Suburbs or Skyscrapers? The effect of China's leasing market on housing decentralization

Peter Christensen*

Abstract

A key policy instrument fueling China's rapid urban growth has been the urban land lease, which generates municipal revenue through the sale of land rights to developers. By linking local infrastructure investment to farmland development, the policy creates the potential for shifts in urban form. This paper examines the impact of China's leasing policy on housing decentralization from 1990-2000, exploiting exogenous variation arising from a pilot and addressing potential selection bias with a matched difference-in-differences estimator. I find that the land leasing policy resulted in a 19.1% decline in construction in urban core and a 26.2% increase in peri-urban areas.

JEL Codes: H12, H70, L85, O21, R14, R31, R38

Univerity of Illinois, Mumford Hall, 1301 Gregory, Urbana, Illinois, 61801. email: pchrist@illinois.edu. I thank Nathan Chan, Robert Fetter, Ken Gillingham, Matt Grant, David Keiser, Matt Kotchen, Robert Mendelsohn, Nancy Qian, Karen Seto, Qingling Zhang, Qian Zhang, and seminar participants at The Yale Environmental Economics Seminar, Northeast Energy and Environmental Economics Conference, and the Lincoln Land Institute Summer Workshop (Biejing) for excellent comments. Thanks to Jiyuan Liu, Xianzheng Deng, and members of the Chinese Academy of Sciences for collaboration and valuable discussions. Support for this research from EPA Grant 91744101, as well as Yale Macmillan and Hixon Centers is gratefully acknowledged. All errors are my own.

1 Introduction

In urbanizing regions, policymakers and planners often face the challenge of responding to rapid shifts in demand for public infrastructure on short time scales and under revenue constraints. In this context, academics and policymakers have advocated leasing of government-owned land as a second-best instrument for public infrastructure financing.[1] China introduced a land leasing system by constitutional amendment in 1988 and many argue that the system has transformed the country's urban land and property markets (Anderson 2012, Ding and Song 2009). The program is specifically designed to stimulate urban growth by allocating revenue from leases to public infrastructure projects. The onset of the leasing program has coincided with China's housing construction boom – the annual rate of residential floorspace production increased by more than a factor of 9 between 1985 and 2000 (China NBS 2000). This creates an ideal setting for examining the impacts of this policy intervention on large-scale patterns of urban growth. This paper examines the impact of land leasing on housing decentralization in China's cities.

I use a difference-in-differences (DD) strategy to estimate the effect of the land leasing policy on urban housing decentralization, making use of exogenous variation that arises from an pilot phase in the implementation of the system. I use a rich set of data on housing construction across 5,877 urban townships to examine changes in the intra-urban housing distribution for China's 100 largest cities. In a first model, I characterize patterns of housing development that emerged at the national level during the two-decades following China's reforms (1980-2000), when urban housing construction began to accelerate in the presence of land market and infrastructure constraints (Dowall 1993). I find that residential construction in nearly every city was highly concentrated in city centers. In the year 2000, the housing distribution in the least dense city in the sample was more dense than that of New York City.[2]

[1] See Peterson (2009) for a discussion of land leasing as a financing strategy. Several features of the leasing instrument result in inefficiencies relative to public goods provision using traditional property taxes or the outright sale of government lands, as discussed in Dale-Johnson (2001), Capoza and Sick (2001), and Anderson (2012). Miceli, Sirmans, and Turnbull (2001) examine the effects of features of contract design on the value of property rights conveyed through leases.

[2] In the year 2000, Zheng and Kahn (2009) estimate that only 33% of New York City residents lived within ten kilometers of its Central Business District. The Chinese city with the lowest concentration of households within 10 km of an urban core in the same year is Suqian with 35%.

Public infrastructure investments are economically important policy decisions, but their effects have been challenging to estimate due to simultaneity between infrastructure planning and growth processes (Fernald, 1999, Pereira and Flores De Frutos 1999, Gramlich 1994). A growing body of work exploits quasi-random variation in the provision of infrastructure to examine impacts on economic growth[3] as well as population decentralization and suburbanization (Duranton and Turner 2012, Baum-Snow 2007). Developing the link between infrastructure provision and urban form allows for a better accounting of the benefits and costs of infrastructure investments in cities, ideally including the full range of positive and negative externalities. This paper contributes to this literature by identifying the effect of a policy instrument that is credited with fueling urban infrastructure growth across China and has gained the attention of policymakers in developing countries.[4]

The land leasing instrument is interesting as it affects housing decentralization differently than traditional property taxes in fee simple systems. The system directly impacts the land supply by adding previously unavailable land resources to China's urban markets. Revenue from leases is captured by local governments in the form of lump sum payments and is invested back into capital infrastructure projects such as transportation and grid infrastructures (State Council 1989), further increasing the rental value of urban land in peripheral zones. Leasing has become an extremely important source of (extrabudgetary) revenue for municipal governments, estimated to equal roughly half of total municipal budgetary revenues (Anderson 2011).[5] To the extent that the leasing revenues have fueled the growth of transportation insfrastructures such as radial highways and ring roads, recent findings by Baum-Snow et al (2014) indicate that it will have had an important effect on population decentralization in China's cities.

The land leasing system was established and monitored within a small sample of urban areas before it was applied to the rest of the country, providing identifying variation that I use to estimate the impact of the policy on housing production in townships that vary in their distance

[3] Recent work examines the effect of transport infrastructure on long-run productivity growth (Qian et al 2012), labor market outcomes in rural areas (Michaels 2008), and inter-city trade (Duranton et al 2014).

[4] Institutional constraints in many countries prohibit the implementation of land taxes, resulting in reliance on alternative instruments such as leasing for infrastrucsture financing (Bird 2006). One set of case studies examines government land leasing activities in Hong Kong, China, Ethiopia and India (World Bank, 2006).

[5] This study covers the period 2004-2008.

from city centers. The primary identification assumption in the paper requires that changes in the spatial distribution of housing production (decentralization) be independent of the assignment of cities to the pilot. I address potential selection bias using a semi-parametric DD estimator that estimates average treatment effects in urban townships conditional on a city's selection likelihood (Heckman et al 1998, 1997). Pilot cities for which there is no suitable set of comparison cities are dropped from the analysis. The use of the Heckman estimator is novel in the empirical literature on urban growth. I discuss particular concerns regarding the construction of valid counterfactuals for city-level policy treatments and directly examine interactions with other policy changes occuring during the study period.

I find that the land leasing policy resulted in a 26.2% increase in housing production in peripheral townships of treated cities. The policy resulted in a simultaneous 19.1% decline in housing production in townships located in city centers. I do not find a significant effect of the policy on the total housing produced in treated cities. When taken together, these results demonstrate that the program displaced construction activities from city centers to their peripheries. The lack of any effect on total housing production is interesting, as it suggests that the instrument may have been more effective as a re-allocation tool than a housing market stimulant. I construct placebo tests to examine the validity of the assumptions underlying counterfactual estimates and find no evidence of spurious effects among untreated cities that have special economic development zones or are afforded special status by the national government.

The paper proceeds as follows: the next section provides a historical context for the land leasing policy. Section 3 provides a motivating model for the impact of land leasing on housing production. Section 4 discusses the data used in the paper. Section 5 presents trends in housing production and urban infrastructure expansion during the study period. Section 6 discusses the primary identification strategy used to estimate the causal impact of the land leasing policy. Section 7 presents empirical results and a variety of robustness checks along with a discussion of the primary findings and alternative explanations. Section 8 concludes.

2 Historical Background on Land Leasing

Between 1980-2000, the length of China's road network expanded by more than a factor of 5, its sewage pipelines by a factor of 6, and the country added approximately 400 million meters of floor space annually to its building stock (China National Yearbooks, 1980-2000). Despite this impressive outlay, by the end of the 1980's many observed that the growth of demand in urban centers was outpacing the expansion of infrastructure services (Dowall 1993, Harrold and Lall 1993, Bird 2004, Wu 1999). Positive economic shocks to growth in urban areas had resulted in dramatic increases in demand for urban infrastructure, but a financing gap emerged as a result of a severely limited revenue base.[6] This constrained the expansion of public infrastructure services, impacting the effective cost of developing urban land (Wang et al 2011, Bird 2004, EIU 1994). During this period, there was also no mechanism to enable the efficient conversion of agricultural to urban land due to the absence of a legal framework for the conveyance of private land use rights, resulting in an important constraint to the buildable land supply.

2.1 The Land Leasing System

In the late 1980's, the national government amended the constitution to create a vehicle for the acquisition of land by municipal governments and the transfer of land use (development) rights to private developers through long-term leases. Local governments can auction or negotiate leases of 40-70 years (70 years for residential and 40 years for industrial use) and retain 60% of the revenue generated by the transaction. Official policy required that revenues accruing to municipal governments must be utilized to finance the development of urban infrastructure (State Council, 1989). Work by Deng (2005) demonstrates that China's land leasing system established a crucial link between the generation of local revenues to the provision of local public goods, particularly infrastructure expansion.

A key feature of the leasing policy in China involves the heterogeneous manner in which

[6] Ding and Song (2009) present an exhaustive list of tax sources in 2002 and their date of initial implementation. The total proportion of 2002 tax revenues that were available as of 1990 was 8.17%. The largest of these sources for urban areas was the urban construction and maintenance tax, which represented 2.75% of total tax revenue in the year 2002. Wu (1999) considers this the only available urban tax in the pre-leasing period.

it was implemented during its first 10 years. Due to concern about potential speculation, the national government employed a "test and monitor" strategy by permitting land leasing in 4 cities for the first 5 years of the program: Shenzhen, Guangzhou, Tianjin, and Shanghai (Li 1996, Wang et al 2011). There is no clear documentation of the exact process or criteria that determined the selection of cities for the pilot phase, but a few features of the program design are evident. First, it is clear that the central government perceived a trade-off between the expected social benefit from broad implementation of a private leasing system and the risk of any unforeseen effects (Deng 2005). The test-and-monitor strategy allowed officials to maintain tight control over outcomes in the initial period. Second, it is clear that the pilot cities are a heterogeneous group. Figure A1 graphs the attributes of the treatment group relative to a large sample of Chinese cities according to population size, population density, roads per capita, wages, and growth of local public expenditures per capita in the city's province. The pilot cities generally fall in the upper 50th percentile for any characteristic, but are not the highest ranked. Shanghai is an exception as it is clearly a leading city.

The first transaction for a leased parcel of land occurred in Shenzhen in December of 1987 (Wills et al 1999). In 1988, an amendment to Article 10 of the Constitution established that while all land belonged to the state, the right of use could be "transferred in accordance with the law." Leasing was formally approved in 1990 and then expanded to cities around the nation beginning in 1992[7] (Deng 2005, Lichtenberg and Ding 1999). Table A1 provides statistics on the growth of income generated from the land leasing program at the national level from 1988-1995, which illustrates the increase in total revenue generated from the policy after expansion in 1992 and a major legislative change in 1995.8 Differential exposure during this period constitutes the treatment that I investigate in this paper.

[7] This follows 1991 legislation that defined the right to use and occupy land and provided the mechanism transferable and tradeable titles through state-sanctioned contracts (*Interim Regulations of the People's Republic of China on Granting and Transferring the Rights to the Use of State-owned Land in Cities and Towns*).

[8] In 1995, the central government enacted the Urban Real Estate Management Law to further strengthen the system by introducing a title registration system (Wills et al 1999).

3 Motivating Theory

3.1 Land Leasing and Housing Decentralization

Before the introduction of the land leasing system, there is evidence that China's urban infrastructure had become highly congested due to constraints on the conversion of non-urban land and insufficient capital infrastructure spending (Wang et al 2011, Bird 2004). The land leasing system increased the supply of agricultural land available for development and provided a vehicle for ramping up public investment in infrastructure. The impact of these changes on housing decentralization is demonstrated in a standard monocentric model (Alonso 1964, Muth 1969, Mills 1967).

Urban residents consume housing and private goods $U(C,H)$, with private consumption (C) equaling the remainder of income net of housing (H) and commuting costs. The consumer's budget constraint is: $r(d)H + c = y - td$. An urban resident therefore chooses the amount of housing space to consume (H) and proximity to the urban center (d), subject to earnings (y), the cost of transport for per unit distance (t), and rent per unit housing at any given distance $r(d)$. Assuming the standard no-arbitrage condition, the urban rent gradient $r(d)$ can be defined as the sum of the compensating differential of commuting costs (td) and the rent at the urban periphery $(\underline{r})$. Rents at the periphery are assumed to equal the value of non-urban land. Comparative statics originally derived by Wheaton (1974) provide the predictions about the equilibrium relationship between rents and transportation costs.

Brueckner (1987) examines the impact of these parameters on the density of housing in a city by providing the complementary model of housing production, where the development of housing at any given location (d) is given by the production function $H = H(L, K)$. (L) and (K) are land and capital inputs. The model assumes that developers bid competitively for land at rental rates of $r(d)$ per unit land and develop housing at levels of density $(\frac{H}{L})$ that are chosen to maximize profits given price (p) and the cost of building at higher densities $c(\frac{H}{L})$. Profits equal $(p(\frac{H}{L}) - c(\frac{H}{L}) - r)$. Comparative statics from the production model illustrate that the housing density gradient $\frac{H}{L}(d)$ will be responsive to changes in the cost of transport and changes in the price of land on the periphery:

$$\frac{\partial \frac{H}{L}}{\partial \underline{r}} > 0, \frac{\partial \frac{H}{L}}{\partial t} > 0 \tag{1}$$

These results offer predictions about the equilibrium density of housing in cities with land leasing relative to the counterfactual case (no active leasing system). The program reduces the shadow price of land as previously restricted lands become available for development through municipal requisition while simultaneously reducing transport costs through infrastructure investments. The land leasing policy is therefore expected to result in housing decentralization through two channels: (1) by reducing the cost of agricultural land on the periphery and (2) by bringing down transportation costs as revenues are invested in infrastructure growth ($\downarrow t(d)$).[9] This paper is designed to test the hypothesis that the leasing system led to housing decentralization in China. I will identify the causal effect of the policy by measuring changes in the spatial distribution of residential floor space constructed in treated cities before and after the policy was implemented, relative to the counterfactual case.

A potential concern when applying this model to China is whether it yields valid predictions regarding housing market outcomes, given distortions in China's housing market during the study period.[10] While the above assumptions are too restrictive to capture the complexity of China's urban markets, empirical work on urban land, population, and housing price gradients in China's cities in the post-reform period has provided evidence in support of its general predictions regarding urban spatial structure (Baum-Snow et al 2014, Deng et al 2008, Zheng and Kahn 2008, Ding 2004, Bertaud and Malpezzi 2003). Bertaud and Malpezzi (2003) find that spatial structures that have emerged in China's largest urban land markets are consistent with those observed in other market economies. The estimation strategy in this paper will focus on time-varying features of urban markets that could affect changes in a city's housing distribution.

Another important question concerns the incentives of local officials, who control the requisitions for agricultural land and first-stage transactions[11] in China's urban land market. Lichtenberg and

[9] The effect of land supply constraints on the housing production and price dynamics has been further illustrated in work by Saiz (2010) and Glaeser et al (2006).

[10] Results from Zheng et al (2006) indicate that housing finance (credit) constraints and ambiguous property rights (affecting resale values in older homes) create obstacles that affect optimal residential sorting in China's largest urban areas. Alternative frameworks have emerged to explain the incentive structures that shape urban form in planned economies, where planning decisions do not favor highest and best land use and can result in excessively low densities (Bertaud and Renaud 1997). In some cases, construction booms in the context of reforms can lead to rapid shifts toward urban concentration (Dale-Johnson 2005).

[11] First-stage transactions refer to the conveyance of land leases by municipal governments. After this first stage, leases contracts may be further traded through private market transactions.

Ding (2009) explicitly examine China's administrative structure and show that the equilibrium shadow prices for urban land in this setting reflect those of a private land market, with two noteworthy caveats: (1) compensation for requisitioned agricultural lands in China is based on agricultural returns on each parcel but is typically fixed at a level that is substantially (10-20 times) lower than conveyance fees collected by the government and (2) the potential for greater tax revenues from urban land enhance the potential returns from land conversion. Both of these factors are expected to stimulate housing decentralization.

4 Data and Estimation

4.1 Measuring Housing Decentralization

This study examines the spatial distribution of decadal changes in the residential housing stock, as measured by the density of constructed floor space per unit land (m2)/km2) in different zones of each city in the sample. Measurements of residential floor space are collected by the China census and aggregated to the level of the township, the smallest administrative unit classified by the national government (China Census 2000).[12] The sample includes 5,877 township observations of residential floor space from in China's 100 largest prefecture cities, as defined by non-agricultural population in the year 2000. Figure 1 provides a map of the sample of cities included in the study.

Within each city, the sample includes measurements from all townships that fall within a 20 kilometer radius of the city center. Housing decentralization is therefore defined relative to historical construction patterns, where each city center is defined using the geometric center of housing constructed before 1950.[13] As a check, I employ an alternate approach by manually selecting each urban core utilizing contemporary, high resolution imagery from the Google Earth archive and available information from the Google maps database. Results are qualitatively unchanged across the two operational definitions. Figure A2 illustrates the township sample surrounding the central city locations of a subset of cities. Decentralization is defined in terms of a change in the

[12] Data are obtained in georeferenced form from the China Data Center at the University of Michigan (China Data Center).

[13] Alternate approaches include identifying economic sub-centers using data on firm activity or the spatial distribution of employment, as in McMillen (2001) and McMillen and Macdonald (1998). Measurements of firm and employment distributions available for this sample and pre-study period.

rate of housing production in city center zones (ex. 0-3 km) relative to changes in peripheral zones (ex. 3-10 km). Table A2 provides summary statistics for township-decade observations of constructed floor space and Table A3 summarizes the changes in the fraction of housing stock produced in zones at 0-3 km, 3-10 km, and 10-20 km from the centers of the largest cities in the sample. The fraction of housing produced in the city center zones of large cities increases by about 13% between the two decades.

5 Trends in Housing Decentralization and Infrastructure Expansion

5.1 Urban Housing Production during the Post-Reform Period

I begin by examining the spatial distribution of the housing stock produced during the 1980's and 1990's. Figure A3 plots a quadratic function to the housing data, illustrating the magnitude and pattern of urban construction occurring at the national scale during the 1990's. The density of housing increased dramatically during this period, with the majority of construction activities occurring in center city zones. By the year 2000, 33% of households and 30% of the urban housing stock were located within 3 km of a city center.

I estimate the magnitude of changes in the urban density gradient over time and across urban areas using the log-linear model[14]:

$$log[\frac{fs_{ijt}}{L_{ijt}}] = \beta^{Dist} D_{ijt} + \beta^{Geo} G_{ij} + \mu_j + \gamma_t + \varepsilon_{it} \tag{2}$$

where density is measured in first-differences as the ratio of floor space density of new constructed floor space (m^2) per unit land (1X1 km^2) in a given urban township (i) in city (j) during period (t).[15] D_{ijt} is the distance from zone (i) to its associated urban center (j), G_{ij} is a vector of time-invariant geographical constraints (fraction of land with slope greater than 14 degrees, freshwater, and coastal boundaries within a perimeter of 30 km^2) that affect the supply of buildable land[16]; μ_j captures unobserved effects that vary across city and γ_t across decade, β_0 is an intercept term and

[14] I follow previous empirical work in assuming a quasi-linear function for consumer utility. I test the fit of a log-linear versus a linear specification with a Box-Cox test (Box and Cox 1964), which supports the log-linear specification.

[15] An alternative measure sums the floor space across different distance intervals and calculates the ratio of this sum to the total land area at each interval $(\sum fs_i)/\pi(d_k - d_j)^2$

[16] This follows the work of Saiz 2010 on geographic determinants of housing supply.

ε_{it} is an error term. A positive estimate of (β^{Dist}) indicates that the distribution of urban floor space has decentralized during the period while a negative estimate indicates densification.

Table 1 reports estimates that describe national changes in density. All specifications include decade and city fixed effects as well as controlling for physical constraints. Column 1 reports the overall density gradient of housing produced during the entire study period. In the national sample, floorspace densities decline by 8.4 percent with every kilometer of distance to an urban center. Column 2 adds a distance-decade interaction term to estimate changes in the density of housing constructed between 1990-2000 relative to the 1980-1990 period. Columns 3-5 examine changes within particular city center zones. These results all illustrate important increases in national urban housing densities during the 1990's. Relative to the gradient for the 1980's, the density of housing production in the national sample declines by an additional 1.9 percentage points with every additional kilometer of distance to an urban center. The density of housing produced within 1 km of a city center increased by 2.2 percentage points and by 1.8 points within 3km.[17] These results are consistent with recent analysis of population decentralization from Baum-Snow et al (2014), who find that China's city center populations grew faster than outlying districts during the 1990-2010 period.

5.2 Evidence on the Timing of Infrastructure Growth using Landsat TM/ETM

The land leasing policy was introduced in the context of the densification of China's urban housing stock. It is important to consider the timing of additional regulatory changes that were implemented during the 1990s. The most influential of these is the onset of national farmland protection regulations that were developed to restrict the encroachment of urban land on existing farmlands. These regulations began in earnest with the passage of the Farmland Protection Regulation in 1994 and continued with a complete moratorium on farmland conversion in 1996 and changes to the Land Administration Law of 1998 (Lin and Ho 2005). Farmland protection regulations acted as an important constraint on the government's ability to requisition and lease lands during the latter half of the decade (Lichtenberg and Ding 2009).

[17] I evaluate the sensitivity of these results to increases in the sample (and the maximum distance) of zones in each city.

In order to better understand the influence of farmland protection on land development in the latter half of the 1990's, I use satellite-derived observations of the outward expansion of urban infrastucture for each urban center during 1988-1995 and 1995-2000 in treated versus comparison cities (Liu 2005)[18]. Infrastructure expansion is defined in terms of the growth of the built-up/constructed land surface (cement, concrete, building rooftops), including land converted for settlements and related activities, such as transportation, factories, quarries and airports. These observations are obtained from the China's National Land Cover Dataset (CLCD), which measures changes in terrestrial land cover imagery from NASA's Landsat TM/ETM sensors. These sensors provide calibrated, optical measurements of the Earth's terrestrial surface at 30X30 meter resolution. Landsat data have been used extensively to examine the expansion of urban infrastructure both within cities and at larger scales (Irwin and Bockstael 2007, Burchfield et al 2006, Angel 2005). The CLCD is constructed from a mosaic of more than 500 scenes for each of the two periods.

The classification algorithm used for the CLCD relies upon max differences in multi-spectral reflectance between infrastructure and other earth surface materials such as vegetated lands, bare lands and water. Landsat scenes were selected based on low atmospheric effects and from the peak agricultural season in order to provide maximum spectral contrast between vegetated and non-vegetated lands. A detailed explanation of the methodology and validation is provided in Liu et al (2005). Classified data have been aggregated to 1X1 km2, with each cell in the grid providing an observation of the proportion of its total (1X1 km2 land area) that has been converted to urban infrastructure. In this study, CLCD data provide a direct measure of the spatial expansion of urban infrastructure (in two dimensions) as a function of distance from urban core areas. The CLCD provides the primary measure of urban land expansion in a related analysis by Deng et al (2008), who use it as a measure of urban density within Chinese counties.

Figure 2 graphs annual percent changes in infrastructure expansion for treated cities and versus the sample of comparison cities during 1988-1995 and 1995-2000. In the early period (1988-1995), urban land expansion in treated cities was outpacing that in comparison cities by a factor of 2.5.

[18] Measurements of the expansion of infrastructure do not capture construction activities on already developed lands, where much of urban construction activities are concentrated during the study period. They are used here to specifically examine the expansion on non-urban land. In the data appendix, I examine the spatial distribution of measurements from Landsat TM/ETM and DSMP-OLS sensors, both of which are truncated in city center areas.

There is also a clear difference in the spatial distribution of land conversion between the two groups – the majority of urban land expansion in the treated cities occurs between 5-15 km from a city center whereas land expansion in comparison cities occurs inside 10 km. These patterns are both consistent with the notion that the land leasing policy led to greater infrastructure expansion during the pilot phase of the program.

Differences in the rate of infrastructure expansion between the two periods are also quite revealing. In treated cities, 82% of the total urban land expansion observed during the period occurred between 1988-1995, whereas only 18% occurred between 1995-2000. This slowdown during the 1995-2000 period may be attributable to farmland protection. In the 1995-2000 period of common exposure, rates in treated cities were more similar to rates in comparison cities. They were both low. These data suggest that expansion occurring during the 1988-1995 period was especially important to growth outcomes during the study period.

6 The Effect of Urban Land Leasing on Housing Decentralization

6.1 Identification Strategy

The ideal experimental setting for estimating the impact of the land leasing policy on urban decentralization would involve random assignment of the treatment to a sample of experimental cities. Random assignment would guarantee clean identification of the effect of exposure to the policy on urban decentralization. As discussed above and as is true of most public policy interventions, the factors determining selection for early exposure to the land leasing system cannot be modeled as random. I follow Heckman et al (1997, 1998) by estimating the effect of the policy using a difference-in-differences approach that estimates the conditional effect of exposure on treated cities by matching cities on their probability of selection into the treatment group.

As in the original framework of Ashenfelter (1978) and Ashenfelter and Card (1984), let there be $j = 1, ..., N$ cities that belong to either a treatment or comparison group $G_j \in \{0,1\}$. Treatment is defined by early exposure to the land leasing program, which is expected to affect the distribution of new floor space. Effects of the policy are observed during the period 1990-2000, which includes a period of unique exposure to the policy followed by a period of common exposure after the system became standardized throughout the country. The effects measured here reflect the impact of differential exposure to the program between the 4 treated cities and the remaining cities during the period 1990-2000.

The density of constructed floor space in township i of a treated city can be written as the sum of the counterfactual outcome in the same township (the absence of early exposure) and the average effect of exposure to the intervention on treated cities, as presented in equation 3.

$$Y_{ijt}(1) = Y_{ijt}(0) + \tau_{ATT} \tag{3}$$

The average treatment effect (τ_{ATT}) captures the affect of exposure on average floor space production in treated townships. However, this does not provide information about the effect of the policy on housing decentralization. Identifying the effect of treatment on housing decentralization ($\tau_{ATT(D)}$) requires an estimate of differential rates of housing production in central versus peripheral zones of treated townships. $\tau_{ATT(D)}$ is given by:

$$Y_{ijt}(1) = Y_{ijt}(D_{ij}, Z_{ij}, 0) + \tau_{ATT(D)} + \varepsilon_i \tag{4}$$

where $Y_t(D_{ij}, Y_i, 0)$ is a time-varying housing production function in which the density of floor space constructed depends on the distance (D_{ij}) of the township to the urban core area, the status of the land leasing program in city j, and a vector of township characteristics Z_{ij}. The land leasing system is hypothesized to impact the density of township i through an affect on transportation costs and agricultural land costs that favor development in peripheral townships.

Figure A4 plots a quadratic function of constructed floor space against distance in pilot and comparison cities. These plots demonstrate clear changes in the pre/post distribution of housing for cities that gained exposure to the land leasing policy. While the housing density gradients for treated and comparison cities have the same basic form in the pre-period, the spatial distribution of floor space in treated cities shifts outward in the period after the leasing policy was established.

6.1.1 The Assignment Mechanism

If the criteria determining selection into the treatment group are orthogonal to changes in the spatial distribution of housing production, then standard difference-in-differences estimates (τ_{ATT}) and ($\tau_{ATT(D)}$) yield unbiased estimates of the effect of early exposure on housing production in the treated cities. The selection concern in this study arises from the fact that the assignment of cities in the pilot phase of the policy may be correlated with unobserved characteristics that also affect changes in the spatial distribution of housing. The primary identifying assumption in (3) and (4) is that of unconfoundedness:

$$E(Y_0|X, G = 1) = E(Y_0|X, G = 0) \tag{5}$$

Conditional on (X), the distribution of the control outcome $Y_{ijt}(0)$ must be the same among treated and untreated cities. If all differences between the cities that were early recipients of the land leasing policy and the rest of the sample are observed, then a standard differences-in-differences estimator (τ_{ATT}) with independent observed covariates (X) provides an unbiased estimate the effect of early exposure on the treated cities, defined as:

$$E(\Delta|X, W = 1) = E(Y(1)|X, G = 1) - E(Y(0)|X, G = 1) \tag{6}$$

Deng (2005) suggests that the test-and-monitor strategy adopted by the government was developed due to concern about the risk of widespread speculation or other potential outcomes associated with uniform treatment. I model this as reflecting a trade-off between the expected social benefit of the program and the risk associated with broad implementation. I therefore treat the 4 cities selected for early exposure $Y_{1,...,4}(1)$ as a subset of a larger set of cities $Y_{5,...,n}(0)$ that were also candidates for the program, but were excluded due to a limit on the size of the program. The treatment group is determined by a cutoff for participation (c):

$$G_j = 1, if X \geq c \tag{7}$$

$$G_j = 0, if X < c$$

The selection decision is defined by of the likelihood that a given city in the sample will exceed the cutoff, or $p(X) \geq c$. Every city in the sample has some probability of gaining early exposure to the land leasing system, which is defined by a city's propensity for treatment (Rosenbaum and Rubin 1983).

6.1.2 Estimating the Propensity for Selection

The conditional DD estimator requires the assumption that treatment outcomes are independent of the selection decision, conditional on the scalar $p(X_i)$:

$$p(X_i) \equiv Pr(G = 1 \mid X) = E(G \mid X) \tag{8}$$

$$E(Y_0|p(X_i), G = 1) = E(Y_0|p(X_i), G = 0)$$

In the presence of a potentially high dimensional X, this paper follows the matching literature by estimating the probability of participation $P(X)$ for each city in the sample using a set of observed covariates (Abadie and Imbens 2006, Imbens 2004, Leuven and Sianese 2003). I adopt a conservative strategy by estimating the propensity for early exposure using variables that are known to be highly correlated with housing decentralization. The theoretical and empirical literatures on urban spatial structure provide a clear basis for covariate selection on this basis. I define the estimated propensity for early exposure $\widehat{p(X)}$ as:

$$\widehat{p(X)} = Pr(G = 1 \mid X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8) \tag{9}$$

where X_1 is urban population in the city's province in 1980, X_2 is the percent of urbanized land area in each city as of 1988, X_3 is the growth in per capita expenditures[19] in the city's province between 1980-1990, X_4 is the total constructed floor space in the city's province as of 1990 (commercial, industrial, and residential), X_5 is a measure of the geophysical suitability of land for agriculture[20], X_{6-8} define the supply of buildable land in each metropolitan region[21] based on: (5) lands with slope greater than 15 degrees, (6) inland bodies of water, (7) and coastlines, X_8 is a measure of the geophysical suitability of land for agriculture.

An important concern when employing matching procedures is ensuring overlap in the covariate distributions between the set of treated and comparison units (Dehijia and Wahba 1999, Heckman et al 1998). Identification of the effect of policies that are applied to large cities poses some intuitive

[19] The largest share of local expenditures (as reported in national yearbooks) is almost always devoted to capital construction. Smaller components are innovation funds, culture, education, science and health care, agricultural supports, and government administration.

[20] The land suitability parameter is based on an index generated by Ramankutty et al (2001) and is estimated at a resolution of .05 decimal degrees. It captures the (exogenous) geophysical quality of land for agricultural production. Additional iformation provided in data appendix.

[21] Work by Saiz (2010) and Rose (1989 a,b) demonstrates they importance of physical constraints to the supply of buildable land on the housing supply. Following Saiz, I define steeply sloped terrain as land with slopes greater than 15 degrees. This is constructed using measurements obtained from the digital elevation model of NASA's Shuttle Radar Topography Mission (SRTM). Measurements of coastal boundaries and inland bodies of water are obtained from MODIS. Additional iformation provided in data appendix.

challenges in this regard, given that city sizes and other parameters that define urban growth are often log-normally or Pareto distributed. Either of these distributions implies that the majority of urban settlements are unlikely to posses characteristics that are similar to high-propensity pilot cities. The number of truly comparable cities will be limited to the upper tail of the propensity score distribution for comparison cities.

Figure A5 plots the propensity scores for treated and untreated cities and illustrates this point.[22] In this sample, propensity scores for all but one of the pilot cities are distributed within the boundaries of the support of $(P(X),\ D = 0)$. The important exception is Shanghai, which is excluded from the analysis. The second-highest propensity city is Shenzhen, whose propensity score is bounded by two comparison cities. However, Shenzhen does not directly overlap either of the two cities and is dropped from the analysis in specifications where the caliper matching threshold is set below 1.25. Figure 3 presents the estimated propensity scores for treated and comparison townships. In this case, propensity scores for all townships in pilot cities are contained within the support of $(P(X), D = 0)$. Figure 4 compares the spatial distribution of floor space in treated versus comparison cities, weighting observations according to city propensity scores.

6.2 Matching with Propensity Scores

This study uses two different matching estimators to construct counterfactual estimates: a radius matching estimator with a caliper distance of .1 $(\tau_{ATT_{R(Cal<.1)}})$ and a kernel matching estimator (τ_{ATT_K}).[23] Weights are defined by the following respective functions:

$$W^R_{N_0,N_1}(j,k) = \frac{1}{N^S_j}\, if\, j \in S(i),\, else\, W_{N_0,N_1} = 0, \tag{10}$$

[22] This measure highlights the intuitive importance of matching procedures for constructing counterfactual outcomes in highly productive or premier cities.

[23] A variety matching estimators are available, including nearest neighbor, radius, caliper, kernel. Radius matching with a caliper distance is chosen because it allows for an additional constraint in the selection of comparison units. Kernel matching have the benefit of flexibility, as discussed below. The choice of caliper distance can have important impacts on the sample. I test the sensitivity of results to variations in caliper distance, using distances of .05, 1, 1.5, 2, 2.5 and 3. A larger caliper tends to increase the magnitude of effects, probably due to a larger sample of cities with lower propensities. I view $R(Cal < .1)$ as a conservative estimate.

$$S(j) = \{p_j | \, \|p_j - p_k\| < r\}$$

where W_{ij} is the weight assigned to cities j and k, $S(j)$ is the set of control cities that are matched to treated cities j with propensity score p_j.

$$W^K_{N_0,N_1}(j,k) = \frac{G_{jk}}{\sum_{l \in I_0} G_{jl}} \tag{11}$$

where W_{ij} is the weight assigned to cities j and k and $G = G_{jl}(X_l - X_j/\alpha_{N_0})$ is a kernel function and α_{N_0} is a bandwidth parameter. One benefit of the kernel estimators is that they do not require parametric assumptions about the relationship between X and the outcome variable W, which can lead to biased estimates (Smith and Todd 2005).

The estimating equation for the affect of treatment on treated cities ($\hat{\tau}_{ATT}$) in semi-parametric difference-in-differences is:

$$\hat{\tau}_{ATT} = \frac{1}{N_{(1)}} \sum_{i \in T_1} \left\{ (Y_{it^1}(1) - Y_{it^0}(0)) - \sum_{j \in T_0} w_{ij}(Y_{jt^1}(0) - Y_{jt^0}(0)) \right\} \tag{12}$$

where Y_{it^0} and Y_{it^1} refer to housing production outcomes within township i in the pre-treatment (1980s) and post-treatment (1990s) periods, respectively. T_1 refers to the set of townships in treated cities and T_0 refers to the set of comparison townships. Differences between pre/post outcomes in treated (i) cities are compared to differences in counterfactual (j) outcomes according to weighting function w_{ij} (eq.10,11), where a counterfactual outcome is defined as a weighted sum of outcomes within a comparison city based on propensity to treat (p(X)). As long as the conditional independence assumption (equation 9) is satisfied, $\hat{\tau}_{ATT}$ will provide an unbiased estimate of the effect of the land leasing intervention on floor space production in the four treated cities.

Estimating the effect of land leasing on the decentralization of housing requires information about heterogeneity in the treatment effect as a function of locational differences. A second estimating equation specifies the effect of treatment on housing decentralization, $\hat{\tau}_{ATT(D)}$:

$$\hat{\tau}_{ATT(D)} = \frac{1}{N_{1,Z_D}} \sum_{i \in T_1, Z_D} \left\{ (Y_{it^1}(1) - Y_{it^0}(0)) - \sum_{j \in T_0} w_{ij}(Y_{jt^1}(0) - Y_{jt^0}(0)) \right\} \tag{13}$$

where D again refers to distance from the nearest urban core. Z_D consists of alternate sets of townships within the central city zones of treated cities (ex. Distance<3km) versus peripheral zones of treated cities (ex. Distance>5km).[24]

7 Primary Results

Table 2 reports estimates of the effect of early exposure to the land leasing program on total housing production in the 1990-2000 period in treated cities, using the specifications given by equation 13. I report the effect of early exposure to the land leasing policy on average new floor space constructed in treated cities $\hat{\tau}_{Kernel}$ and $\hat{\tau}_{Radius}$ alongside the difference-in-differences estimate using the entire sample of comparison cities ($\hat{\tau}_{unmatched}$). The matched estimates indicate that the land leasing policy did not have a statistically significant effect on short-run housing production in treated cities. On average, housing production increased by 4,992 m2/km2 between the 1980s and 1990s, versus an increase of 4,742-4,755 m2/km2 in the counterfactual case. The results suggest that housing production in treated cities did accelerate relative to the entire set of comparison cities, which can be attributed to factors other than the leasing policy. Changes in housing production in treated cities are 2,365 m2/km2 larger than the average the entire sample of untreated cities ($\hat{\tau}_{unmatched}$), which is equivalent to about 10% of their total new floor space .[25]

Table 3 reports estimates of the effect of early exposure to the land leasing policy on housing production in city centers and peripheral zones, where I find large and opposing effects. In zones inside 3 km of a city center, estimated effects $\hat{\tau}_{ATT(D<3)}$ range from -6,453 to -7,218 m2/km2. This is equivalent to a decline of 19.1-20.7% in the floor space constructed in central city areas.[26] The opposite effect is observed in peripheral zones. In zones outside 5 km of a city center ($\hat{\tau}_{ATT(D>5)}$), treated cities experience a 26.2-26.6% increase in production, or 2,926-3,095 m2/km2.[27] These

[24] A more common approach to estimating heterogeneous treatment effects interacts the treatment effect parameter with the heterogeneity parameter in a parametric model (Fowlie 2012). While the present approach restricts the sample size, comparing estimates of the average treatment effect in downtown versus peripheral zones provides a direct and readily interpretable measure of the effect of the policy change on decentralization of treated cities and is not affected by parametric assumptions about functional form.

[25] Floor space in the average treated city increased by 15,787 m2/km2 during the 1990-2000 period.

[26] Housing production in zones falling inside 3 km of a treated city core increased by 23,082 m2/km2 on average during the 1990-2000 period.

[27] Production in zones falling outside 5 km of a treated city core increased by 12,224 m2/km2 on average during the 1990-2000 period.

estimates indicate that the policy had a substantial effect on housing decentralization in treated cities. Taken together, the effects on aggregate housing production and housing decentralization are revealing. They indicate that the land leasing policy displaced construction activities from core to peripheral areas but did not increase housing production in the short-run.

7.1 Placebo Tests

I address potential selection bias above by testing for conditional effects. However, it is difficult to fully rule out the possibility that assignment to the early exposure group was determined by an unobserved variable that is not captured in (X_i). The conditional independence assumption from equation 9 will be violated if an unobserved factor that is orthogonal to X determines selection as well as time-varying differences in the spatial distribution of housing production. This would bias estimates of the effect of the policy on housing production and decentralization. While conditional independence is not directly testable, it is possible to test for conditions that would lead to concern about bias in $\hat{\tau}_{ATT}$ and $\hat{\tau}_{ATT(D)}$.

One possible concern is that selection for treatment and decentralization result from differential treatment by the central government, perhaps acting through political or other influence that I do not observe. I test for a pseudo average treatment effect in China's top-tier cities (N=16).[28] Top-tier cities are granted special status by the central government and are afforded greater administrative independence than other urban jurisdictions. They are generally considered to be the nation's leading urban centers. I test for differences in changes in housing production in this pseudo-treatment group against a counterfactual using the same procedure that is used to estimate policy effects. If top-tier status and not the policy itself makes cities more likely to decentralize, then the estimates should parallel the policy effects discussed in the previous section.

Results for top-tier cities are reported in Table A5, which presents effects on aggregate housing production in column 1 and decentralization effects in columns 2-5. These estimates indicate that

28

Cities that are designated as top-tier as of the onset of the program: Beijing, Changchun, Chengdu, Chongqing, Dalian, Guangzhou, Hangzhou, Harbin, Jinan, Nanjing, Ningbo, Qingdao, Shenyang, Wuhan, Xiamen, Xi'an.

average housing production accelerated in top-tier cities during the 1990's relative to matched counterparts. This effect is quite different from the findings for the actual treatment group, which reveal no difference in aggregate production. Results reported in columns 2-5 also indicate that top-tier cities densified, rather than decentralized, relative to their matched counterparts. In the absence of the policy, there is no evidence of a decentralization effect.

Another possible concern is that trade regulations governing international investment will affect the housing market differently in treated cities than in comparison cities. Indeed, the treated cities were among 14 Chinese cities that had SEDZs by 1984 .[29]This could affect changes in the spatial distribution of housing construction in the 1990's, relative to the 1980's. I estimate pseudo average treatment effects for cities that had special economic development zones as of the start of the land leasing period and report results in Table A6. The placebo effects for cities with SEDZs have the sign as those for top-tier cities. Housing production accelerated and cities with SEDZs densified. As an additional check, I construct a test of the true treatment effect by constraining the sample of 10 comparison cities to cities that have special economic development zones. Results on decentralization are consistent with primary results reported in Table 3, though standard errors are higher due to the smaller sample size.

7.2 Robustness

I test the robustness of the decentralization effect in a variety of ways. I test the sensitivity of the estimated effects to changes in the city center and periphery definitions. Results on city center effects are reported in Table A7 and results on periphery effects are reported in Table A8. The magnitude of policy effects is sensitive to these changes, as each of these specifications estimates a unique effect in a distinct sample. In treated cities, the effect is most pronounced between 3 and 5 km from a city center. The effects on increases are not significant in the test includes zones at distances from 2-20 km.

29

Special economic development zones were created in Zhuhai, Shantou, and Xiamen in 1980 and in Dalian, Qinhuangdao, Yantai, Qingdao, Lianyungang, Nantong, Ningbo, Wenzhou, Fuzhou, Zhanjiang and Beihai in 1984.

To test the robustness of results to the city-level matching design, I use an alternate specification that matches treated and comparison units at the township level rather than at the city level. A benefit of this approach is that the support of the propensity score distribution for treated townships is completely bounded by the support of the comparison group, increasing the size and variance in outcomes drawn from the treatment group (Figure 4). A concern is the possibility that the counterfactual estimates in this model represent assemblages of zones drawn from discrete markets, although it appears that townships of the same city are tightly clustered on the support of the propensity score distribution. I estimate this model as a test of the robustness of the decentralization result and find a parallel (Table B1 in the Appendix) decentralization effect. The effect on declines in city center zones is 4-7 percentage points higher than in the primary specification. This difference in magnitude may be attributable to the inclusion of Shanghai in the treatment group in the township-matching model – Shanghai's townships fall within the boundary of the support of the propensity score distribution for comparison cities. When I drop Shanghai from this sample, results are are consistent with the city-level specification.

8 Conclusion

Urban land leasing has become a primary instrument for financing urban infrastructure in China and has gained attention from policymakers and international development agencies. To my knowledge, this is the first economic study of the causal effect of the land leasing instrument on patterns of urban growth. I estimate the effect of exogenous variation in exposure to the land leasing system using a rich panel of data on floor space construction in more than 5,877 zones in 100 Chinese cities and a difference-in-differences identification strategy that compares changes in housing production in treated cities with counterfactual outcomes from a matched sample.

This paper sheds light on national patterns of housing production during China's post-reform construction boom. I demonstrate that housing production in most cities was highly concentrated in city center zones during the 1980-2000 period. Relative to the 1980s, the density of housing produced within 1km of an urban core increased by 2.2% during the 1990's. By the year 2000, 33% of households and 30% of the urban housing stock were located within 3 km of a city center. In other words, on average China's already dense cities became more dense. This finding is consistent with known land market constraints and evidence of a lag in public infrastructure provision in the early post-reform period, which have important implications for productivity in urban areas.

The paper's primary finding is that differential exposure to the newly formed land leasing market resulted in a large effect on the decentralization of urban housing. In treated cities, the policy resulted in a decline of 19.1% in housing constructed in urban core areas and a simultaneous increase of 26.2% in housing in peripheral areas. I do not find evidence of an effect of leasing on increases in short-run housing production overall, suggesting that the policy was more effective in shifting the locus of housing production than in stimulating production in pilot cities. The land leasing instrument is a critical component of the national government's current efforts to urbanize the 250 million residents by 2025. These findings provide insights into how the program could effect urban spatial structure and suggest a role for additional research on the contemporary expansion of the program.

This study is among the first to examine the causal effect of a policy that has direct impacts on infrastructure provision in a developing country. In a concurrent analysis of the effect of ring-roads on population decentralization in Chinese cities, Baum-Snow et al (2018) have found large effects of transport infrastructure on urban decentralization during the 1990-2010 period. They estimate that producing a radial highway in an average Chinese city results in a 5% reduction in central city population and a ring road results in a 20% reduction. These estimates are not directly comparable to estimates of the effect of the land leasing instrument, as they involve distinct treatments, outcome variables, and methodological approaches. They provide distinct and complementary looks at the process of urban growth in China's post-reform period.

There are active public policy debates regarding public infrastructure investments and financing instruments in urban areas, particularly in developing country cities. These decisions are complicated, as they involve high fixed costs and benefits that are difficult to estimate in a comprehensive manner. A more comprehensive approach to evaluating the impact of these policy choices must address the fact that public infrastructure programs exert substantial influence over the production of positive and negative externalities in cities. By demonstrating the effect of policy on urban spatial structure, the present study lends itself to important extensions in this regard. One involves estimating the effect of the leasing instrument on road and highway congestion, which is a key concern in China's cities. A growing body of work has shown that infrastructure provision is unlikely to relieve congestion due to induced demand, although these findings are limited to studies in high income countries (Duranton and Turner 2011, Cervero 2002). Further analysis of the effects of infrastructure provision on congestion externalities in China could yield valuable insights about the impacts in settings characterized by high urban densities and low rates of private vehicle ownership. Other important extensions include effects on employment growth in China's urban areas as well as damages from pollution exposures, both of which are affected by patterns of urban growth that are emerging in the world's most populous nation.

References

A. Smith, Jeffrey and Petra E. Todd. 2005. "Does matching overcome (LaLonde's) critique of nonexperimental estimators?" *Journal of Econometrics* 125 (1-2):305–353.

Abadie, Alberto. 2005. "Semiparametric Difference-in-Differences Estimators." *The Review of Economic Studies* 72 (1):1–19.

Abadie, Alberto, David Drukker, Jane Leber Herr, and Guido W Imbens. 2004. "Implementing matching estimators for average treatment effects in Stata." *Stata journal* 4:290–311.

Abadie, Alberto and Guido W Imbens. 2006. "Large sample properties of matching estimators for average treatment effects." *Econometrica* 74 (1):235–267.

———. 2009. "Matching on the estimated propensity score." Tech. rep., National Bureau of Economic Research.

Alonso, William. 1964. *Location and land use. Toward a general theory of land rent.*

Anas, Alex and Hyok-Joo Rhee. 2006. "Curbing excess sprawl with congestion tolls and urban boundaries." *Regional Science and Urban Economics* 36 (4):510–541.

———. 2007. "When are urban growth boundaries not second-best policies to congestion tolls?" *Journal of Urban Economics* 61 (2):263–286.

Anderson, John. 2012. *Value Capture and Land Policies*, chap. Collecting Land Value Through Public Land Leasing. Lincoln Institute of Land Policy.

Angel, S., S. C. Sheppard, D. L. Civco, R. Buckley, A. Chabaeva, L. Gitlin, A. Kraley, J. Parent, and M. Perlin. 2005. "The dynamics of global urban expansion." *Transport and Urban Development Department, The World Bank* 1 (2):3.

Angel, Shlomo, Jason Parent, Daniel L. Civco, Alexander Blei, and David Potere. 2011. "The dimensions of global urban expansion: Estimates and projections for all countries, 2000-2050." *Progress in Planning* 75 (2):53–107.

Arnott, Richard. 2007. "Congestion tolling with agglomeration externalities." *Journal of Urban Economics* 62 (2):187–203.

Ashenfelter, Orley. 1978. "Estimating the effect of training programs on earnings." *The Review of Economics and Statistics* :47–57.

Ashenfelter, Orley C and David Card. 1984. "Using the longitudinal structure of earnings to estimate the effect of training programs."

Athey, Susan and Guido W Imbens. 2006. "Identification and inference in nonlinear difference-in-differences models." *Econometrica* 74 (2):431–497.

Au, Chun-Chung and J. Vernon Henderson. 2006a. "Are Chinese Cities Too Small?" *The Review of Economic Studies* 73 (3):549–576.

———. 2006b. "How migration restrictions limit agglomeration and productivity in China." *Journal of Development Economics* 80 (2):350–388.

Banerjee, Abhijit, Esther Duflo, and Nancy Qian. 2012. "On the road: Access to transportation infrastructure and economic growth in China." Tech. rep., National Bureau of Economic Research.

Baum-Snow, Nathaniel. 2007. "Did Highways Cause Suburbanization?" *The Quarterly Journal of Economics* 122 (2):775–805.

Baum-Snow, Nathaniel, Loren Brandt, J Vernon Henderson, Matthew A Turner, and Qinghua Zhang. 2018. "Roads, railroads and decentralization of Chinese cities." Working Paper.

Baum-Snow, Nathaniel and Matthew Turner. 2018. "Transportation and the decentralization of Chinese cities." Working Paper.

Bertaud, Alain and Stephen Malpezzi. 2003. "The spatial distribution of population in 48 world cities: Implications for economies in transition." *Rapport, World Bank* .

Bertaud, Alain and Bertrand Renaud. 1997. "Socialist Cities without Land Markets." *Journal of Urban Economics* 41 (1):137–151.

Bird, Richard M. 2004. "Getting it Right: Financing Urban Development in China." International Tax Program Paper 0413, International Tax Program, Institute for International Business, Joseph L. Rotman School of Management, University of Toronto.

———. 2006. "Taxing Land and Property in Emerging Economies: Raising Revenue...and More?" Tech. rep.

Box, G. E. P. and D. R. Cox. 1964. "An Analysis of Transformations." *Journal of the Royal Statistical Society. Series B (Methodological)* 26 (2):211–252.

Brownstone, David and Thomas F. Golob. 2009. "The impact of residential density on vehicle usage and energy consumption." *Journal of Urban Economics* 65 (1):91–98.

Brueckner, Jan K. 1987. "The structure of urban equilibria: A unified treatment of the Muth-Mills model." *Handbook of regional and urban economics* 2:821–845.

Brueckner, Jan K. 1997. "Infrastructure financing and urban development:: The economics of impact fees." *Journal of Public Economics* 66 (3):383–407.

———. 2007. "Urban growth boundaries: An effective second-best remedy for unpriced traffic congestion?" *Journal of Housing Economics* 16 (3-4):263–273.

Brueckner, Jan K., Edwin Mills, and Michael Kremer. 2001. "Urban Sprawl: Lessons from Urban Economics." *Brookings-Wharton Papers on Urban Affairs* :65–97.

Brueckner, J.K., J.F. Thisse, and Y. Zenou. 1999. "Why is central Paris rich and downtown Detroit poor? An amenity-based theory." *European Economic Review* 43 (1):91–107.

Cavallo, Eduardo and Christian Daude. 2011. "Public investment in developing countries: A blessing or a curse?" *Journal of Comparative Economics* 39 (1):65–81.

Cunningham, Christopher R. 2007. "Growth Controls, Real Options, and Land Development." *Review of Economics and Statistics* 89 (2):343–358.

Dale-Johnson, David, Christian L. Redfearn, and W. Jan Brzeski. 2005. "From Central Planning to Centrality: Krakow's Land Prices After Poland's Big Bang." *Real Estate Economics* 33 (2):269–297.

Deng, F. Frederic. 2005. "Public land leasing and the changing roles of local government in urban china." *The Annals of Regional Science* 39 (2):353–373.

Deng, Xiangzheng, Jikun Huang, Scott Rozelle, and Emi Uchida. 2008. "Growth, population and industrialization, and urban land expansion of China." *Journal of Urban Economics* 63 (1):96–115.

Ding, Chengri. 2003. "Land policy reform in China: assessment and prospects." *Land Use Policy* 20 (2):109–120.

Ding, Chengri. 2004. "Urban Spatial Development in the Land Policy Reform Era: Evidence from Beijing." Urban Studies 41 (10):1889–1907.

Ding, Chengri and Erik Lichtenberg. 2011. "Land and Urban Economic Growth in China." *Journal of Regional Science* 51 (2):299–317.

Donaldson, Dave. Forthcoming. "Railroads of the Raj: Estimating the impact of transportation infrastructure." *American Economic Review* .

Dowall, David E. 1993. "Establishing Urban Land Markets in the People's Republic of China." *Journal of the American Planning Association* 59 (2):182–192.

Duranton, Gilles, Peter M Morrow, and Matthew A Turner. 2014. "Roads and Trade: Evidence from the US." *The Review of Economic Studies* 81 (2):681–724.

Duranton, Gilles and Matthew A Turner. 2011. "The Fundamental Law of Road Congestion: Evidence from US Cities." *American Economic Review* 101 (6):2616–2652.

Duranton, Gilles and Matthew A. Turner. 2012. "Urban Growth and Transportation." *The Review of Economic Studies* 79.

Fernald, John G. 1999. "Roads to prosperity? Assessing the link between public capital and productivity." *American Economic Review* 89:619–638.

Fernandez, John E. 2007. "Resource Consumption of New Urban Construction in China." *Journal of Industrial Ecology* 11 (2):99–115.

Fowlie, Meredith, Stephen P Holland, and Erin T Mansur. 2012. "What do emissions markets deliver and to whom? Evidence from Southern California's NOx trading program." *The American Economic Review* 102 (2):965–993.

Frederic Deng, F and Youqin Huang. 2004. "Uneven land reform and urban sprawl in China: the case of Beijing." *Progress in Planning* 61 (3):211–236.

Gar-On Yeh, Anthony and Xia Li. 1999. "Economic Development and Agricultural Land Loss in the Pearl River Delta, China." *Habitat International* 23 (3):373–390.

Geshkov, M.V. and J.S. Desalvo. 2012. "The effect of land-use controls on the spatial size of U.S. urbanized areas." *Journal of Regional Science* 52 (4):648–675.

Glaeser, Edward L. 2008. "Cities, Agglomeration, and Spatial Equilibrium." Tech. rep., Oxford University Press.

Glaeser, Edward L., Joseph Gyourko, and Raven E. Saks. 2006. "Urban growth and housing supply." *Journal of Economic Geography* 6 (1):71–89.

Glaeser, Edward L. and Matthew E. Kahn. 2010. "The greenness of cities: Carbon dioxide emissions and urban development." *Journal of Urban Economics* 67 (3):404–418.

Glaeser, Edward L. and Bryce A. Ward. 2009. "The causes and consequences of land use regulation: Evidence from Greater Boston." *Journal of Urban Economics* 65 (3):265–278.

Gramlich, Edward M. 1994. "Infrastructure investment: a review essay." *Journal of economic literature* 32:1176–1196.

Harrold, P. and R. Lall. 1993. "China: Reform and Development in 1992-93." World Bank - Discussion Paper 215, World Bank.

Heckman, J. 1998. "Characterizing Selection Bias Using Experimental Data." Tech. Rep. 6699.

Heckman, James J., Hidehiko Ichimura, and Petra E. Todd. 1997. "Matching As An Econometric Evaluation Estimator: Evidence from Evaluating a Job Training Programme." *The Review of Economic Studies* 64 (4):605–654.

Hilber, Christian AL and Frédéric Robert-Nicoud. 2013. "On the origins of land use regulations: Theory and evidence from US metro areas." *Journal of Urban Economics* 75:29–43.

Hsu, Wen-Tai and Hongliang Zhang. 2014. "The fundamental law of highway congestion revisited: Evidence from national expressways in Japan." *Journal of Urban Economics* 81:65–76.

Ihlanfeldt, Keith R. 2007. "The effect of land use regulation on housing and land prices." *Journal of Urban Economics* 61 (3):420–435.

Imbens, Guido M and Jeffrey M Wooldridge. 2008. "Recent developments in the econometrics of program evaluation." Tech. rep., National Bureau of Economic Research.

Li, Ling-hin and Project Muse. 1996. *Privatization of urban land in Shanghai*. Hong Kong: Hong Kong University Press.

Lichtenberg, Erik and Chengri Ding. 2008. "Assessing farmland protection policy in China." *Land Use Policy* 25 (1):59–68.

———. 2009. "Local officials as land developers: Urban spatial expansion in China." *Journal of Urban Economics* 66 (1):57–64.

Lin, George C. S. 2001. "Metropolitan Development in a Transitional Socialist Economy: Spatial Restructuring in the Pearl River Delta, China." *Urban Studies* 38 (3):383–406.

Liu, Jiyuan, Mingliang Liu, Hanqin Tian, Dafang Zhuang, Zengxiang Zhang, Wen Zhang, Xianming Tang, and Xiangzheng Deng. 2005a. "Spatial and temporal patterns of China's cropland during 1990-2000: An analysis based on Landsat TM data." *Remote Sensing of Environment* 98 (4):442–456.

Liu, Jiyuan, Hanqin Tian, Mingliang Liu, Dafang Zhuang, Jerry M. Melillo, and Zengxiang Zhang. 2005b. "China's changing landscape during the 1990s: Large-scale land transformations estimated with satellite data." *Geophysical Research Letters* 32 (2).

McDonald, John F. 1989. "Econometric studies of urban population density: A survey." *Journal of Urban Economics* 26 (3):361–385.

McGrath, Daniel T. 2005. "More evidence on the spatial scale of cities." *Journal of Urban Economics* 58 (1):1–10.

Michaels, Guy. 2008. "The effect of trade on the demand for skill: Evidence from the interstate highway system." *The Review of Economics and Statistics* 90 (4):683–701.

Mills, Edwin S. 1967. "An Aggregative Model of Resource Allocation in a Metropolitan Area." *The American Economic Review* 57 (2):197–210.

Muth, Richard F. 1969. "Cities and Housing: The Spatial Pattern of Urban Residential Land Use." .

Parry, Ian WH and Kenneth A Small. 2005. "Does Britain or the United States have the right gasoline tax?" *The American Economic Review* 95 (4):1276–1289.

Paulsen, Kurt. 2012. "Yet even more evidence on the spatial size of cities: Urban spatial expansion in the US, 1980-2000." *Regional Science and Urban Economics* 42 (4):561–568.

Pereira, Alfredo M and Rafael Flores de Frutos. 1999. "Public capital accumulation and private sector performance." *Journal of Urban economics* 46 (2):300–322.

Perez-Lombard, Luis, Jose Ortiz, and Christine Pout. 2008. "A review on buildings energy consumption information." *Energy and Buildings* 40 (3):394–398.

Peterson, G.E., W. Bank, and P.P.I.A. Facility. 2009. *Unlocking Land Values to Finance Urban Infrastructure*. PPIAF trends and policy options. World Bank. URL `http://books.google.com/books?id=EeychzftnhcC`.

Peterson, George E. 2006. *Land Leasing And Land Sale As An Infrastructure-Financing Option*. The World Bank. URL `http://elibrary.worldbank.org/doi/abs/10.1596/1813-9450-4043`.

Quigley, J.M., S. Raphael, E. Ulsen, C. Mayer, and M. Schill. 2005. "Regulation and the high cost of housing in California." *American Economic Review* 95 (2):323–328.

Rose, Louis A. 1989a. "Topographical constraints and urban land supply indexes." *Journal of Urban Economics* 26 (3):335–347.

———. 1989b. "Urban land supply: Natural and contrived restrictions." *Journal of Urban Economics* 25 (3):325–345.

Rosenbaum, Paul R and Donald B Rubin. 1983. "The central role of the propensity score in observational studies for causal effects." *Biometrika* 70 (1):41–55.

Ross, Stephen and John Yinger. 1999. "Chapter 47 Sorting and voting: A review of the literature on urban public finance." In *Handbook of Regional and Urban Economics*, *Applied Urban Economics*, vol. Volume 3, edited by Paul Cheshire and Edwin S. Mills. Elsevier, 2001–2060.

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

Seto, K. C., C. E. Woodcock, C. Song, X. Huang, J. Lu, and R. K. Kaufmann. 2002. "Monitoring land-use change in the Pearl River Delta using Landsat TM." *International Journal of Remote Sensing* 23 (10):1985–2004.

Song, Yan and Chengri Ding. 2009. *Smart urban growth for China*. Lincoln Institute of Land Policy.

Tan, M., X. Li, H. Xie, and C. Lu. 2005. "Urban land expansion and arable land loss in China - A case study of Beijing-Tianjin-Hebei region." *Land Use Policy* 22 (3):187–196.

Venables, Anthony J. 2007. "Evaluating urban transport improvements: cost-benefit analysis in the presence of agglomeration and income taxation." *Journal of transport economics and policy* 41:173–188.

Wang, De, Li Zhang, Zhao Zhang, and Simon Xiaobin Zhao. 2011. "Urban Infrastructure Financing in Reform-era China." *Urban Studies* 48 (14):2975–2998.

Wheaton, William C. 1974. "A comparative static analysis of urban spatial structure." *Journal of Economic Theory* 9 (2):223–237.

Wills, David, Jean Jinghan Chen et al. 1999. *The Impact of China's Economic Reforms Upon Land, Property And Constuction*. Ashgate Publising Limited.

Wu, Fulong and Anthony Gar-On Yeh. 1999. "Urban Spatial Structure in a Transitional Economy." *Journal of the American Planning Association* 65 (4):377–394.

Wu, JunJie and Andrew J. Plantinga. 2003. "The influence of public open space on urban spatial structure." *Journal of Environmental Economics and Management* 46 (2):288–309.

Wu, Weiping. 1999. "Reforming China's Institutional Environment for Urban Infrastructure Provision." *Urban Studies* 36 (13):2263–2282.

Yang, Wei and Niklaus Kohler. 2008. "Simulation of the evolution of the Chinese building and infrastructure stock." *Building Research & Information* 36 (1):1–19.

Yearbook, China Statistical. 1980. "China National Statistical Yearbooks."

Zhang, Tingwei. 2000. "Land market forces and government's role in sprawl: The case of China." *Cities* 17 (2):123–135.

Zhao, N, M Mcneil, and Lin-j. Price l. Rue du can s. Sathaye j Fridley, d. 2007. "Energy Use in China: Sectoral Trends and Future Outlook." Tech. Rep. lbnl-61904, Lawrence Berkeley National Laboratory, Berkeley, Ca.

Zheng, Siqi, Yuming Fu, and Hongyu Liu. 2006. "Housing-choice hindrances and urban spatial structure: Evidence from matched location and location-preference data in Chinese cities." *Journal of Urban Economics* 60 (3):535–557.

Zheng, Siqi and Matthew E. Kahn. 2008. "Land and residential property markets in a booming economy: New evidence from Beijing." *Journal of Urban Economics* 63 (2):743–757.

Zheng, Siqi, Rui Wang, Edward L. Glaeser, and Matthew E. Kahn. 2009. "The Greenness of China: Household Carbon Dioxide Emissions and Urban Development." Working Paper 15621, National Bureau of Economic Research.

Table 1: CHANGES IN HOUSING DENSITY: NATIONAL MODEL

	National Model				
Dependent Variable: log(floor space) (m^2/km^2)	(1)	(2)	(3) 0-1 km	(4) 0-2 km	(5) 0-3 km
City Center*1990s			**.022*** (.0058)**	**.021*** (.0049)**	**.018*** (.0045)**
Distance*1990s		**-.019*** (.003)**			
Distance (km)	**-.084*** (.006)**	**-.08*** (.007)**	**-.080*** (.007)**	**-.074*** (.007)**	**-.066*** (.007)**
Observations	11,663	11,663	11,663	11,663	11,663
R-squared	.622	.627	.623	.625	.627

Notes: (1) Robust standard errors (in parentheses) clustered at the city level (2) All models control for steep slopes, inland and marine water bodies (3) All models include city and time fixed effects (4) *** p<0.01, ** p<0.05, * p<0.1

Table 2: EFFECT OF LAND LEASING POLICY ON TOTAL HOUSING PRODUCTION

Difference-In-Differences Estimates			
Dependent Variable: floor space (m^2/km^2)	τ_{Kernel} (1)	$\tau_{\text{Radius (Cal < .1)}}$ (2)	$\tau_{\text{Unmatched}}$ (3)
Policy Effect (ATT): Average Production	**250.86** **(1138)**	**237.24** **(1010.99)**	**2635.76***** **(829.37)**
Treated	4992.25	4992.25	5854.65
Counterfactual	4742.38	4755.01	3488.90
Observations	5,459	5,459	5,648
Pseudo R2 (probit model)	.54	.54	.54

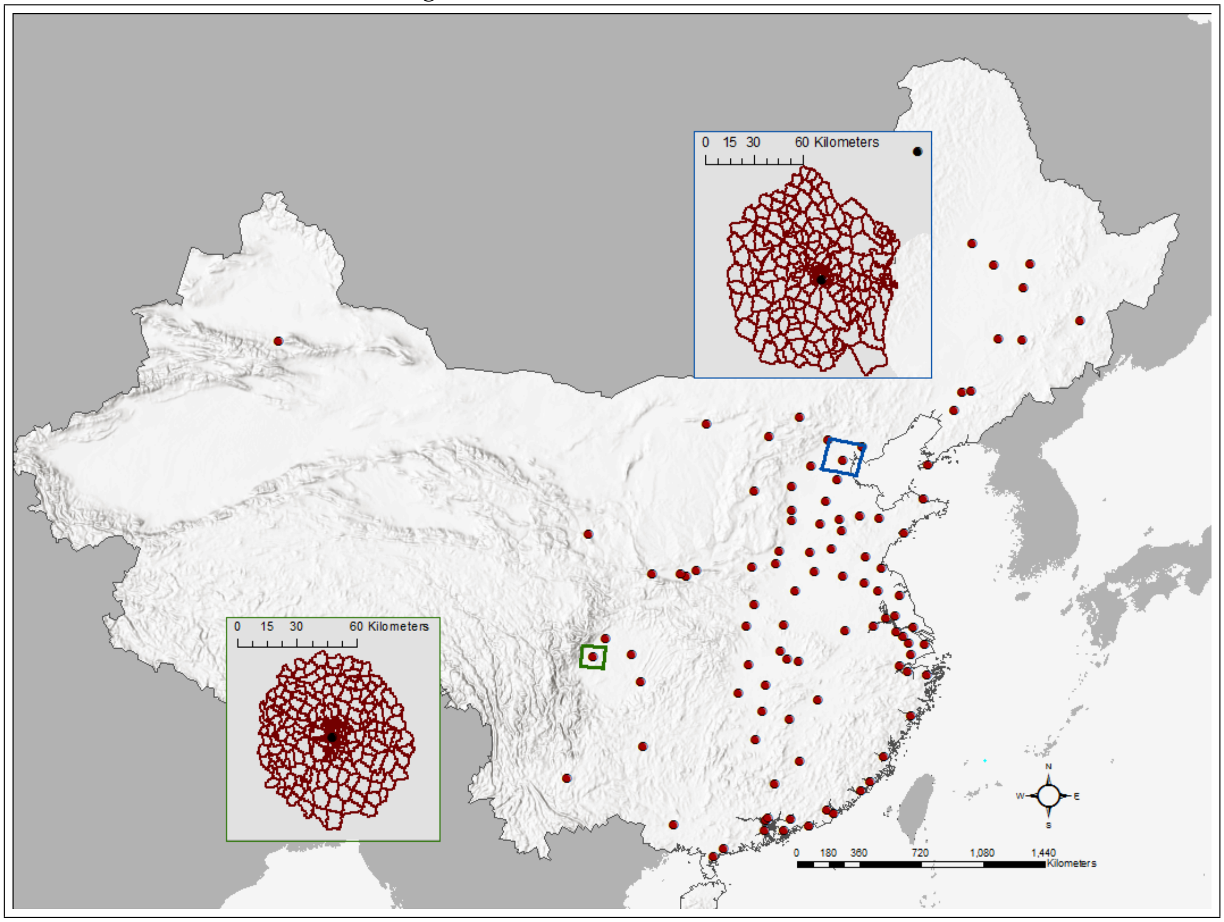
Notes: (1) τ_{Kernel} and τ_{Radius} are estimates of the policy effect (ATT) on average housing production and $\tau_{\text{Unmatched}}$ is a standard DD estimate (standard errors in parenthesis). Treated and counterfactual estimates refer to within-group differences in floor space production for entire sample (unmatched) and with kernel and radius matching estimators. Changes in the experimental sample reflect constrained estimation to match on a common support (ie outlier cities are dropped). (2) p(Xi) estimated with a probit model as a function of: population in 1980, fertility of agricultural land, fraction of land area with slope<14 degrees, fraction of land area within 20km of urban core not impeded by freshwater or marine coastline, percentage of metropolitan land area urbanized as of 1988, growth in local expenditures per capita between 1980-1990, total floorspace in 1990. Pseudo R2 is reported for the probit model. (3) *** p<0.01, ** p<0.05, * p<0.1

Table 3: EFFECT OF LAND LEASING POLICY ON HOUSING DECENTRALIZATION

Difference-In-Differences Estimates				
	Housing Production by Zone			
Dependent Variable: **floor space (m^2/km^2)**	**0-2 km** (1)	**0-3 km** (2)	**3-20 km** (3)	**4-20 km** (4)
Policy Effect (τ_{Kernel})	**-6026.76****	**-6453.26*****	**2675.21****	**2926.26****
	(2719.76)	**(1384.97)**	**(1260.78)**	**(1306.17)**
Treated	5404.12	3353.7	5778.79	5137.49
Counterfactual	11430.88	9572.78	3103.58	2211.23
Observations	932	1,417	4,042	3,613
Policy Effect ($\tau_{Radius(Cal<.1)}$)	**-6721.64****	**-7218.49*****	**2931.76****	**3095.22****
	(1138)	**(2510.9)**	**(1170.58)**	**(1190.84)**
Treated	5404.12	3119.52	5778.79	5137.49
Counterfactual	12125.76	10338.01	2847.02	2042.27
Observations	932	1,417	4,042	3,613
Full Sample ($\tau_{Unmatched}$)	**-2994.64**	**-3592.57*****	**4385.7*****	**4688.04*****
	(1897.81)	(1384.97)	(557.55)	(567.77)
Treated	4895.19	3353.7	6671.8	6563.77
Counterfactual	7889.83	6946.27	2286.1	1875.73
Observations	955	1,453	4,195	3,750
Pseudo R2 (Probit Model)	.54	.54	.54	.54

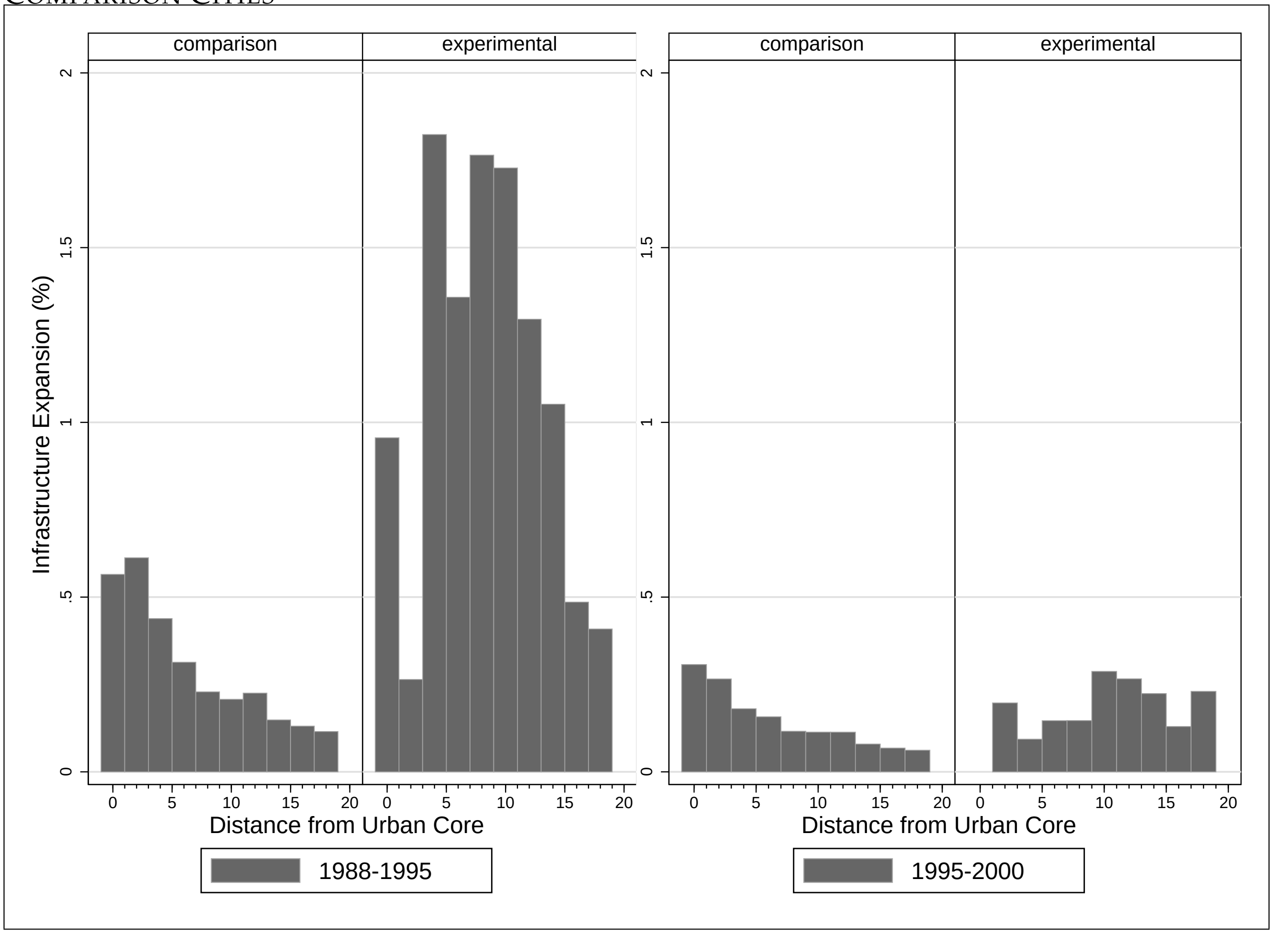
Notes: (1) τ_{Kernel} and τ_{Radius} are estimates of ATT and $\tau_{Unmatched}$ is a standard DD estimate , with standard errors in parenthesis. Treated and comparison estimates refer to within-group differences in floor space production for entire sample (unmatched) and with kernel and radius matching estimators. Changes in the experimental sample reflect constrained estimation to match on a common support (ie outlier cities are dropped). (2) $p(X_i)$ estimated with a probit model as a function of: population in 1980, fertility of agricultural land, fraction of land area with slope<14 degrees, fraction of land area within 20km of urban core not impeded by freshwater or marine coastline, percentage of metropolitan land area urbanized as of 1988, growth in local expenditures per capita between 1980-1990, total floorspace in 1990. Pseudo R2 is reported for the probit model. (3) *** p<0.01, ** p<0.05, * p<0.1

Figure 1: FULL SAMPLE OF CITIES



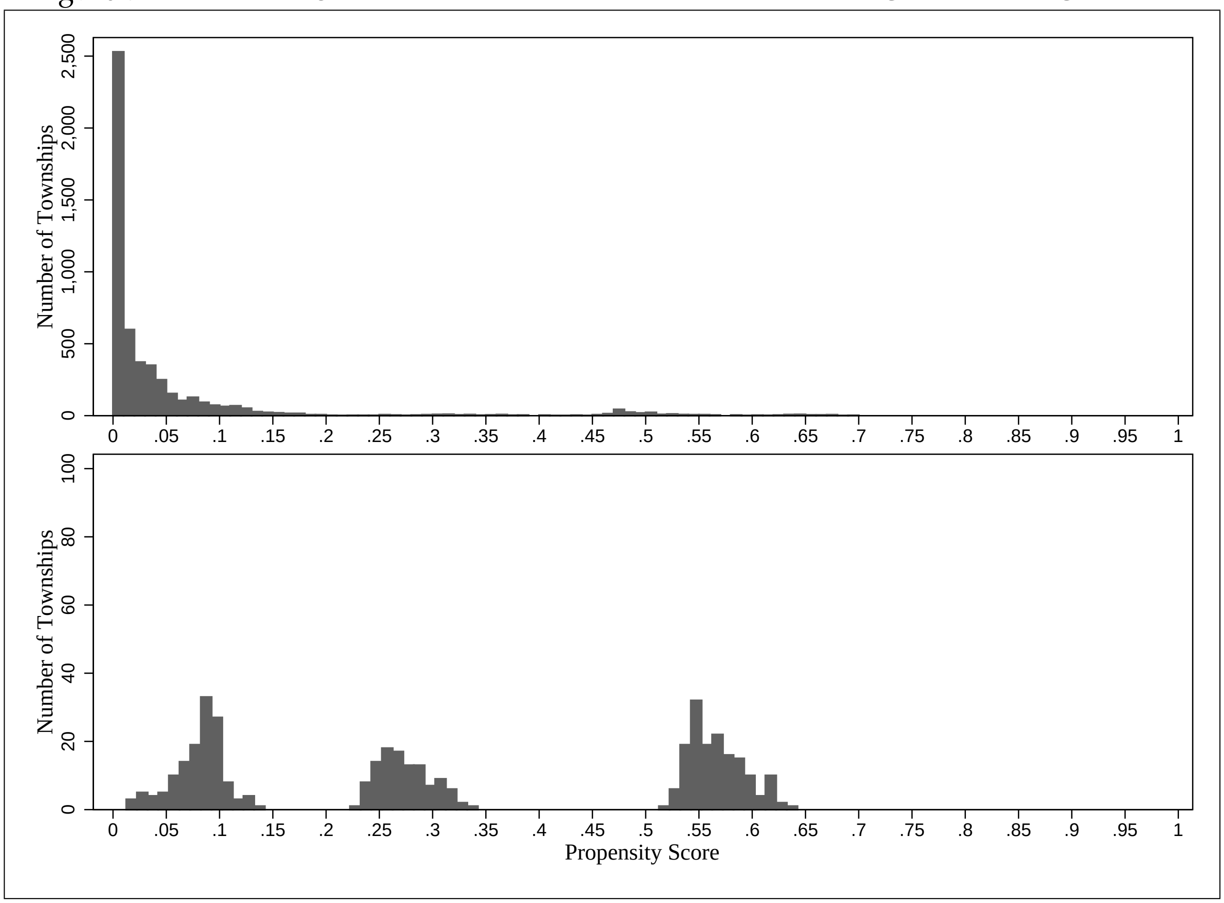
Notes:
(1)Township data includes urban townships within 50km from a city center. Primary model specifications include townships within 20km. Cities in this sample contain an average of 71 townships. The average size of townships in the sample is 34.8 km2.

Figure 2: LANDSAT TM MEASUREMENTS OF URBAN EXPANSION: TREATED VERSUS COMPARISON CITIES



Notes:
(1) Y-axis refers to annual percent change in urban land in average 1X1 km grid cells within each 2km distance interval with respect to treated and comparison city centers.
(2) Y-axis refers to percent change in urban land in average 1X1 km grid cell.

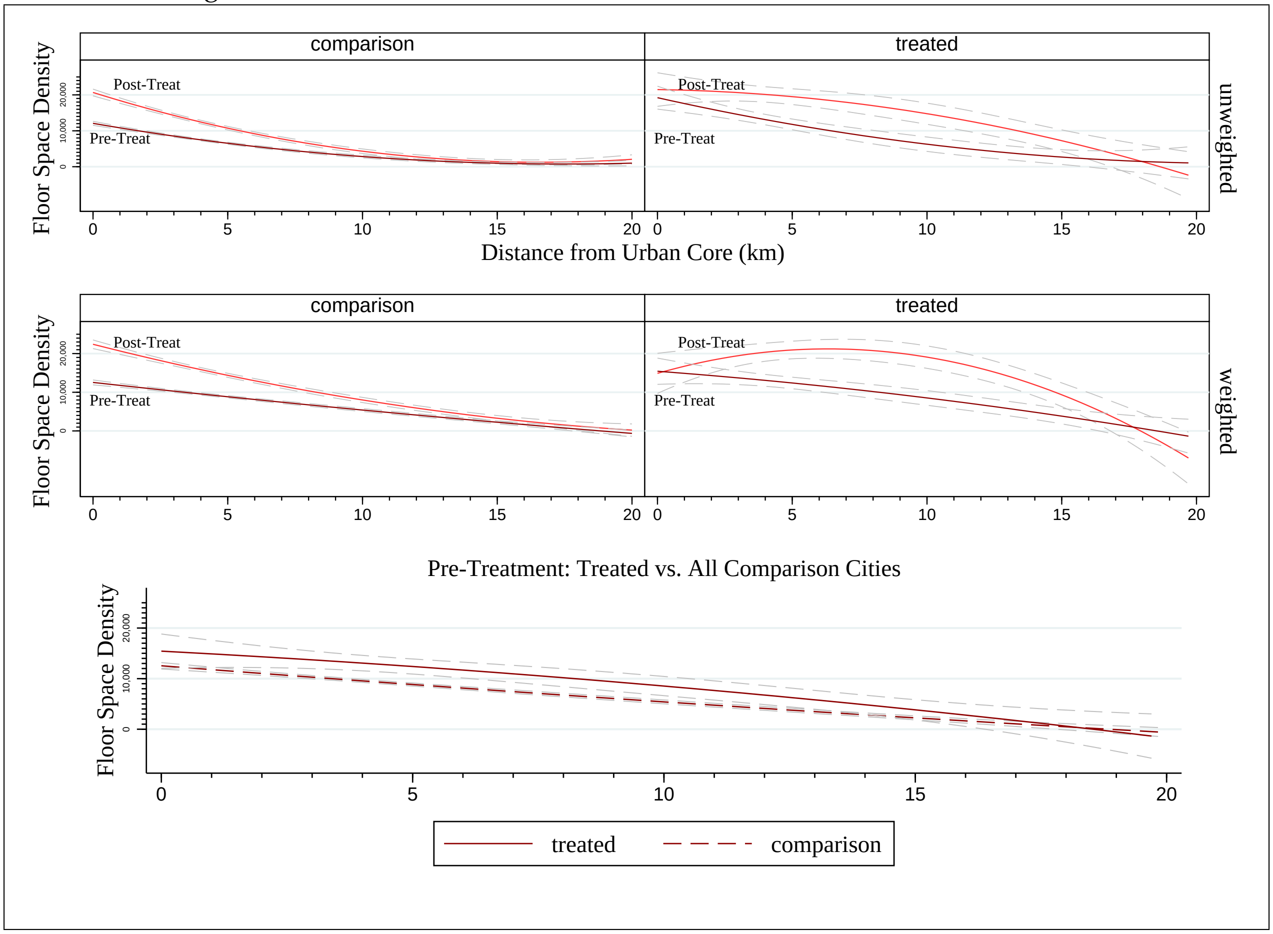
Figure 3: PROPENSITY SCORES FOR TOWNSHIPS IN TREATED VERSUS COMPARISON CITIES



Notes:

(1) Propensity score distribution for comparison cities in the middle graph is truncated (p(X)>.5) to display the upper tail. The entire distribution is shown in the upper graph. (2) p(Xi) is estimated in a standard probit model and is a function of: population in 1980, physical suitability of land for agriculture, fraction of land area with slope<14 degrees, fraction of land area within 20km of urban core not impeded by freshwater or marine coastline, percentage of metropolitan land area urbanized as of 1988, growth in local expenditures per capita between 1980-1990, total floor space in 1990, distance to urban core, and squared distance to urban core.

Figure 4: NEW FLOOR SPACE: TREATED VERSUS COMPARISON CITIES



Notes:
(1) Floor space density (m2/km2) constructed during pre-period (1980-1990) and post-period (1990-2000) for all townships in treated cities (n=4) and remainder of sample (n=95). Distance is measured as euclidean distance to nearest city center. All observations weighted by propensity scores but not matched.

9 Appendix

9.1 Appendix A

Table A1: GROWTH OF LAND LEASING SYSTEM

	National Revenue per Year Million yuan
1988	786
1989	747
1990	871
1991	1,538
1992	4,274
1993	8,393
1994	9,594
1995	19,440
1996	12,034

Source: Li 1999

Table A2: SUMMARY STATISTICS: TOWNSHIP-DECADE OBSERVATIONS

Township-Decade	Mean	St Dev
Constructed Floorspace (m2)		
1980s	**28010.5**	**22260.3**
1990s	**44540.1**	**41901.0**
Size of Townships (km2)	**34.8**	**47.9**
Sample Size	**5682**	

Notes: Summary statistics for full sample. Observations are by township-decade.

Table A3: SUMMARY STATISTICS: FRACTION OF HOUSING PRODUCED ACROSS ZONES

	0-3km		3-10km		10-20km	
	1980-1990	1990-2000	1980-1990	1990-2000	1980-1990	1990-2000
Baoding	16.7	26.0	34.8	35.8	48.5	38.2
Beijing	12.2	6.0	47.0	49.8	40.8	44.3
Cangzhou	23.2	28.7	36.1	39.2	40.7	32.1
Changchun	31.9	40.0	52.2	49.3	15.9	10.7
Chengdu	14.8	14.7	43.9	43.4	41.4	41.9
Chongqing	18.2	17.4	41.8	42.9	40.0	39.6
Ganzhou	32.2	38.7	21.2	25.2	46.6	36.1
Guangzhou	34.8	18.7	39.2	56.1	25.9	25.2
Haerbin	21.6	23.8	57.0	53.2	21.4	23.0
Handan	15.8	25.1	30.4	29.1	53.8	45.9
Hangzhou	17.3	13.9	28.3	27.6	54.4	58.5
Hengyang	21.5	20.3	41.0	38.0	37.5	41.8
Heze	20.7	27.4	21.4	21.1	57.9	51.4
Huanggang	33.2	36.8	26.0	25.0	40.8	38.2
Jingzhou	25.3	31.8	37.9	36.5	36.8	31.7
Jining	29.7	37.3	18.0	16.8	52.2	45.8
Linyi	18.2	28.6	34.8	37.2	47.0	34.2
Luoyang	20.8	20.3	44.2	45.6	35.0	34.1
Maoming	17.0	20.9	29.8	23.2	53.1	56.0
Nanchong	23.6	44.0	21.9	20.9	54.4	35.1
Nanning	61.0	60.3	13.7	14.4	25.3	25.3
Nantong	21.3	18.5	25.7	21.6	53.0	59.9
Nanyang	29.8	32.3	29.0	33.4	41.3	34.3
Qingdao	25.9	30.1	49.9	48.7	24.2	21.2
Quanzhou	16.6	17.5	20.3	22.5	63.2	60.1
Shanghai	9.0	4.9	50.6	60.4	40.3	34.7
Shangqiu	15.2	26.4	29.6	31.1	55.2	42.5
Shenyang	21.5	28.3	58.6	54.7	19.9	17.0
Shenzhen	41.2	32.8	41.0	47.6	17.9	19.6
Shijiazhuang	20.9	20.9	41.6	50.3	37.4	28.9
Tangshan	30.3	26.2	27.2	32.7	42.5	41.1
Tianjin	23.7	24.5	48.8	52.7	27.5	22.8
Weifang	22.3	29.3	27.8	30.9	49.9	39.8
Wenzhou	8.6	9.9	31.7	31.4	59.7	58.7
Wuhan	18.8	18.1	54.5	55.9	26.7	26.0
Xingtai	21.8	32.7	28.6	25.4	49.6	41.9
Xinyang	30.7	33.1	24.2	25.9	45.1	41.0
Xuzhou	17.2	21.2	52.0	52.9	30.8	26.0
Yancheng	18.4	23.2	30.1	38.5	51.5	38.3
Yantai	13.4	19.7	40.0	38.2	46.6	42.1
Zhanjiang	18.6	22.6	32.4	36.3	49.0	41.1
Zhengzhou	31.1	32.8	34.9	44.1	34.0	23.2
Zhoukou	14.5	22.7	30.5	28.6	55.1	48.7
Total	22.8	25.8	35.6	37.1	41.6	37.2
Observations	43					

Notes:

(1) Summary statistics for experimental cities and cities with populations above sample mean.

(3) Source: China Census 2000

Table A4: SUMMARY STATISTICS: TREATED AND COMPARISON GROUPS

	Treated	Comparison		
		Weighted	Norm Dif	Unweighted
Propensity Scores	**.323** **(.112)**	**.316** **(.214)**	**.023**	**.051** **(.112)**
Covariate Distributions				
1980 Population	2.42 (2.01)	3.33 (1.69)	**.348**	4.71 (1.83)
Fraction Steep Slopes	0.00011 (0.0000095)	0.00010 (0.000013)	**.621**	0.0000998 (0.0000181)
Terrestrial Area	173590.6 (40160.3)	150310.2 (43677.3)	**.392**	203185.1 (44827.01)
Inland H20	1.99 (6.78)	9.41 (15.82)	**.431**	0.566 (4.46)
Fraction Urban (1988)	0.663 (0.209)	0.731 (0.371)	**.160**	.321 (.243)
Local Per Capita Expenditure Growth	.028 (.01)	.025 (.017)	**.152**	.015 (.015)
Total Floor Space 1990	1176.05 (853.47)	1537.9 (922.96)	**.288**	1514.92 (1250.08)
Township Observations Per City	**120.32** **(35.4)**	**115.32** **(39.62)**		**133.76** **(59.52)**
Total Observations	**402**	**5,246**		**5,246**

Notes: Mean propensity scores and covariate distributions for treated versus weighted and unweighted samples. Normalized differences obtained using kernel weighting function. Summary statistics report sizes of township sample for treatment and comparison groups and mean number of townships per city for each group. Standard deviations in parenthesis.

Table A5: PLACEBO TEST: TREATMENT EFFECTS IN TOP-TIER CITIES

Difference-In-Differences Estimates					
	Housing Production by Zone				
Dependent Variable: **floor space (m^2/km^2)**	**Total** (1)	**0-2 km** (2)	**0-3 km** (3)	**3-20 km** (4)	**4-20 km** (5)
Placebo Effect (τ_{Kernel})	**2880.4*** **	**3966.77** **	**4207.15*** **	**2051.11*** **	**1658.09*** **
	(484.72)	**(1686.77)**	**(1187.47)**	**(463.23)**	**(470.17)**
Treated	5271.74	10600.91	9492.36	3687.35	2978.63
Counterfactual	2391.34	6634.14	5285.21	1636.24	1320.53
Observations	4,996	854	1,290	3,706	3,325
Placebo Effect ($\tau_{Radius(Cal<.1)}$)	**2665.44*** **	**3826.87** **	**3847.58*** **	**2188.81*** **	**1639.03*** **
	(467.93)	**(1644.16)**	**(1151.21)**	**(480.72)**	**(453)**
Treated	5271.74	10600.91	9492.36	3687.35	2978.63
Counterfactual	2606.31	6774.05	5644.78	1498.54	1339.6
Observations	4,996	854	1,290	3,706	3,225
Unmatched	**3078.85*** **	**4905.52*** **	**4312.16*** **	**2543.11*** **	**2176.06*** **
	(344.91)	**(1151.67)**	**(858.99)**	**(341.82)**	**(345.42)**
Treated	5909.25	11767.21	10296.63	3687.41	3611.58
Counterfactual	2830.4	6861.7	5984.47	1750.29	1435.52
Observations	5,246	897	1,354	3,892	3,485
Pseudo R2 (Probit Model)	.28	.28	.28	.28	.28

Notes: (1) τ_{Kernel} and τ_{Radius} are estimates of ATT and $\tau_{Unmatched}$ is a standard DD estimate , with standard errors in parenthesis. Treated and comparison estimates refer to within-group differences in floor space production for entire sample (unmatched) and with kernel and radius matching estimators. Changes in the experimental sample reflect constrained estimation to match on a common support (ie outlier cities are dropped). (2) $p(X_i)$ estimated with a probit model as a function of: population in 1980, fertility of agricultural land, fraction of land area with slope<14 degrees, fraction of land area within 20km of urban core not impeded by freshwater or marine coastline, percentage of metropolitan land area urbanized as of 1988, growth in local expenditures per capita between 1980-1990, total floorspace in 1990. Pseudo R2 is reported for the probit model. (3) *** p<0.01, ** p<0.05, * p<0.1

Table A6: PLACEBO TEST: CITIES WITH SPECIAL ECONOMIC DEVELOPMENT ZONES

Difference-In-Differences Estimates					
		Housing Production by Zone			
Dependent Variable: **floor space (m^2/km^2)**	**Total** (1)	**0-2 km** (2)	**0-3 km** (3)	**3-20 km** (4)	**4-20 km** (5)
Placebo Effect (τ_{Kernel})	**3433.85*** **	**9908.66*** **	**7932.62*** **	**2162.73*** **	**2415.14** **
	(916.47)	**(3194.29)**	**(132417.77)**	**(860.22)**	**(872.24)**
Treated	5427.06	15195.75	12692.22	3120.66	3050.95
Counterfactual	1993.2	5287.09	4759.61	957.92	635.80
Observations	5,181	893	1,347	3,834	3,433
Placebo Effect ($\tau_{Radius(Cal<.1)}$)	**3345.4*** **	**9558.92** **	**7996.45*** **	**2052.0*** **	**2358.8** **
	(865.63)	**(3127)**	**(2340.55)**	**(796.35)**	**(800.29)**
Treated	5427.06	15195.75	12692.22	3120.66	3050.95
Counterfactual	2081.66	5636.83	4695.78	1068.66	692.814
Observations	5,181	893	1,347	3,834	3,433
Unmatched	**2237.03*** **	**7280.98*** **	**5745.14*** **	**1447.22*** **	**1861.8** **
	(493.28)	**(1736.79)**	**(1328.63)**	**(476.33)**	**(471.74)**
Treated	5521.24	14594.51	12237.4	3594.63	3558.03
Counterfactual	3284.21	7313.52	6492.26	2147.4	1696.22
Observations	5,246	897	1,354	3,892	3,485
Pseudo R2 (Probit Model)	.33	. 33	. 33	. 33	. 33

Notes: (1) τ_{Kernel} and τ_{Radius} are estimates of ATT and $\tau_{Unmatched}$ is a standard DD estimate, with standard errors in parenthesis. Treated and counterfactual estimates refer to within-group differences in floor space production for entire sample (unmatched) and with kernel and radius matching estimators. Changes in the experimental sample reflect constrained estimation to match on a common support (ie outlier cities are dropped). (2) $p(X_i)$ estimated with a probit model as a function of: population in 1980, fertility of agricultural land, fraction of land area with slope<14 degrees, fraction of land area within 20km of urban core not impeded by freshwater or marine coastline, percentage of metropolitan land area urbanized as of 1988, growth in local expenditures per capita between 1980-1990, total floorspace in 1990. Pseudo R2 is reported for the probit model. (3) *** p<0.01, ** p<0.05, * p<0.1

Table A7: ROBUSTNESS: POLICY EFFECT OF LAND LEASING POLICY IN CITY CENTERS

Difference-In-Differences Estimates				
Dependent Variable: **floor space (m^2/km^2)**	**Housing Production by Zone**			
	0-2 km	**0-3 km**	**0-4 km**	**0-5 km**
	(1)	(2)	(3)	(4)
Policy Effect (τ_{Kernel})	**-6026.76****	**-6453.26*****	**-4903.51****	**-3441.45***
	(2719.76)	**(1384.97)**	**(2110.82)**	**(1852.04)**
Treated	5404.12	3119.52	4773.53	5763.06
Counterfactual	11430.88	9572.78	9677.04	9114.51
Observations	932	1,417	5,648	2,234
Policy Effect ($\tau_{Radius(Cal<.1)}$)	**-6721.64****	**-7218.49*****	**-5389.04*****	**-3744.34****
	(1138)	**(2510.9)**	**(2151.42)**	**(1890.37)**
Treated	5404.12	3119.52	4773.53	5763.06
Counterfactual	12125.76	10338.01	10162.56	9417.41
Observations	932	1,417	1,846	1,846
Biased Effect ($\tau_{Unmatched}$)	**-2994.64**	**-3592.57*****	**-2198.33***	**-1198.64***
	(1897.81)	**(1384.97)**	**(1153.84)**	**(1033.49)**
Treated	4895.19	3353.7	4483	5202.27
Counterfactual	7889.83	6946.27	6681.34	6400.91
Observations	955	1,453	1,898	2,300
Pseudo R2 (Probit Model)	.54	.54	.54	.54

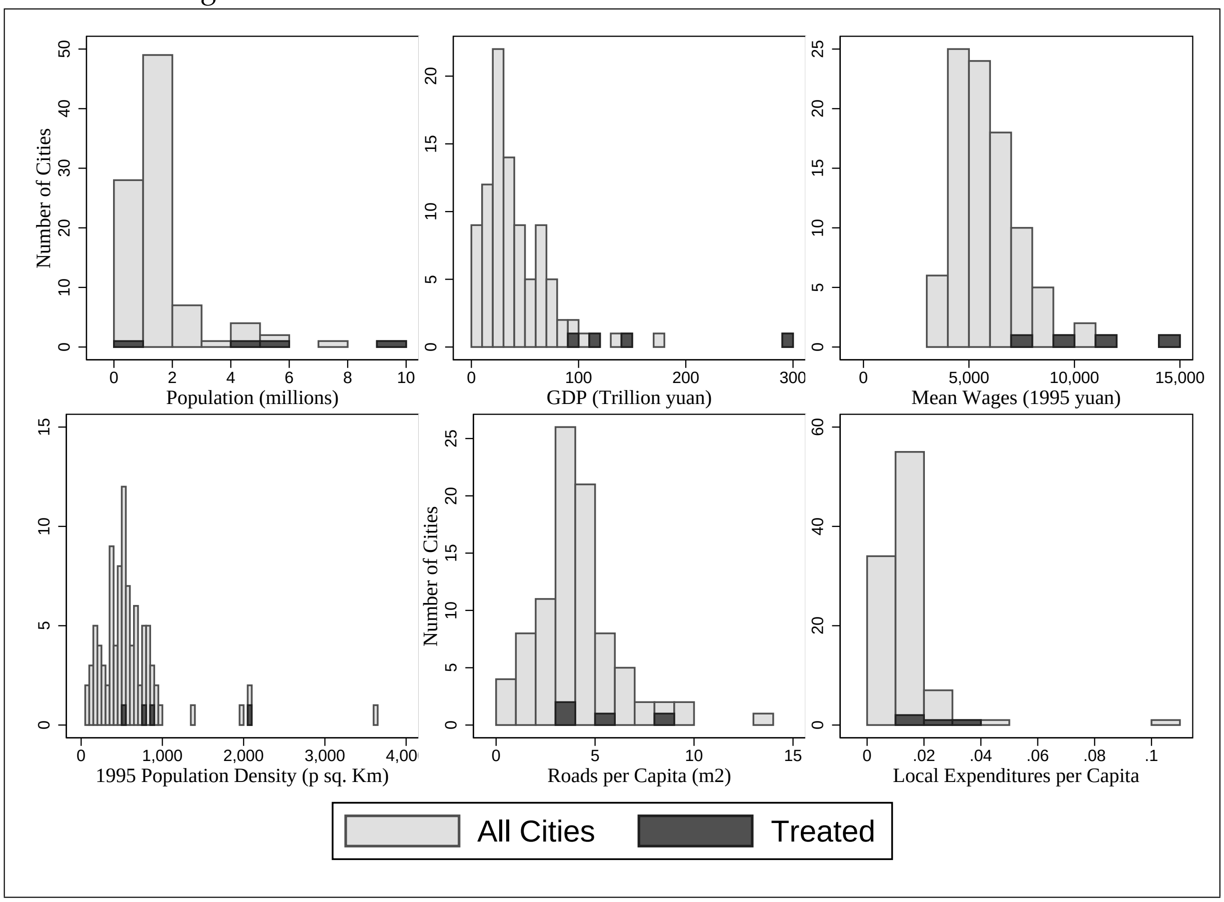
Notes: (1) τ_{Kernel} and τ_{Radius} are estimates of ATT and $\tau_{Unmatched}$ is a standard DD estimate, with standard errors in parenthesis. Treated and comparison estimates refer to within-group differences in floor space production for entire sample (unmatched) and with kernel and radius matching estimators. Changes in the experimental sample reflect constrained estimation to match on a common support (ie outlier cities are dropped).
(2) $p(X_i)$ estimated with a probit model as a function of: population in 1980, fertility of agricultural land, fraction of land area with slope<14 degrees, fraction of land area within 20km of urban core not impeded by freshwater or marine coastline, percentage of metropolitan land area urbanized as of 1988, growth in local expenditures per capita between 1980-1990, total floorspace in 1990. Pseudo R2 is reported for the probit model.
(3) *** p<0.01, ** p<0.05, * p<0.1

Table A8: ROBUSTNESS: POLICY EFFECT OF LAND LEASING POLICY IN PERIPHERAL ZONES

Difference-In-Differences Estimates				
	Housing Production by Zone			
Dependent Variable: **floor space (m^2/km^2)**	**2-20 km** (1)	**3-20 km** (2)	**4-20 km** (3)	**5-20 km** (4)
Policy Effect (τ_{Kernel})	**1579.66**	**2675.21****	**2926.26****	**2544.28***
	(1245.03)	**(1260.78)**	**(1306.17)**	**(1390.7)**
Experimental	4911.26	5778.79	5137.49	4305
Counterfactual	3331.59	3103.58	2211.23	1760.62
Observations	4,527	4,042	3,613	3,225
Policy Effect ($\tau_{Radius(Cal<.1)}$)	**1730.17**	**1170.58****	**3095.22****	**2653****
	(1170.84)	**(2931.76)**	**(1190.84)**	**(2653)**
Experimental	4911.26	5778.79	5137.49	4305
Counterfactual	3181.09	2847.02	2042.27	1652
Observations	4,527	4,042	3,613	3,225
Unmatched	**3435.23*****	**4385.7*****	**4688.04*****	**4484.45***
	(541.11)	**(557.55)**	**(567.77)**	**(558.51)**
Experimental	6016.42	6671.8	6563.77	6347.5
Counterfactual	2581.18	2286.1	1875.73	1503.05
Observations	4,693	4,195	3,750	3,348
Pseudo R2 (Probit Model)	.54	.54	.54	.54

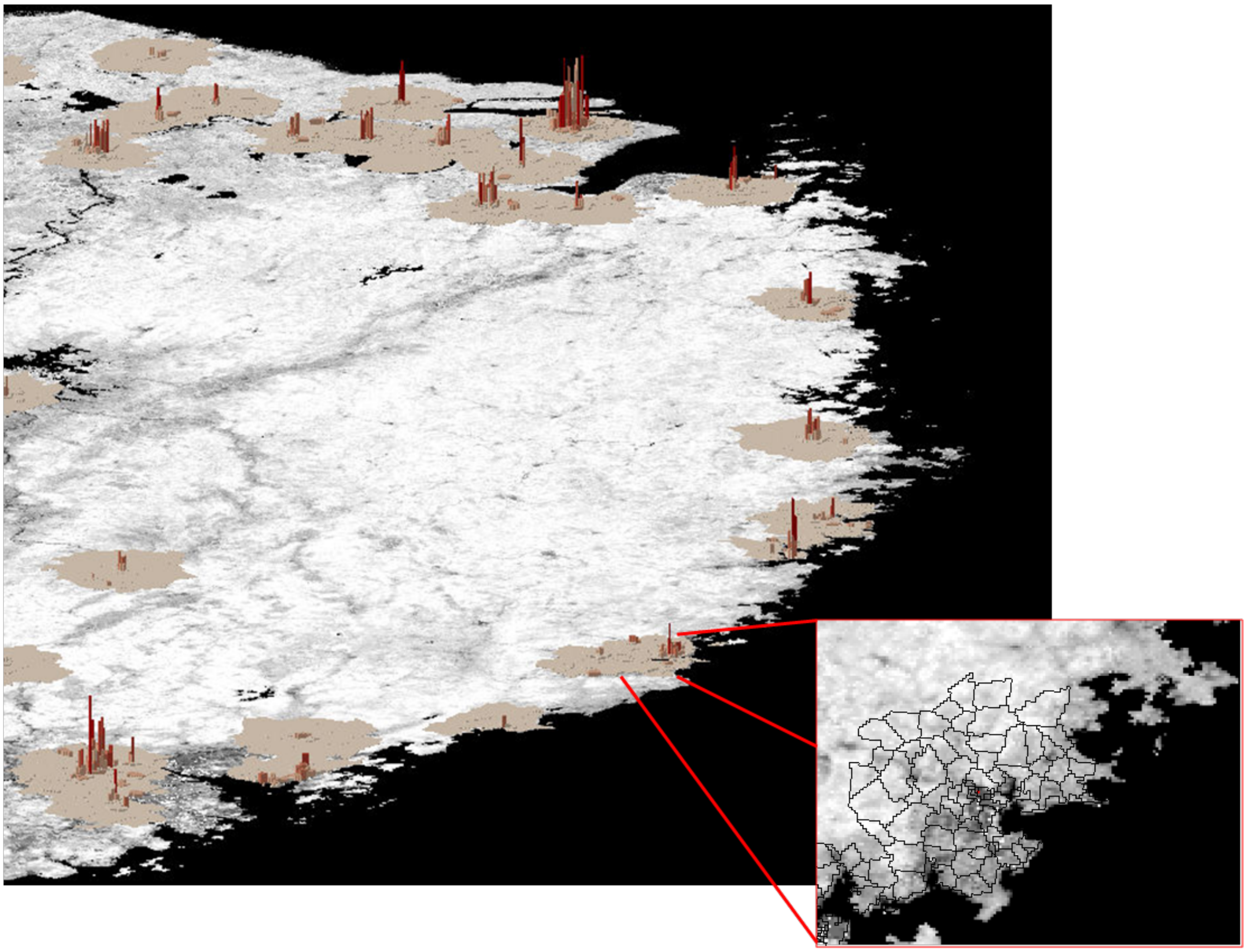
Notes: (1) τ_{ATT} measures the effect of the land leasing policy on total housing production in experimental cities, with standard errors in parenthesis. Experimental and counterfactual estimates refer to decadal changes in floor space production for entire sample (unmatched) and with kernel and radius matching estimators. Changes in the experimental sample reflect constrained estimation to match on a common support (ie outlier cities are dropped). (2) $p(X_i)$ estimated with a probit model as a function of: population in 1980, fertility of agricultural land, fraction of land area with slope<14 degrees, fraction of land area within 20km of urban core not impeded by freshwater or marine coastline, percentage of metropolitan land area urbanized as of 1988, growth in local expenditures per capita between 1980-1990, total floorspace in 1990. Pseudo R2 is reported for the probit model. (3) *** p<0.01, ** p<0.05, * p<0.1

Figure A1: CHARACTERISTICS OF PILOT CITIES RELATIVE TO SAMPLE



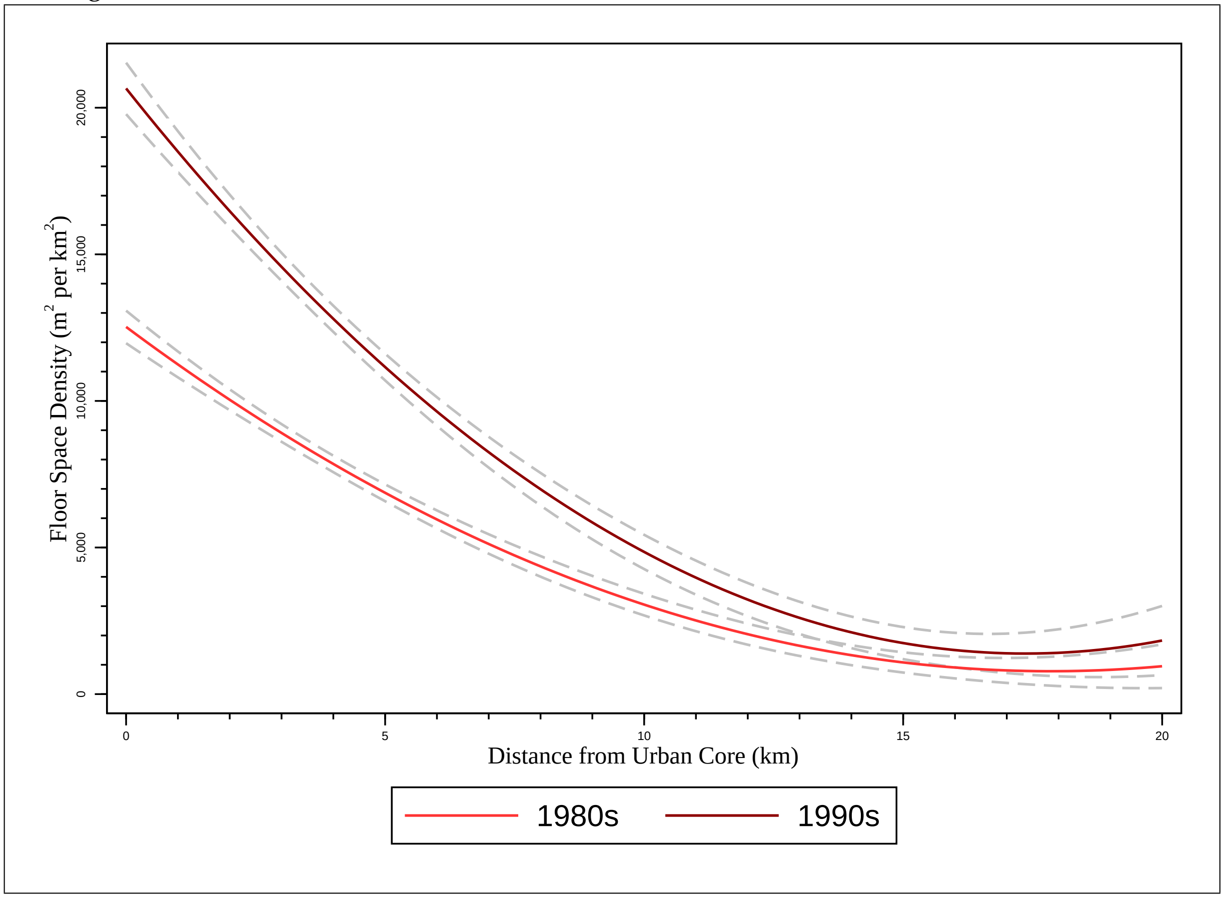
Notes:
(1) City-level data from China City Statistical Yearbooks: 1995/1996. These city-level parameters are not available for the pre-leasing period. These can not be interpreted as independent of the effect of the program, but offer a descriptive illustration of the sample during the mid-1990's. (2) Outlier city is Shanghai in every case. (3) Currency in year 1995/1996 yuan/dollars.

Figure A2: SPATIAL DISTRIBUTION OF URBAN FLOOR SPACE FOR A SAMPLE OF CITIES



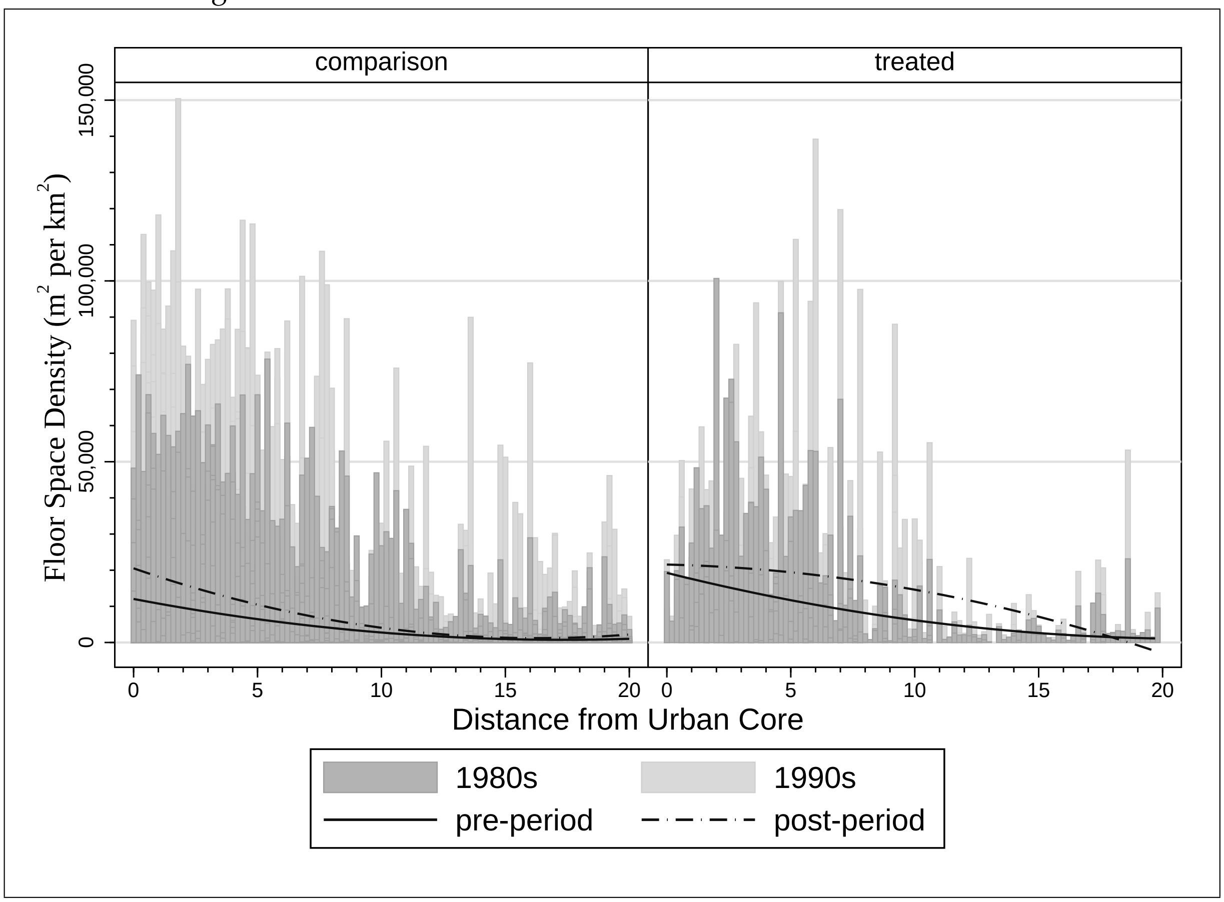
Notes:
(1) On average, cities in the sample contain an average of 71 townships. The average size of townships in the sample is 34.8 km2.

Figure A3: SPATIAL DISTRIBUTION OF FLOOR SPACE PRODUCTION: NATIONAL MODEL



Notes: Quadratic function of observed floor space growth for all 5682 townships between 0-20km of an urban core during the periods 1980-1990 and 1990-2000. 95 percent confidence interval.

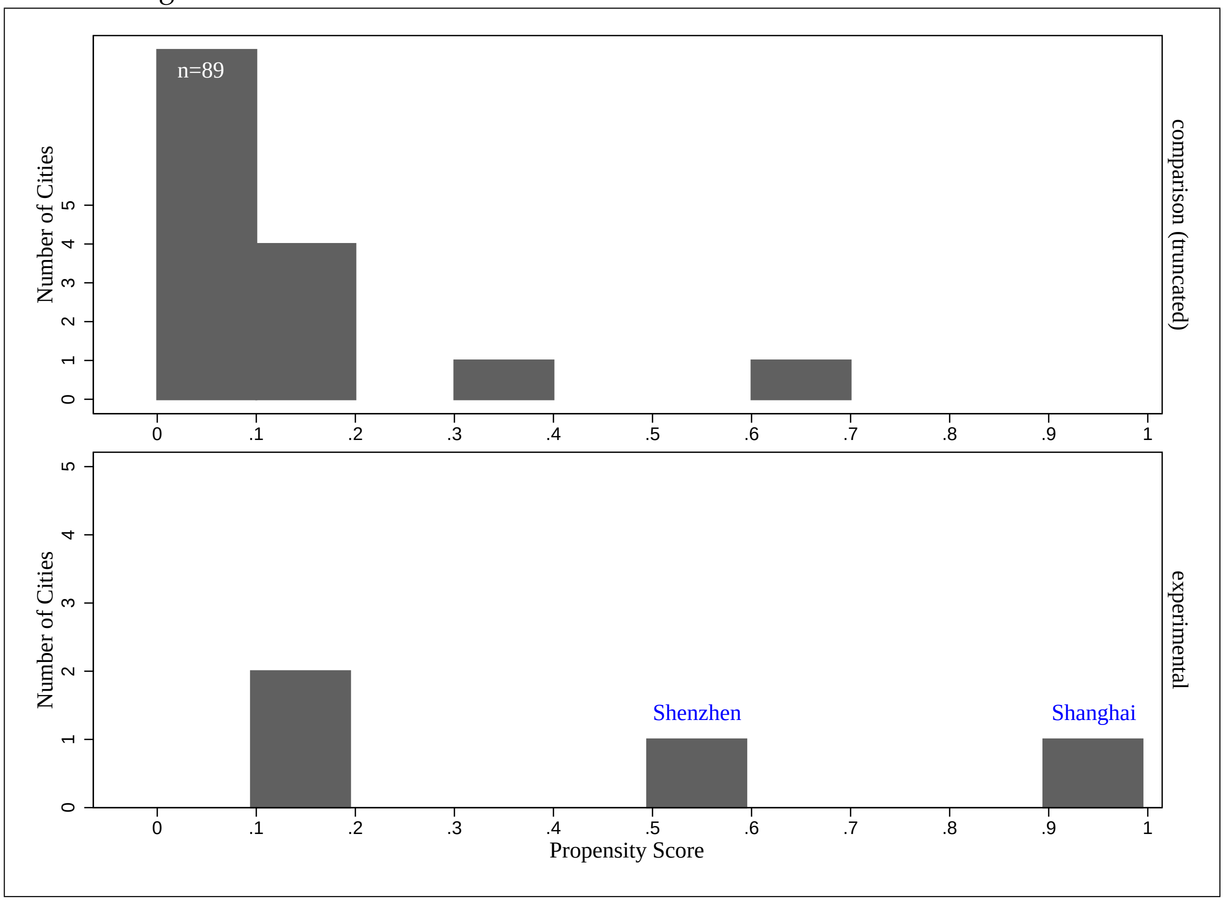
Figure A4: NEW FLOOR SPACE IN TREATED VS COMPARISON CITIES



Notes:

(1) Floor space density (m2/km2) constructed during pre-period (1980-1990) and post-period (1990-2000) for all townships in treated cities (n=4) and remainder of sample (n=95). Distance is measured as euclidean distance to nearest city center.

Figure A5: PROPENSITY SCORES FOR TREATED VERSUS COMPARISON CITIES



Notes:
(1) Propensity score distribution for comparison cities is truncated (p(X)>.1) to display the upper tail. The number of comparison cities whose propensity scores fall in that interval is 89.
(2) p(Xi) is estimated in a standard probit model and is a function of: population in 1980, physical suitability of land for agriculture, fraction of land area with slope<14 degrees, fraction of land area within 20km of urban core not impeded by freshwater or marine coastline, percentage of metropolitan land area urbanized as of 1988, growth in local expenditures per capita between 1980-1990, total floor space in 1990.

9.2 Appendix B

Table B1: EFFECT OF LAND LEASING ON HOUSING PRODUCTION (TOWNSHIP MATCHING)

		Policy Effect		Placebo Effect	
		semi-parametric kernel	semi-parametric radius (Cal < .1)	semi-parametric kernel	semi-parametric radius (Cal < .1)
	Dependent Variable: Floorspace (m^2/km^2)	(1)	(2)	(4)	(5)
AVERAGE PRODUCTION	τ_{ATT}	1692.95*	1265.74	1016.27***	587.15
		(942.79)	(829.37)	(284.44)	(340.91)
	$\tau_{Unmatched}$	2365.76***	2365.76***	1647.27***	1611.95***
		(553.48)	(553.48)	(285.19)	(284.13)
	Observations	5,648	5,648	5,246	5,246
PRODUCTION BY ZONE (DECENTRALIZATION)	$\tau_{ATT(D)}$	-10154.48***	-7954.23***	479.78	-218.47
	inside 2km	(2267.92)	(1985.14)	(918.46)	(1006.17)
	$\tau_{ATT(D)}$	-8761***	-7426.83***	171.76	-794.56
	inside 3km	(2242.33)	(1780.53)	(699.91)	(773.74)
	$\tau_{ATT(D)}$	2675.84**	3398.77***	478.60*	380.65
	outside 5km	(1323.48)	(1245.01)	(268.52)	(309.21)
	$\tau_{ATT(D)}$	3292.51***	3114.11**	263.66	148.02
	outside 6km	(1329.22)	(1238.59)	(185.20)	(211.08)

Notes:

(1) τ_{ATT} measures the effect of the policy on housing production in experimental cities.
(2) $p(X_i)$ estimated with a probit model as a function of: population in 1980, fertility of agricultural land, fraction of land area with slope<14 degrees, fraction of land area within 20km of urban core not impeded by freshwater or marine coastline, percentage of metropolitan land area urbanized as of 1988, growth in local expenditures per capita between 1980-1990, total floorspace in 1990. *** p<0.01, ** p<0.05, * p<0.1

9.3 Data Appendix

Measurements of Constructed Floorspace using Township-level Data

Data on constructed floor space come from the short form of the census and are recorded at the level of the township. Township-level data are geo-referenced by the China Data Center at the University of Michigan. Township locations and sizes are recorded in offical government data but spatial boundaries for townships are considered approximate.[30] This is an important characteristic of the data. For the purposes of this analysis, measurement error in exact location of township boundaries is assumed to be orthogonal to time-varying differences in floorspace production (conditional on the distance of the township and township size, which are both known). Results in the national model are robust to estimation using area-weighted versus unweighted differences in floorspace production as well as by defining township location in terms of centroid versus polygon location.

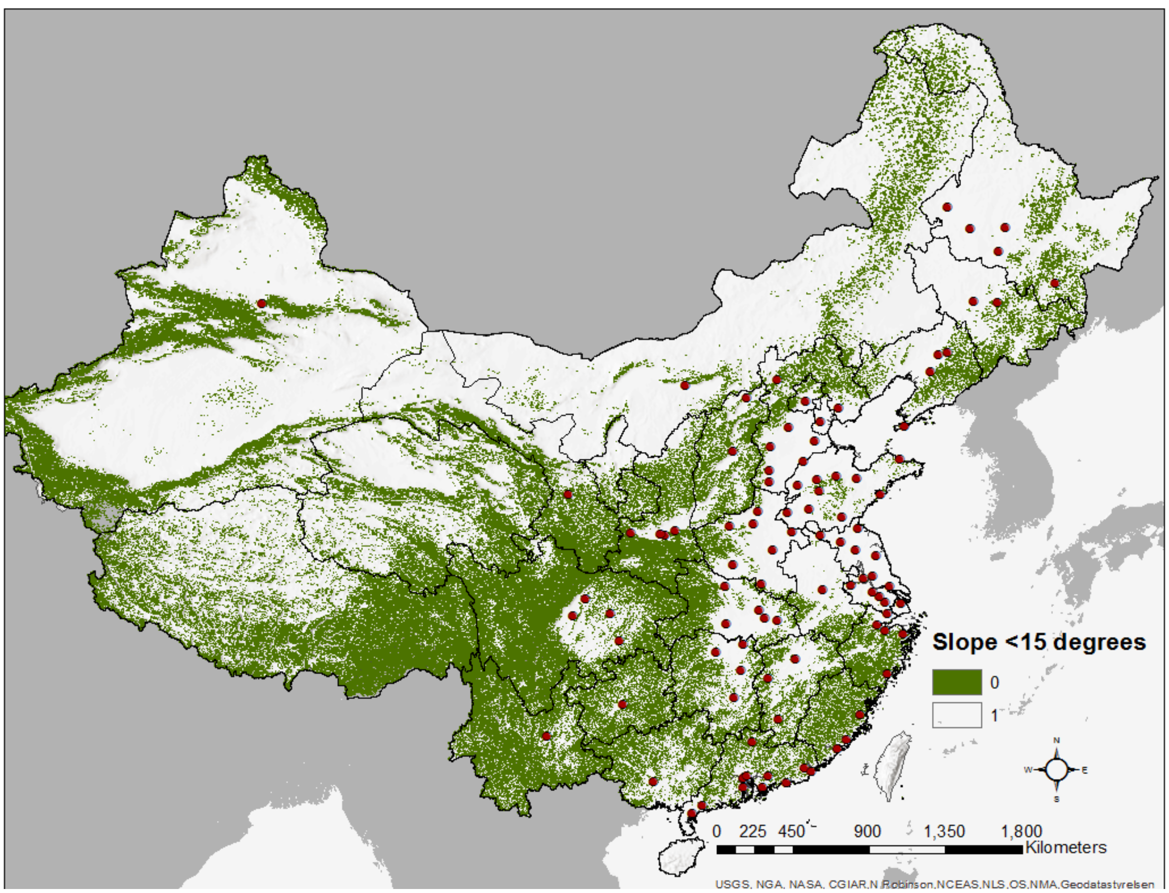
[30] Personal correspondence with China Data Center 6/22/2012

Geophysical Parameters

Geophysical constraints to the land supply are calculated in terms of the sum within a 30 km radius around city centers in the sample. The measures include sloped lands, inland water bodies, coastlines, and the geophysical suitability of land for cultivation.

(1) Sloped lands are calculated using an SRTM digital elevation model that is produced at 3 arc-seconds (see Figure 10). Slopes are computed using the standard rate of maximum change in z-value between grid cells. The measure is converted to an indicator variable that assumes a value of 1 if the slope is less than 15 degrees.

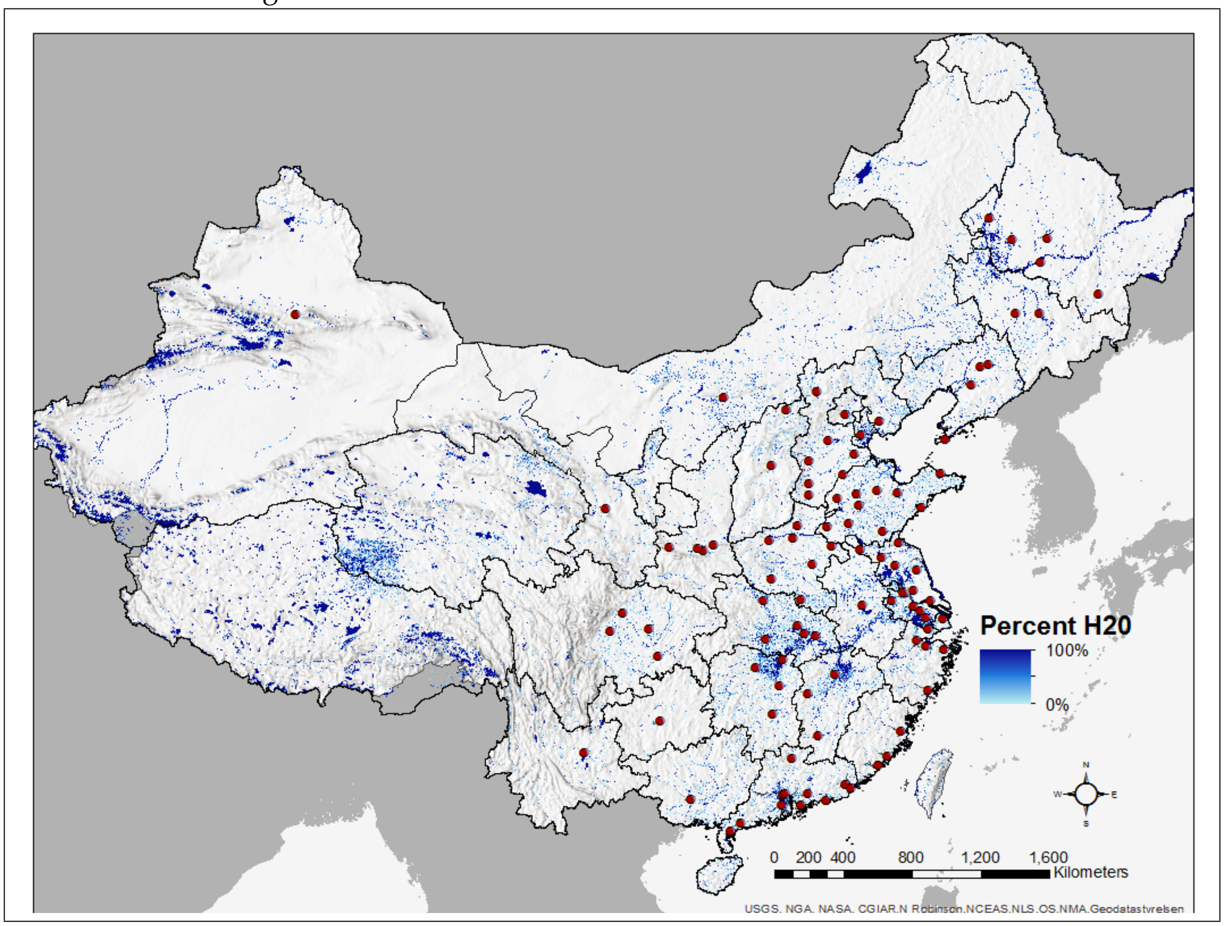
Figure 10: LANDS WITH SLOPES<15 DEGREES



Notes: (1) Elevation measurements come from SRTM Digital Elevation Model sampled at 3 arc-seconds (roughly 90 m2): http://www2.jpl.nasa.gov/srtm/.

(2) Measurements of inland water are extracted from the China Land Cover Dataset, which is derived from Landsat TM at 30X30 m2 (see Figure 11). Inland water bodies include canals, lakes, reservoirs, permanent glaciers, shoals, and beaches. The measure refers to the fraction of a 1X1km grid cell that contains inland water.

Figure 11: LAND AREA CONSTRAINED BY INLAND WATER

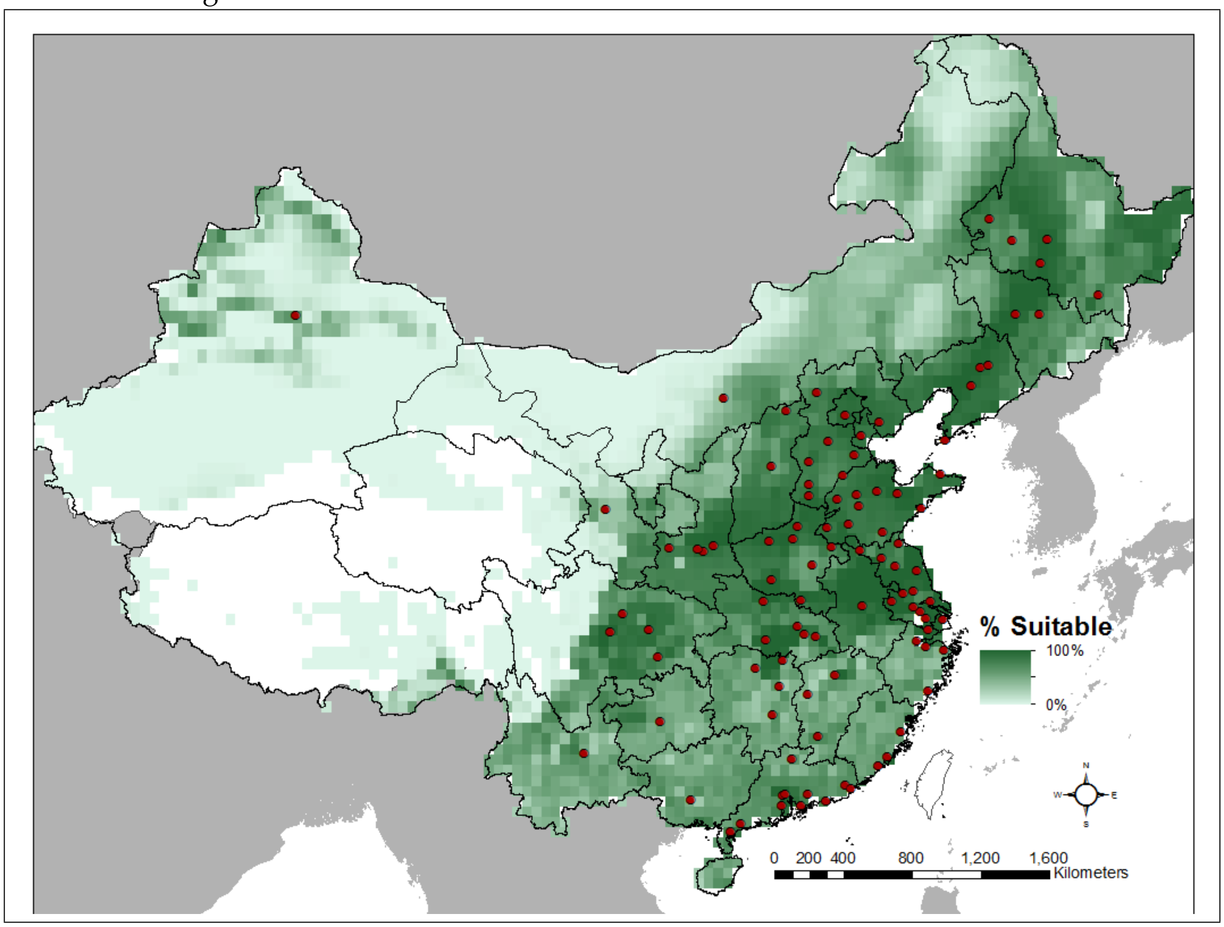


Notes: (1) Measurement is percent of 1x1km grid cell. Source: China Land Cover Dataset (Liu et al 2005)

(3) The fraction of marine area within 30km of a city center and is produced using MODIS global water mask. The resolution of the MODIS water mask is 250 m2 (http://glcf.umd.edu/data/watermask/).

(4) The geophysical land suitability parameter measures the fraction of a .05 decimal degree grid cell that is suitable for agricultural production in terms of soil moisture availability, soil carbon density, and soil ph (http://www.sage.wisc.edu/atlas/maps.php?datasetid=19&includerelatedlinks=1&dataset= Suitability for agricultulture does not constrain the land supply, but affects the productivity and rental value of local agricultural lands. For this variable I compute the average suitability within the 30 km zone.

Figure 12: GEOPHYSICAL SUITABILITY OF LAND FOR AGRICULTURE



Notes: (1) Measurement is percent of 1x1km grid cell. Source: Ramankutty et al 2001

Correlations Between Housing Data and Landsat TM/ETM and DSMP-OLS (nightlights)

This analysis indicates that a large fraction of housing construction activities were concentrated in urban core areas during the study period. Satellite data from optical sensors such as Landsat TM/ETM and DSMP-OLS (nightlights) have been used to measure urban development in China. In order to evaluate the use of these data in the present study, I compare plots of the spatial distributions of these various measures in terms of levels in the year 2000. Cities are binned by population size. Figures 13-14 plot the IQR of measurements from Landsat TM and DSMP-OLS (nightlights) by distance to a city center for cities of 0-1 million, 1-5 million, 5-10 million, and +10 million inhabitants.[31] The graphs of Landsat TM and DSMP-OLS suggest that both distributions are truncated in city center areas (0-3km), with larger important effects in large cities. In the present study, these figures suggest that there are potential limitations in using data from these sensors to augment my measurements of growth. In particular, Landsat TM/ETM does not provide information regarding demolition and reconstruction activities in already built-up zones (existing impervious surfaces). Saturation effects in DSMP-OLS measurements also create a challenge for accurate detection of downtown re-development. In this sample, approximately 20% of the floorspace construction observed in the 1990's occurs in zones that are affected by saturation.

[31] Growth is 1988-2000 for Landsat and 1992-2000 for nightlights.

Figure 13: LANDSAT TM BUILT AREA BY CITY POPULATION AND DISTANCE: 2000 (LEVEL)

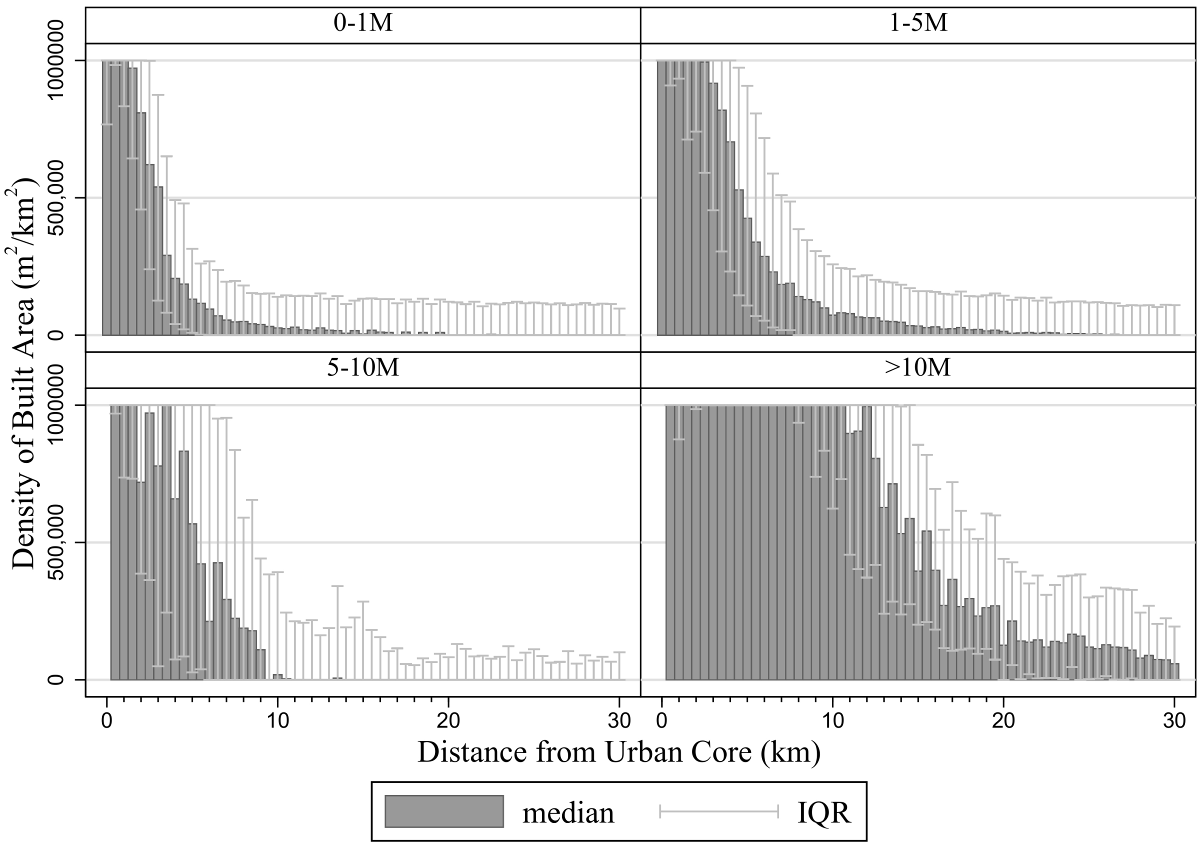
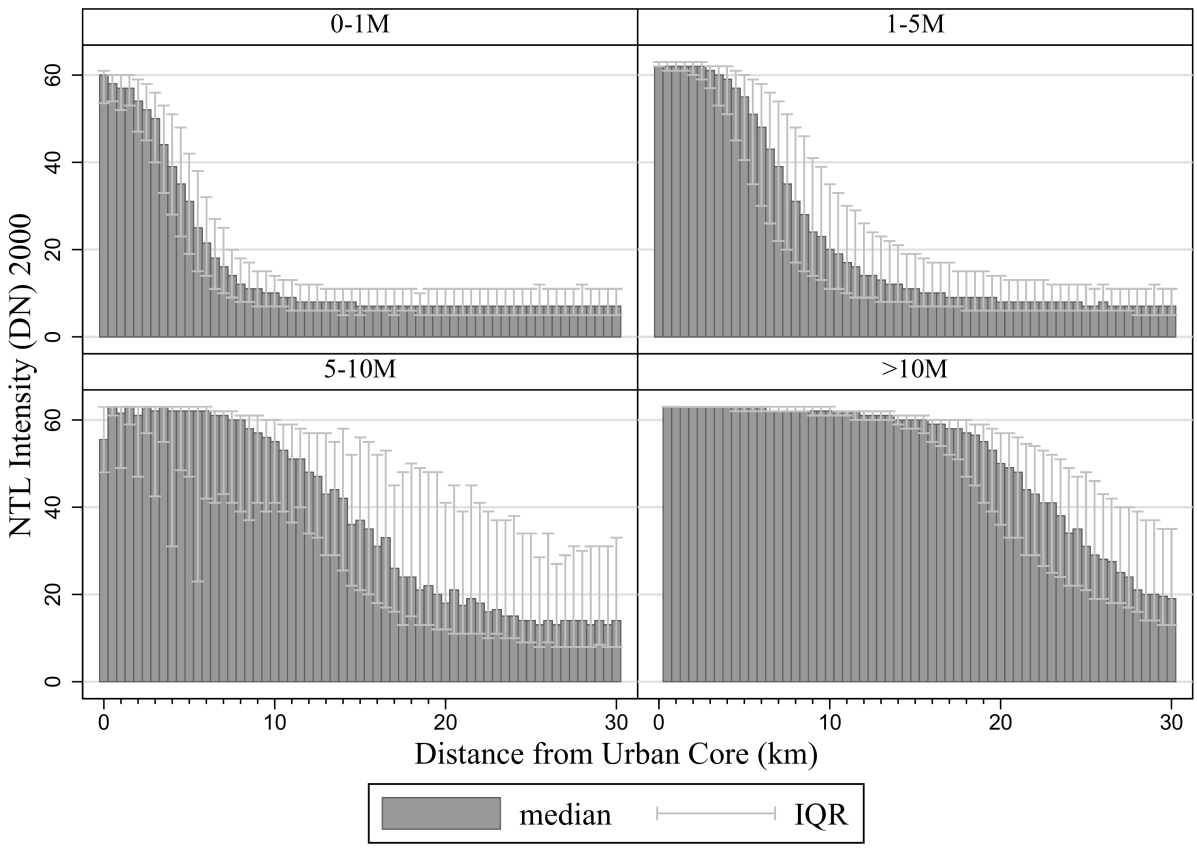


Figure 14: NIGHTLIGHT INTENSITY (DSMP-OLS) BY CITY POPULATION AND DISTANCE: 2000 (LEVEL)



Radiance calibrated DSMP data have been used to reduce the effects of saturation. Figures 15 and 16 plot correlations between 2000 residential housing densities and nightlight intensity using average stable lights and radiance calibrated stable lights. The fraction of floor space production occurring in saturation-affected zones declines to 1.6%. These plots suggest that the radiance calibrated measurements may shift down the entire distribution of saturated NTL values, but do not improve the correlation with housing densities.

Figure 15: CORRELATION BETWEEN DMSP-OLS NIGHTLIGHTS AND FLOORSPACE (YEAR 2000)

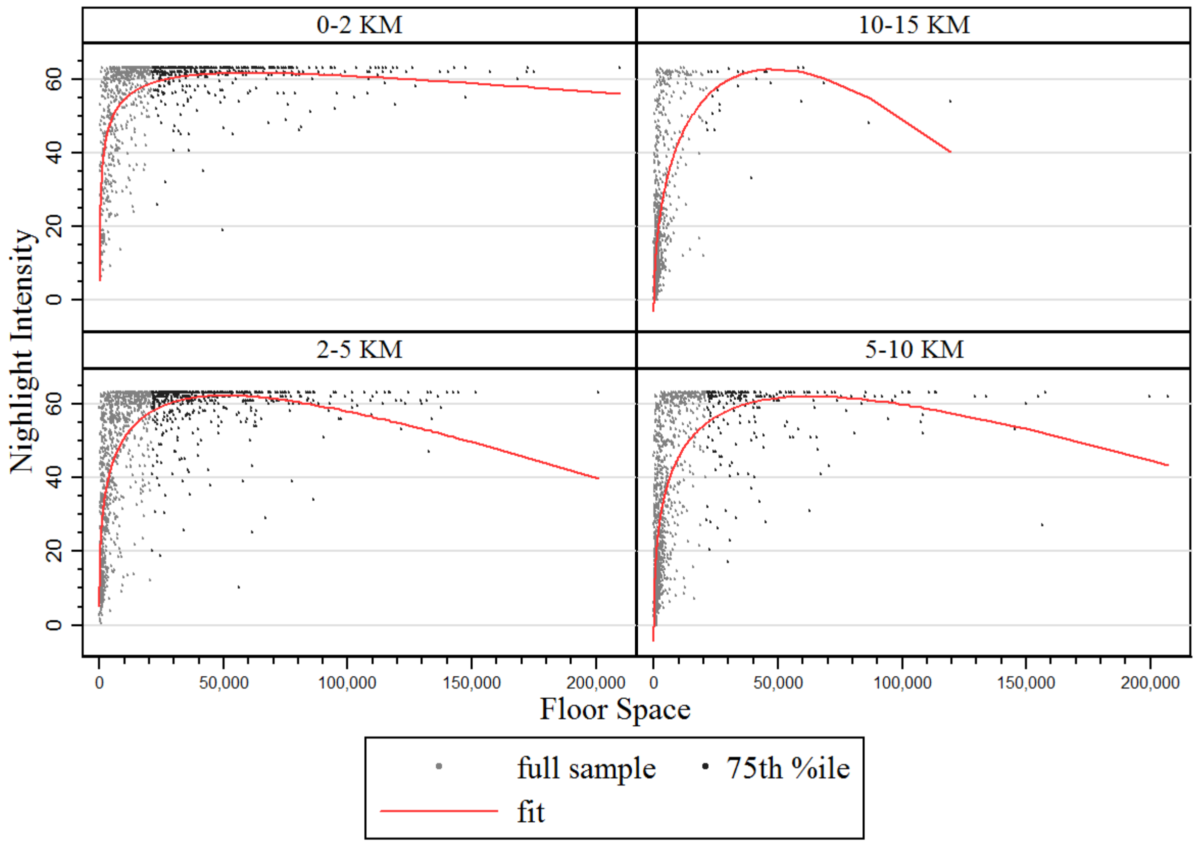


Figure 16: CORRELATION BETWEEN RADIANCE CALIBRATED DMSP-OLS NIGHTLIGHTS AND FLOORSPACE (YEAR 2000)