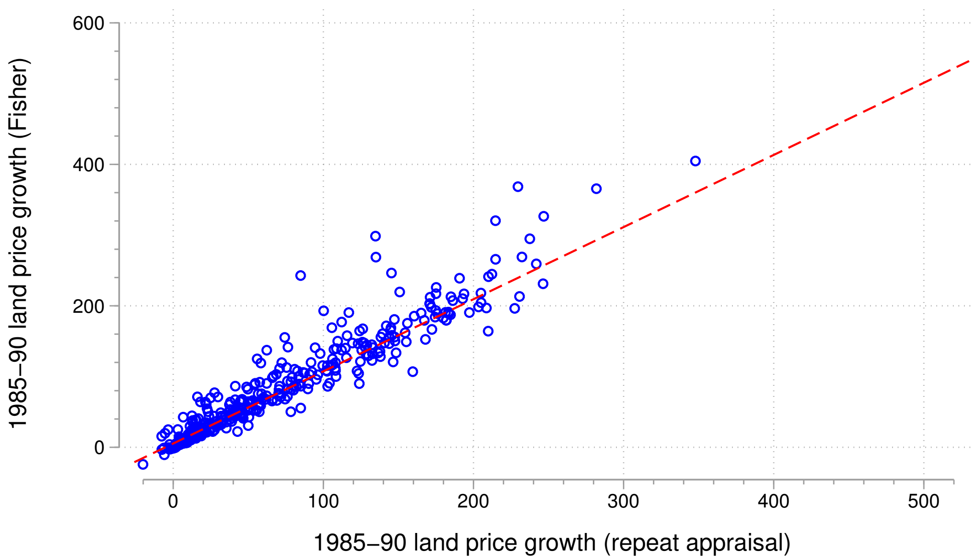
I compare the cumulative growth rates in land values between 1985 and 1990 implied by my preferred repeat appraisal index and the alternative indexing methods outlined above. I do this separately for indices restricting to commercial use, residential use, and for indices computed by pooling all land types. Table A.1 displays the results of this exercise for the regression-based indices, including the official JREI index and my repeat appraisal index, and for chained versions of the expenditure-based indices discussed in this subsection.

While the magnitude of the aggregate cycle in land values depends heavily on the choice of

[82] For the same reason, a Walsh index which would weight the individual prices in each period by the geometric average of quantities in t and $t-1$ would be virtually identical to both the Laspeyres and Paasche indices.

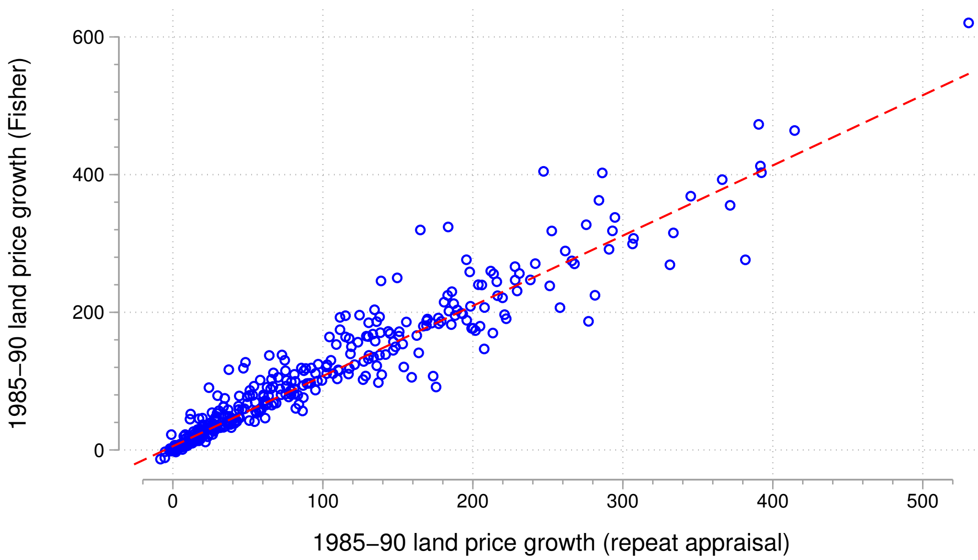
FIGURE A.4. Repeat Appraisal vs. Fisher Indices in the Cross-Section

A. 1985-90 Growth Rates for All Land



β = 1.10
N = 409
R−squared = 0.9082

B. 1985-90 Growth Rates for Commercial Land



β = 1.04
N = 386
R−squared = 0.9200

Table A.1. Land Value Growth (1985-90) under Alternative Indices

Index method	Equal weight	Commercial	Residential	All land
Repeat appraisal (FE)	Y	66.62%	52.39%	56.27%
Repeat appraisal (RE, GLS)	Y	66.91%	52.49%	56.43%
Repeat appraisal (RE, MLE)	Y	66.89%	52.48%	56.44%
Official (JREI)	Y	62.26%	37.60%	46.34%
Jevons (geometric average)	Y	63.31%	50.75%	53.26%
Hedonic	Y	119.79%	34.55%	83.03%
Sato-Vartia	N	132.39%	89.35%	132.88%
Törnqvist	N	190.25%	97.45%	149.61%
Fisher	N	158.16%	92.24%	133.33%

whether to equally weight individual plots in the index construction, this distinction is irrelevant for heterogeneity in the size of the cycle across different cities. To show this, I compute repeat appraisal and chained year-on-year Fisher indices for each city in my sample and plot the 1985-90 growth rates in commercial land values under the Fisher index against the same growth rates computed from the repeat appraisal method in Figure A.4. The top panel of the figure shows that in the cross-section the Fisher index yields, on average, only ten percentage points more growth than the repeat appraisal index. The bottom panel conducts the same exercise, restricting to commercial land; in this case the Fisher index yields, on average, only four percentage points more growth than the repeat appraisal method. The cross-sectional correlation between the growth rates is 0.95 for all land, and 0.96 for commercial land. Thus, the facts documented in this paper on geographic heterogeneity in the boom-bust cycle in 1980s Japan are robust to indexing methods that weight properties by their value relative to the value of the total stock of real estate in an area.

A.4 Indices from Systems of National Accounts (SNA) Data

In this appendix subsection, I construct prefectural land price indices using the Systems of National Accounts (SNA) data for Japan and compare them to my repeat appraisal indices.[83] These data report for each year and prefecture a measure of the total stock of land in 2000 yen for land with building and cultivated land for the private household and private corporate (including financial institutions) sectors. To create indices for each land-sector category available in SNA, I simply rescale each value by the value for year 2000 in the series, which matches the base year used for price indices throughout this paper.

Panel A of Figure A.5 compares the aggregate time series behavior of indices within the SNA data for the household and corporate sectors and for land with a building and cultivated land without buildings. Panel B compares the SNA indices for land with building to the residential and commercial/industrial price indices constructed via the repeat appraisal method from the property

[83] Systems of National Accounts data are available from the Japanese Cabinet Office at http://www.esri.cao.go.jp/en/sna/data/kakuhou/files/kako_top.html.

tax appraisal data.[84]

A few patterns emerge from this figure. First, in Panel A the time series for land with building and cultivated land generally comove, although cultivated land price growth is more muted during the late 1980s for both the household and corporate sectors. This suggests that land itself accounts for the bulk of fluctuations in the value of real estate, consistent with the findings of other studies which decomposed property prices into separate series for land and building (Davis & Heathcote 2007; Knoll et al. 2017). Second, the SNA indices exhibit higher price levels and much higher growth during the boom period (e.g. 64% commercial growth for the appraisal indices vs. 174% in the SNA). This reflects the fact that SNA is a weighted version of the appraisal indices, as properties included in SNA are not valued individually but using prices imputed from plots in more centralized downtown areas within the prefecture (Nakamura & Saita 2007; Hagino et al. 2011).

Importantly for the cross-sectional estimation results in this paper, across prefectures the growth rates of my repeat appraisal indices are highly correlated with those obtained from the prefectural SNA indices. The cross-sectional correlation between the household sector land with building and residential appraisal indices is 0.87, with a correlation of 0.87 between the corporate sector land with building and commercial/industrial appraisal indices.

A.5 MLIT Appraisal Methodology

This subsection discusses the processes the Ministry of Land, Infrastructure, Transport, and Tourism (MLIT) uses to conduct their annual appraisals at the national and prefectural levels. The basic procedures for the national appraisal survey, also known as the Official Land Price Announcements, can be summarized in five steps:

1. The Land Appraisal Committee selects appraisers from a nationwide professional license registry (2,419 appraisers selected in 2016).

2. The Committee then sorts appraisers into regional subcommittees, resulting in two or three subcommittees per prefecture (196 total in 2016).

3. Regional subcommittees meet, review the list of land plots surveyed in the previous year, and determine which plots continue to meet selection criteria based on representativeness within a land use category and geographic area.

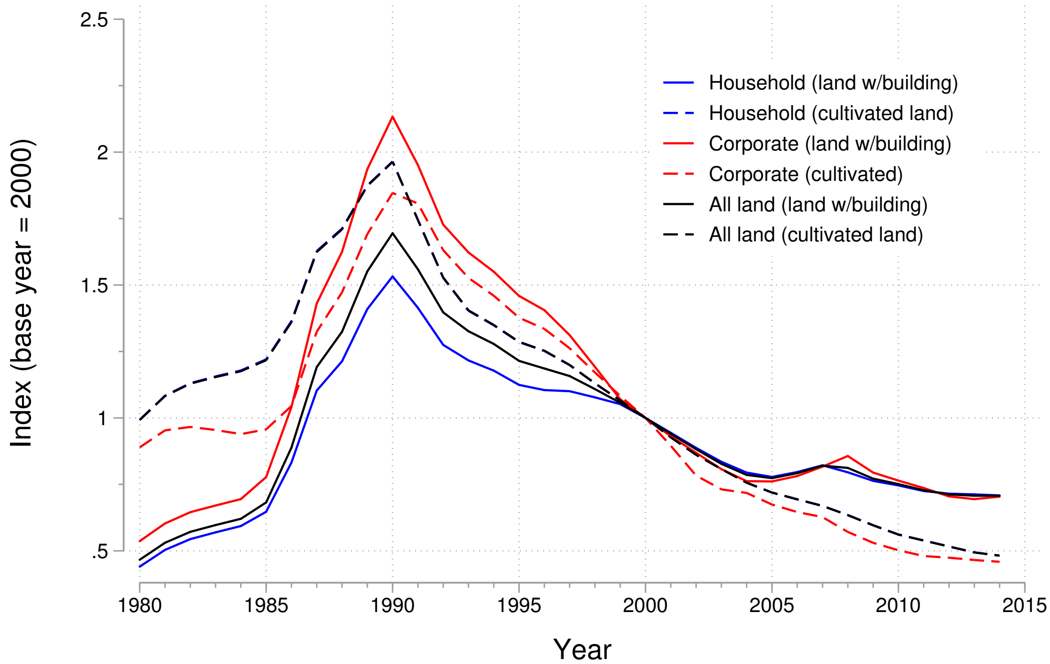
4. Two appraisers are assigned to each plot deemed to meet the selection criteria and report their evaluation in price per m^2 terms as of January 1st of the survey release year. The appraisers also record characteristics relevant to their assessment about the land itself (e.g. the shape of the plot), the location of the land (e.g. the address), and the building or structure on top of the land (e.g. number of above-ground floors). Appraisers are instructed to take existing buildings into account to the extent that these structures indicate the optimal usage of the property.[85]

[84] For the exercise in Panel B, to render the indices comparable I purge the small number of plots which appear to be located on vacant land from the appraisal data.

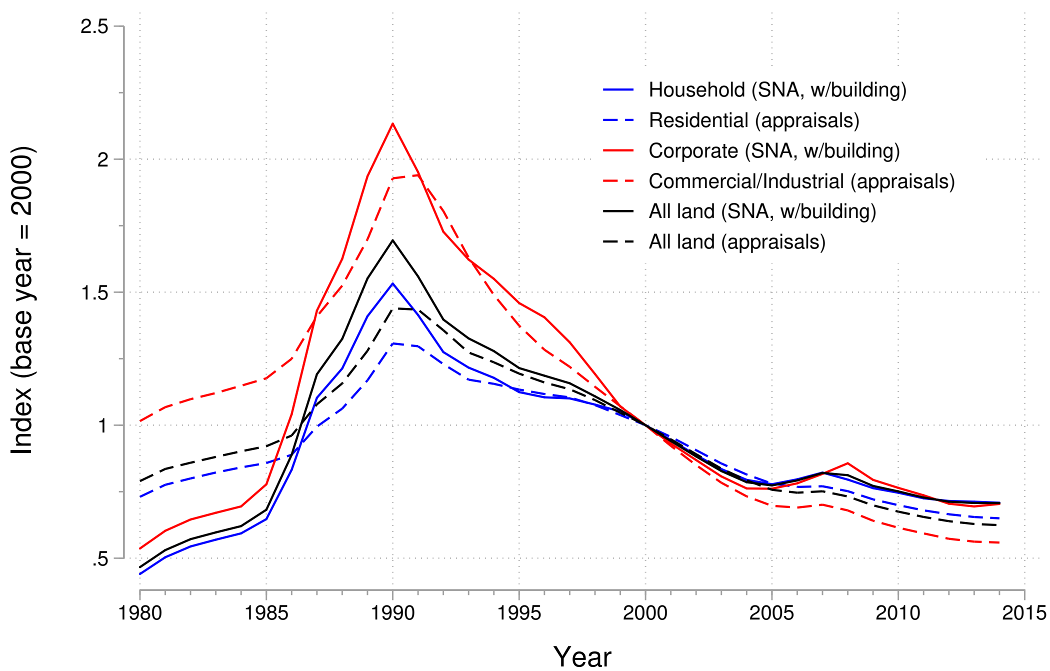
[85] This is consistent with the IRS valuation concept of "Highest and Best Use." See the IRS real property valuation guidelines described here: https://www.irs.gov/irm/part4/irm_04-048-006.

FIGURE A.5. Land Price Indices from System of National Accounts

A. SNA Indices for Land with vs. without Building



B. SNA Indices vs. Repeat Appraisal Indices



5. The appraisers submit their reports to the national Land Appraisal Committee, which reconciles the two evaluations for each land plot and announces land values for each surveyed plot in late March of the release year.

The Prefectural Land Survey is conducted in a similar way under the guidance of MLIT but administered at the prefectural level. However, there is one key difference with respect to the timing of appraisals. The national-level survey consists of appraisals with January 1 valuation dates, while the appraisals themselves are conducted in Q3 and Q4 of the preceding year. In contrast, the prefectural-level survey consists of appraisals with July 1 valuation dates, and the appraisals are conducted in Q1 and Q2 of the same year. Thus, to ensure all variables in my dataset are observed within the same calendar year, I treat appraisals from the national-level survey as year-end observations from the previous year.

B Firm Balance Sheet Data Construction

This appendix describes my construction of geocoded balance sheet data for listed firms in Japan. I combine balance sheet subtotals provided by the Development Bank of Japan (DBJ) with more granular information, including facility locations, reported by firms in their annual filings to the FSA (*yuhō*). I downloaded PDFs of all disclosure documents filed from 1980 to 1990 for firms in the DBJ sample through the Pronexus eol Corporate Information Database.

B.1 Collecting Facility Information

A distinctive feature of corporate filings in Japan is a section called "Condition of Facilities" (*setsubi jōkyō*) in which firms provide a list of facility names, city-level locations for each facility (including the HQ), and facility features including the number of employees, number and net book value of machines and equipment deployed at the location, and the size and net book value of land, buildings, and construction in progress. Firms also describe the amount of real estate assets and equipment that are rented from or leased to third parties, including the amounts and in many cases the length of the rental contracts. I use this information for two main purposes: (i) to determine whether firms own their HQ facilities or hold real estate assets in the HQ city, as reported in Section 4, and (ii) to obtain more precise estimates of the strength of the real estate collateral channel by taking into account the spatial distribution of labor and physical capital inputs within the firm's domestic network (Section 5.3).

With the help of assistants trained to read the *yuhō*, I hand-collected information on the name and general purpose of the facilities, employment, and size and net book values of real estate assets for all 1,570 firms in the DBJ sample. I did this for a single year, selecting 1980 because more firms have downloadable PDFs in this year than in other pre-reform years (i.e. pre-1983 years) for which my land price indices are available. Using 1980 as a baseline for establishing the distribution of corporate real estate assets also matches the timing of the land use reform exposure measures I use as instruments for real estate values.

While firms were not required to provide facility addresses prior to the 1988 filing year, most firms provide facility locations in 1980 at the city level by either including the city name in the facility's sobriquet (e.g. the "Yokohama warehouse") or explicitly listing the city and prefecture in the *setsubi jōkyō* section. In any case, companies are always required to provide the precise address of their actual HQ (*honten*) and the main correspondence location (*renraku basho*) on the cover page of their filings. In my analysis, I always consider the *honten* to be the HQ location, as in many cases the *renraku basho* refers only to a mailing address rather than a site of business activity.[86]

Nevertheless, there are still cases where no city location is provided in the *setsubi jōkyō* and it is necessary to impute city-level locations for non-HQ facilities. For instance, a firm may simply list a facility as the "Kansai factory," where Kansai refers to a large Census region containing many major cities. In such cases, I implement the following steps to assign locations:

1. If the facility name corresponds to one of the branches CC'ed with an address on the report cover page, I assign the city code based on that address.

2. Within the same firm, facility names infrequently change across filing years. If the facility name corresponds to a facility name listed in the firm's 1988 *yuhō*, I assign the city code based on the address listed in the 1988 *yuhō*.

3. If the first two steps are not possible, but the facility name contains a Census region, I assign the largest city in that region to the facility.

4. If the facility name contains a colloquial name for a neighborhood, I assign the city code that contains that neighborhood.

5. In cases where the firm owns a company dormitory with an unlisted location, I assign the city code of the HQ facility. This step is based on the observation that among firms which do list the location of their dormitories, these facilities tend to be located near the HQ.

6. In cases where the firm geographically groups facilities together rather than itemizing by each individual location, I follow the previous steps in attempting to match each individual location to a city code based on names. I then assign a city code to the subtotal that contains the majority of the individual locations represented in that subtotal. For instance, if a company lists subtotals for its "Tokyo factory" but this line item aggregates across two factories located in central Tokyo and one warehouse located in Chiba, a city to the east of Tokyo, I assign the city code associated with central Tokyo.

7. Finally, I assign all foreign facilities (e.g. the Singapore branch office) to the same city code (99999) which is not attached to any domestic location. Since my balance sheet data pertain to non-consolidated balance sheets which exclude assets and liabilities of subsidiaries, very few firms list non-leased foreign facilities. Parent firms tend to have foreign subsidiaries which separately report such non-domestic real estate holdings.

B.2 Determining Facility Ownership

Japanese firms do not directly report ownership status of facilities listed in the *setsubi jōkyō* section. For each facility, the typical firm reports the number of m^2 of land and buildings that are rented and number of m^2 that are leased to a third party. Since rented real estate is not an asset, accounting for the former is crucial to determining the spatial distribution of the firm's collateralizable assets.

Using reported information on rented real estate, I apply the following definition to determine whether a firm owns each facility it lists:

[86] Among firms that list both, 61% report an actual HQ and correspondence address located in the same city. I obtain similar results when I instead use the correspondence address to allocate real estate assets to a single city within the firm's network.

(i) The firm owns the facility if it reports a strictly positive amount of non-leased square meters of land or buildings.

(ii) Or, if the firm does not report the size of each facility, they own the facility if they report a positive net book value for both land and buildings at the site.

(iii) I distinguish between full and partial ownership of facilities by classifying firms as partial owners if they report leasing a portion of the land or building area at that location, but satisfy at least one of the first two criteria.

This definition accounts for the fact that firms which lease a facility may list a positive amount of net capital in buildings for which they have no ownership stake. This will be the case in instances where the firm rents office space in a building but has invested either in renovations or furnishings for the space. However, because these capital improvements are less closely tied to fluctuations in the underlying value of land and buildings, assigning facility ownership purely on the basis of this component would amount to a placebo and would thus reduce the precision of my estimates.

Examples of Itemized Real Estate Holdings

Consider the following three examples of corporate real estate holdings itemized by location and reported in the *setsubi jōkyō* section for each firm's fiscal year 1980 filing with the FSA. To start, Ezaki-Glico, a large food company famous for its candy products with a headquarters in Osaka, provides the following table of properties:

Facilities of Ezaki-Glico Co., Ltd. (1980)

Location	Land		Buildings		Employees	Ownership	Usage
Osaka	45 m^2	23,847	8,333 m^2	377,362	399	Full	HQ/general operations
Osaka	185,709 m^2	1,168,707	20,793 m^2	379.451	296	Full	Candy/food manufacturing
Osaka	0 m^2	0	579 m^2	5,289	116	Partial	Branch office/sales operations
Tokyo	17,431 m^2	8,964	21,443 m^2	554,004	266	Partial	Candy/food manufacturing
Tokyo	2,154 m^2	97,106	1,949 m^2	116,774	172	Partial	Branch office/sales operations
Saga	29,485 m^2	16,654	15,643 m^2	306,110	197	Full	Candy manufacturing
Sapporo	1,827 m^2	20,823	709 m^2	14,114	27	Partial	Branch office/sales operations
Sendai	2,658 m^2	82,403	0 m^2	139	49	Partial	Branch office/sales operations
Nagoya	321 m^2	2,868	405 m^2	4,477	42	Partial	Branch office/sales operations
Hiroshima	0 m^2	0	0 m^2	104	36	Leased	Branch office/sales operations
Fukuoka	849 m^2	21,137	134 m^2	643	64	Partial	Branch office/sales operations
Total	240,479 m^2	1,442,509	69,988 m^2	1,758,467	1,664		

Notes: Net book values for land and buildings are reported in units of 1,000 JPY (≈ 10 USD). Monetary values are rounded to the nearest thousand JPY.

Additionally, Ezaki-Glico reports maintaining various dormitories (no location provided) with net book values of 84,511 and 141,047 for land and buildings, respectively. On top of the assets listed in the table above, Ezaki-Glico leases 4,108 m^2 of land at its Tokyo manufacturing facility and 3,558 m^2 of office space spread across its branch office locations: Sapporo (87), Sendai (478), Tokyo (1,030), Nagoya (364), Osaka (519), Hiroshima (424), Fukuoka (656). Of the 11 facilities listed, only the Hiroshima branch office is fully leased, as Ezaki-Glico reports owning no portion of the land or on-site buildings. Overall, 61% of the net book value of Ezaki-Glico's geocoded real estate holdings (land + buildings) and 49% of its employees are located in the HQ city.

In another example, Nintendo, a major video game company, reports the following real estate assets in its 1980 financial disclosures. The table below reflects the fact that in 1980 Nintendo was transitioning from its traditional role as a producer of playing card games to video game development. In addition to the holdings in the table, Nintendo reports owning land used for general sales purposes (no location provided) with a net value of 52,187. While Nintendo maintains full ownership of all its facilities, it leases 774 m^2 of its office space spread across its facilities to third parties: Kyoto HQ (81), Tokyo (500), Osaka (131), Nagoya (50), Okayama (12). Overall, 53% of the net book value of Nintendo's geocoded real estate holdings (land + buildings) and 76% of its employees are located in the HQ city.

Facilities of Nintendo Co., Ltd. (1980)

Location	Land		Buildings		Employees	Ownership	Usage
Kyoto	50,050 m^2	409,156	16,502 m^2	265,053	223	Full	HQ/playing card production
Uji (Kyoto)	16,680 m^2	32,868	6,676 m^2	91,589	105	Full	Video game production
Tokyo	4,611 m^2	143,121	4,906 m^2	416,603	37	Full	Branch office
Osaka	171 m^2	207	1,206 m^2	75,682	26	Full	Branch office/sales division
Nagoya	1,368 m^2	12,528	1,070 m^2	25,663	18	Full	Branch office/sales division
Okayama	331 m^2	8,112	559 m^2	11,226	13	Full	Branch office/sales division
Sapporo	496 m^2	7,232	382 m^2	9,282	8	Full	Branch office/sales division
Total	73,707 m^2	613,224	31,301 m^2	895,098	430		

Notes: Net book values for land and buildings are reported in units of 1,000 JPY (≈ 10 USD). Monetary values are rounded to the nearest thousand JPY.

Finally, consider the real estate holdings reported by Suzuki, a large automotive manufacturer headquartered in present-day Hamamatsu, Shizuoka Prefecture:

Facilities of Suzuki Motor Corp. (1980)

Location	Land		Buildings		Construction	Employees	Ownership	Usage
Hamamatsu (Shizuoka)	173,106 m^2	95,000	115,849 m^2	2,616,000	242,000	3,168	Partial	HQ/factory
Iwata (Shizuoka)	246,301 m^2	592,000	38,911 m^2	1,082,000	165,000	1,160	Partial	Factory
Kosai (Shizuoka)	561,460 m^2	730,000	82,155 m^2	1,328,000	364,000	896	Partial	Factory
Ōsuka (Shizuoka)	104,548 m^2	151,000	24,098 m^2	593,000	111,000	312	Full	Factory
Toyokawa (Aichi)	213,427 m^2	705,000	71,938 m^2	975,000	203,000	731	Partial	Factory
Oyabe (Toyama)	84,495 m^2	58,000	42,986 m^2	592,000	80,000	711	Full	Factory
Tokyo	1,071,049 m^2	7,895,000	157,239 m^2	3,068,000	420,000	1,469	Partial	Branch office/agency
Total	2,454,386 m^2	10,226,000	533,176 m^2	10,254,000	1,585,000	8,447		

Notes: Net book values for land and buildings are reported in units of 1,000 JPY (≈ 10 USD). Monetary values are rounded to the nearest 100,000 JPY.

Suzuki also reports owning various warehouse facilities with a net book value of land of 130,000, a net book value of buildings of 516,000, and construction in progress of 50,000. In total, Suzuki rents 685,959 m^2 in land and 2,198 m^2 in buildings across its partially owned facilities, with the majority of rented space located in the Tokyo office. The firm also leases 321,018 m^2 in land and 101,265 m^2 in buildings to third parties. Unlike the previous two firm examples, Suzuki reports values for construction in progress, which is a non-depreciable component of PPE and real estate assets, for each of its seven facility locations. Overall, 36% of the net book value of Suzuki's geocoded real estate holdings (land + buildings + construction) and 66% of its employees are located in the vicinity of the HQ.

B.3 Matching Firms to Local Land Prices

After assigning city codes to corporate facilities based on the location information provided in the *yuhō*, I take additional steps to match each of these facilities to a local land price index constructed using appraisal survey data. There are two reasons why additional steps are necessary: first, due to a series of recent municipal mergers in Japan, many cities and towns that existed in the 1980s no longer exist.[87] Second, in cases where a firm owns real estate in rural locations, there may not be enough plots in the appraisal survey to estimate a land price index.

To address these issues, I apply the following procedures:

1. I standardize locations over time by imposing current municipal boundaries throughout the sample period. I do this by assigning the currently applicable city code to each land plot in the appraisal data and to each facility location in the firm-level data.[88] All geocoded variables used throughout this paper reflect municipal boundaries as of 2015.

2. I then construct a local land price index for each resulting city code as long as the city code averages ten commercial or industrial land plots per year over the sample time period. Since the number of plots surveyed in a year is proportional to municipal population, this threshold effectively excludes the least populous quartile of city codes.

3. If after conducting the above two steps a facility cannot be merged to a local land price index due to an insufficient number of commercial and industrial appraisal records, I make additional adjustments as follows:

    (i) If the facility's city code corresponds to a township (*machi* or *mura*) which is part of a collection of towns known as a district (*gun*), I pool all plots within the district to create a district-level index and assign this index to the facility.

    (ii) If instead the facility's city code corresponds to a small city rather than a township in a rural district, I assign the local land price index of the closest city code within the same prefecture as the unmatched city code (measured by distance from city center to city center).

[87] With many rural areas facing declining population and revenue, the government reassigned municipal boundaries on a large scale beginning in 2005. These and an earlier series of mergers reduced the number of municipalities from 3,278 city codes in 1980 to 1,741 in 2015.

[88] A full list of current city codes can be found at http://nlftp.mlit.go.jp/ksj-e/gml/codelist/AdminAreaCd.html. While I originally created my own crosswalk between old and new Census city codes, I cross-validated my crosswalk with another one recently made available by Keisuke Kondo at RIETI and available for download at https://www.rieti.go.jp/en/publications/summary/19030013.html.

B.4 Sample Restrictions and Summary Statistics

I make two sample restrictions to ensure that firms in the DBJ sample can be matched to a local land price index. These restrictions yield an estimation sample of 1,489 firms. First, I require firms to have non-missing total assets for at least five consecutive years over the period 1980-1987. In effect, this means that to appear in my sample firms must report business activities for at least one year prior to and after the enactment of reforms to land use regulation in the 1980s.

Second, for many Japanese firms (53% in 1980) the fiscal year runs from April in year $t-1$ to March in year t. To account for the fact that local land values in my data are assigned to calendar years, I assign firm-fiscal year observations to the calendar year in which the majority of their business activities occur. Thus, I assign a firm with a fiscal year ending in March in calendar year t to a local land index value in calendar year $t-1$. To limit any measurement errors due to timing, I drop firm-year observations with filing dates in May, June, or July, and any firm-year observations which change their fiscal year start and end months during the sample period. I obtain similar results when I instead restrict to the subset of firms with fiscal year end of March, as is standard among papers using balance sheet data from Japanese firms (e.g. Amiti & Weinstein 2018).

To ensure that my results are statistically robust, I winsorize all real estate and investment variables using as thresholds the median plus/minus five times the interquartile range. For variables pertaining to debt issues, I use the second/ninety-eight percentiles as thresholds, since the interquartile range for these variables is close to zero.

Table B.1 reports summary statistics for the sample of firms matched to a local land price index. The merged dataset includes 1,489 firms with corporate headquarters located across 161 cities. There is large heterogeneity in my main outcome variables (Panel A), firm real estate holdings (Panel B), and in the size of the city-level shocks (Panel C) generated by the land use reforms. Assuming 2% building depreciation, a firm-year at the 90th percentile in my sample has a market value of real estate assets equal to roughly six times that of the firm-year at the 10th percentile. At the city-level, during the boom period between 1985 and 1990, commercial and industrial real estate values grew by 242% in the city at the 90th percentile, compared to 21% in the city at the 10th percentile. This heterogeneity is also mirrored in the two variables which capture *ex ante* land use regulatory constraints, as 10% of the cities in my matched sample contain no plots which are constrained by FAR limits prior to the reform.

C Geography-based Measures of Local Real Estate Supply

In this appendix I summarize the replication of the methodology in Saiz (2010) by Hosono et al. (2018) and show how geography-based measures are poor proxies for local real estate supply constraints in 1980s Japan.[89]

There are two measures of geography-based supply inelasticity commonly used in the literature and based on Saiz (2010). One measure, outlined in Section II of Saiz (2010), is called the unavailable land share, which captures the fraction of land in an area around the city center which is unsuitable for development either due to the presence of a body of water or a steep incline of the land. The other measure is a supply inelasticity estimated from regressions of long-run differences in housing prices on long-run differences in the housing stock, and long-run differences in the housing stock

[89]More documentation on the Saiz measures for Japan can be found at http://www.ier.hit-u.ac.jp/hit-refined/English/database/elas.html.

Table B.1. Summary Statistics for Sample Time Period (1977-1995)

	Mean	Median	SD	10th pct.	90th pct.	N
Panel A: Firm-level outcomes						
RE inv.	0.07	0.04	0.13	−0.01	0.22	27,944
PPE inv. (CAPEX)	0.20	0.16	0.21	0.02	0.43	27,944
Non-RE inv.	0.16	0.11	0.35	−0.10	0.50	27,944
Net total debt issues	0.03	0.00	0.31	−0.22	0.35	27,872
Net long-term debt issues	0.00	0.00	0.18	−0.16	0.16	27,872
Total bond issues	0.03	0.00	0.20	−0.06	0.18	27,872
Panel B: Other firm-level variables						
Net book RE	0.66	0.62	0.30	0.35	0.98	27,944
Net market RE ($\delta = 2\%$)	4.98	3.73	4.08	1.57	10.09	27,944
Net market RE ($\delta = 4\%$)	1.97	1.66	1.46	0.61	3.53	27,944
PPE/Total	0.26	0.23	0.16	0.07	0.47	27,944
EBITDA	0.60	0.46	0.52	0.19	1.19	27,944
Dividend ratio	0.05	0.00	0.53	0.00	0.11	27,177
Avg. RE age ($\delta = 2\%$)	21.7	21.9	5.8	14.3	28.9	27,944
Avg. RE age ($\delta = 4\%$)	10.9	10.9	2.9	7.2	14.4	27,944
Panel C: City-level data						
Comm/Ind land price % growth (1985-90)	116	95	86	21	242	161
Comm/Ind land price % growth (1990-95)	−28	−31	24	−58	−1	161
1980 FAR limit share	0.12	0.09	0.11	0.00	0.27	160
1980 median road width	11.5	10.8	4.3	7.0	18.0	160

Notes: All yen-denominated variables are scaled by lagged book properties, plant, and equipment (PPE). CAPEX is defined to be COMPUSTAT equivalent: the change within the year in the net book value of PPE plus accounting depreciation. Real estate is defined as the change in the sum of the net book value of buildings, land, and construction in progress plus accounting depreciation. Other investment is defined as the change within the year in the net book value of machines, tools, and transportation vehicles plus accounting depreciation on those items. Net long-term debt issues is defined as the year-on-year change in long-term loans payable. Total bond issues refers to the year-on-year change in the value of bonds payable. Net total debt issues is the sum of net long-term and total bond issues. PPE/Total refers to the ratio of book PPE to total book assets. EBITDA is computed as operating income plus depreciation and amortization. I compute the dividend ratio as dividend payouts relative to operating income. 1980 FAR limit share refers to the share of land plots constrained by land use regulations (in the city where the HQ is located). 1980 median road width is the median width in meters of adjacent, front-facing roads among land plots in the HQ city. I report the average age of real estate on the firm's portfolio assuming a depreciable life of 50 years ($\delta = 2\%$) and assuming a depreciable life of 25 years ($\delta = 4\%$).

interacted with the unavailable land share. This specification is based on the model in Section III of Saiz (2010) which maps the unavailable land share into a supply elasticity.

Below I outline the steps involved in creating these measures for Japan and linking the unavailable land share measures to my local repeat appraisal indices. I focus on the unavailable land share measure because it does not require a local price index as an input. However, the ranking of cities from most to least constrained is entirely unchanged across the unavailable land share and supply inelasticity measures provided by Hosono et al. (2018).

1. Group cities into urban employment areas (UEA) following the methods outlined by the Center for Spatial Information Science (CSIS) at University of Tokyo. These groupings are based on commuting patterns and result in 108 UEAs based on 2010 boundaries.

2. Estimate a local land price index by sorting appraised residential land plots into a UEA and estimating the repeat appraisal regressions described in Section 2.2.[90]

3. Consider a 50 km radius from the central city within each UEA and exclude 250m $\times$ 250m grids that either (i) have an average slope exceeding 15% or grids, (ii) contain bodies of water (ocean, rivers, lakes, or ponds). The unavailable land share is then obtained by taking the ratio of the total number of grids excluded according to these two criteria relative to the total number of grids in the 50 km ring around the central city located within the UEA.

4. To convert the unavailable land share to the supply inelasticity measure, estimate the following regression in log differences between 1975 and 2000:

$$\Delta \log P_j = \beta^s \cdot \Delta \log H_j + \beta^{LAND} \cdot (1 - \Lambda_j) \times \Delta \log H_j + \sum_k R_j^k + \epsilon_j \tag{C.1}$$

   where P_j is the local housing price index for UEA j, H_j is the local housing stock, $(1 - \Lambda_j)$ is the share of available land, and R_j^k are a full set of Census region fixed effects. Housing stock H_j is measured as the number of housing units in the UEA.[91]

5. Using the equation derived in Proposition 1 of Saiz (2010), the implied fitted values of $\hat{P}_j$ from estimating equation (C.1) are then used to compute the individual inverse supply elasticity measures β_j^s for each city.

Figure C.1 examines the relationship between the unavailable land share and real estate booms in Japan and the U.S. The top panel of the figure plots the cumulative growth in Japanese residential land prices over 1985-1990 against the unavailable land share constructed in Hosono et al. (2018) using the above procedures. I do this by constructing repeat appraisal indices for the 108 UEAs with available geographic data. The bottom panel plots the cumulative growth in U.S. housing prices over

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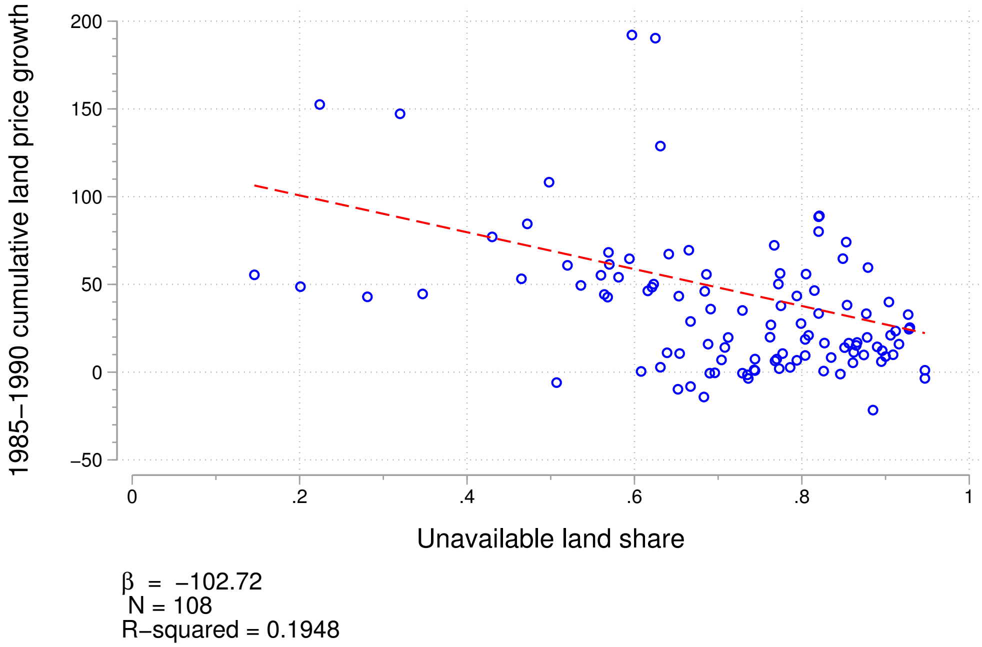
[90] I use residential land in this exercise to ensure that my indices are directly comparable to the residential property indices used in the literature on the Saiz instrument in the U.S. The correlations documented in this section are of the same sign and similar magnitudes for each country if I instead use the Zillow commercial property indices for the U.S. and indices based on commercial land plots for Japan.

[91] The results are virtually unchanged by the inclusion of terms capturing regulatory constraints (captured here by floor-to-area ratios, and long differences in local construction costs. To account for the fact that housing stock is an equilibrium outcome and therefore endogenous, it is typical to use Bartik industry-shares and annual sunlight as instruments for $\Delta \log H_j$.

Figure C.1: Saiz Unavailable Land Share and Real Estate Price Movements

Japan 1985-1990 Growth Rates for Residential Land



U.S. 2000-2005 Growth Rates for Housing

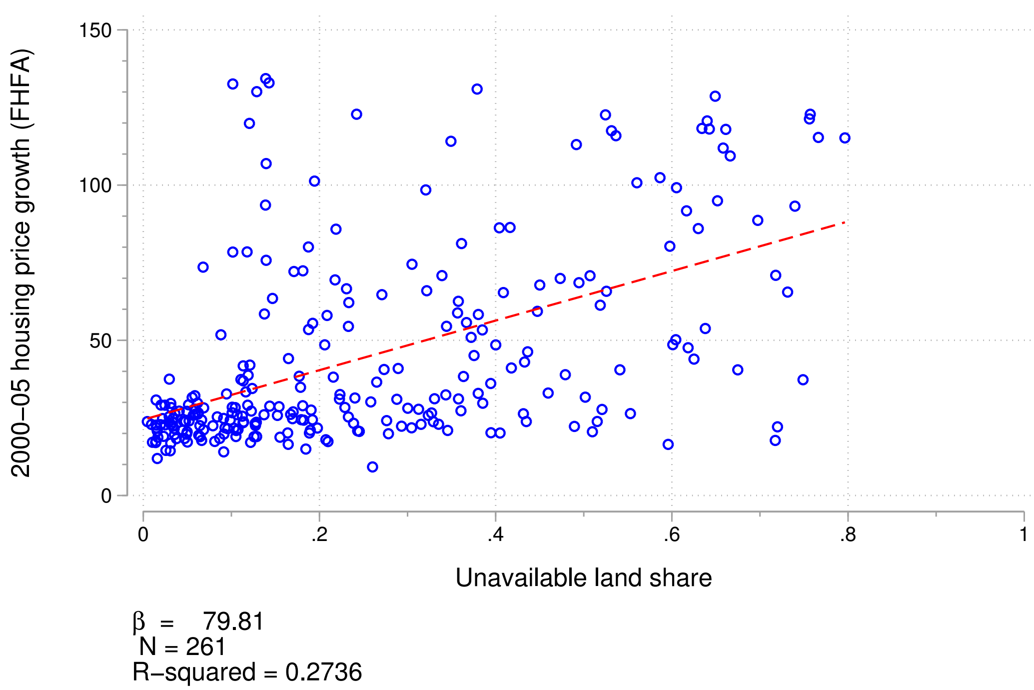
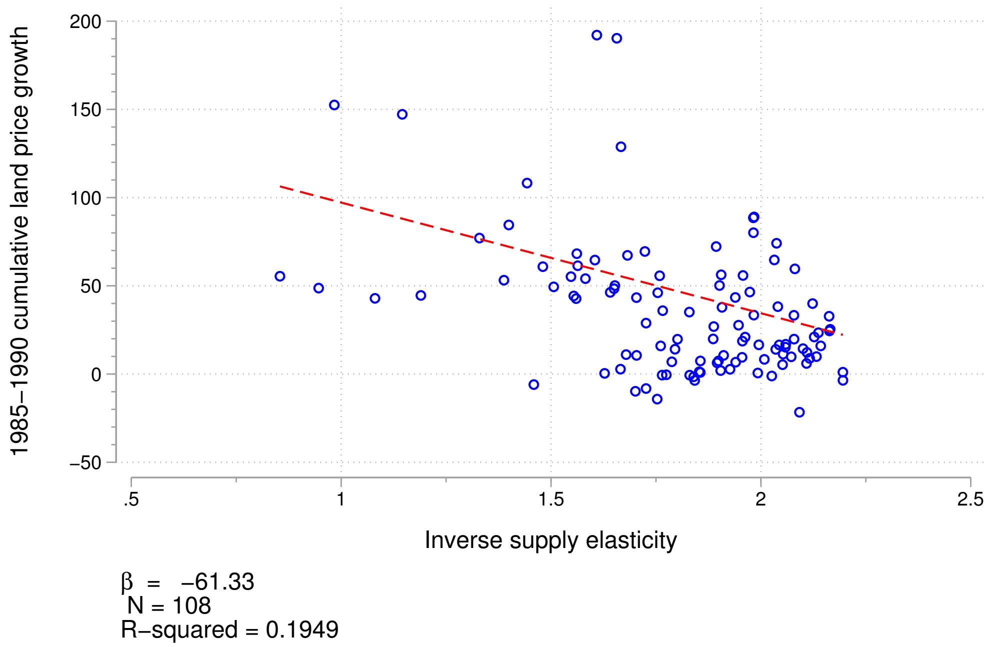
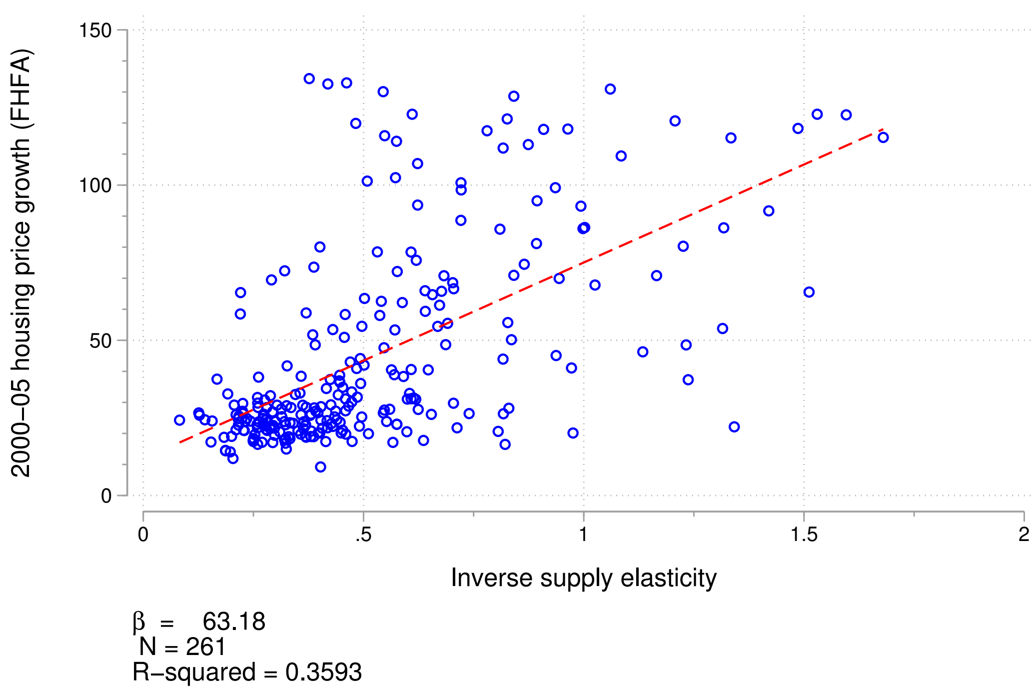


Figure C.2: Saiz Inverse Supply Elasticity and Real Estate Price Movements

Japan 1985-1990 Growth Rates for Residential Land



U.S. 2000-2005 Growth Rates for Housing



2000-2005 against the MSA-level unavailable land shares made available in the online data appendix to Saiz (2010). To construct MSA-level housing growth rates for the U.S., I use the annual housing price indices from the Federal Housing Finance Agency (FHFA) using all transactions (refinances, appraisals, and sales).[92] The FHFA indices are constructed using the Case-Shiller methodology but with equal weights applied to the transactions rather than the value weights typically applied to a repeat sales index. The growth rates are thus constructed in a comparable way between my local repeat appraisal indices for Japan and the FHFA indices.

The most striking feature of Figure C.1 is that the sign of the relationship between land unavailable for development and price growth is completely flipped across the two real estate booms. In the 2000s U.S., the Saiz-style measures of supply constraints deliver strong first stage estimates when used as instruments for city-level real estate values. That period is generally characterized as one in which a national positive credit supply shock passes through differentially to local real estate prices depending on the inelasticity of the local real estate supply curve. Hence, the correlation between the unavailable land share and housing price growth is positive in the 2000s U.S.

In contrast, for 1980s Japan the correlation between the unavailable land share and growth in residential land values is highly negative. In a simple supply and demand framework, this can be rationalized by a scenario where the size of local housing demand shocks during this period are highly negatively correlated with supply inelasticity. In other words, if geography is a good proxy for local real estate supply constraints in Japan, it must be the case that areas which saw an increase in demand were those that were the least supply constrained. This is contrary to the evidence in Section 3.2 that it was the areas which were most supply constrained due to the stringency of land use regulations which saw the greatest increase in demand during the boom. Overall, this suggests geography is an imperfect proxy for supply constraints in Japan during the 1980s.[93]

Figure C.2 displays similar relationships between property values and geographic constraints for the two boom episodes using the inverse supply elasticity measure. For Japan, the ordinal ranking of UEAs from most to least constrained is entirely preserved regardless of whether I use the unavailable land share or inverse supply elasticity measure obtained from estimating equation (C.1). The negative correlation between growth in land values and these geographic measures for Japan is also robust to replacing the residential land price growth with commercial and/or industrial land price growth.

D Details on the Spatial Sorting Model

D.1 Empirical Evidence of Labor Market Agglomeration

Figure D.1 plots the cumulative percentage growth in land values for each city against the cumulative percentage growth in a measure of employed population during the boom. In each panel, the y-axis and x-axis variables are plotted in z-scores, so that the slope of the linear trend line represents a cross-sectional correlation. Regardless of whether I use the population of employed residents (Panel A) or population (Panel B) to measure worker flows into a city during the boom,

[92] There were eight MSAs with supply inelasticity measures that I was unable to match to an FHFA index in the early 2000s. I obtain similar results when I instead use the FHFA files that restrict to home purchases or the expanded sample linked to county transaction records at the cost of decreased MSA coverage.

[93] Hosono et al. (2018) provide further evidence that this negative correlation between geographic constraints and land values holds for other time periods.

the cross-sectional correlation between the growth in land values and employed population growth is roughly 0.5.[94] This indicates that there was both a high degree of worker mobility during this time period and that the predictions of the agglomeration channel are consistent with the data.

D.2 Graphical Depiction of the Land Use Reform

For expositional purposes, suppose that land use regulations translate to a statutory maximum number $\overline{L}_j$ of workers who can locate in a city. This $\overline{L}_j$ can, in principle, vary across cities, as I show in Section 3.2 is indeed the case in Japan due to features of the pre-existing road network and pre-reform FAR limits in an area. Together these limits on building capacity imply that the real estate supply curve will be perfectly inelastic for levels of local employment at $L_j \geq \overline{L}_j$. The elasticity ε_j of the real estate supply curve can be summarized via:

$$\varepsilon(L_j) = \begin{cases} \varepsilon_j & \text{if } L_j < \overline{L}_j \\ 0 & \text{if } L_j \geq \overline{L}_j \end{cases} \tag{D.1}$$

In the regulated real estate market, the local supply inelasticity parameter γ_j captures the average of the elasticities across these two regions of the supply curve. Hence, a city with a higher threshold level of employment stipulated by land use laws will have a lower supply inelasticity parameter γ_j, since the elastic region of the supply curve will be larger under more lax land use restrictions.

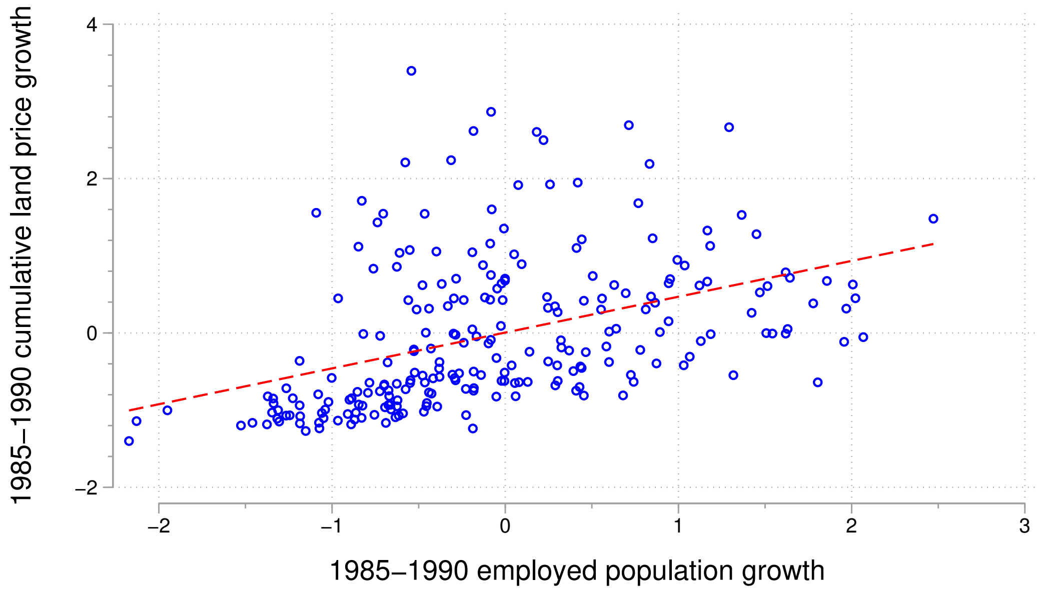
Against this backdrop, Figure D.2 graphically depicts local real estate markets when $\omega > 1-\alpha-\eta$ for an unconstrained city where prior to the reform $L_j < \overline{L}$, and a constrained city where prior to the reform $L_j = \overline{L}$. In the unconstrained city, the pre-reform regulations are non-binding in the sense that property demand is insufficient to saturate building capacity. In contrast, in the constrained city, wages and amenity values are high enough that more workers and firms wish to sort into the city than the pre-reform regulatory environment can support. In the absence of any agglomeration channel, the post-reform equilibrium in the real estate market would occur at the transparent circle and prices would fall due to the flattening of the supply curve. However, when the agglomeration channel is strong enough, real estate prices rise and the new equilibrium occurs at a point such as L^{**} which is contained within the new threshold $\overline{\overline{L}}$.[95]

[94] I computed these historical population flow measures using five-year historical Census data. If I instead use daytime working population as my worker flow measure, the cross-sectional correlation with land price growth remains high at 0.49.

[95] The figure abstracts from the evidence in Section 3.2 that, in general, the magnitude of the difference in pre-reform and post-reform thresholds $\overline{\overline{L}} - \overline{L}$ was larger in unconstrained cities. I account for this when I calibrate the model in Section 7.2.

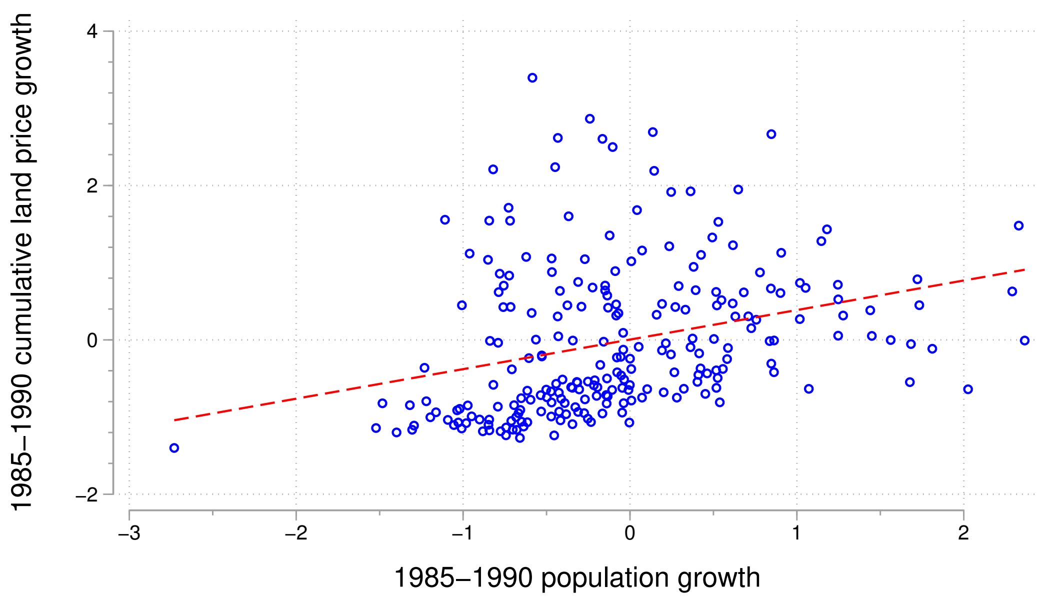
FIGURE D.1. City-level Price Growth and Worker Flows (1985 – 1990)

A. Employed Population Growth and Land Values



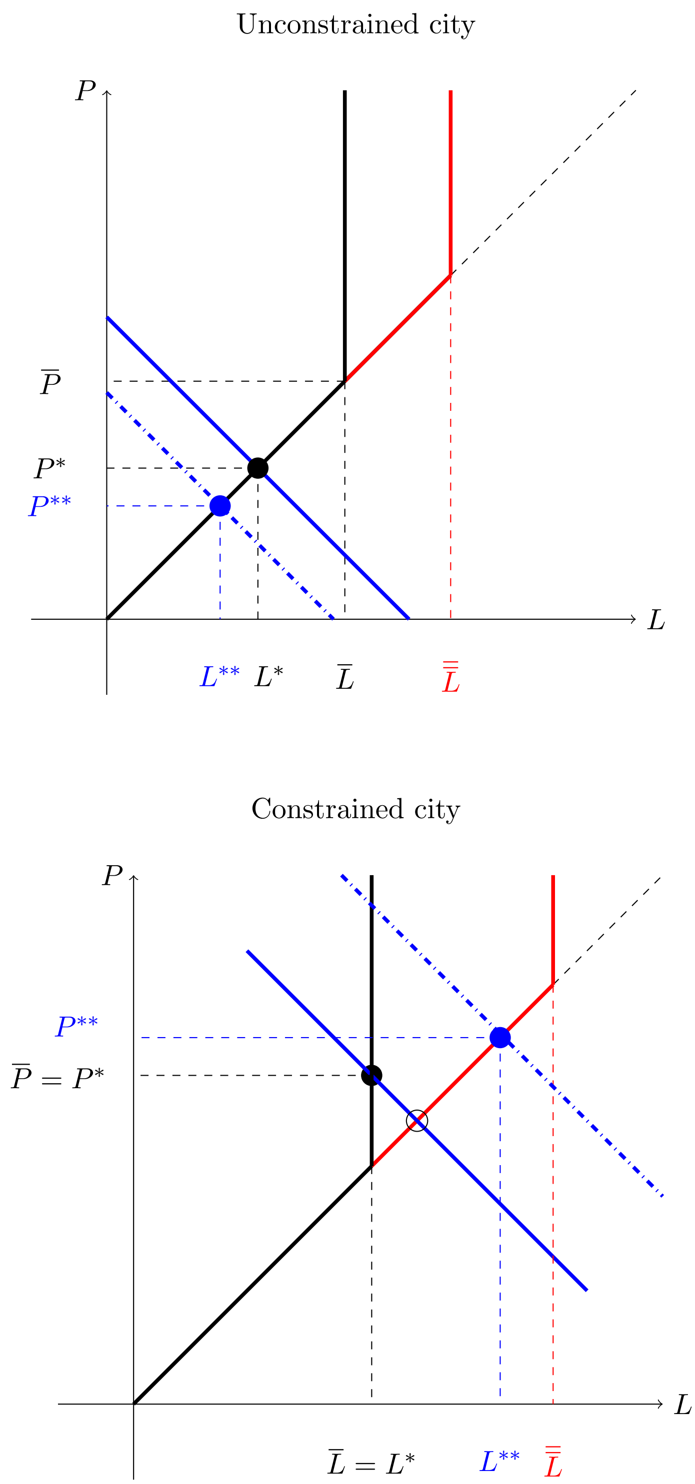
β = 0.46
N = 237
R–squared = 0.1763

B. Overall Population Growth and Land Values



β = 0.38
N = 237
R–squared = 0.0918

FIGURE D.2. Effects of Land Use Reform in Spatial Equilibrium



D.3 Derivations of Results

Condition for $\gamma \downarrow \implies P \uparrow$ (Static Model)

Let the pre-reform and post-reform variables in equation (7.5) be indexed by 0 and 1, respectively.

$$\Delta \log P_j = (\gamma_{j,1} + \xi) \cdot \log L_{j,1} - (\gamma_{j,0} + \xi) \cdot \log L_{j,0} > 0 \tag{D.2}$$

$$\iff \frac{\gamma_{j,1} + \xi}{\gamma_{j,0} + \xi} > \frac{\log L_{j,0}}{\log L_{j,1}} \iff \frac{\gamma_{j,1} + \omega/\beta(1-\eta)}{\gamma_{j,0} + \omega/\beta(1-\eta)} > \frac{1 - \alpha - \eta + \beta\gamma_{j,1}(1-\eta)}{1 - \alpha - \eta + \beta\gamma_{j,0}(1-\eta)} \tag{D.3}$$

$$\iff \gamma_{j,1} \cdot (1 - \alpha - \eta - \omega) > \gamma_{j,0} \cdot (1 - \alpha - \eta - \omega) \iff \omega > 1 - \alpha - \eta \tag{D.4}$$

where the last inequality follows from the fact that $\gamma_{0,j} > \gamma_{1,j}$ according to the assumed negative shock to real estate supply inelasticity.

Is this scenario empirically relevant? Kline & Moretti (2014) estimate a constant agglomeration elasticity with respect to city (or representative firm) size of approximately 0.4. Under the Cobb-Douglas production function assumed for local output in (7.1), the share of land in production is the residual of costs after accounting for capital and labor inputs. Standard estimates in the literature on estimating these factor shares are $\alpha = 0.65$ and $\eta = 0.25$, implying a residual share of 0.10 (Basu & Fernald 1997; Piketty 2014).[96] Thus the case where $\omega > 1 - \alpha - \eta$ and local real estate appreciates in response to the lifting of land use restrictions is empirically plausible.[97]

Local Steady State Equilibrium Conditions (Dynamic Model)

Assume $\theta R < 1$, so that the collateral constraint always binds for the representative firm in each city. Combining the labor sorting condition in equation (7.2) with the FOC from the firm's problem in equation (7.8), and the condition that the employed population is equal to the overall population, I obtain the following set of five equations in five unknowns:

$$\alpha L^{\alpha+\omega-1} \Big[f(K^R, K^N) \Big]^{\eta} T^{1-\alpha-\eta} = V P^{\beta} / Z \tag{D.5}$$

$$(1 - \theta R) \cdot \psi P = [1 - \theta(1-\delta)] \cdot f'_R - \theta L^{\omega} \cdot F'_{K^R} \tag{D.6}$$

$$\theta A(N) \cdot F'_{K^N} = [1 - \theta(1-\delta)] \cdot f'_N \tag{D.7}$$

$$\psi P K^R = D \tag{D.8}$$

$$P = \overline{P} \cdot L^{\omega\xi+\gamma} \cdot (K^R)^{\sigma} \tag{D.9}$$

where as in the main text $f(K^R, K^N)$ aggregates real estate and non-real estate capital inputs, and $F(K, L, T) = L^{\alpha} K^{\eta} T^{1-\alpha-\eta}$ is the firm production function without the productivity externality.

[96] Even under the more conservative estimate of 0.55 for the total labor share in Japan (compensation of employees divided by GDP) provided by Karabarbounis & Neiman (2014), the residual share accruing to land is 0.15.

[97] In Appendix D.1 I provide results from running the regression implied by (7.5) using my city-level price indices and the Census employment data. The coefficients are of the correct sign implied by the model for differences taken from 1980 to 1990, and the implied agglomeration elasticity ω is large. However, this regression overestimates the agglomeration elasticity by not taking into account local general equilibrium feedback effects on prices through firm investment responses.

The first equation defines the labor market equilibrium by setting the firm's marginal product of labor equal to the net wage. The second and third conditions describes, respectively, the firm's optimal real estate and non-real estate investment decision. The fourth condition indicates that the collateral constraint binds, so that each firm can only issue debt up to a fraction of the market value of real estate capital. The final condition is the price of real estate after taking into account the capitalization of the production externality into prices.

D.4 Model with Imperfect Mobility

I assumed that workers had perfect mobility in the baseline version of the spatial sorting model studied in Section 7.1. In this type of model, imposing perfect mobility is equivalent to assuming that workers have no intrinsic preference to locate in one city over another; workers simply sort into cities such that the marginal benefit derived from amenities and wages equals the marginal cost imposed by housing expenditures.

Following Hsieh & Moretti (2019) a straightforward way to relax this condition is to suppose that each worker i has a city-specific preference shock for city j. Then indirect utility of worker i living in city j is given by

$$V_{i,j} = \epsilon_{i,j} \cdot \frac{W_j Z_j}{P_j^{\beta}} \tag{D.10}$$

where $\epsilon_{i,j}$ is a random variable which captures how workers are particularly attached to cities for idiosyncratic reasons. To simplify the analysis, suppose these shocks are drawn jointly from an extreme value distribution

$$F(\epsilon_1, \ldots, \epsilon_N) = \exp\Big(- \sum_{j=1}^{N} \epsilon_j^{-\nu} \Big) \tag{D.11}$$

Here the parameter $1/\nu$ governs the strength of individual preferences over locations, or the long-run elasticity of local labor supply. In this case with imperfect mobility the labor market sorting condition for workers is:

$$W_j = \overline{V} \cdot \frac{P_j^{\beta} L_j^{1/\nu}}{Z_j} \tag{D.12}$$

where city-level wages are now pinned down by the average indirect utility level $\overline{V}$. As $\nu \to \infty$ workers' labor supply becomes perfectly elastic as in the perfect mobility scenario, whereas with finite ν the labor supply curve will be upward sloping.

Introducing imperfect mobility dampens the positive effect of the land use reform on local real estate prices by rendering the labor supply curve upward sloping. This translates to a "pile-up" problem in Figure D.2, whereby in certain cities where a large number of workers prefer to locate, there will be excess demand at the kink in the real estate supply curve determined by the pre-reform limit on local land use. Thus, in cities which are *ex ante* constrained by land use regulation, real estate prices will start from a higher level than in the perfect mobility case. When the land use reform relaxes constraints and shifts out the kink in the supply curve, prices fall in the absence of any agglomeration effect. Which effect dominates between the increased local productivity of land and the flattening of the supply curve depends on ν and the size of the shock to γ_j.

Without changing any other features of the model, with imperfect mobility equilibrium employment is now

$$L_j = \left(\frac{\alpha^{1-\eta}\eta^{\eta}}{R^{\eta}\overline{V}^{1-\eta}} T_j^{1-\alpha-\eta} Z_j^{1-\eta} \cdot \overline{P}_j^{-\beta(1-\eta)} \right)^{\frac{1}{1-\alpha-\eta+(1-\eta)(\beta\gamma_j+1/\nu)}} \tag{D.13}$$

Again, I impose full employment in equilibrium, or $L_j = N_j$. Consider a one-time permanently negative shock to the average supply inelasticity parameter γ_j due to deregulation. Adopting the same notation as in Appendix D.3, local real estate prices will rise in response to this shock whenever the following condition is satisfied:

$$\Delta \log P_j = (\gamma_{j,1} + \xi) \cdot \log L_{j,1} - (\gamma_{j,0} + \xi) \cdot \log L_{j,0} > 0 \tag{D.14}$$

$$\iff \frac{\gamma_{j,1} + \xi}{\gamma_{j,0} + \xi} > \frac{\log L_0}{\log L_1} \iff \frac{\gamma_{j,1} + \omega/\beta(1-\eta)}{\gamma_{j,0} + \omega/\beta(1-\eta)} > \frac{1-\alpha-\eta+(1-\eta)(\beta\gamma_{j,1}+1/\nu)}{1-\alpha-\eta+(1-\eta)(\beta\gamma_{j,0}+1/\nu)} \tag{D.15}$$

$$\iff \gamma_{j,1} \cdot \Big(1-\alpha-\eta+(1-\eta)/\nu\Big) > \gamma_{j,0} \cdot \Big(1-\alpha-\eta+(1-\eta)/\nu\Big) \tag{D.16}$$

$$\iff \omega > 1-\alpha-\eta+(1-\eta)/\nu \tag{D.17}$$

where the last inequality follows from the fact that $\gamma_{0,j} > \gamma_{1,j}$ according to the assumed negative shock to real estate supply inelasticity.

With imperfect mobility, the condition in (D.4) such that local real estate prices rise in response to the relaxation of land use law becomes less likely to be satisfied. This is because the agglomeration elasticity with respect to city size ω must now exceed the share of land in production $1-\alpha-\eta$, plus an additional term which captures the extent to which there was pent up demand for employment in a previously constrained city. In cases where many individuals have an intrinsic preference for living in constrained cities (i.e. when $1/\nu$ is high), it becomes less likely that the land use reform will have a positive effect on local prices because new demand from sorting will be less pronounced.

While allowing for imperfect mobility dampens the strength of the productivity spillover onto real estate prices, the case where $\Delta \log P_j > 0$ is still empirically relevant. Plausible estimates from the literature on agglomeration in the U.S. suggest $\omega = 0.4$ (Kline & Moretti 2014), a residual value of production accruing to land of $1-\alpha-\eta = 0.15$ (Karabarbounis & Neiman 2014), and $1/\nu = 0.3$ (Hornbeck & Moretti 2018). These estimates satisfy the condition in equation (D.17), since $\omega = 0.4 > 0.15 + 0.3 \cdot (0.7) = 0.36$. Further, the evidence on employed population flows in Appendix D.1 suggests that 1980s Japan is likely closer to the perfect mobility benchmark than the U.S., which renders agglomeration a more pronounced channel in the Japanese context.

D.5 Calibration Procedures

This appendix subsection expands on the calibration procedures described in Section 7.2.

Agglomeration and real estate investment elasticities. I set these parameters using two methods. In the first method, I solve the model for values of $\omega, \sigma < 1$ and then pick the combination which minimizes the distance between the reduced form estimates and the model-implied average responses to the shock. The static shock implied by ω is captured by the reduced form effect of the reform on corporate real estate values where the quantity of assets is fixed from the pre-reform period. The reduced form effect on real estate investment captures the dynamic effect of σ.

In the second method, I run the regression implied by equation (7.17) on city-level data between 1980 and 1990, where γ_j is defined according to the developer's problem in equation (7.4). I adopt the following procedures to aggregate up from floor-to-area ratio (FAR) limits on individual plots in my data to a city-level supply inelasticity:

1. I compute $\overline{H}_j$ as the total amount of allowed floor space in a locality. For each plot I compute the maximum allowed floor space as the statutory FAR limit times the plot area and then sum across plots located within the city planning area.

2. Total floor space H_j is not readily observable in each city-year. I compute an upper bound measure of H_j by taking the total floor space allowed at the plot-level according to the building coverage ratio (BCR) and then sum across plots located within the city planning area.

3. Finally, since I do not have complete coverage of all plots in an area and their land use restrictions, I scale up $\overline{H}_j$ and H_j by a factor x_j which is the ratio of total land area covered by my sample relative to the total land mass covering the city planning area. This is a valid approach under the assumption that my sample of plots is representative of the entire city planning area. The inelasticity parameter defined by these procedures is then:

$$\gamma_{j,t} = \frac{\overline{H}_{j,t} \cdot x_{j,t}}{\overline{H}_{j,t} \cdot x_{j,t} - H_{j,t-1} \cdot x_{j,t-1}} \tag{D.18}$$

Under both the minimum distance and regression methods, I obtain an agglomeration elasticity of roughly $\omega = 0.3$ and a real estate investment elasticity of roughly $\sigma = 0.6$. Table D.1 shows the full results from running the following regression analog of equation (7.17).

$$\Delta \log P_j = a \cdot \Delta\Big(\gamma_j \cdot \log L_j\Big) + \omega\xi \cdot \Delta \log L_j + \sigma \cdot \Delta \log K_j^R + \epsilon_j \tag{D.19}$$

where I scale γ_j by some global constant a such that the coefficient on the first term represents the relative strength of the standard supply channel relative to the other two channels. I back out ω by dividing the estimated regression coefficient on $\Delta \log L_j$ by $\xi = 1/\beta(1-\eta) \approx 9.5$. Compared to the static and dynamic effects of the reform arising from labor and firm demand for real estate, the data assign a minimal effect on non-residential prices to supply movements during the 1980s.

Amenities. I follow a large trade and urban literature in setting amenities equal to the residual between housing costs and wages in a city. My measure of wages is taxable income per taxpayer, which I obtained from historical municipal balance sheets from the Cabinet Office. Besides prices, the other parameter that pins down amenities is the share of housing costs (rent + mortgage payments + repairs) in total expenditures, which I calculate from Family Income and Expenditure Survey (FIES) data by taking a time series average share over 1981-1990 for each municipality. I find minimal heterogeneity in housing expenses in the cross-section and over time. I obtain a similar vector of amenities regardless of whether I use one of my repeat appraisal residential price indices or average annual housing costs to proxy for P_j in the residual condition $Z_j = P_j^{\beta}/W_j$.

Table D.1. Model-Implied Regression Using City-Level Data

Time period:	1980-90	1980-85	1985-90
Panel A: Employed population			
a	-0.007	0.003^{***}	-0.007^{*}
ω	0.284^{***}	0.110^{***}	0.567^{***}
σ	0.454^{***}	0.116^{***}	0.403^{***}
Adj. R^2	0.764	0.557	0.757
Panel B: Overall population			
a	-0.010^{*}	0.003^{***}	-0.009^{**}
ω	0.232^{***}	0.125^{***}	0.600^{***}
σ	0.664^{***}	0.144^{***}	0.737^{***}
Adj. R^2	0.694	0.524	0.644

Notes: Each column and panel combination represents the results from estimating the long-differences equation in (D.19) using data from two steady state years. Panel A uses local employed population, while Panel B uses the overall population residing in the area as the measure of equilibrium labor L_j. I compute local real estate capital growth $\Delta \log K_j^R$ as the asset-weighted average of real estate assets of firms with an HQ located in city code j. $^{***}p < 0.01, ^{**}p < 0.05, ^{*}p < 0.1$

D.6 Welfare Implications of the Land Use Deregulation

In this class of spatial sorting models, the worker's optimality condition expressed in terms of indirect utility allows for straightforward welfare calculations. Rearranging this condition in equation (7.2) of the baseline model and aggregating across localities yields an expression for aggregate steady state worker welfare:

$$\sum_j V = \sum_j \frac{Z_j \cdot W_j}{P_j^{\beta}} = \alpha \sum_j \frac{Z_j \cdot L_j^{\omega+\alpha-1} K_j^{\eta} T_j^{1-\alpha-\eta}}{\left[\overline{P}_j \cdot L_j^{\omega\xi+\gamma_j} \cdot \left(K_j^R\right)^{\sigma}\right]^{\beta}} \tag{D.20}$$

In the steady state where local supply inelasticity is governed by the stock of real estate H_j, differences across cities in the residual pricing parameter $\overline{P}_j$ reflect geographic differences in wages paid by the developer to construction workers and the labor demanded by the developer to meet local demand for properties:

$$\overline{P}_j \propto (1-\rho_j) \cdot W_j^D \cdot \left(L_j^D\right)^{-\rho_j} \tag{D.21}$$

Under the simplifying assumption that these parameters do not vary across localities, the change in worker welfare $\Delta \sum_j V$ across the pre-reform and post-reform steady states is proportional to changes in equilibrium labor and capital in (D.20). This assumption is equivalent to fixing H_j at some initial pre-reform value and assigning all cross-sectional variation in the post-reform inelasticity to differences in land use restrictions, as I do in (D.18) to map my instrument into a supply inelasticity. When I adopt these procedures, I find that aggregate worker welfare increases by 25% in the model with no binding collateral constraints, increases by 66% when the constraint always binds in the cross-section, and decreases by 13% in the version of the model where borrowing constraints bind for only some firms.

What explains these results? First, in the model with no binding collateral constraints, even though output contracts due to the shifting of workers towards low marginal productivity areas, welfare increases since prices fall by far more than wages in the ghost towns. Hence, workers who choose to live in the more numerous ghost towns have higher purchasing power. The fact that workers do not share in the economic profits earned by firms breaks the link between changes in aggregate output and aggregate welfare.[98] Second, welfare increases significantly in the version of the model where all firms face binding borrowing limits, because the land use reform generates large positive shocks to supply elasticity in some areas, which automatically mitigates both borrowing frictions and spatial misallocation of labor.

The story is more complicated in the empirically relevant version of my model where the collateral constraint binds for roughly two-thirds of firms. In my setting, firms at their borrowing limit also tend to be located in areas that were very exposed to the land use reform. In the model, such firms rely heavily on debt to make further real estate investments, which dramatically props up real estate prices. But welfare falls in the more exposed areas, as wages rise only modestly since firms can now rely on debt issued against their real estate holdings without hiring many workers. Thus, the shock to borrowing capacity induced by the land use reform leads to both credit and factor misallocation during the real estate boom.

E Accounting Definitions

E.1 Book to Market Conversions for Real Estate Assets

Since firm real estate values reported in the balance sheet data are measured at acquisition cost, I first convert these values to market value to estimate the causal effect of appreciations in market real estate on firm borrowing and investment behaviors. To perform this conversion from book to market values, I follow the methods used in Chaney et al. (2012) and Lian & Ma (2019), with a few adaptations to the Japanese data. The three steps to estimate market value are:

1. I compute the net book value of firm real estate as the sum of the net book value of buildings, land, and construction in progress. Net book value is equal to gross book value minus accumulated depreciation.

2. I estimate the average purchase year of firm real estate by comparing accumulated depreciation and gross book value. I assume linear depreciation and a 50-year depreciation horizon, so that in each year t the purchase year is $t - 50 \times ACCDEP/BUILDINGS$, where $ACCDEP$ is accumulated depreciation reported for buildings, and $BUILDINGS$ is the gross book value of buildings. I estimate this 2% annual depreciation rate using a dataset of commercial property transactions which report the age of the property.

[98] Future work will address the implications of profit sharing rules for spatial equilibrium outcomes. Allowing workers to choose between rentership and ownership with sticky rents would also help restore the link between changes in output and changes in worker welfare.

3. I estimate the market value in each year by inflating the net book value by the cumulative inflation in land values between the purchase year and the current year. I calculate cumulative inflation in land values using my city-level repeat appraisal indices for years after 1975 and the historical CPI series constructed from Bank of Japan data in Knoll et al. (2017) in all years prior to 1975.[99]

There are two key differences between the book to market conversion described above and the steps followed by other authors in the corporate finance literature using U.S. COMPUSTAT data. These differences reflect the fact that my data are sufficiently detailed that I can overcome some of the measurement issues inherent in previous book to market conversions of corporate real estate assets. One distinction is that in U.S. COMPUSTAT data accumulated depreciation on buildings is unavailable after 1993, which has led authors to index market real estate values after 1993 to a benchmark year and add in the year-on-year change in gross book real estate. In contrast, I observe itemized accumulated depreciation in all years in my data, so such an indexing procedure is unnecessary.

Other authors have relied on regional residential real estate price indices due to the lack of publicly available commercial real estate price indices with wide geographic coverage. Since the building values reported on firms' balance sheet pertain to commercial and industrial facilities and mostly exclude residential real estate holdings, inflating historical values using non-residential prices is a more appropriate route. I pool appraisals of land designated for commercial and industrial use to create local repeat appraisal indices using the methods described in Section 2. I then match firms' real estate assets to a local land price index using the corporate headquarter address, which I hand-collected from annual financial disclosure reports.

My estimate of 2% annual real estate depreciation yields conservative estimates of corporate borrowing and investment responses to fluctuations in market real estate values. In the book to market conversion described above, I estimate the average age of a firm's real estate assets using an *economic* measure of commercial property depreciation. An alternative calculation estimates an annual depreciation rate by comparing the acquisition cost of buildings to annual accounting depreciation for buildings in each firm-year and then averaging over the panel. Across firms, this results in a median depreciable life for buildings of approximately 25 years, which implies a 4% linear depreciation rate. Assuming a higher depreciation rate is equivalent to assuming that firms hold a portfolio of newer properties, and in the book to market conversion this would assign more weight to local land price indices in determining market real estate values. To account for these differences between economic and accounting depreciation for buildings, I show robustness of my results to both definitions in Appendix G.2. I explain the hedonic model and property transactions data used to estimate economic depreciation rates for commercial real estate in Appendix F.

E.2 Book to Market Conversions for Other Fixed Assets

In Section 5.1.2 I show that the market value of non-real estate fixed assets does not predict debt issuance. Here I provide details for the book to market conversion for these assets, which include the non-real estate components of PPE: machines, tools, and transportation vehicles. The steps are similar to the procedure used for real estate assets, except that I estimate linear depreciation rates

[99] While Knoll et al. (2017) construct an historical housing price index by splicing together series pertaining to agricultural and urban land across different time periods and subsamples of cities. I use the historical CPI to deflate pre-1975 real estate values due to the consistency of the data underlying the CPI series.

by comparing acquisition cost to annual accounting depreciation rather than using transactions data. The steps to estimate market value are:

1. I compute the net book value of machines, tools, and transportation vehicles as the gross book value of each component minus accumulated depreciation.

2. I estimate the average purchase year of each item by comparing accumulated depreciation to gross book value. To obtain an estimate of linear depreciation rates, for each item I compare the gross book value to accounting depreciation to get depreciable life.[100] I then take the median of this value for each item in my sample of firms and assign the depreciation rate consistent with that measure of depreciable life. This results in a median depreciable life of 15 years for machines ($\delta = 6.7\%$), 10 years for transportation ($\delta = 10\%$), and 11 years for tools ($\delta = 9.1\%$).

3. I inflate the net book value for each item by the cumulative inflation in the corporate goods price index (CGPI) between the purchase year and the current year.[101] For machines I use the "general machinery" CGPI, for tools I use the "precision instruments" series, and for transportation I use the "transportation and equipment" series.

E.3 Identifying Credit Constrained Firms

Here I provide details for the construction of measures of financing constraints used to document heterogeneous borrowing responses. For each firm, I compute the following four measures as of the year directly prior to the land use reforms (1982). The basic idea of each of these measures is that they proxy for external financing costs. All variables in italics refer to COMPUSTAT equivalent items. Brackets indicate shorthand names often used in the corporate finance literature.

1. Kaplan-Zingales (KZ) index based on Kaplan & Zingales (1997) and Lamont et al. (2001):

$$\begin{aligned}
&-1.001909\Big[\underbrace{(ib + dp)/laggedppent}_{\text{CF}}\Big] + 0.2826389\Big[\underbrace{(at + prcc \times csho - ceq - txdb)/at}_{\text{Q}}\Big] \\
&+ 3.139193\Big[\underbrace{(dltt + dlc)/(dltt + dlc + seq)}_{\text{TLTD}}\Big] - 39.3678\Big[\underbrace{(dvc + dvp)/laggedppent}_{\text{TDIV}}\Big] \\
&- 1.314759\Big[\underbrace{che/laggedppent}_{\text{CASH}}\Big] \qquad \text{(E.1)}
\end{aligned}$$

where CF is a measure of cash flow, Q is Tobin's Q, TLTD is a measure of total long-term debt, TDIV is total dividends, and CASH is cash and short-term investments.

[100] To account for bonus depreciation of certain types of physical capital (e.g. airplanes) I right-censor the ratio at 1. Unfortunately, bonus depreciation claims are not available in the balance sheet data prior to 2000.

[101] I use the version of the index which takes an index-weighted average across the domestic, export, and import price indices to take input tradability into account. I obtain similar results, not shown here, using instead the domestic CGPI to conduct the book to market conversion. All indices are chain-weighted Laspeyres. The base 2000 CGPI can be found at https://www.boj.or.jp/en/statistics/pi/cgpi_2000/index.htm/.

2. Cleary (1999) index based on the construction in Hennessy & Whited (2007):

$$
\begin{aligned}
&0.11905\Big[\underbrace{act/lct}_{\text{CURAT}}\Big] + 1.903670\Big[\underbrace{dltt/at}_{\text{TLTD}}\Big] - 0.00138\Big[\underbrace{(oibdp - dp)/(xint + dvc + dvp)}_{\text{COVER}}\Big] \\
&- 1.45618\Big[\underbrace{ib/oibdp}_{\text{IMARG}}\Big] - 2.03604\Big[\text{SG}\Big] + 0.04772\Big[\underbrace{(che + 0.5invt + 0.7rect - dlc)}_{\text{SLACK}}\Big] \qquad \text{(E.2)}
\end{aligned}
$$

where CURAT is the ratio of current assets to current liabilities, COVER is operating income divided by after-tax interest expenses plus dividend payments, IMARG is the ratio of net income to net sales, SG is own-firm sales growth, and SLACK is cash and short-term investments plus 0.5× inventory plus 0.7× accounts receivable less short-term loans divided by book PPE.

3. Whited-Wu (WW) index based on Whited & Wu (2006) and Hennessy & Whited (2007):

$$
\begin{aligned}
&- 0.091\Big[\underbrace{(ib + dp)/at}_{\text{CF}}\Big] - 0.062\Big[\underbrace{\mathbb{1}(dvc + dvp > 0)}_{\text{DIVPOS}}\Big] + 0.021\Big[\underbrace{dltt/at}_{\text{TLTD}}\Big] \\
&- 0.044\Big[\underbrace{\log(at)}_{\text{LNTA}}\Big] + 0.102\Big[\text{ISG}\Big] - 0.035\Big[\text{SG}\Big] \qquad \text{(E.3)}
\end{aligned}
$$

where DIVPOS refers to a dummy equal to unity if the firm issues dividends, LNTA is log of total book assets, and ISG refers to industry sales growth obtained from averaging across sales growth for all firms within the same three-digit industry code.

4. Hadlock & Pierce (2010) (HP) index, which is the following quadratic in firm age and size:

$$
-0.737Size + 0.043Size^2 - 0.040Age \qquad \text{(E.4)}
$$

where *Size* refers to the log of inflation-adjusted total assets (at), and *Age* is the number of years the firm has been listed as of 1982. In the original Hadlock-Pierce index, *Size* and *Age* are capped at 4.5 billion USD and 37 years, respectively. Given that firms in my sample are older than the typical sample of COMPUSTAT firms, I also test additional calibrations of (E.4) where I do not censor the *Age* and *Size* variables and using age measured from the time of establishment rather than the listing date. I find the results virtually unchanged for these alternative versions of the index, which supports the argument in Hadlock & Pierce (2010) that for the largest and oldest firms there is essentially no relation between financing constraints and these firm characteristics.

E.4 Zombie Index Construction

In Section 6.2, I adopt the measure of Caballero et al. (2008) to identify firms as recipients of zombie loans. To construct this index, I compute the minimum required interest payment $R^*_{i,t}$ for each firm-year as the sum of interest payments on short-term bank debt (BS), long-term (BL), and bonds outstanding ($Bonds$) under prime rates.

$$R^*_{i,t} = rs_{t-1} \cdot BS_{i,t-1} + \left(\frac{1}{5}\sum_{k=1}^{5} rl_{t-k}\right) \cdot BL_{i,t-1} + rcb_{5yrmin,t} \times Bonds_{i,t-1} \tag{E.5}$$

Here rs_t, rl_t, and $rcb_{5yrmin,t}$ refer to the average short-term prime rate in year t, average long-term prime rate in year t, and the minimum interest rate charged on convertible corporate bonds issued in the last five years before year t, respectively.[102] I scale the difference between the minimum interest payment and the observed payment by total borrowing in the preceding year $B_{i,t-1} = BS_{i,t-1} + BL_{i,t-1} + Bonds_{i,t-1}$ to obtain the interest gap:

$$g_{i,t} = \left(R_{i,t} - R^*_{i,t}\right)/B_{i,t-1} \tag{E.6}$$

The crisp zombie index is a dummy equal to unity if $g_{i,t} < 0$, indicating that the firm's payment falls short of the required payment at the most advantageous interest rates. To check robustness of my results, I also compute a fuzzy version of the index which is allowed to vary continuously on [0,1] for values of $g_{i,t}$ in the open intervals (0 bps,50 bps) or (-25 bps,75 bps).[103]

Figure E.1 confirms the time series trends in zombie lending documented in Caballero et al. (2008) using my sample of Japanese firms. The figure plots the asset-weighted zombie percentages for all firms and for firms sorted into broad sectors obtained from versions of the crisp and fuzzy zombie indices. There is a pronounced uptick in the incidence of zombie lending starting in the mid-1990s, and across all sectors the percentage of zombie firms peaks at the onset of the Asian Financial Crisis in 1997. The fraction of zombies in the crisis period was highest in the sector of the economy which held a large share of assets in real estate, which includes real estate and leasing, construction, and railroad companies.

E.5 Sufficient Statistics Method for Computing Input Shares

I adapt the sufficient statistics approach of Hayashi & Inoue (1991) to my data in order to recover the firm-level shares of each input in aggregate capital stock and construct a measure of physical capital investment that takes these shares into account.[104] The basic idea is that the input shares for each profit-maximizing firm are a function of the user costs, since the marginal rate of substitution in the capital aggregate between any two inputs will be equal to the ratio of the user costs.

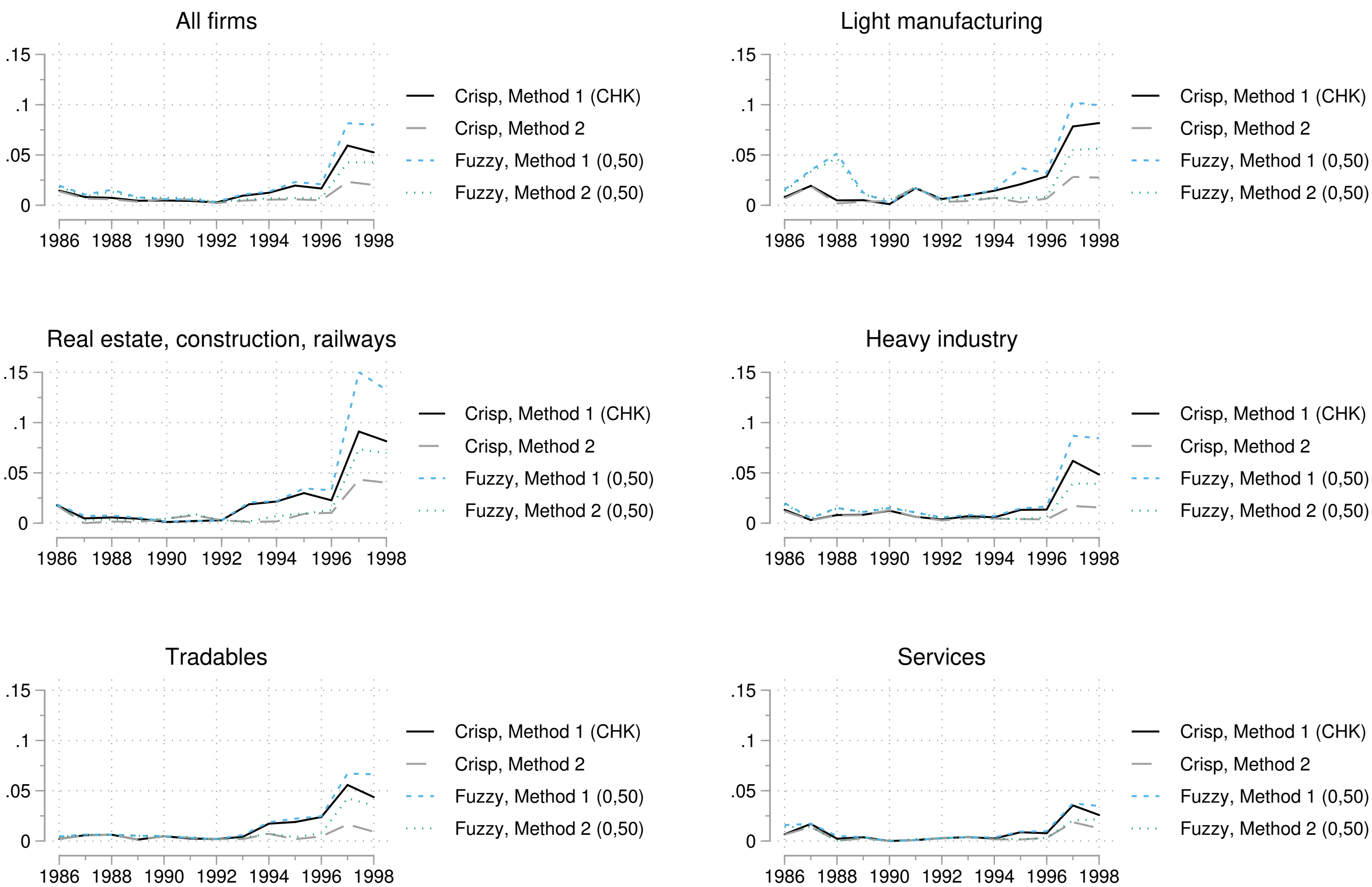
I now outline the procedure used to recover the shares. I suppress the firm index in the following equations for simplicity. The approach is valid under three straightforward assumptions: (i) firms are profit-maximizing, (ii) the profit function is homogeneous of degree one in the capital inputs,

[102]Presumably Caballero et al. (2008) take an average of five year lags to reduce the impact of the temporary spike in long-term prime rates between 1990 and 1991. Abandoning this averaging produces an overall lower incidence of zombies after 1991 but does not qualitatively change my results. I refer to the zombie indices replacing the five-year average rate with rl_{t-1} as Method 2.

[103]For more discussion on the zombie index construction see Section B and the Online Appendix of Caballero et al. (2008). Historical short-term and long-term prime lending rates for principal banks were obtained from the Bank of Japan and can be found at `http://www.boj.or.jp/en/statistics/dl/loan/prime/index.htm/`.

[104]I am able to simplify a number of steps in the original Hayashi & Inoue (1991) algorithm due to the availability of additional accounting variables in my data. Other than these adjustments, I exclude inventories from my definition of aggregate physical capital investment to better map to the firm's problem in my model in Section 7.

FIGURE E.1. Asset-weighted Zombie Percentages by Sector



Notes: This figure plots the time series of asset-weighted zombie percentages using variations on the index measure defined by equations (E.5) and (E.6) and following Caballero et al. (2008). Crisp refers to a binary version of the index equal to 1 for firm-years with a negative interest gap. Fuzzy refers to a version of the index which is equal to $(d_2 - g)/(d_2 - d_1)$ for interest gap values on the closed interval $(d_1, d_2) = (0 \text{ bps}, 50 \text{ bps})$. Method 2 replaces the 5-year lagged average of the long-term prime rate with the one-year lagged rate rl_{t-1}. Light manufacturing firms include those engaged in non-industrial manufacturing. Heavy industry firms include those engaged in chemical manufacturing, oil and metal refinery, metal product manufacturing, and general machinery. Tradables includes wholesale and retail firms, while services includes non-transportation services firms.

and (iii) there is a capital aggregator $f(K)$ which is homogeneous of degree one in physical capital goods k_i. Taking a first-order Taylor expansion of $f(\cdot)$ around zero and applying Euler's theorem, one can show that

$$\frac{f(K_{t+1}) - f(K_t)}{f(K_{t+1})} \approx \sum_{i=1}^{n} \frac{c_{i,t} \cdot (k_{i,t+1} - k_{i,t})}{\sum_{j=1}^{n} c_{j,t} \cdot k_{j,t+1}} \equiv \chi_{t+1} \tag{E.7}$$

where $c_{i,t}$ are the user costs of each capital input i, which can be expressed as a function of observable parameters:

$$c_{i,t} = \left[1 - (1 - \delta_i) \cdot \mathbb{E}_t\left(\theta^R_{i,t,t+1}\right)\right] \cdot \frac{(1 - z_{i,t}) \cdot Pk_{i,t}}{(1 - \tau_t) \cdot P_t} \tag{E.8}$$

$$\theta^R_{i,t,t+1} = \theta_{t,t+1} \cdot \frac{(1 - z_{i,t+1}) \cdot Pk_{i,t+1}}{(1 - z_{i,t}) \cdot Pk_{i,t}} \tag{E.9}$$

Equation (E.9) refers to the asset-specific real discount factor from t to $t + 1$, which is obtained by adjusting the nominal overall discount factor $\theta_{t,t+1}$ for asset-specific inflation (Pk_i) and changes to depreciation allowances for that asset type (z_i). I compute the firm's weighted average cost of capital (WACC) and set $\theta_{t,t+1} = 1/(1 + WACC_t)$. I take $\mathbb{E}_t(\theta^R_{i,t,t+1})$ to be the average value of $\theta^R_{i,t,t+1}$ over the panel. User costs in equation (E.8) reflect output prices net of the corporate income tax rate (τ).

I then recover the capital aggregator $f(K)$ as an index by setting a value for $f(K_{T^*})$ in benchmark year $T^* = 1977$, rearranging equation (E.7) and iterating forward. This recursive method can be defined by the following two equations:

$$f(K_{T^*+1}) = \frac{f(K_{T^*})}{1 + \chi_{T^*+1}} \tag{E.10}$$

$$f(K_{T^*}) = \sum_{i=1}^{n} (1 - \delta_i) \cdot k_{i,T^*} \tag{E.11}$$

where equation (E.11) says that the benchmark value for the capital index is the sum of the reproduction cost of all undepreciated physical capital goods.

Some additional structure is required to back out the shares of each input in the firm's aggregate capital stock. I suppose $f(K)$ takes the form:

$$f(K_t) = \prod_{i=1}^{n} k_{i,t}^{\omega_{i,t}} \quad \text{s.t.} \quad \sum_{i=1}^{n} \omega_i = 1 \tag{E.12}$$

which implies the aggregator is homogeneous of degree one, as assumed in the construction of $f(K)$. Along with these two conditions, profit maximization implies that the marginal rate of substitution in the capital aggregate between any two capital inputs equals the relative user cost:

$$\frac{\partial f(K_t)/\partial k_{i,t}}{\partial f(K_t)/\partial k_{j,t}} = \frac{\omega_{i,t} \cdot k_{j,t}}{\omega_{j,t} \cdot k_{i,t}} = \frac{c_{i,t}}{c_{j,t}} \tag{E.13}$$

Solving this system of equations for ω_i yields individual input shares in the overall capital stock. Excluding real estate and construction firms, I find the average shares of inputs in my sample of firms over 1977-1995 are 0.28 for buildings, 0.11 for land, 0.03 for structures, 0.14 for machines, 0.03 for tools, and 0.41 for transportation. Therefore, the share of real estate (buildings + land) in the average firm's aggregate capital stock is 0.39, or 0.42 if structures are included.

I use the following data sources to form the aggregator $f(\cdot)$ from the six physical capital inputs in the balance sheet data. These inputs are land, non-residential buildings, structures (e.g. a loading dock), tools, machines, and transportation vehicles.

- **Depreciation rates:** I compute accounting depreciation rates δ_i by comparing accumulated depreciation to gross book value, as described in Appendix E.2.

- **Output prices:** For non-service sector firms (76% of my sample) I assign output prices P_t based on the component of the corporate goods price index (CGPI) that matches each firm's industry classification. For service sector firms, I use the relevant component of the CPI (e.g. I assign the public transportation CPI series to railway firms).

- **Input prices:** I assign input prices $Pk_{i,t}$ the "general machinery" CGPI for machines, the "precision instruments" series for tools, and the "transportation and equipment" series for transportation vehicles. For structures I use the overall Construction Cost Deflator from MLIT pertaining to private construction projects. To be consistent with the rest of the paper, I match firms based on 1980 HQ location to one of my local non-residential land price indices.

- **Corporate income tax rates:** the effective corporate income tax rate τ_t reflects the combination of a national income tax rate u_t and a local enterprise tax rate v_t which varies by firm location. Since local enterprise taxes paid in t are deductible from income in $t+1$, the effective corporate income tax rate is

$$\tau_t = \frac{(u_t + v_t)(1 + r_t)}{(1 + r_t + v_t)} \tag{E.14}$$

  where r_t is a short-term nominal interest rate proxied by the three month T-bill rate. To simplify the data collection, I impute u_t and v_t as the average tax rates at the firm level by taking the ratio of national and local taxes paid to taxable income.

- **Tax savings from depreciation:** I compute $z_{i,t}$ as the EPV of tax savings per dollar of investment in capital good i using the formula:

$$z_{i,t} = \sum_{j=1}^{y_i} \frac{D_i(j-1,t)}{(1+r)^{j-1}} \tag{E.15}$$

  where y_i refers to the depreciable life of the asset for tax purposes, and r is the short-term nominal interest rate. I use the formula for tax savings from depreciation $D_i(x,t)$ as a function of asset age x from Hayashi (1990) and Hayashi & Inoue (1991). $D_i(x,t)$ takes into account the fact that firms may claim bonus depreciation in addition to normal depreciation. Note this is a formula for the marginal rate of tax savings per dollar of new investment in capital good i. I set y_i to 34 for buildings, 28 for structures, and 10 years for machines, tools, and transportation to match values reported in the National Wealth Survey for these assets.[105]

[105] I obtain similar results when I instead set y_i to be the depreciable life implied by the linear accounting depreciation rates computed in Appendix E.2.

- **Conversion to real capital inputs:** I use the perpetual inventory method to recover real capital inputs. This involves iterating on the investment law of motion for each input:

$$Pk_{i,t} \cdot k_{i,t+1} = (1 - \delta_i) \cdot Pk_{i,t}k_{i,t} + NOMI_{i,t} \tag{E.16}$$

  where nominal investment $NOMI_{i,t}$ is the change in net book value of assets of type i plus accounting depreciation. To start the recursion, I convert assets from book to market value using the methods in Appendix E.1 and Appendix E.2 and set $Pk_{i,t}k_{i,t}$ to this market value in the benchmark year of 1977. I also truncate the investment series by setting $NOMI_{i,t}$ equal to the book value of assets i as of the end of the year prior to the benchmark year.

E.6 COMPUSTAT-Equivalent Variable Definitions

Table E.1 summarizes the construction of the main firm-level variables used in this paper and any COMPUSTAT equivalents. In general, a direct mapping to COMPUSTAT is not possible for variables which involve the decomposition of liabilities or assets by sources. On the assets side, this COMPUSTAT does not provide separate variables for the components of non-real estate assets. On the liabilities side, COMPUSTAT does not distinguish between bank debt and non-bank debt. See Cvijanović (2014) for details on the Capital IQ Debt Structure dataset which allows for a further decomposition of non-financial COMPUSTAT firms' liabilities.

Table E.1. Construction of Main Firm-Level Balance Sheet Variables

Variable	**Construction**	**Source**	**COMPUSTAT equivalent**
Net debt issuance	Δ total long-term loans + bond issuance	DBJ	Δ DLTT
Bond issuance	straight + convertible + subscription bond issues	DBJ	Not applicable
Real estate (RE)	buildings + land + construction in progress, see Appendix E.1 and Chaney et al. (2012)	DBJ, Pronexus eol, MLIT appraisals	Buildings (item No. 263) + Land and Improvements (item No. 260) + Construction in Progress (item No. 266)
Real estate investment	Δ net book RE + accounting depreciation for buildings	DBJ	Not applicable
Other fixed assets (OTHER)	transportation (vehicles + vessels) + tools + machines	DBJ	Machinery and Equipment (item No. 264)
Other fixed investment	Δ net book OTHER + accounting depreciation for transportation, tools, machines	DBJ	Not applicable
PPE	RE + vehicles + vessels + tools + machines + structures	DBJ	PPENT
CAPEX	Δ PPE + accounting depreciation for buildings, transportation, tools, machines, structures	DBJ	CAPX
EBITDA	operating income + depreciation & amortization	DBJ	EBITDA, or OIBD + DP
OCF (net cash receipts)	EBITDA + non-operating income + special items + sale of PPE - income taxes + deferred taxes or refunds + Δ taxes payable + Δ accounts payable - Δ accounts receivable, - Δ inventory + Δ unearned revenue - Δ prepaid expenses see Lian & Ma (2019)	DBJ	OANCF+XINT, or EBITDA + NOPI + SPI + SPPE - TAX - DTAX - Δ ATAX + Δ AP - Δ AR - Δ INV + Δ UR - Δ PX + OCFO
Cash	quick assets - accounts receivable	DBJ	CHE
Market to book ratio	market equity (close)/shareholders' equity	DBJ, Nikkei NEEDS	(PRCC × CSHO)/(AT - DLTT - DLC)
Q ratio	(total assets + market equity (close) - common equity - deferred taxes or refunds from prior period)/total assets	DBJ, Nikkei NEEDS	(DLTT+DLC+PRC × SHROUT)/AT, or (AT + PRCC × CSHO - CEQ - TXDB)/AT
ROA	(net income + interest expenses)/total assets	DBJ	(NI + XINT)/AT
Firm age	# years since min{listing year, incorporation}, see Cloyne et al. (2018)	DBJ, Pronexus eol	Not applicable
Interest coverage	EBITDA/interest expenses	DBJ	EBITDA/XINT
Short-term bank debt	Short-term loans from credit banks + city banks + trust banks + regional banks	DBJ, Nikkei NEEDS	Not applicable
Long-term bank debt	Long-term loans from credit banks + city banks + trust banks + regional banks	DBJ, Nikkei NEEDS	Not applicable
Long-term bank leverage	(Long-term loans from credit banks + city banks + trust banks + regional banks)/total assets	DBJ, Nikkei NEEDS	Not applicable
Total borrowing	long-term bank debt + short-term bank debt + bonds payable + commercial paper	DBJ, Nikkei NEEDS	≈ DLTT + DLC
Debt to equity ratio	total borrowing/shareholders' equity	DBJ, Nikkei NEEDS	≈ (DLTT + DLC)/(AT - DLTT - DLC)
Cost of equity	dividends/share price (close) + average dividend growth rate	DBJ, Nikkei NEEDS	$R^e = \frac{\text{DVC+DVP}}{\text{PRCC}} + \frac{1}{T}\sum_{t=1}^{T} \frac{\Delta(\text{DVC+DVP})}{L.(\text{DVC+DVP})}$
WACC	(market equity (close)/(debt + equity))× cost of equity + (interest expenses/(debt + equity)) × (1-τ), see Appendix E.3 and Appendix E.5	DBJ, Nikkei NEEDS	$\frac{\text{PRCC}\times\text{CSHO}}{\text{DLTT + DLC + (PRCC}\times\text{CSHO)}} \times R^e + \frac{\text{XINT}}{\text{DLTT + DLC + (PRCC}\times\text{CSHO)}} \times \frac{\text{NI}}{\text{NI+TAX}}$
Main creditor	Lender with largest share of outstanding loans conditional on loan share > 20%	DBJ, Nikkei NEEDS	Not applicable

F Estimating Real Estate Depreciation

In this appendix, I follow the methods of Yoshida (2016), who estimated building and property depreciation rates using an older vintage of the MLIT transactions data described in Appendix A.2. The building depreciation rate is a key input to the book to market conversion methods I apply to corporate real estate assets in this paper. Unfortunately, building age is not provided in the property appraisal data or in the securities filings for the vast majority of firms in my sample. To obtain commercial real estate depreciation rates, I use the complete set of MLIT transactions data (2005-2017) which provide building age for properties constructed in the postwar period.[106] In applying depreciation rates estimated from a relatively recent set of transactions to the historical firm real estate data, I assume that the relationship between age and transaction prices has not changed over time, conditional on a large set of observable property characteristics.

Following Epple et al. (2010), two main assumptions underlie the estimation of real estate depreciation. First, real estate production is a generalized CES function of building and land quantities. Second, property owners are assumed to maximize profits subject to paying shadow prices for structure and land. Under these assumptions one can show that the overall property depreciation rate is the building depreciation rate δ_a times the building value share $s_{t,a}$ in real estate production:

$$-\frac{\partial \log P_{t,a}}{\partial a} = \delta_a \cdot s_{t,a} \equiv \delta \tag{F.1}$$

where δ_a is a function of the age a of the building at time t, the production inputs (i.e. floor area and plot size), and any factors that augment the productivity of the inputs.

This motivates estimating hedonic regression models with the following translog form:

$$\begin{aligned}
&\log P_{i,j,t} = \alpha_0 + f(A,S,L,D) + \beta_1 \log S_i + \beta_2 (\log S_i)^2 \\
&+ \beta_3 \log L_i + \beta_4 (\log L_i)^2 + \beta_5 D_i + \beta_6 D_i^2 + \beta_7 D_i^3 \\
&+ \beta_8 \log S_i \times \log L_i + \beta_9 \log S_i \times D_i + \beta_{10} \log L_i \times D_i \\
&+ \psi X_{i,j,t} + \gamma_j + \delta_t + \epsilon_{i,j,t} \\
&f(A,S,L,D) = \alpha_1 A_i + \alpha_2 A_i \times \log S_i + \alpha_3 A_i \times \log L_i + \alpha_4 A_i \times \log D_i
\end{aligned} \tag{F.2}$$

where $P_{i,j,t}$ denotes the price of property i located in township j traded in time t, $\log S_i$ is log floor area, $\log L_i$ is log plot size, and D_i is distance to the nearest train station.[107] The function $f(A,S,L,D)$ captures how prices vary with building age A_i and interactions of age with building size, plot size, and distance. The vector $X_{i,j,t}$ includes a full set of indicators for city planning zone, building shape, buliding material, and whether the property is located on a private road. γ_j and δ_t

[106] Building age is left-censored at 1945 to prevent researchers from identifying the owners of unique and historical properties. This means the depreciation rates I estimate will not apply to properties older than 70 years, but this is older than 75% of firms in my sample.

[107] A township here refers to a smaller administrative unit than the concept of a city used in the rest of the paper. For properties in a large city, a township refers to a neighborhood within that city, while outside large cities, a township maps one-to-one to a city Census code used in the rest of the paper.

are a full set of location and quarter-year fixed effects, respectively.[108]

I also estimate versions of equation (F.2) where the function $f(A,S,L,D)$ is stepwise in age:

$$f(A,S,L,D) = \sum_g \Big[\alpha_{1,g}\mathbb{1}_g + \alpha_{2,g}\mathbb{1}_g \times \log S_i + \alpha_{3,g}\mathbb{1}_g \times \log L_i + \alpha_{4,g}\mathbb{1}_g \times D_i\Big] \tag{F.3}$$

The stepwise function allows me to parametrically estimate how the depreciation rate varies at different age groups g, which I create by taking five year intervals of age.[109] I start by estimating non-parametric polynomial versions of the relationship between price and age for different submarkets. Figure F.1. plots price relative to the price of a new property (of age equal to one year or less) as a function of building age. For commercial properties outside Tokyo, there is a roughly linear relationship between prices and building age. Overall, commercial and Tokyo properties tend to depreciate more slowly than non-Tokyo and residential properties, and beyond age 50 Tokyo residential properties begin to appreciate, perhaps reflecting historic value.

Table F.1. provides the linear depreciation rates implied by estimating the average marginal effect (AME) of age from the continuous hedonic model (odd columns) and the stepwise model (even columns). Consistent with the non-parametric results, residential and non-Tokyo properties depreciate more quickly. For commercial real estate outside Tokyo, the average annual depreciation rate is 1.9%, while within Tokyo commercial properties depreciate at an average rate of 1.1%. However, these differences in depreciation rates between the Tokyo and non-Tokyo markets are concentrated in properties younger than 5 years old, and the overall depreciation rate for all commercial properties is 1.8%. I therefore take $\delta = 2\%$ as my main estimate of economic real estate depreciation to perform the book to market conversion for firm real estate assets. As noted previously, this results in a median firm real estate age of 22 years, at which the stepwise function yields an estimated depreciation rate of 1.8% for Tokyo and 2% for non-Tokyo properties. Therefore, this book to market conversion is also internally consistent with the profile of depreciation rates over the lifespan of a commercial property.

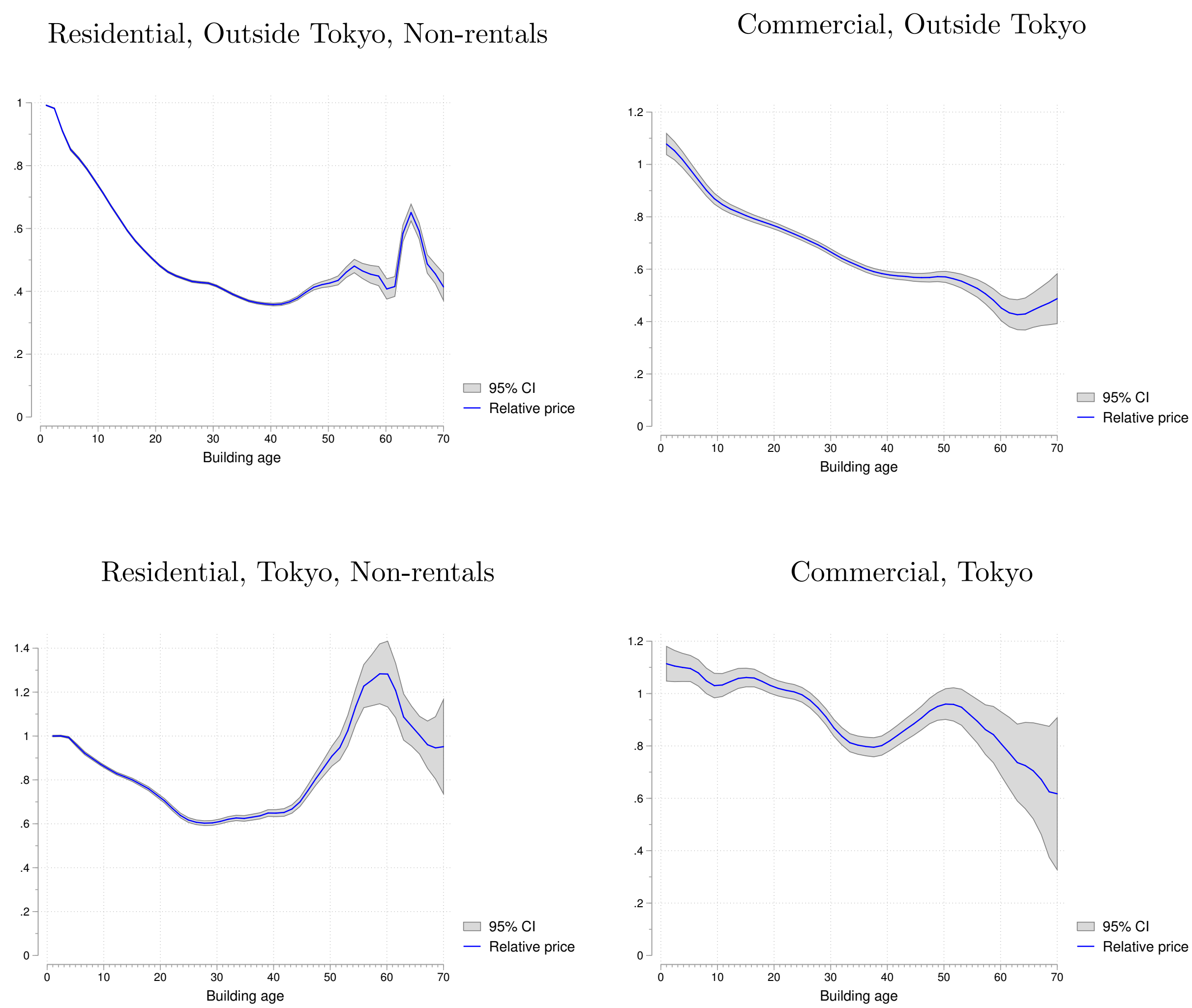
The estimates in Table F.1. capture the overall real estate depreciation rate δ given by equation (F.1). While there is no accounting depreciation associated with land, the economic value of a parcel of land might depreciate independently of the building for a variety of reasons, including the introduction of new commuting patterns or demographic changes. To isolate building depreciation, I compute $\delta_a = \delta / s_{t,a}$. Under the two assumptions on real estate production described above the building value ratio is equal to $\partial \log P_{t,a} / \partial \log S = s_{t,a}$. The ratio of the AME with respect to age divided by the AME with respect to floor area from estimating equation (F.2) thus isolates the building depreciation rate. For commercial properties, I estimate an average building value share of 0.64, implying an annual building depreciation rate of 2.9%.[110] In unreported results, I find effects of similar magnitude to my baseline estimates for firm borrowing and investment responses using this building-specific depreciation rate to value corporate real estate.

[108]To obtain a sample of properties comparable to corporate real estate holdings, I restrict to transactions involving the sale of bundles of land and building. Land-only transactions typically pertain to agricultural land and do not have an age, and building-only transactions pertain to condos or apartment units within a larger building complex.

[109]In unreported specifications, I obtain similar results when I use a $f(\cdot)$ that is stepwise in age but includes continuous interactions between age and three factors S, L, D.

[110]Remarkably, this matches the 36% share of land value in the aggregate housing stock reported by Davis & Heathcote (2007) for the U.S. over 1975-2006.

FIGURE F.1. Non-parametric Estimates of Prices by Building Age



Notes: Each panel in the figure plots the non-parametric polynomial functions of the transaction price relative to the price of a new property of age one year or less with respect to age. Outside Tokyo refers to properties outside Tokyo Prefecture, and commercial refers to properties specified as commercial or industrial use. Building age is defined as the transaction year minus the build year plus one.

Table F.1. Hedonic Estimates of Property Depreciation

	Outside Tokyo				Tokyo			
	Residential		Commercial		Residential		Commercial	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Building age	0.027***		0.019***		0.017***		0.011***	
	(0.000)		(0.000)		(0.000)		(0.001)	
𝟙(1-5 years)		0.051***		0.044***		0.032***		0.055***
		(0.000)		(0.004)		(0.001)		(0.007)
𝟙(6-10 years)		0.036***		0.032***		0.023***		0.035***
		(0.000)		(0.001)		(0.000)		(0.003)
𝟙(11-15 years)		0.030***		0.027***		0.021***		0.027***
		(0.000)		(0.001)		(0.000)		(0.001)
𝟙(16-20 years)		0.026***		0.023***		0.020***		0.022***
		(0.000)		(0.001)		(0.000)		(0.001)
𝟙(21-25 years)		0.023***		0.020***		0.017***		0.018***
		(0.000)		(0.000)		(0.000)		(0.001)
𝟙(26-30 years)		0.021***		0.018***		0.015***		0.016***
		(0.000)		(0.000)		(0.000)		(0.001)
𝟙(31-35 years)		0.019***		0.017***		0.014***		0.014***
		(0.000)		(0.000)		(0.000)		(0.001)
𝟙(36-40 years)		0.017***		0.016***		0.013***		0.013***
		(0.000)		(0.000)		(0.000)		(0.000)
𝟙(41-45 years)		0.016***		0.014***		0.012***		0.011***
		(0.000)		(0.000)		(0.000)		(0.001)
𝟙(46-50 years)		0.014***		0.013***		0.011***		0.011***
		(0.000)		(0.000)		(0.000)		(0.001)
Controls	✓	✓	✓	✓	✓	✓	✓	✓
Location FEs	✓	✓	✓	✓	✓	✓	✓	✓
N	734,841	734,841	54,846	54,846	87,893	87,893	6,137	6,137
Adj. R^2	0.723	0.732	0.775	0.777	0.773	0.783	0.848	0.852

Notes: Each column in the table provides estimates of annual property depreciation rates from the MLIT transaction data. Specifications in odd columns show the average marginal effect with respect to age from estimating equation (F.2), while even columns show the average marginal effect at different 5-year age bins from estimating the stepwise hedonic model in equation (F.3). Controls include the set of variables in the $X_{i,j,t}$ vector described in the text. Outside Tokyo refers to properties outside Tokyo Prefecture, and commercial refers to properties specified as commercial or industrial use. Building age is defined as the transaction year minus the build year plus one.

G Additional Results and Robustness

G.1 City-level Effects of Land Use Reform Exposure on Land Values

I estimate a city-level version of my first stage regression:

$$\log P_{j,t} = \gamma_j + \delta_t + \beta \cdot \left(\mathbf{T_j^{Pre}} \times Post_t\right) + \epsilon_{j,t} \tag{G.1}$$

where the vector $\mathbf{T_j^{Pre}}$ contains my measures of local land use reform exposure defined in Section 3, $P_{j,t}$ is a repeat appraisal price index for city j, γ_j is a full set of city code fixed effects, and δ_t are year fixed effects. This is a DD which compares the effects of the deregulation on local real estate prices across cities with different city planning landscapes. Table G.1 shows that the reform to FAR limits led to higher prices in the non-residential segment of local real estate markets. The reform to height limits was far more important for local housing prices, as FAR limits are rarely the binding restriction for plots in residential areas.

Table G.1. City-level Effects of Land Use Reform on Prices

	Non-residential				Residential			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
FAR limit share × Post	0.364^{***}		0.228^{**}	0.246^{**}	-0.049		-0.391^{***}	-0.475^{***}
	(0.112)		(0.107)	(0.105)	(0.071)		(0.056)	(0.056)
Median road width × Post		-0.014^{***}	-0.012^{***}	-0.011^{***}		-0.095^{***}	-0.140^{***}	-0.141^{***}
		(0.003)	(0.003)	(0.003)		(0.012)	(0.012)	(0.010)
City & time FEs	✓	✓	✓	✓	✓	✓	✓	✓
Sample time period	1975-95	1975-95	1975-95	1975-90	1975-95	1975-95	1975-95	1975-90
N	5,895	5,895	5,895	5,895	5,895	5,895	5,895	5,895
Adj. R^2	0.801	0.803	0.804	0.800	0.818	0.831	0.838	0.819
# Cities	281	281	281	281	281	281	281	281

Notes: The dependent variable in each regression is the log of the repeat appraisal price index for city j within a land use area (commercial/industrial or residential). Robust standard errors clustered at the city level. The coefficient on FAR limit share × Post represents the effect on post-reform prices of increasing the share of plots constrained by pre-existing FAR constraints from 0 to 1, while the coefficient on median road width × post represents the effect of increasing pre-reform road width by one meter. $^{***}p < 0.01, ^{**}p < 0.05, ^{*}p < 0.1$

G.2 Additional First Stage Estimates

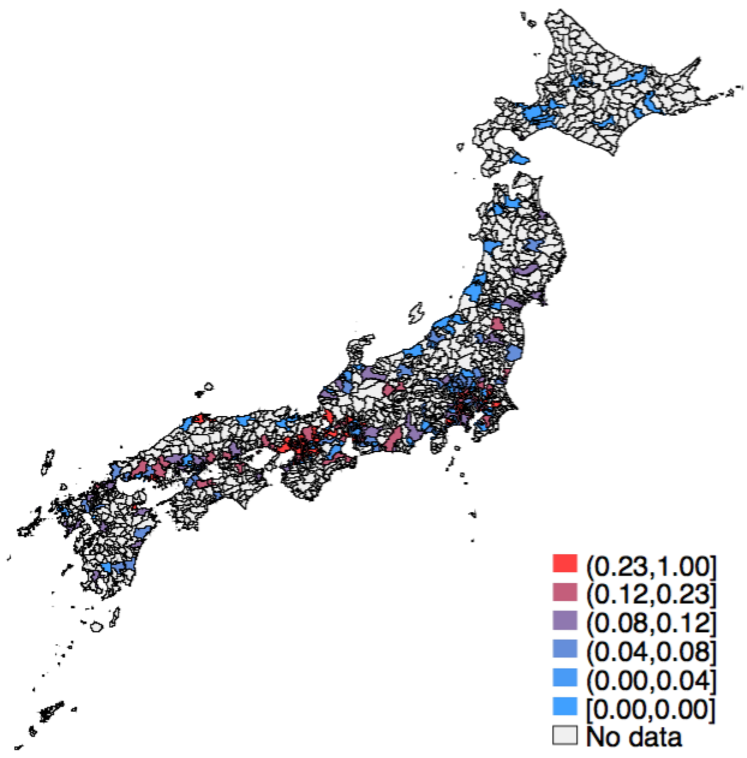
This appendix provides additional first stage results for regressions of firm real estate values on the land use reform exposure instruments introduced in Section 4.

Binned First Stage

Figure G.2 displays a binned version of the first stage, where the y-axis represents average post-reform firm real estate values, and the x-axis is the share of plots in the HQ city constrained by FAR limits in the pre-reform period. Each point in the figure represents a unique value for the

FIGURE G.1. Map of Non-residential Price Growth and FAR Constraints

A. Share of Constrained Plots in 1980 (FAR measure)



B. Cumulative Growth in Land Prices, 1985-90

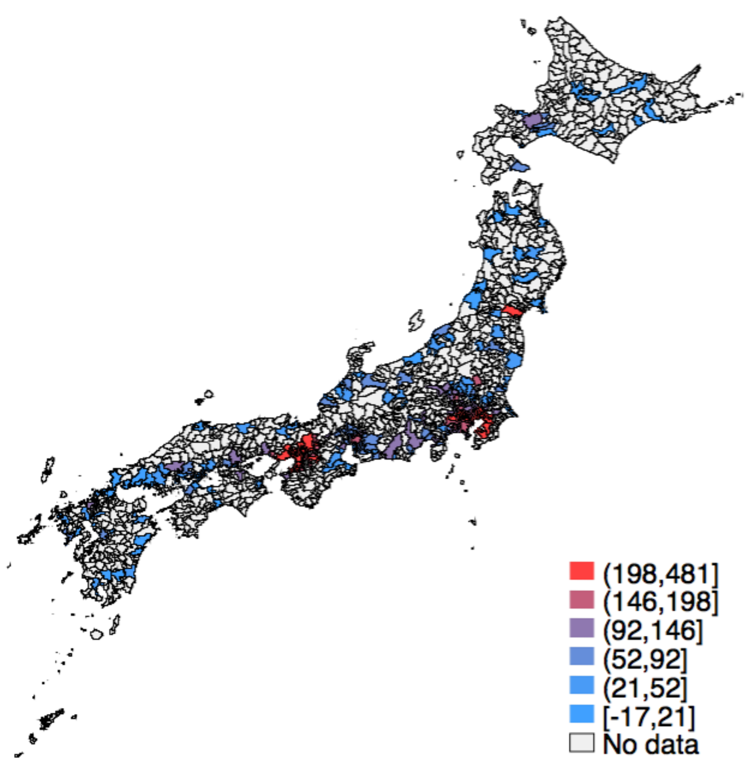
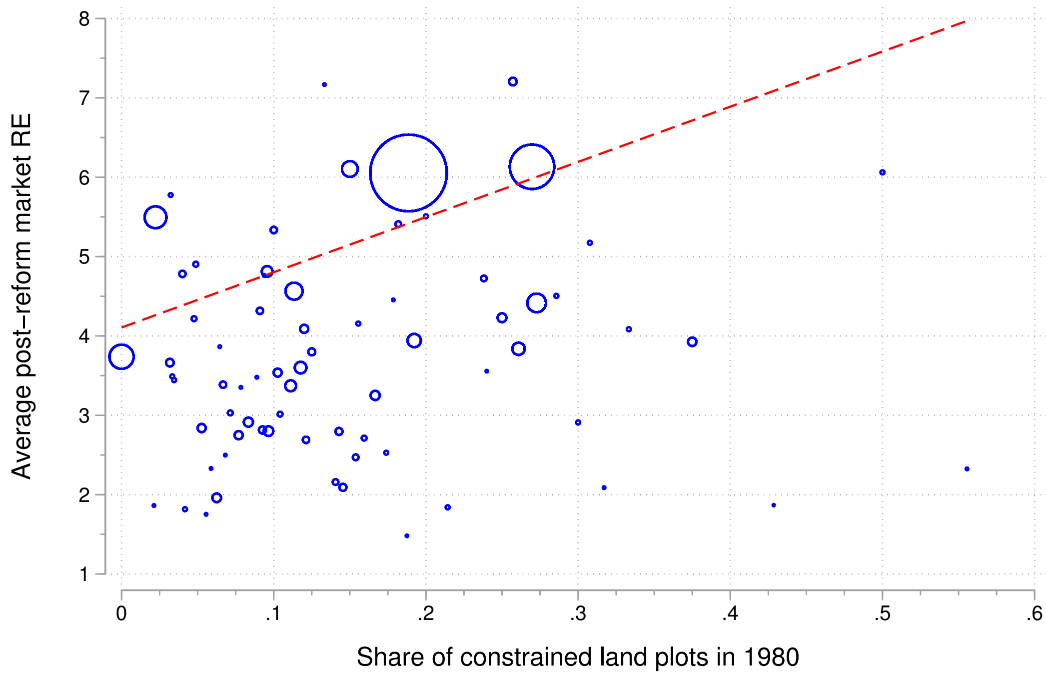


FIGURE G.2. Graphical First Stage (FAR Limit Share Measure)



Notes: This figure is based on equation (4.2), which estimates the first-stage effect of the land use reform exposure instruments on firm market real estate values. The x-axis is the city-level share of commercial and industrial land plots constrained by statutory FAR limits in 1980. The y-axis represents the average market real estate value for firms in the post-reform period (1983-1995). Each point on the graph represents the average post-reform value of real estate assets across firms at a unique value ($N = 73$ bins) for the share of constrained land plots in 1980 according to FAR limits. Each bin is weighted by the number of firms with a 1980 share of constrained plots located in that bin.

share of FAR constrained land plots in 1980, and the size of each point represents the number of firms located in that bin. Given the large number of firms concentrated in the Tokyo and Osaka metro areas, both of which have FAR constraint measures above the median, the firm-level first stage is essentially an employment-weighted version of the city-level first stage in Appendix G.1.

Using Alternative Depreciation Rates

Based on the estimates from commercial property transactions in Appendix F, I assume a linear depreciation rate for corporate buildings of $\delta = 2\%$ to generate my baseline results. Table G.2 provides first stage estimates assuming instead a constant depreciation rate of $\delta = 4\%$ based on the accounting method outlined in Appendix E.1. Applying a higher depreciation rate is equivalent to assuming a lower average age of real estate on firm balance sheets. The results are qualitatively similar to the baseline results in Table 2 for $\delta = 2\%$.

The main difference here is that the first stage F-test statistics are roughly halved by the doubling of the depreciation rate. However, the F-test statistics are still sufficiently high such that the worst case bias of the IV estimates relative to OLS is limited. For the estimates which use city-level

Table G.2. First Stage Estimates under Accounting Depreciation ($\delta = 4\%$)

	1977 – 1995		1977 – 1990	
	(1)	(2)	(3)	(4)
Average road width × Post	0.030**		0.050**	
	(2.24)		(2.57)	
Median road width × Post		0.047***		0.079***
		(2.75)		(3.34)
FAR limit share × Post	2.72***	3.51***	3.33***	4.68***
	(4.58)	(5.91)	(3.56)	(5.38)
Montiel Olea & Pflueger F-test	12.96	16.97	9.36	15.23
First stage F-test (cluster-robust)	10.54	18.72	6.35	14.64
First stage F-test (Cragg-Donald)	173.11	195.00	243.21	299.86
Sargan-Hansen J-test (p-value)	0.63	0.86	0.51	0.30
N	27,925	27,925	20,590	20,590
# Firms	1,488	1,488	1,488	1,488
# Cities	160	160	160	160
Adj. R^2	0.28	0.28	0.16	0.16

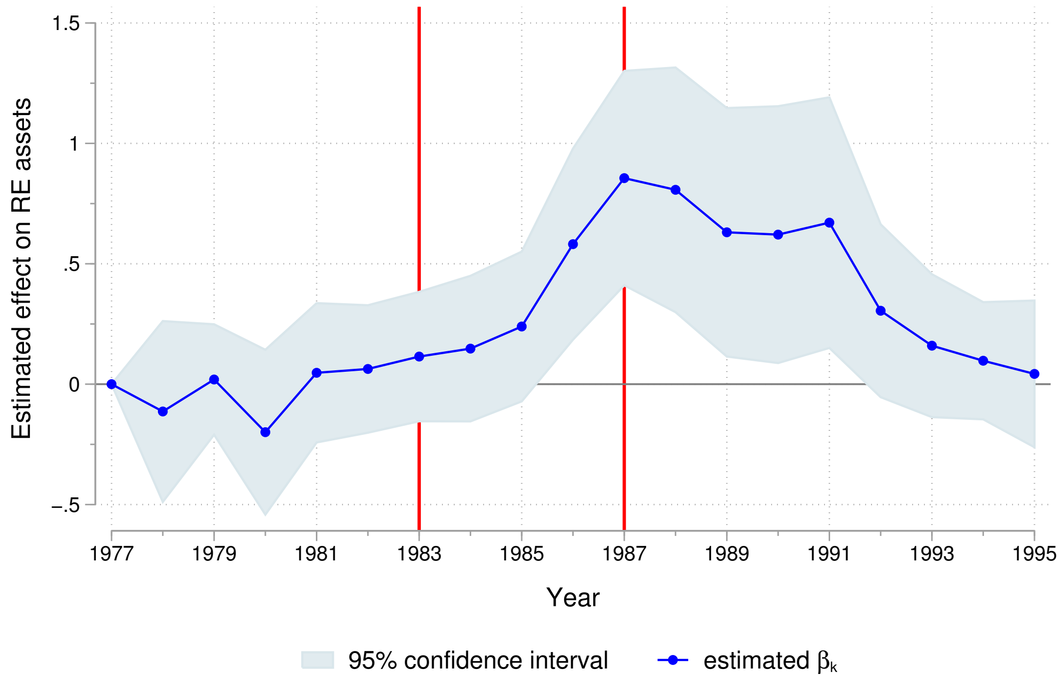
Notes: The dependent variable in each regression is the ratio of firm market real estate to lagged book assets. In the IV estimations, excluded instruments are 1980 average road width or 1980 median road width, and the 1980 share of plots constrained by FAR limits, each interacted with a post-reform dummy equal to unity in years after 1983. All regressions include firm and year fixed effects. The book to market conversion for real estate assets is conducted by combining the historical CPI series from Knoll et al. (2017) and the local repeat appraisal land price indices, assuming a building depreciation rate of 4%. t-statistics in parentheses obtained by clustering standard errors by city code. $^{***}p < 0.01, ^{**}p < 0.05, ^{*}p < 0.1$

median road width as an excluded instrument and 1977-1995 as the sample period, the Montiel Olea-Pflueger F-test for the excluded instruments, which is robust to clustering by city code and to heteroskedasticity, exceeds the thresholds for 5% worst case bias relative to OLS at the 5% confidence level. With the exception of the estimates in column (3) which use the average road width measure as an excluded instrument in the 1977-1990 period, the Montiel Olea-Pflueger F-test exceeds the thresholds for 10% worst case bias relative to OLS at the 5% confidence level.

Just-identified First Stage

My baseline IV specifications use an over-identified first stage with the share of FAR-constrained plots and median road width as instruments for firm real estate values. While including median road width as an instrument improves precision of the estimates by accounting for the fact that FAR limits can bind in areas with both wide and narrow roads, the FAR constraint measure drives most of the variation in corporate real estate prices in response to the land use deregulation. Figure G.3 plots the coefficients from a dynamic version of the just-identified first stage with the FAR constrained share as the lone instrument. Compared to the over-identified dynamic first stage in Figure 5, the just-identified first stage yields the same boom-bust dynamics but overall lower point

FIGURE G.3. Just-identified First Stage Regression (FAR Limit Share)



Notes: This figure is based on equation (4.4), which estimates an event study version of the first-stage effect of the share of plots *ex ante* constrained by FAR limits (in standard deviations) on the ratio of firm market real estate values to lagged book assets. Standard errors for partial effect estimates were obtained from clustering by city code. The regression includes firm and year fixed effects and a full set of year × industry code and year × Census region code dummies. Vertical red lines indicate the two years when provisions of the land use reforms were officially codified.

estimates for the effect of the land use reform on firm real estate assets.

G.3 Additional Exclusion Restriction Tests

In this appendix subsection I provide additional tests of the validity of my identifying assumption that there are no unobserved differences driving investment and borrowing among firms operating in areas more or less exposed to land use deregulation. Table G.3 demonstrates that firms with corporate HQs in more or less exposed areas are balanced on a wide array pre-reform observables, including measures of outstanding debt, interest coverage, assets, and employment. The exception is on HQ location, for which I find firms in more exposed areas are 7 p.p. more likely to be located in Tokyo or Osaka prefectures. For this reason, I include region-year interactions as controls in my main results tables.

One concern is that the land use deregulation might have made firms more profitable through channels orthogonal to the positive shock to real estate values, which would mean that firms' investment opportunities may have improved independently of the pricing shock. This would be the case if, for instance, the land use deregulation induced more upstream firms to locate in an area, creating more competition among upstream firms and thus lowering input costs for incumbent

Table G.3. Firm Balance on Pre-Reform Observables

	More exposed	Less exposed	Difference
Assets (100 billion JPY)	1.35	1.07	0.28
Employees	2,613	2,505	108
Firm age	52.35	50.34	2.02
RE firm	0.15	0.16	−0.01
Tokyo/Osaka HQ	0.72	0.65	0.07***
Avg. RE age	21.44	21.27	0.17
Number of creditors	18.32	17.90	0.42
Main bank loan share	0.31	0.32	−0.01
Interest coverage	8.71	12.07	−3.36
ROA	0.06	0.06	0.00
Market to book	3.18	2.60	0.58
PPE/assets	0.23	0.24	−0.01*
Short-term loans/assets	0.13	0.12	0.01
Long-term loans/assets	0.15	0.14	0.01
Bonds payable/assets	0.02	0.02	0.00
N	363	1,126	1,489

Notes: The table shows descriptive statistics for firms in my sample. All variables are measured as of the end of the benchmark pre-reform year 1980. PPE and debt variables are scaled by total book assets. Firm age refers to number of years since the listing date. RE firm is an indicator equal to unity if the firm is in the real estate and leasing, construction, or railway sectors. Tokyo/Osaka HQ is an indicator equal to unity if the firm HQ is located in Tokyo or Osaka prefectures. I use the 2% linear depreciation rate for commercial buildings assumed in the rest of the paper to compute average age of real estate assets. Main bank loan share is the proportion of loans provided by the creditor which accounts for the largest share of firm loans. Interest coverage is EBITDA divided by interest expenses. ROA is defined as net income + interest expenses relative to total book assets. Market to book is market capitalization relative to shareholder's equity. More (less) exposed refers to firms with an HQ in a location above (below) the median in exposure to the land use reforms (roughly the top quartile of the FAR constrained share). The difference column refers to the difference in means between the more exposed and less exposed subsamples. $^{***}p < 0.01, ^{**}p < 0.05, ^{*}p < 0.1$ for t-tests of the difference in means across the two groups.

Table G.4. Response of Firm Value to Land Use Reform Instruments

	1977-1995		1977-1990	
	(1)	(2)	(3)	(4)
FAR limit share × Post	0.158	−0.128	0.239	−0.090
	(0.166)	(0.095)	(0.214)	(0.107)
Median road width × Post	0.004	0.001	0.004	0.002
	(0.004)	(0.002)	(0.005)	(0.002)
Controls × year FEs		✓		✓
N	27,812	27,684	20,487	20,392
# Firms	1,486	1,478	1,486	1,478
# Cities	158	158	158	158
Adj. R^2	0.43	0.73	0.48	0.76

Notes: The dependent variable in each regression is the Q ratio, or the ratio of the market value of the firm (total assets + market equity - common equity - deferred tax payments relative to book assets). Excluded instruments are 1980 median road width and the 1980 share of plots constrained by FAR limits, each interacted with a post-reform dummy equal to unity in years after 1983. All regressions include firm and year fixed effects. Columns (2) and (4) include controls for industry codes, region fixed effects, size, and age bin dummies interacted with year fixed effects. Standard errors in parentheses are clustered by city code. $^{***}p < 0.01, ^{**}p < 0.05, ^{*}p < 0.1$.

downstream firms in my sample. To test this idea, I show in Table G.4 that the Q ratio (total market value of the firm relative to total book assets), a common measure for Tobin's Q or the value of a company, does not change in the cross-section of firms in response to each of my instruments. This holds true both when I include the bust years and when I restrict to the boom period. These results suggest that while the land use deregulation inflated the value of real estate assets on exposed firms' balance sheets, it did not render such firms more valuable to potential investors.

G.4 Alternative Book to Market Conversion Methods

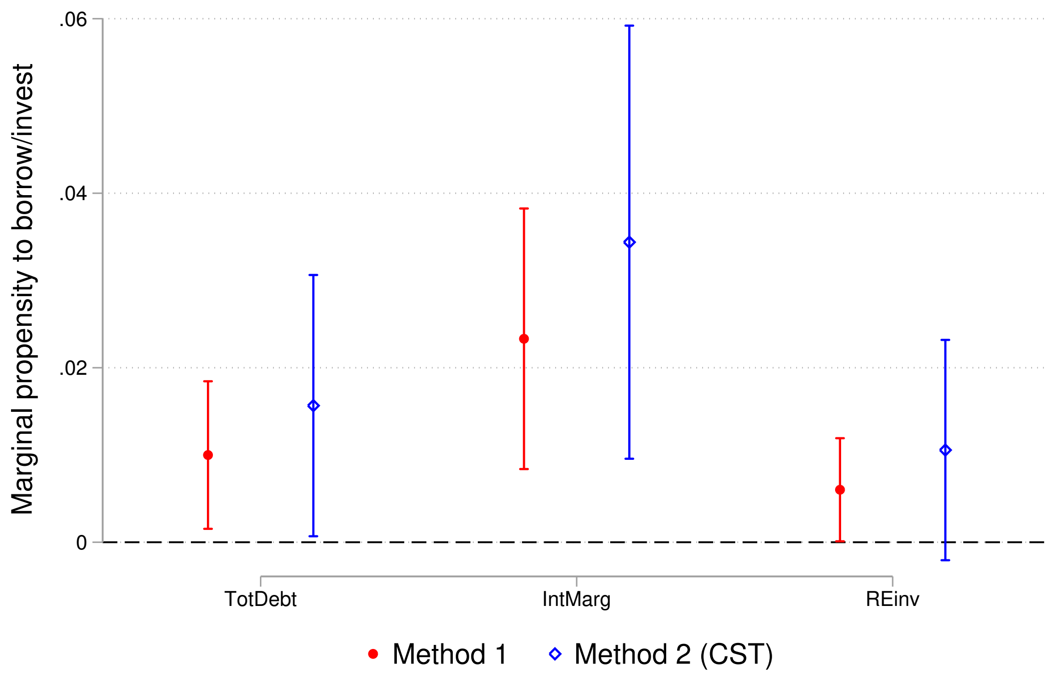
Traditional Estimates using Benchmark Year

The methods I describe in Appendix E.1 for converting corporate real estate assets from historical book to market value differ slightly from those of Chaney et al. (2012) [CST]. The difference stems from the fact that accumulated depreciation on buildings is unavailable in COMPUSTAT starting in 1993, which leads those authors to benchmark their estimates of market real estate values using 1993 as a benchmark year. I obtain similar results for long-term borrowing and real estate investment outcomes when I match the CST conversion methods.

In particular, I compute the market value of real estate assets of firm i as of the benchmark year $\tau = 1977$ by comparing accumulated depreciation to acquisition cost. I then apply the following accounting law of motion to generate a series of market real estate values in subsequent years:

$$RE^j_{i,\tau+1} = (1-\delta) \times RE^j_{i,\tau} \times P^j_{i,\tau+1}/P^j_{i,\tau} + \Delta GBRE_{i,\tau,\tau+1} \tag{G.2}$$

FIGURE G.4. Sensitivity to Book to Market Benchmarking



Notes: Each point estimate obtained via IV estimation of (4.1) and (4.2), with 95% confidence intervals in brackets. TotDebt refers to net debt issues, IntMarg refers to intensive margin debt issues, and REinv is real estate investment. Method 1 refers to estimates obtained using my preferred book to market conversion in Appendix E.1, while Method 2 refers to estimates obtained using the law of motion in (G.2) from Chaney et al. (2012).

where $\Delta GBRE$ is the year-on-year change in gross book real estate values, and δ is the linear rate of depreciation for buildings. Beyond the benchmark year, the market real estate series in (G.2) will differ more from the series obtained by separately inflating assets each year when the purchases included in $\Delta GBRE$ consist of older buildings. In my setting, applying the approximation based on CST leads to notably larger and more imprecisely estimated yen-for-yen estimates of borrowing and investment responses. This is because iterating on market value from a benchmark year eliminates the portion of cross-sectional volatility in firm real estate values that originates from some firms investing in new buildings, and others investing in old ones.

Historical Housing Price Index for Old Buildings

In my baseline estimates, I follow earlier work in using historical CPI to compute cumulative inflation for corporate real estate values in years prior to 1975. Knoll et al. (2017) also provide an historical aggregate housing price index (HPI) for Japan dating back to 1913.[111] The strength of the first stage falls when I use the HPI; for the over-identified first stage the Cragg-Donald F-stat declines from 312 to 42.

[111]While CPI are constructed from historical BOJ statistics, the historical land price index is an amalgam of series from several different sources, which capture prices from different geographic segments of the real estate market. Both indices are geometric average price indices.

FIGURE G.5. Historical Housing Price Index and CPI

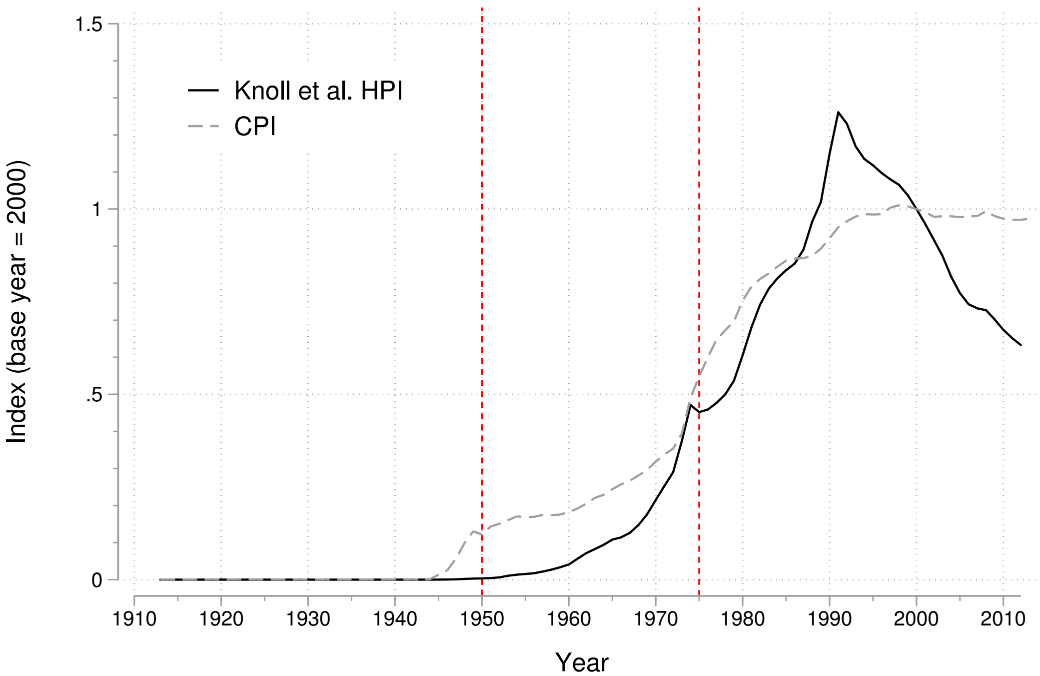


Figure G.5 illustrates why the relevance of the instruments is sensitive to the choice of an historical price index. CPI grows gradually in the postwar period, while the HPI starts skyrocketing in 1955. The discontinuities at 1955 and 1974 originate from changes in the coverage of local real estate markets in the appraisal surveys. In the book to market conversion, the explosive growth in the HPI in the pre-1975 period renders any growth in local non-residential prices in the post-1975 period relatively unimportant. This weakens the link between market real estate values and land use deregulation in cases where the firm's real estate portfolio dates back prior to 1975. Consistent with this logic, using a high building depreciation rate (e.g. $\delta = 4\%$) makes the choice of historical indices less consequential, as this implies corporate facilities will be on average much newer.

G.5 Robustness to Winsorizing

To assess the robustness of my estimates to outliers, Table G.5 compares my baseline estimates of firm borrowing and investment responses to the corresponding median regression estimates of (4.1) in Panel A. I also use the quantile IV (QIV) estimator of Chernozhukov et al. (2015) for a cross-sectional version of my baseline specifications. Evaluated at the median, this estimator is an IV counterpart to the least absolute deviations (LAD) regression used in Gan (2007a) and Lian & Ma (2019). In particular, Panel B of the table shows QIV estimates from the following cross-sectional specification:

$$Y^j_{i,POST} = \alpha + \beta \cdot RE^j_{i,POST} + \gamma \cdot \mathbf{X^j_i} + u^j_i \tag{G.3}$$

$$RE^j_{i,POST} = \mu + \psi \cdot \mathbf{T^{Pre}_j} + \gamma \cdot \mathbf{X^j_i} + v^j_i \tag{G.4}$$

where $Y_{i,POST}^{j}$ is an average outcome over the post-reform period (1983-1995) normalized by pre-reform physical assets in 1980, and $RE_{i,POST}^{j}$ is average market real estate assets over the post-reform period, also normalized by pre-reform physical assets. The vector $\mathbf{T_j^{Pre}}$ contains my two measures of land use reform exposure based on firm i's HQ location. Industry, region, size, and age bin fixed effects are included in the vector $\mathbf{X_i^j}$.

Table G.5. Baseline Results vs. Least Absolute Deviations

Panel A: Panel regressions	Debt issues (int. margin)			Real estate investment		
	(1)	(2)	(3)	(4)	(5)	(6)
Market RE	0.014***	0.013***	0.023***	0.016***	0.014**	0.006**
	(0.001)	(0.004)	(0.008)	(0.003)	(0.006)	(0.003)
Estimation	OLS	LAD	IV	OLS	LAD	IV
N	12,474	12,474	12,403	27,947	27,947	27,890
# Firms	1,459	1,459	1,417	1,489	1,489	1,486
# Cities	157	157	154	160	160	158

Panel B: Cross-sectional regressions	Debt issues				Real estate investment			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Market RE	0.023***	0.007***	0.015***	0.003*	0.020***	0.015***	0.007**	0.010***
	(0.008)	(0.001)	(0.004)	(0.002)	(0.003)	(0.001)	(0.003)	(0.001)
Estimation	OLS	LAD	IV	QIV	OLS	LAD	IV	QIV
Controls	✓	✓	✓	✓	✓	✓	✓	✓
N	1,480	1,480	1,477	1,477	1,480	1,480	1,477	1,477
# Firms	1,480	1,480	1,477	1,477	1,480	1,480	1,477	1,477
# Cities	159	159	157	157	159	159	157	157

Notes: Panel A displays OLS, LAD, and IV estimates for the baseline panel specifications defined by (4.1) and (4.2), with standard errors clustered by HQ city in parentheses. Panel B displays OLS, LAD, IV, and QIV estimates from the cross-sectional regressions in (G.3) and (G.4), obtained using the median QIV estimator of Chernozhukov et al. (2015). For the cross-sectional regressions, non-parametric bootstrapped standard errors are in parentheses.

G.6 Other Outcome Variables

Table G.6. Corporate Bond Issuance Response to Increase in RE Values

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Market RE	0.002***	0.002***	0.002***	0.006***	0.006**	0.003	0.002
	(0.000)	(0.000)	(0.000)	(0.002)	(0.003)	(0.005)	(0.005)
Effect in standard deviations	0.04	0.04	0.04	0.13	0.13	0.06	0.04
Estimation	OLS	OLS	OLS	IV	IV	IV	IV
Main bank × year		✓	✓		✓	✓	✓
Industry & region × year		✓	✓			✓	✓
Size & age bin × year			✓				✓
First stage F-test (cluster-robust)	–	–	–	33.08	38.78	21.25	20.07
First stage F-test (Cragg-Donald)	–	–	–	294.67	233.62	96.36	92.60
N	27,744	27,218	27,206	27,687	27,292	27,176	27,164
# Firms	1,489	1,481	1,480	1,486	1,486	1,479	1,478
# Cities	160	159	159	158	158	158	158

Notes: The dependent variable in each regression is total bond issuance, which is defined as the yearly change in issues of straight, convertible, and subscription bonds. All regressions include firm and year fixed effects. Standard errors in parentheses and F-stats are clustered by city code. $^{***}p < 0.01, ^{**}p < 0.05, ^{*}p < 0.1$

Table G.7. Bank Leverage Ratio Response to Increase in RE Values

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Market RE	0.001	0.000	0.000	0.026***	0.021***	0.011	0.013
	(0.001)	(0.001)	(0.001)	(0.009)	(0.008)	(0.015)	(0.015)
Effect in standard deviations	0.01	0.00	0.00	0.28	0.23	0.12	0.14
Estimation	OLS	OLS	OLS	IV	IV	IV	IV
Main bank × year		✓	✓		✓	✓	✓
Industry & region × year		✓	✓			✓	✓
Size & age bin × year			✓				✓
First stage F-test (cluster-robust)	–	–	–	32.38	37.09	19.84	18.74
First stage F-test (Cragg-Donald)	–	–	–	301.09	239.13	95.50	90.47
N	27,501	26,989	26,978	27,444	27,062	26,947	26,936
# Firms	1,480	1,472	1,471	1,477	1,477	1,470	1,469
# Cities	159	158	158	157	157	157	157

Notes: The dependent variable in each regression is bank leverage, which is defined as long-term loans from credit banks, city banks, trust banks, and regional banks relative to total assets. All regressions include firm and year fixed effects. Standard errors in parentheses and F-stats are clustered by city code. $^{***}p < 0.01, ^{**}p < 0.05, ^{*}p < 0.1$

Table G.8. CAPEX Responses to Increase in RE Values

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Market RE	0.019***	0.021***	0.022***	0.013**	0.015**	0.016**	0.015*
	(0.001)	(0.001)	(0.001)	(0.006)	(0.007)	(0.008)	(0.008)
Effect in standard deviations	0.36	0.40	0.41	0.24	0.28	0.30	0.28
Estimation	OLS	OLS	OLS	IV	IV	IV	IV
Industry & region × year		✓	✓		✓	✓	✓
Size bin × year			✓			✓	✓
Age bin × year			✓				✓
First stage F-test (cluster-robust)	–	–	–	31.78	21.07	18.85	18.25
First stage F-test (Cragg-Donald)	–	–	–	311.86	110.29	98.28	97.49
N	27,944	27,884	27,872	27,925	27,868	27,868	27,856
# Firms	1,489	1,486	1,485	1,488	1,485	1,485	1,484
# Cities	160	159	159	158	158	158	158

Notes: The dependent variable in each regression is investment in PPE (CAPEX) relative to lagged book assets, which is defined as the yearly change in the net book value of plants, properties, and equipment. All regressions include firm and year fixed effects. Standard errors in parentheses and F-stats are clustered by city code. $^{***}p < 0.01, ^{**}p < 0.05, ^{*}p < 0.1$

G.7 Reduced Form Estimates of Static and Dynamic Multipliers

The original model of Kiyotaki & Moore (1997) distinguished between static and dynamic effects of an initial shock to firm capital values on the real economy. In the context of this paper, the static effect refers to the response of real estate prices to a one-time shock to land values. The dynamic effect is the effect of a one-time shock to land values when there is a feedback loop between corporate borrowing capacity and real estate values. The quantitative importance of collateral constraints hinges on the dynamic multiplier, and several papers have shown that in less stylized theoretical settings amplification may be minute (Kocherlakota 2000; Cordoba & Ripoll 2004).

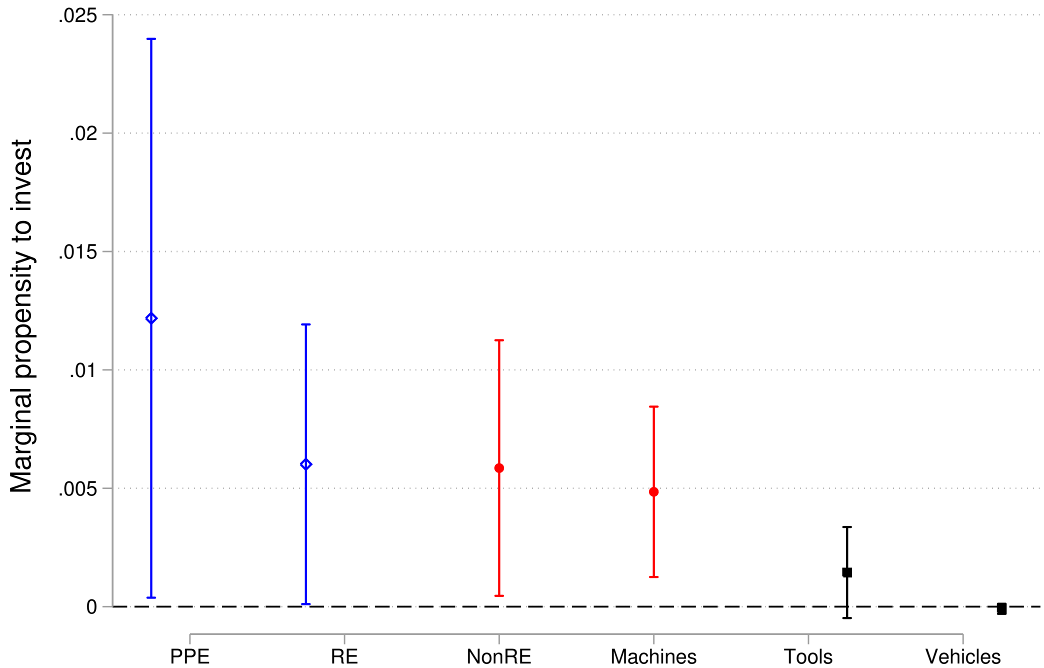
Here I attempt to separate the static effects of the land use reform from the dynamic effects of the feedback loop in a reduced form way. Estimating the regression specification in equation (4.1) using a measure of $RE^j_{i,t}$ that does not take into account any property acquisitions firms might make in response to the shock identifies a static effect. Taking $\tau = 1977$ as the benchmark year I compute firm real estate values based on HQ city j via the following equation:

$$RE^j_{i,\tau+1} = (1-\delta)^k \times RE^j_{i,\tau} \times P_{j,\tau+k}/P_{j,\tau} \tag{G.5}$$

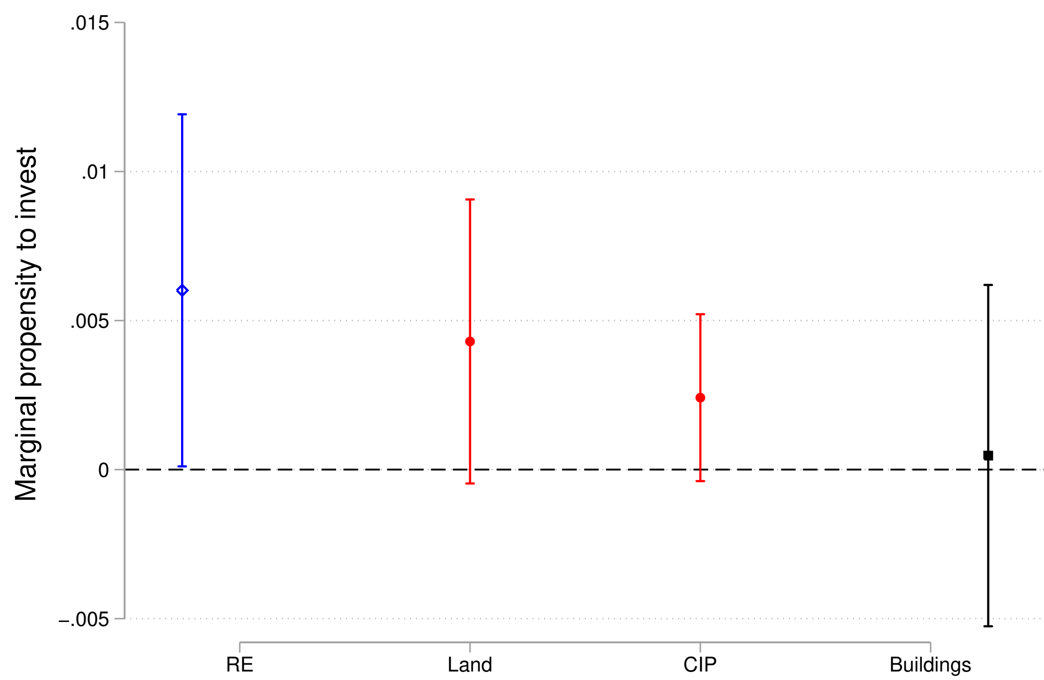
where δ is the linear depreciation rate of (assumed to be 2% in the baseline estimates), and $P_{j,t}$ is the local repeat appraisal index for land values in the HQ city. Equation (G.5) computes the market value of real estate assets held by a firm in 1977 net of any depreciation accumulated between the benchmark year τ and year $t = \tau + k$.

FIGURE G.6. Decomposing Physical Capital Investment Responses

A. Responses by Major Capital Good



B. Responses by Real Estate Component



Notes: Each point estimate was obtained via IV estimation of (4.1) and (4.2), with 95% confidence intervals in brackets. NonRE refers to investment in the sum of machines, tools, and vehicles. CIP refers to construction in progress, a component of real estate (RE).

Table G.9. Dynamic vs. Static Firm Responses to Real Estate Shocks

	Total debt issues (int. margin)				Real estate investment			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Market RE	0.008***	0.014***	0.034**	0.022***	0.011***	0.013***	0.011	0.007**
	(0.001)	(0.001)	(0.015)	(0.008)	(0.002)	(0.000)	(0.013)	(0.003)
Effect in standard deviations	0.16	0.18	0.68	0.28	0.57	0.41	0.57	0.24
Multiplier	Static	Dynamic	Static	Dynamic	Static	Dynamic	Static	Dynamic
Estimation	OLS	OLS	IV	IV	OLS	OLS	IV	IV
First stage F-test (cluster-robust)	–	–	5.53	25.01	–	–	7.79	31.78
First stage F-test (Cragg-Donald)	–	–	28.47	114.42	–	–	74.58	311.86
N	12,528	12,528	12,478	12,478	27,872	27,944	27,853	27,925
# Firms	1,459	1,459	1,419	1,419	1,489	1,489	1,488	1,488
# Cities	157	157	155	155	161	161	160	160

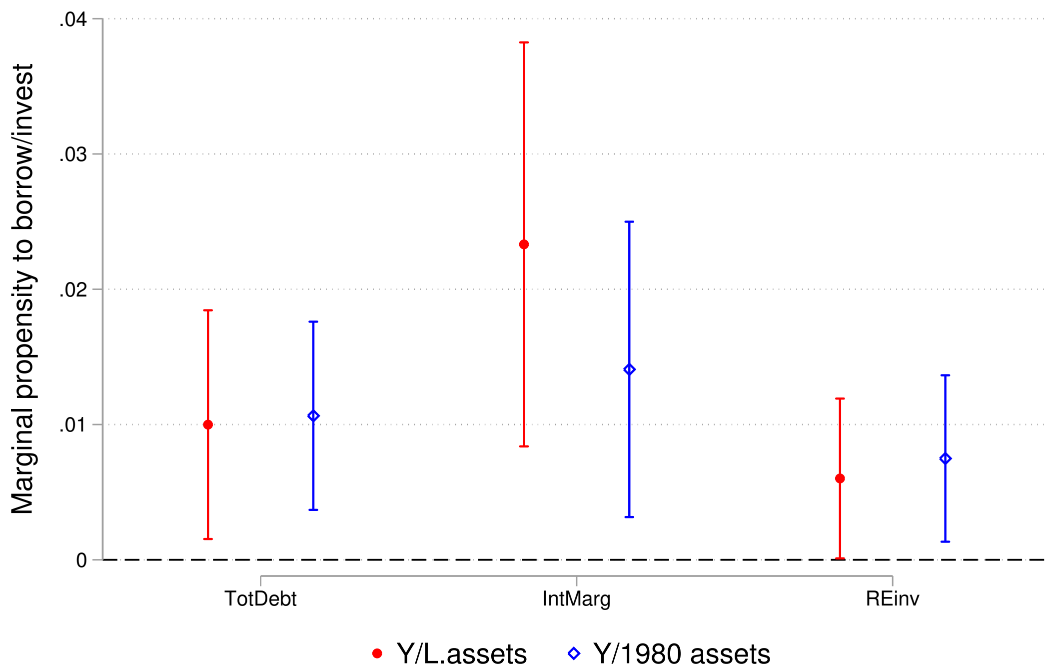
Notes: The dependent variable is either intensive margin total net debt issues or real estate investment. In the IV estimations, the excluded instruments are 1980 median road width, and the 1980 share of plots constrained by FAR limits, each interacted with a post-reform dummy equal to unity in years after 1983. Dynamic refers to the book to market conversion in Appendix E.1, while static refers to the book to market conversion in equation (G.3). Standard errors in parentheses and F-stats are clustered by city code. $^{***}p < 0.01, ^{**}p < 0.05, ^{*}p < 0.1$

Table G.9 compares estimates obtained previously for the response of total debt issues along the intensive margin and real estate investment with estimates obtained from re-estimating equation (4.1) using the static measure of real estate assets in equation (G.3). The results of this exercise provide limited empirical evidence of amplification on the real estate investment margin. However, for the OLS estimates of the response of debt issues on the intensive margin, there is evidence of a moderately large dynamic multiplier. However, the magnitude of the IV estimates should be interpreted with caution given that the first stage F-stat is much lower for the static estimates. This is unsurprising given that the instruments were conceived to capture local general equilibrium impacts of the land use reforms, as shown in the city-level evidence in Section 3.2.

G.8 Normalizing by Pre-reform Assets

In my baseline specifications, I normalize outcomes and market real estate values by lagged physical assets. Figure G.7 shows how my baseline IV estimates compare to IV estimates obtained by normalizing by physical assets in a benchmark year (e.g. 1980). In general, normalizing by a measure of pre-reform assets results in slightly larger and more precise estimates of overall debt issuance and real estate investment responses. Normalizing by assets fixed from benchmark year also has little effect on the strength of the first stage – for instance, for debt issuance the cluster-robust F-stat is 29.6 compared to 33.1 in the baseline estimates in Table 3.

FIGURE G.7. Sensitivity to Asset Normalization



G.9 Heterogeneity by Credit Constrainedness

Do firms which are more *ex ante* financially constrained borrow more than unconstrained firms in response to the land use reform shock? To directly examine the role of credit access I split my sample of firms according to several proxies for the presence of financing constraints. These measures include a range of indices in the corporate finance literature which have been shown to predict qualitative proxies for firm credit constraints (Kaplan & Zingales 1997; Cleary 1999; Whited & Wu 2006; Hadlock & Pierce 2010).[112] I classify firms in my sample as credit constrained according to each of these indices if their index value puts them above the median in the year prior to the enactment of the land use reform (1982).

I find firms which are more constrained according to these *ex ante* financing constraint measures account for the bulk of the debt issuance response to the land use reform shock. Table G.10 shows the results when I rerun the IV specification in equations (4.1) and (4.2) for each of the four indices after splitting firms by above vs. below median index values. According to three out of the four indices, the exception being the KZ index for which there is no significant borrowing response in either subsample, more financially constrained firms display a much larger borrowing response, and the point estimates for the unconstrained subsamples are not statistically significant. I find similar patterns in Figure G.8 when I look at physical capital investment responses for high vs. low HP index firms. According to this measure, firms which were credit constrained prior to the reform exhibit PPE and real estate investment responses almost twice as large as unconstrained firms. This provides suggestive evidence that the overall investment response to the land use reform was driven by firms which had pent up demand due to binding collateralized borrowing limits.

[112] I describe the construction of these indices in Appendix E.3.

Table G.10. Main Borrowing Results by *ex ante* Credit Constraints

	KZ		Cleary		WW		HP	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Market RE	0.004	0.011	0.018**	0.007	0.015*	0.009	0.021***	0.004
	(0.005)	(0.007)	(0.009)	(0.005)	(0.008)	(0.006)	(0.007)	(0.006)
Estimation	IV	IV	IV	IV	IV	IV	IV	IV
Constrained	Yes	No	Yes	No	Yes	No	Yes	No
First stage F-test (cluster-robust)	29.07	17.03	12.82	25.16	13.15	34.56	22.22	20.59
First stage F-test (Cragg-Donald)	125.69	133.92	120.13	138.73	82.97	209.97	161.11	96.91
N	13,283	13,681	13,435	13,529	13,320	13,644	13,693	13,271
# Firms	716	735	721	730	717	734	732	719
# Cities	115	90	94	111	111	96	94	112

Notes: The dependent variable in each regression is net debt issues relative to lagged book assets. All regressions are estimated by IV according to equations (4.1) and (4.2) with 1980 median road width, and the 1980 share of plots constrained by FAR limits, each interacted with a post-reform dummy, as the excluded instruments. Odd-numbered columns include firms with above-median values for one of the four indices (Kaplan-Zingales, Cleary, Whited-Wu, Hadlock-Pierce), indicating that such firms face greater external financing costs. All regressions contain firm and year fixed effects. Standard errors in parentheses and F-stats are clustered by city code. $^{***}p < 0.01, ^{**}p < 0.05, ^{*}p < 0.1$

FIGURE G.8. Investment Responses by *ex ante* Credit Constraints (HP Index)