

# ZONING ADVISORY PANEL PUBLIC COMMENT

Received Between June 18, 2021 (noon) and July 9, 2021 (noon)

As part of the County's strong commitment to an open and transparent public process, comments received from any Citizen which reference the Zoning Advisory Panel (ZAP) are usually made available to the general public through uploading the comments to the County's website prior to the next ZAP meeting. Similarly, if the commenter requests, the information may also be forwarded to the ZAP Members directly.

*\* Please Note: Inclusion of Public Comments herein, does not imply any support nor opposition of the comments by the County.*

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**From:** [Thomas, Andrew](#)  
**To:** [County Planning Mail](#)  
**Subject:** ZAP Meeting 6.3.2021 Public Comments  
**Date:** Thursday, June 24, 2021 11:21:01 PM  
**Attachments:** [ZAP Meeting 6.23.2021, A. Thomas Comments.docx](#)  
[Housing Prices and Land Use Regulations A Study of 250 Major US Cities.pdf](#)  
[The Effect of Land Use Regulation on Housing Prices.pdf](#)

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Hello,

Please see attached public comments and supporting documentation. If you can please forward this electronically to the ZAP panel members so they can easily access the links in the comments.

Thank you,

Andrew Thomas

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**Andrew R. Thomas**

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## ZAP Meeting 6.23.2021, Public Comment, Andrew Thomas

1. **Comment:** Although there are many possible ways to address a discussion politics below is a list of articles /videos that describe both regional as well as national dynamics that likely have an impact on land use and other issues. These include political, social, economic considerations.

1. **Biden's Win Shows Rural-Urban Divide Has Grown Since 2016**  
<https://www.npr.org/2020/11/18/934631994/bidens-win-shows-rural-urban-divide-has-grown-since-2016>
2. **Guest opinion: Montanans must bridge urban-rural divide**  
[https://billingsgazette.com/news/opinion/guest/guest-opinion-montanans-must-bridge-urban-rural-divide/article\\_92dd53f7-5757-5bbc-97f8-23a21c24e424.html](https://billingsgazette.com/news/opinion/guest/guest-opinion-montanans-must-bridge-urban-rural-divide/article_92dd53f7-5757-5bbc-97f8-23a21c24e424.html)
3. **The State of the Urban/Rural Digital Divide** <https://www.ntia.doc.gov/blog/2016/state-urbanrural-digital-divide>
4. **Rural America is now experiencing 'disaster gentrification' as wealthy Covid-19 evacuees from the hotspot cities flock to the 'safety' of small towns in the flyover states - putting pressure on the local workforce and resources,**  
<https://www.dailymail.co.uk/news/article-8180805/Rural-america-experiencing-disaster-gentrification-wealthy-Covid-19-evacuees-flee.html>
5. **Gentrification in America Report Read our report on how gentrification has reshaped a growing number of urban neighborhoods**  
<https://www.governing.com/archive/gentrification-in-cities-governing-report.html>
6. **Affordable housing in Montana:**  
<http://www.bber.umt.edu/pubs/econ/AffordableHousing2020.pdf>
7. **Montana's Unaffordable Housing Crisis**  
<https://www.montanabusinessquarterly.com/montanas-unaffordable-housing-crisis/>
8. **The Red Wave No One Saw Coming**  
[https://www.realclearpolitics.com/articles/2020/11/10/the\\_red\\_wave\\_no\\_one\\_saw\\_coming\\_144631.html#!](https://www.realclearpolitics.com/articles/2020/11/10/the_red_wave_no_one_saw_coming_144631.html#!)
9. **United Rural Democrats leader on how party lost rural America**  
<https://www.msn.com/en-us/news/politics/united-rural-democrats-leader-on-how-party-lost-rural-america/ar-BB1bIqrr>
10. **Montana Loss Shows the Democrats Still Have a Rural Problem**  
<https://washingtonmonthly.com/2017/05/26/montana-loss-shows-the-democrats-still-have-a-rural-problem/>
11. **Concerns over the role of institutional investors in real estate and the financialization of housing:**
  - a. Frustrated Homebuyers Are Competing With Investment Funds That Are Buying Up Entire Neighbourhoods, <https://www.youtube.com/watch?v=LEJfbAAZlf4>
  - b. How corporations are buying up houses — robbing families of the American Dream <https://nypost.com/2020/07/18/corporations-are-buying-houses-robbing-families-of-american-dream/>

- c. **Tucker Carlson: This is happening everywhere**  
<https://www.youtube.com/watch?v=zxdx1buMRqk>
  - d. **Krystal Ball: How Wall St Is DESTROYING Housing Like It Destroyed The World** , <https://www.youtube.com/watch?v=mThWJFGy9-I>
  - e.
- 12. Rural perceptions of land use polices gone wrong in other areas:**
- a. **Hirst Decision by Supreme Court unleashes wrath of “Futurewise” upon property owners by taking their water** <https://www.wethegoverned.com/hirst-decision-by-supreme-court-unleashes-wrath-of-futurewise-upon-property-owners-by-taking-their-water/>
  - b. **17-Year Land Use Battle in Oregon**, Ward Ockenden spent 17 years trying to get his property rezoned back to its original rural residential zoning after it was arbitrarily rezoned as resource land because the state of Oregon forced the county to meet a quota for resource zoned land.  
<https://www.youtube.com/watch?v=7GMvGZJ842Y>
  - c. **Rycke Brown - Land use laws stop farming**, Rycke Brown, natural gardener, would like to start a small U-Pick farm in Josephine County, where she lives. However, according to Oregon state land use laws, to be zoned as farmland, a tract has to be at least 80 acres. To be allowed to build a house on a farm, you have to have 160 acres. This prevents people from starting small farms  
<https://www.youtube.com/watch?v=MpFS4AcAslg>
  - d. **Don Rowlett - Senate Bill 100**, Don Rowlett, owner of the Box R Ranch, was one of the first victims of Oregon's Senate Bill 100. His property has been down-zoned, re-zoned, farm-zoned, and overlaid, and he's sick of the government telling him he can't do anything on his own property.  
<https://www.youtube.com/watch?v=d4byBoq3CSM>
  - e. **Glen Archambault - Land use bureaucracy, Glen Archambault**, sheep rancher, was originally a supporter of Senate Bill 100, which implemented state-wide land use planning, and was intended to protect the resource industries. He now realizes that it's doing just the opposite, and the "planners" know nothing at all about the industries they're regulating.  
<https://www.youtube.com/watch?v=gHf94cdRi9g>
  - f. **Bud Combe - Regulated to death**, Bud Combe, a cattle rancher for almost 50 years, talks about all the "new regulations coming down the pike" that make it more and more difficult to operate a farm, from dust regulations to a "burp and fart tax" on cattle. <https://www.youtube.com/watch?v=xnhAOkSG33s>
  - g. **Bob Crouse - Battling bureaucracy**, Bob Crouse, owner of Fort Vannoy Farm, talks about his battle with the local irrigation district over how to irrigate his farm. The Water Resources Dept. agreed with him, but the state Supreme Court ruled that the local irrigation district is the guardian of his water right and they can tell him how and when to use it. <https://www.youtube.com/watch?v=IuWnspCC6eY>

2. **Comment:** Although the current spike in housing prices does have some temporary factors such as lumber prices, interest rates and construction capacity, and increased demand from people moving to L&C county, when variables are isolated there is a cost to land use regulation

that is reflected in housing prices (See Below and Attached). In a more detailed sense, we should consider whether regulation can facilitate affordability by making more land, and potential housing units available through rational polices geared towards addressing issues (water, infrastructure, wildfires etc.) while not being excessively restrictive. Also, we should consider whether regulations in the form of building codes or infrastructure projects can provide the opportunity for more desirable and high-quality housing to be made available. With regards to the later one area that has been repeatedly mentioned that extending public utilities to certain areas will allow for more development. In any of these instances it is necessary to view the situation as a complex dynamic rather than a simple, single variable, model.

In particular it is useful to reflect upon Dr. Eicher's analysis of the impact of regulations on housing prices:

*The analysis does not address whether more regulations are better, worse, or misguided. This would be a value judgment that requires the documentation of both costs and benefits of regulations. Ultimately, the increase in housing prices may be below or above citizens' valuation of the absence of sprawl. To elicit a benefit valuation of regulations is beyond the scope of this research project. Economic methods to study the contingent valuation are widespread in environmental economics, but they are time intensive (and costly) and infrequently used in the housing regulation literature to establish the benefits of regulations. The alternative is to rely on the electorate. After being informed about the costs of regulations, voters can decide whether to support further regulations, or whether to abolish existing ones. While this study details the private costs of regulations (the increased cost of housing), it does not include the social cost of regulations, since costs for changed commuting, parking and pollution patterns are not available. Also, while higher housing prices represent a windfall for sellers, they also constitute a redistribution from buyers to sellers as well as a reduction in housing affordability.<sup>33</sup> Land use regulations that increase housing prices also have a time dimension: current owners are the beneficiaries of such regulations, but their children and future migrants to the area bear the costs. This represents redistribution over time and generations, which may affect the location decisions of individuals and companies to limit productivity growth. The design of land use policy is hampered by the complexity of the urban housing market that is difficult to model and predict (for economists and policy makers alike). It is therefore imperative to evaluate whether policies designed to maximize the citizens' welfare actually achieve the policy goal without unintended side effects.*

1. The Effect of Land Use Regulation on Housing Prices: Theory and Evidence from California, <https://realestate.wharton.upenn.edu/working-papers/the-effect-of-land-use-regulation-on-housing-prices-theory-and-evidence-from-california/#:~:text=Land%20use%20regulation%20may%20affect%20housing%20prices>

[%20through,that%20captures%20price%20feedback%20effects%20on%20location%20choice.](#)

2. Housing Prices and Land Use Regulations: A Study of 250 Major US Cities  
<https://faculty.washington.edu/te/papers/Housing051608.pdf>

# **Housing Prices and Land Use Regulations: A Study of 250 Major US Cities\*\***

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University of Washington

Income and population growth are key determinants of housing demand, while land use regulations are designed to affect housing supply. Previous studies of housing price determinants focus either on specific regulations in particular cities/regions, or on selective subsets of major cities and regulations. This study examines the impact of land use regulations on housing prices in 250 major US cities from 1989 to 2006. Aside from factors that are commonly associated with housing demand (income, population growth and density), housing prices are found to be associated with local cost-increasing land use regulations (approval delays) and with statewide regulations. Since statewide regulations factor prominently into the results, specific examples of the impact of different types of land use regulations are provided for 5 cities in the state of Washington. The estimated increase in housing prices associated with regulations is, on average (over 250 cities), substantially larger than the effects of income and population growth. While the estimated dollar costs associated with regulations may be sizable at times, the results are remarkably consistent with previous studies that were based on smaller cross sections.

\*Draft 5/2/08. Do not cite or distribute without permission, te@u.washington.edu.

†I thank Kriss Sjoblom, Dick Conway, Debora I. Dusselich, Kenneth J. Dueker, Hart Hodges, Richard Allen Nelson, Lillian Lyons, Marty Lyons, Catherine O'Donnell, and Bob Roseth for helpful comments.

## 1. Introduction

Housing prices follow the fundamental laws of supply and demand. The challenge for economists is to identify the specific factors that are associated with housing supply and demand. Economic theory is clear: changes in housing prices are associated primarily with income and demographic factors on the demand side, and with costs considerations (e.g., land use regulations) on the supply side.<sup>1</sup> Price, income, and demographic data are readily available from government sources, but it has proven to be extraordinarily costly and time consuming to obtain objective and comparative land use regulation data for informative, representative studies.

In surveying the housing literature, one is struck by the abundance of studies that focus on the effects of *specific regulations in particular cities*. Authors surveying the literature at times succumb to the temptation of generalizing results from the numerous city/region-specific studies, in hopes of establishing broad patterns that link regulations to housing prices (see, for example Nelson et al. 2004).<sup>2</sup> Although studies of individual jurisdictions may be informative, it is unclear whether it is possible to generalize their findings. For example, the economic impact of zoning restrictions that affect lot sizes in California are distinctly different from building height restrictions in New York. Individual city studies may also be susceptible to “selection bias” by which researchers’ site selection and data collection may systematically influence results to validate prior expectations. Even cross-city studies that examine several dozen major metropolitan areas may be subject to selection bias. Glaeser and Gyourko (2002) point out, for example, that smaller datasets which feature only large metropolitan areas may oversample highly regulated cities and underrepresent the bulk of American housing that featured robust growth and available land.

This paper examines 250 major US cities documents to identify the effects of land use regulations on housing prices. This regulatory dataset was produced by an extensive land use study at the Wharton Business School for the University of Pennsylvania. Researchers at Wharton’s Zell/Lurie Real Estate Center executed a nationwide survey of residential land use

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<sup>1</sup> At times public opinion and policy makers seem to be taken aback that housing prices depend on regulations. It is the expressed *purpose and design* of regulations to influence the housing supply. The conceptual framework in Section 3 clarifies that housing prices may rise or fall due to regulations.

<sup>2</sup> Nelson et al. (2004) are often cited as providing academic evidence that regulations do not affect housing prices. Even cursory reading of the executive summary reveals that such statements are at odds with the conclusions of their paper. The authors present only their perspectives on previous housing studies, not original work. Connerly (2004) summarizes the evidence surveyed in Nelson et al. (2004); Appendix 3 Table A3.2 reproduces Connelly’s Table.



regulations in over 2,700 US communities (Gyourko et al., 2008). Aside from legal variables, the Wharton database is therefore not based on researchers' or consultants' assessments but it represents data collected from each city's planning director that is now made available to researchers. The dataset provides a first opportunity to examine the specific regulations that can be associated with changes in housing prices across a large number of US cities. The broad cross section approach eliminates nagging doubts whether a particular result for a particular city is also relevant to other regions.

Often-cited reasons for the escalation of US housing prices in the past 10-20 years include lower mortgage rates, creative mortgages, and income/employment growth. These factors, which may well contribute to increasing housing prices, all relate exclusively to *housing demand*. *Housing supply* factors, however, are harder to quantify and are typified by opposing view points: for example, environment vs. sprawl, builders vs. planners, parks vs. high-rises, and state vs. local growth management. Growth management often refers to: 1) *urban growth boundaries*, 2) *regulation of development densities* (e.g., minimum lot-size rules), and 3) *cost-increasing regulations* (facility development and/or regulatory delays in the approval process).

The Wharton database provides objective and comparative information on 70 land use regulations that cover growth boundaries, density and cost-increasing regulations. This paper reports how this data can be used in regression analysis<sup>3</sup> to identify the effects of land use regulations on housing prices. The results are highly statistically significant<sup>4</sup> and indicate a substantial association between regulations and changes in housing prices. Aside from demand factors, four regulations are shown to be robustly related to changes in real housing prices across the 250 cities between 1989 and 2006: 1) permit delays, 2) statewide land use regulations, 3) court support for statewide regulations, and 4) growth management.

Since these regulations speak to both local and state wide regulations, it is useful to provide an example of the effects of regulations on different cities within one state. Such an

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<sup>3</sup> For non-economists, footnotes are included below to provide brief background information for key statistical terms throughout the paper. "Regression analysis" is a statistical method used to examine relationships between a variable of interest (housing prices in this case) and explanatory variables. Regressions allow the researcher to estimate the quantitative effect of explanatory variables upon the variable of interest. The reported "statistical significance" of regressors then indicates a degree of confidence that the true relationship is close to the estimated effect.

<sup>4</sup> "Statistical significance" is an expression in statistics that indicates how likely it is that an event occurred by pure chance. So a 99 percent significance level indicates that there is a 1 percent chance that the finding could be the result of a random accident.

example can highlight that the costs of regulations can differ *even within* a particular state (Washington State) among cities that are subject to similar statewide regulations. The variations in the costs of regulation are then due to substantially different *local* regulation and demand environments, as well as the degrees to which municipalities are affected by the statewide regulations. While the magnitudes reported may seem surprisingly large, Section 6.1 shows that these findings are remarkably consistent with results from a number of previous studies based on smaller cross sections of cities.

Combining the 2730 cities in the Wharton Sample with 2006 Census data renders a sample of 250 major US cities. The city of Seattle features prominently among these cities: it ranks 5<sup>th</sup> among all cities in terms of overall land use restrictions as measured by the Wharton Residential Land Use Regulatory Index, and also 5<sup>th</sup> in terms of permit and zoning approval delays. Seattle also belongs to the group of cities that ranks first among all cities in terms of the impact of state political involvement and growth management.<sup>5</sup> Across all 2730 cities in the sample, Appendix 2 shows that many of Washington's cities rank in the top 10 percent in terms of land use restrictions across a variety of regulatory measures.<sup>6</sup> This warrants a discussion of Seattle in specific, and Washington State in general. The comparison highlights that the city-specific impacts of statewide land use regulations may vary substantially across municipalities.

The focus on the link between regulatory restrictions and housing prices is controversial in the planning literature. As Glaeser (2004) points out, housing demand factors have long been considered central determinants of housing prices. In the early 1980s, Poterba (1984) and Summers (1981) documented that inflation increased the interest rate subsidy on mortgages to such an extent that the resulting shift in housing demand explained much of the run up in housing prices in the 1970s. Mankiw and Weil (1991) highlighted that demographics also drive housing demand. Given the aging of the US population, their results yielded the ominous prediction that “real housing prices will fall substantially over the next two decades.” Contrary to

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<sup>5</sup> Seattle ranks in the top 10% for State Court Involvement in Regulations, State Legislature Involvement in Regulations, Total # of Initiatives 1996-2005, Local Political Pressure Index, Environmental Review Board Requirements, Permit Lag for Subdivisions Approval (<50 units), Community Pressure Involvement in Regulations, Permit Lag for Subdivisions Approval (multi family project), Permit Lag for Rezoning (<50 units), Permit Lag for Rezoning (multi family project), Permit Lag for Review Time (multi family project), Permit Lag for Review Time (single family), Permit Lag for Rezoning, (>50 units), Design Review Board Approval Requirements.

<sup>6</sup> About 50 other Washington cities were included in the Wharton sample; see Appendix 2.

the Mankiw and Weil forecast, housing prices across 250 major US cities rose 54 percent (after accounting for inflation) from 1989-2006.<sup>7</sup>

Housing supply determinants have only recently come under intense scrutiny. Seminal was the special issue of the *Journal of Real Estate Finance and Economics* devoted to housing supply (Rosenthal, 1999), which contains several surveys that cover distinct dimensions of housing supply. Subsequently, Green et al. (2005) estimate a detailed housing supply function for 45 major cities. This line of research has culminated in a voluminous literature that documents a robust association between housing prices and the stringency of land use regulations. Glaeser (2004) summarizes the evidence and provides broad and compelling support from studies of US regions and cities (see also Appendix 3).

Finally, it is also important to highlight that the economic analysis below provides cost estimates of regulations, but it cannot identify whether such regulations are socially optimal. For the same reason it cannot provide value judgments that identify regulations as “good,” “bad,” or “misguided.” Think about it this way: citizens may well value regulations *even more* than the price they have to pay for them! Nelson et al. (2004) make this point forcefully when they point out that growth restrictions in Boulder, Colorado, drove up the price of housing near green belts, and that this price increase reflected nothing other than the willingness to pay (in the sense that wealthier citizens simply revealed their preference for pretty views).

What is often neglected, however, is that these very examples also highlight that regulations and affordable housing have been mutually exclusive (see, e.g., Seattle Times, 2008). In the absence of normative guidance, it falls to the electorate to decide whether the benefits derived exceed the associated costs in terms of housing price increases. Alternatively, the cost estimates here provide guidance that can assist policy reviews/updates. As Nelson et al. (2004) point out, “if housing prices may increase in any land use environment, then the decision is between good and bad regulation to improve housing choice.” Brueckner (2007) reminds us that growth management policy interventions “are often well-meaning, being designed to achieve ends that are thought to be socially desirable.” The problem is that the complexity of the urban real estate markets may create subsidiary effects that are either unanticipated or unforeseen by policy makers and planners alike. To assure against adverse effects, policy review must be frequent to reoptimize when unintended effects compromise the designed effects of regulations.

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<sup>7</sup> Based on Census data for median real price of owner-occupied housing described in detail below.

## 2. Previous Comparative Studies of Housing Prices and Regulations

### 2.1 Comparative Studies of US Metropolitan Areas

A large number of studies exist that examine the effects of specific demand and supply factors on housing prices in particular cities. As discussed in the introduction, it is difficult to derive general implications from such studies. Instead, the results below are based on a large cross section. Before these results are presented, however, it is important to review the methods and findings from previous cross sectional studies of housing prices and regulations. This review focuses only on relationships between housing prices and regulations. Other papers, not cited below, focus on the impact of regulations on permits, construction, and land availability.

Black and Hoben (1985) first developed a measure of “restrictive”, “normal”, or “permissive” regulations for 30 US metropolitan areas. They report a correlation of  $-0.7$  between their regulation index and 1980 prices for developable lots.<sup>8</sup> Segal and Srinivasan (1985) surveyed planning officials in 51 metropolitan areas to find the percentage of undeveloped land taken out of production due to land use regulations. They estimated that regulated cities have 1.7 percent faster annual housing price increases than unregulated cities. With compounding, this actually turns out to generate a dramatic impact on housing prices over a decade (about 20 percent). As an alternative, Guidry et al. (1991) employed land use and environmental data from the American Institute of Planners (AIP, 1976) to find that land prices in cities with more stringent land use controls increased 16 percent for every 10 percent increase in their regulatory measure. Guidry et al. (1991) also examined regulation data from the Urban Land Institute<sup>9</sup> to find that average lot prices in the most restrictive cities in 1990 were about \$26,000 higher, than in the least regulated cities.

One of the most prominent comparative studies is Malpezzi (1996) who examines 56 US metropolitan areas. He built his analysis on regulatory data collected by the Wharton Urban Decentralization Project carried out by Linneman et al. (1990).<sup>10</sup> Despite its comparatively large

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<sup>8</sup> To obtain a visual example how tight a  $-0.7$  correlation is, see <http://en.wikipedia.org/wiki/Correlation>.

<sup>9</sup> The data is based on a survey of 11 real estate experts who ranked land use restrictiveness of 30 metropolitan areas on a 10-point scale. Instead of a single regulation criterion, the survey covered 6 broad areas of land use regulations. The Urban Land Institute data covers: 1) wet land management, 2) power plant regulation, 3) critical areas and wilderness, 4) strip mining, 5) flood plains, and 6) tax incentives. The variable is unfortunately binary, indicating only whether regulations exist or not.

<sup>10</sup> Unfortunately, communication with the authors of the study indicates that this data has been lost.

coverage, Malpezzi's data lacks information on key metropolitan areas (such as Seattle). He focuses squarely on cost-increasing regulations (zoning and permit time costs) and adds a variable to indicate when states regulate environmental impacts (coastal, wetland or floodplain management). His findings imply that moving from lightly regulated to highly regulated cities reduces housing permits by 42 percent and increases housing prices by 51 percent. Malpezzi et al. (1998) use a hedonic price index and show that regulations increased housing prices by 31-46 percent. Phillips and Goodstein examined 37 metropolitan areas and found that the Malpezzi (1996) regulatory index was associated with higher housing prices, although a proxy for the effect of the urban growth boundary in Portland was shown to be less than \$10,000 per unit. Downs (2002) increased the sample of metropolitan areas to 86 and examines the period of 1990 to 2000. He does not find an effect of regulations on housing prices for all periods, only for 1990-2000, 1990-94 and 1990-96.

Glaeser and Gyourko (2002) examine lot prices in 40 US cities, controlling for the change in the cost of construction. They label the gap between the actual housing prices and the cost of construction (minus the lot price) provocatively the "zoning tax." Table 1 is a reproduction of their results showing the change in housing prices relative to construction costs in major cities and suburbs. They associate their zoning taxes with cost-increasing regulations (time to permit issuance for zoning requests) and find a statistically significant relationship.

## **2.2 Comparative Regional Studies**

Other large scale studies are regional, such as Katz and Rosen's (1987), who analyzed 85 cities in the San Francisco Bay area to find that housing prices increased between 17-38 percent in communities with growth control measures. Levine (1999) expanded Katz and Rosen's approach to 490 Californian cities and 18 different land use measures. He finds that land use restrictions "displaced new construction, particularly rental housing, possibly exacerbating the expansion of the metropolitan areas into the interiors of the state." Pollakowski and Wachter (1990) examined 17 zoning jurisdictions in Montgomery County, Maryland, over a period of eight years and found that a 10 percent increase in these zoning restrictions increased housing prices by 27 percent. Interestingly, they also provided evidence on the externalities<sup>11</sup> associated

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<sup>11</sup> An externality is an economics term that describes that a decision imposes costs or benefits to third party. This implies that agents in private economic transactions do not all bear costs or reap all benefits of the transaction.

with regulations: housing prices are shown to rise when the restrictiveness of zoning measures in adjacent jurisdictions increased.

Downs (1992) examined the effects of growth management plans in San Diego County, CA, to find a housing shortage in the five largest cities was aggravated by growth controls that increased prices of existing homes by 54 percent and prices of new homes by 61 percent in three years. Cho and Linneman (1993) examine 10 districts in Virginia and found that zoning restrictions had a significant impact on housing price within the district and via spillovers to nearby jurisdictions. Green (1999) examined zoning and permitting regulations in 39 municipalities in Wisconsin and found that two of the regulatory variables had modest impacts on price increases. Finally, Gyourko and Summers (2006) analyze 218 jurisdictions around Philadelphia and find that areas with average land use regulations saw slightly negative increases in the real cost of single family lots over 10 years. The most restrictive municipalities, in contrast, saw lot cost increases of up to 70 percent (for a summary see Appendix 3). Finally Glaeser et al. (2006a, b) report on a study of 187 communities in eastern Massachusetts to find that regulation, not density, has caused low levels of new construction and high housing prices in the Greater Boston area. The reduction in permits caused by the regulations has had a significant effect on regional housing prices, which were increased median housing prices by 23-36 percent or about \$156,000.

The sample of cities featured in this paper is roughly identical in size to the samples in Gyourko and Sommers (2006), and Glaeser et al. (2006a, b); instead of covering only one *region*, however, the sample below is comprised of 250 major US cities. It shares with previous comparative studies that zoning restrictions and approval delays are considered, but it also extends the focus of previous analyses to include statewide measures, such as growth management plans and even court rulings regarding regulatory enforcement. Malpezzi (1996) also considers statewide measures, but the structure of his data assumes that the effect of such regulations is identical across cities. Instead, the Wharton database provides information on the degree to which each city is impacted by statewide regulations. Finally, instead of focusing on only one or a couple of regulations, it is also examined whether a given individual regulation in the Wharton database potentially affects housing prices.

### **3. Supply and Demand for Housing**

Before moving to the formal statistical analysis, it is important to review the basic mechanics of housing supply and demand. The following section closely follows the lucid framework laid out by Malpezzi (1996); it can also be found in any introductory urban/real estate economics textbook (e.g., O’Sullivan, 2003). Figure 1 represents a simple housing market for identical units. In a free market, supply and demand curves ( $S_1$  and  $D_1$ , respectively) intersect at the equilibrium point,  $A$ . Point  $A$  maximizes private welfare as it equates the private costs to the private benefits for housing units.

In the presence of an externality<sup>12</sup>, however, society faces a potential market failure. In the context of real estate economics, an example of such an externality would be the public’s desire for parks and green spaces. Such desires raise the social cost of supplying housing above the private cost to shift the supply curve up to  $S_2$ . From society’s perspective, the equilibrium at point  $A$  now represents “too much” housing at “too low” a price and policies that regulate housing to coincide with point  $B$  would deliver the socially preferred outcome. The difference between the housing quantities and prices at  $A$  and  $B$  is then the social cost of attaining the public benefit of reduced housing. This cost includes a welfare loss that each citizen incurs due to the reduction in housing units and the associated increase in prices.

Note that there also exist housing externalities that *increase* social benefits *beyond* private benefits. Such externalities lower the social cost of housing supply.<sup>13</sup> In this case, the

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<sup>12</sup> Malpezzi (1996) mentions the following externalities that raise the social cost of housing: “1. *Congestion*. Building additional housing units in a community generally increases traffic locally (although it may reduce total commuting distance). 2. *Environmental costs*. Building additional housing units may reduce the local supply of green space; reduce air quality; and increase pressure on local water, sanitation, and solid waste collection systems (although again the global impact is less clear). 3. *Infrastructure costs*. Costs may rise as communities invest to grapple with environmental problems and congestion. Effects will depend on whether the particular community has yet exhausted economies of scale in the provision of each type of infrastructure. 4. *Fiscal effects*. In addition to the obvious effects from the above, demand may increase for local public services (education, fire and police protection, new residents believing libraries should be open on Sundays in contradiction to local custom). New residents may or may not pay sufficient additional taxes to cover the marginal costs. 5. *Neighborhood composition effects*. New households may be different from existing households. If existing households prefer living with people of similar incomes, or the same race, they will perceive costs if people different from them move in.”

<sup>13</sup> Malpezzi (1996) points to “1. *Productivity and employment*. A well-functioning housing market is generally required for a well-functioning labor market. In particular, labor mobility may be adversely affected and wages may rise to uncompetitive levels if housing markets are not elastic. 2. *Health benefits*. At least at some level, less crowding and improved sanitation may be associated with lower rates of mortality and morbidity. 3. *Racial and economic integration*. One person’s external cost may be another person’s external benefit if some households value heterogeneity, for themselves or for others. For those particularly concerned about employment of low-income households or minorities, concerns about the productivity and employment effects mentioned earlier are reinforced. 4. *Externalities associated with homeownership*. More housing units or lower housing prices may be associated with

welfare maximizing policy interventions are regulations that expand housing and lower its price (take, for example, affordable housing requirements). The housing framework therefore highlights two important insights: 1) there is no reason to expect housing prices to rise, due to regulations that are intended to attain the social optimum, 2) a rise in housing prices due to regulations indicates that policy-makers associate a negative externality with the supply of housing. Finally, note that the cost increases associated with regulations must match the associated social valuation. To understand whether cost increases and social valuations match requires a clear understanding of the cost and benefits of regulations. It is easier to support regulations when the associated costs are not identified.

The supply and demand relationships are approximated by a model that provides the foundation to the empirical approach outlined in Section 4. Readers less interested in the exact mechanics of the model can skip to Section 4.3. The interim sections employ economics and statistics jargon to provide the necessary methodological foundations. The housing model presented below is largely identical to Malpezzi (1996). More complex models of housing prices can certainly be constructed; their empirical implementation is, however, often associated with insurmountable obstacles.<sup>14</sup> The below analysis is therefore a compromise that acknowledges the tradeoff between model complexity and data availability.

The standard model of the median owner-occupied house depends on the demand and supply of owner occupied housing,  $Q_{ho}^D$  and  $Q_{ho}^S$ , respectively. Demand is a function of the relative price of the median owner occupied home,  $P_{ho}$ , median income,  $I_{ho}$ , and demographic variables,  $D$ , that relate to density and population size. The demand relationship can then be formally represented as

$$Q_{ho}^D = F^D[P_{ho}, I_{ho}, D]. \quad (1)$$

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greater opportunity for homeownership. Homeownership has been argued to be associated with many desirable social outcomes, ranging from improved maintenance of the housing stock to greater political stability.”

<sup>14</sup> Pogodzinski and Sass (1991) provide a structured review of diverse approaches to modeling the effect of housing supply on housing prices. They highlight the multitude of different regulation criteria that have been employed in regional studies, which emphasizes how tenuous the generalizations are that link “regulations” to housing prices, based on individual city studies. Green et al. (2005) provide the most sophisticated empirical implementation of a theory based housing supply model. Although they control for regulations, it is not the objective of their paper to quantify the effects of regulations on housing prices.



The supply of the median owner occupied housing,  $Q_{ho}^S$ , is assumed to depend on the relative price of the median owner occupied home,  $P_{ho}$ , land use regulations,  $R$ , and the prices of all  $i$  inputs,  $P_i^S$  (e.g., construction costs)

$$Q_{ho}^S = F^S [P_{ho}, R, P_i^S]. \quad (2)$$

Construction costs are largely set at the national level and are also considered in the methodology as described below. Aside from construction costs, other input prices (such as land) may themselves be contaminated by regulations. In this case, Malpezzi suggests to rewrite (2) by substituting for  $P_i^S$  to represent the supply side equation as the following reduced form

$$Q_{ho}^S = F^S [P_{ho}, R]. \quad (2')$$

The reduced form in equation (2') has received additional validity from Green et al. (2005), who estimate detailed, theory-based housing supply equations and find that regulations and low supply elasticities are strongly positively correlated with heavily regulations in metropolitan areas. The specification in (2') highlights that regulatory changes affect housing prices both directly and indirectly. The direct effect of regulations is a reduction in the supply of housing and an increase in the price of housing. An indirect effect of regulations is a change in input prices, which would then affect the supply of housing. The statistical analysis below captures the net impact of both the direct and indirect effects.

In equilibrium, supply and demand are equalized, allowing us to solve equations (1) and (2') simultaneously for the housing price. This renders housing prices a function of land use regulations, income, and demographic variables

$$P_{ho} = F [R, I_{ho}, D, \varepsilon]. \quad (3)$$

To translate the structural model into a statistical regression model, a stochastic term,  $\varepsilon$ , is added in (3). Evidence for omitted variables or measurement error is captured in the error term. To examine the validity of the proposed empirical model, the properties of this error term are examined extensively in the robustness analysis reported in Appendix 1.

## 4. Econometric Implementation of the Housing Model

### 4.1 The Empirical Model

The reduced form in (3) is commonly estimated “in levels,” which indicates that the variable of interest,  $P_{ho}$ , is the price *level*. In terms of the econometrics, the standard cross-section estimator (be it ordinary least squares, or any variant that allows for non-spherical disturbances) is only consistent when individual city characteristics (so called “fixed effects”) can be assumed to be uncorrelated with the variable of interest. It is doubtful whether this assumption is valid in the context of housing prices. City fixed effects, such as the designation as state capital, proximity to Disney World, or to nature, may well drive the *level* of housing prices. One approach to address fixed effects is to estimate (3) in terms of growth rates, so that the omitted variable bias associated with city-specific fixed effects is mitigated. While “nature” and “geographical characteristics” may influence cities’ price levels, it is a much taller order to link them to changes in prices.

The second issue is that level regressions are generally thought to be susceptible to spurious correlations in the absence of true causal relationships. Causality is certainly not guaranteed in growth regressions, they do mitigate spurious correlation. This renders growth regressions a much more stringent empirical test. Third, in contrast to level regressions, growth regressions can address the frequent confusion in the public debate about the short and long term drivers of housing. The demand for housing – as seen above – is determined by variables that can change quite quickly over time (income, migration, and density). Housing supply instead is by its very nature much more inelastic, especially in the short run (it takes months to purchase land, obtain permits, construct a home, and sell it). Examining the *change* in housing prices over long time periods (17 years, in the sample below) allows the regressions to capture the effects of both supply and demand measures with some confidence.<sup>15</sup>

Most importantly, however, growth regressions speak effectively to the question at hand: *which variables can be associated with the change in housing prices across major US cities? Or: did housing prices increase because of land use restrictions and/or income/population growth?* Level regressions, instead, speak only to the question of whether housing prices are high in cities with high incomes, large populations, and extensive regulations. The estimates below are therefore based on growth regressions where the variable of interest is the annual compounded growth rate of housing prices from 1989-2006. This renders the regression to be estimated

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<sup>15</sup> For a complete discussion of growth vs. level regressions, see Caselli et al. (1996).

$$\hat{P}_{ho} = \alpha + \beta_1 R + \beta_2 \hat{I}_{ho} + \beta_3 \hat{Pop} + \beta_4 Density + \varepsilon \quad (4)$$

where variables with “^” subscripts represent growth rates, *Pop* is the population and *Density* is the population density of a particular city (see Appendix 2).<sup>16</sup> The constant,  $\alpha$ , is included to account for effects that are common to all cities over this period of time. Such effects might represent changes in the national level of unemployment, changes in mortgage rates or lending procedures, or liquidity in the mortgage market.<sup>17</sup>

#### 4.1 Housing Price Data

Much of the housing literature wrestles not only with the development of meaningful land use regulation data; even the measurement of its key variable, housing prices, is subject to controversy. There are three alternative approaches to housing prices: *i*) median housing prices for owner occupied homes as reported by the Census, *ii*) sales price data collected by the National Association of Realtors, and *iii*) so-called “hedonic” price indices that take into account the characteristics of the housing unit. All three measures are used in the literature as each measure features distinctly different advantages.

It has been suggested that the correlation among these three housing price measures is so high that one should not expect the choice of the type of price data to drive qualitative results (Malpezzi, 1996). Prices given by *i*) and *ii*) suffer the drawback that they do not control for quality increases (such as larger homes, smaller lots, nicer appliances, etc.). While Census data has the broadest coverage, it reports only median owner occupied housing prices. The National Association of Realtor data features a broader breadth of data, since it is based on multiple listings. However, multiple listing data does not capture the entire market, so *ii*) also does not constitute a representative sample.

In theory, hedonic price indices adjust housing prices for housing quality. This method requires the use of a “hedonic regression” to obtain the estimates of the contribution of each

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<sup>16</sup> Since a reduced form is estimated, coefficients are not exact supply and demand elasticities (in the sense that it is impossible to isolate exact supply and demand effects of, for example, a change in income). The coefficients do provide an estimate of the impact on prices due to changes in the right-hand-side variables. When the terms “demand” and “supply” are used below, they thus refer to variables that are associated primarily with demand and supply effects.

<sup>17</sup> At times the relationship between prices and regulations is seen to be nonlinear (e.g., Malpezzi, 1996). This possible specification is discussed in the robustness section below.

housing characteristic (e.g., an extra bathroom) to the price of a home. These estimates are then used to artificially construct an imputed quality-adjusted housing price. This quality-adjusted price construct is as reliable and error prone as the hedonic regression itself. If the true regression model is not known, the estimated housing price is subject to measurement and omitted variable errors that bias the contributions of all characteristics to the imputed, quality-adjusted price. Housing price studies seldom report the actual hedonic regressions that are the basis for the quality-adjusted housing prices used; if the information is provided, it highlights at times the problematic nature of the procedure.

For example, in a study of housing prices in eight Washington State counties, Crellin et al. (2006) account for quality by controlling for a) assessed value, b) lot size, c) dwelling size, and d) number of bathrooms. Their hedonic regressions imply that the number of bathrooms either has no influence on housing prices or a counterintuitive effect (e.g., more bathrooms imply lower housing prices) for some counties. Malpezzi et al. (1998) also report their hedonic regressions, using a much larger sample than Crellin et al. (2006) by examining 373 US locations with a median sample size of 3000 home owners each (some samples exceed 70,000 owners). Their hedonic regressions control for 19 different housing quality characteristics; but at least one quarter of their mean regression coefficients exhibit counterintuitive effects, and many are estimated with such large standard errors that few characteristics can be expected to be statistically significant (e.g., to affect the housing price). Problematic properties of hedonic regressions then contaminate the imputed quality adjusted housing price. Heravi and Silver (2002) have also questioned the usefulness of the hedonic approach on theoretical grounds, by highlighting how sensitive such regressions are to the small changes in methodologies.<sup>18</sup>

The 2006 Census data does not provide sufficient information to attempt hedonic regressions, which simplifies the choice of housing data. To cover the largest possible sample and to avoid oversampling highly regulated cities, the only option is to follow the examples in scholarly journals set by Malpezzi (1996), Thorson (1996), Malpezzi et al. (1998), Green (1999), Phillips and Goldstein (2000), and Malpezzi (2002) to employ housing price data from the US Census Bureau. Two additional sources of pricing data are at times mentioned in the public press

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<sup>18</sup> The insight that different variants of hedonic regression techniques generate fundamentally different answers dates back to at least Triplett and McDonald (1977; 150, see Diewert 2003). In markets with finite numbers of goods, Pakes (2003) details the various biases of the hedonic regressions and outlines necessary conditions when proper hedonic indices can be constructed.

(though never in large cross sectional studies). One is the Standard & Poor's/Case-Shiller Home Price Index, the other is the Shelter Component of the Consumer Price Index (CPI) produced by the US Bureau of Labor Statistics.

The S&P/Case-Shiller data controls best for housing quality as it tracks repeat sales of specific single family homes. Going back to 1990, the index features, however, only 15 metropolitan areas and excludes new construction. The exclusion of new construction is especially relevant to the analysis here, since new construction represents the balance between housing supply and demand in unrestricted markets. The cost of not using the quality adjusted S&P index turns out to be small. The index produces similar growth rates of housing prices as the US Census data used below. For example, for Seattle, LA, NY, San Francisco, Denver, Boston, Portland and San Diego, the difference between the nominal annual growth (1989/90-2006) in housing prices for the Standard & Poor's/Case-Shiller *metropolitan areas* and the Census *cities* is less than 1 percent.<sup>19</sup>

The Shelter Component of the CPI is both controversial and problematic. It experienced nine major revisions since its inception in 1950 and two fundamental revisions over the period of analysis in this paper. The Shelter Component tracks only consumption-related housing costs while regulations affect the asset price of a home. Housing consumption costs are essentially proxied by the apartment rental prices and an implicit “rental equivalence” that had been imputed for owner occupied housing. Since the Bureau of Labor Statistics’ 1997 revision of the shelter component, it is widely acknowledged that the measure has “lost what little connection it had recognized between the rental and owner-occupied markets” (Carson, 2006). This disconnect is reflected in the sharp rise in housing prices in the early 2000s (as tracked by the Bureau of Labor Statistics’ own data), which was associated with a sharp drop in home owners’ “rental equivalence” (perhaps due to the lower cost of funds or factors specific to the rental market).

## **4.2 Housing Demand Data**

Census data for the 2730 jurisdictions in the Wharton database are available only from the decennial Census. To provide a timely analysis, the 2006 Census Bureau’s Public-Use

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<sup>19</sup> The unit of analysis is the “city” for the Census and the “metropolitan area” for S&P data. Therefore the data is not directly comparable (for example, Detroit City experienced a 4 percent greater nominal annual growth in housing prices than the Detroit metropolitan area). Nevertheless it is important to report that the quality adjusted S&P data features an even greater correlation with the Wharton Index than the Census data.

Microdata Sample (PUMS) is used here, which covers a sample of major US cities with a minimum of 10,000 inhabitants. The intersection between the 2730 jurisdictions in the Wharton Database and the 2006 PUMS Census data renders a universe of about 250 cities (depending on the exact variable). The Census is also the source of the population data that was used to calculate population and land area (to obtain city density). Finally, the Census also provided data on median household income. Summary statistics are provided in Appendix 2.

### **4.3 Land Use Regulation Data**

As mentioned in the introduction, the land use literature is now fortunate enough to find at its disposal a full dataset of 70 land use indicators. The Wharton Regulatory Database speaks to all three major components of land use regulations: urban growth boundaries, regulation of development densities, and cost-increasing regulations. A list of the data collected in the Wharton database is provided in Table 2. Many of these variables are highly correlated; therefore Gyourko et al. (2008) suggest the construction of a “Wharton Index” (formally the *Wharton Residential Land Use Regulation Index*).

The Wharton Index itself is composed of 11 sub-indices that reflect *i) Local Political Pressure, ii) State Political Involvement Index, iii) State Court Involvement Index, iv) Local Zoning Approval Index, v) Local Project Approval Index, vi) Local Assembly Index, vii) Density Restrictions Index, viii) Open Space Index, ix) Exactions Index, x) Supply Restrictions Index, and xi) Approval Delay Index*. The exact definitions of these indices are documented in Gyourko et al. (2008). One key sub-index is the *Approval Delay Index*, which will be of consequence below. It is defined as the average time lag (in months) for three types of projects: i) relatively small, single-family projects involving fewer than 50 units; ii) larger single-family developments with more than 50 units, and iii) multifamily projects of indeterminate size. Table 3 ranks the 50 states by their regulatory stringency (Washington State is the 7<sup>th</sup> most regulated state) and Table 4 provides the rankings for metropolitan areas (the Seattle metropolitan is ranked 5<sup>th</sup> most regulated in the nation).

Gyourko et al. (2008) report average regulatory statistics by state and by metropolitan area. While it is common to use major metropolitan areas as the unit of analysis in cross sectional studies, actual city limits are used in the regressions below, since some important metropolitan areas are missing data for crucial cities that constitute substantial segments of the metropolitan

region (for example, the Seattle metropolitan is lacking information on Bellevue). Most importantly, however, the land use data was collected at the city level; hence a city-level analysis best reflects the relationship between the observed prices and regulations. While the Wharton Index is informative as a broad measure of regulations, it is also of interest to conduct a deeper analysis that identifies which of the Wharton Index' subcomponents may be related to changes in housing price. Examining each specific subcomponent's explanatory power results in a clearly defined and readily interpretable set of variables associated with changes in housing prices.

## **5. Estimates of Supply and Demand Effects on Housing Prices**

Figures 2a-d report simple correlations between the annual compounded growth in housing prices and the Wharton Index (Figure 2a), income growth (Figure 2b), population growth (Figure 2c), and population density (Figure 4d). The Figures exhibit clear, positive correlations, but also indicate that housing prices are not explained by any one variable alone. Multivariate regression analysis must be employed to capture all effects on housing prices. A regression that features *only* the influences of demand factors (income growth, population growth and density) on housing prices is provided in column 1 of Table 5. In total, demand factors explain about 20 percent of the variation in the housing price data (as indicated by the adjusted  $R^2$ ), and all three demand factors are highly significant.

The next regression adds the supply side to the regression and allows the Wharton Index to proxy for regulatory measures that influence supply. The results in column 2 of Table 5 indicate that the proportion of the variation in housing prices that is explained by the regression jumps over 20 percent when the Wharton Index is included. The root mean square errors<sup>20</sup> indicate that the statistical model improves when the regression accounts for the association between land use regulations and housing prices. Thus there is clear evidence that land use regulations are tightly associated with the growth of housing prices in the broad cross section of 250 major US cities. This should not be surprising given a visual inspection of Figure 2a.

It is also crucial to note that the coefficients for the demand side regressors (income, population, and density) hardly change as land use regulations are added to the regression model (from Table 5 column 1 to column 2). This is a crucial insight, since it implies that land use

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<sup>20</sup> The mean squared error quantifies the amount by which estimates differs from the observed quantity of interest. Lower values indicate smaller errors and better estimates.

regulations explain a *different dimension* of the variation in housing prices (e.g., the supply side). The invariance of the demand side coefficient estimates to the inclusion of land use regulation indicates also that the supply factors do not explain variation in housing prices at the expense of demand side measures. Instead, supply factors *complement* the insights derived from the effects of demand side measures on housing prices. Complementary here means that the inclusion of regulatory measures improves the statistical model and its predictive power without detracting from the importance of the demand side effects in explaining housing prices.

Since the coefficient associated with the Wharton Index in column 2 of Table 5 is positive and highly statistically significant; this indicates that more stringent land use regulations are associated with an increase in housing prices. The low value for the Wharton Index in the dataset is -2.12, and the maximum is 4.65. The coefficient associated with the Wharton Index in column 2 of Table 5 then implies that housing prices in the most highly regulated cities are about 50 percent higher than those in the least regulated cities.<sup>21</sup> Interestingly, this implied increase in housing prices between lowest and highest regulated cities is just about identical to the finding in Malpezzi (1996), who based his study on 56 (vs. 250) cities, different regulation measures, and a regression in levels.

The analysis can be taken one step further to identify exactly which subcomponent(s) of the Wharton Index is (are) closely related to the change in housing prices. The advantage of constructing indices is that they summarize a wealth of information into one single figure; the disadvantage is that, for policy purposes, an index is difficult to interpret. The Wharton Index combines a wealth of information from 70 different types of land use regulations and it seems natural to ask whether specific regulations are particularly closely associated with changes in housing prices? Are prices driven, for example, by state or local policies, citizen opposition or growth management regulations, cost-increasing permit delays or limits on lot size?

To achieve this level of detail, the Wharton Index can be disaggregated into its subindices which can then be further dissected into their respective subcomponents (see Gyourko et al., 2008). A simple stepwise regression algorithm can then be used to examine one subcomponent

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<sup>21</sup> Since the low value for the Wharton Index is -2.12, and the maximum is 4.65 in the dataset, one can substitute for these values in column 2 of Table 5 and find that the annual compounded growth rates in highly regulated cities is 2.41 percent higher than the growth rate in a city with the most permissive land use regulations. Over 17 years this implies that the difference in the annual compounded growth rate raises the level of housing prices in the most regulated city 50 percent above the level of housing prices in the least regulated cities.



after another to see whether the subindex holds explanatory power, and whether a subcomponent of a subindex holds explanatory power. If any of the subcomponents are significant, they are maintained in the regression; if not they are discarded. In the case of the approval delay subindex, the eight variables that constitute the index are highly sensitive to the inclusion of other subcomponents. Their explanatory power may be impacted by multicollinearity (e.g., cities with long permit delays for multi family projects with less than 50 units may also have long permit delays for multi family projects with more than 50 units). Therefore the approval delay index is maintained as a whole.

The final result of the disaggregation exercise is reported in column 3 in Table 5, which shows that a remarkably concise but diverse set of regulations can be shown to exhibit both economic and statistically significant association with housing prices. The regression model in column 3 in Table 5 explains 61 percent more variation in housing prices than the pure demand side regression in column 1 of Table 5. The disaggregated regression in column 3 also explains about 35 percent more variation in housing prices than the regression model that is based on the composite Wharton Index alone (Table 2b). Decomposing the Wharton Index to allow the individual dimensions of land use regulation to covary with housing prices thus clearly improved the regression model.

The specific regulatory variables from the Wharton database that have been substituted for the aggregate Wharton Index in regression 3 consist of statewide indicators, specifically indicators that speak to the executive, legislative and judicial branches of government. In addition, the types of regulations that are associated with changes in housing prices also speak to local regulations, cost-increasing regulations that involve permit and zoning delays:

- I) **Autonomous Change in Housing Prices** is the intercept, or constant, term that picks up autonomous changes that are common to all cities, such as changes in the national unemployment rate, changes in mortgage interest rates or changes in the availability of credit over the period.
- II) **Increase in Income and Population**
- III) **Population Density**
- IV) **Land Use Regulations** imposed by
  - IVa) **Statewide Land Use Restrictions Imposed by Executive and Legislature**, defined as the effects on major cities due to the level of activity in the executive and

legislative branches over the past ten years, which were directed toward enacting greater statewide land use regulations.

**IVb) Municipal Land Use Restrictions Upheld by Courts**, defined as the effects on major cities due to the tendency of appellate courts to uphold or restrain land use regulation.

**IVc) Involvement of Growth Management and Residential Building Restrictions**, defined as the effects on cities due to the involvement of the state legislature in affecting residential building activities and/or growth management procedures.

**IVd) Approval Delays**, given by 8 indicators that measure the average duration of the review process, the time between application for rezoning and issuance of a building permit, the time between application for subdivision approval and the issuance of a building permit conditional on proper zoning being in place. Each indicator considers three types of projects:

- i) Small single-family projects involving fewer than 50 units
- ii) Larger single-family developments with more than 50 units
- iii) Multifamily projects of indeterminate size

The statistical significance of each land use regressor is strong; all but Approval Delays are significant at the 99.99 percent confidence level (Approval Delays are significant at the 90 percent level).<sup>22</sup>

The quality of these statistical results is discussed extensively in Appendix 1. The appendix examines the residuals of the regression, which are defined as the difference between the actual housing price data and the predicted prices generated by the regression model. The appendix highlights two important features. First, there is no evidence that a key variable has been omitted from the statistical model in column 3. Second, the predictions of the model do not feature a systematic error across the 250 cities that might violate the statistical assumptions underlying the regression analysis. This provides evidence that the prediction errors of the regression model are random (e.g., accidental and not systematic).

## **6. The Cost of Regulations**

### **6.1. Costs Implied by the 250 City Study**

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<sup>22</sup> All regressors except one are found to be highly robust to alternative specifications and iterations of the stepwise procedure. The Approval Delays subindex of the Wharton Index is sensitive to the inclusion of other cost increasing measures, for example, impact fees or lot development costs. The Approval Delay subindex was maintained, because of its broad interpretation and because it represents the largest possible data sample (several alternative, cost increasing measures reduce the size of the sample substantially).

The association between regulations and housing prices can be expressed in terms of actual dollar costs. One approach is to compare housing prices associated with the highest/lowest levels of land use restrictions (as in Section 5). This approach is standard in the literature and easily executed when only one regulation is considered. The above model consists, however, of four different dimensions of regulations, so there is no clear “lowest” and “highest” level of land use restriction. In this case, it is most informative to report the actual estimated dollar value that each regulation adds to housing prices. San Francisco is the city with the greatest direct dollar cost of regulations. After adjusting for inflation, all regulatory measures combined are estimated to have contributed \$409,332 to San Francisco’s housing price between 1989 and 2006 (or 51 percent of the 2006 price). Since several regulations are state wide regulations, it is instructive to show, using 5 cities in the same state (Washington State) as an example, the cost of each regulation in each city.<sup>23</sup>

Table 6 indicates that, for example in Seattle, the price of the median owner occupied home was \$137,000 in 1989. In 2006, the US Census reports this price to be \$448,000. The total price increase in Seattle from 1989 to 2006 was therefore \$311,000. It is important to keep in mind, however, that the general price level increased from 1989 to 2006. Adjusting the data for inflation, housing prices in Seattle rose about \$227,000, which represents the real (102 percent) increase in housing prices above and beyond the rise in the general price level. This is the price increase examined in the analysis above. Real price increases in the other cities in Table 6 are also substantially above the national average, which is 54 percent in this sample.

Demand factors (income and population growth) contributed \$35,000 to the increase in real housing prices in Seattle from 1989-2006. This demand effect is significantly greater than the national average (\$4,000) over the same period. This result is not surprising, since Seattle experienced above-average income and population growth over the past two decades. In Tacoma and Everett, income and population growth were lower than in Seattle and therefore demand factors are associated with smaller price increases in these areas. Kent and Vancouver, on the other hand, saw substantial increases in housing demand, perhaps due to their proximity to Seattle and Portland, respectively. Specifically, Vancouver’s increase in housing demand drove

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<sup>23</sup> These are the only Washington State cities contained in the sample of 250 major cities. Appendix 2 reports the regulatory data for all 50 cities in Washington State that responded to the Wharton survey. If a city is included in Appendix 2, but not included in the sample of 250 cities, it is because the 2006 Census data was not available.

40 percent of its real housing price increase (\$54,000).<sup>24</sup> This indicates that even within a Washington State, variations in the demand are clearly reflected in the housing prices.

For all five Washington cities, the largest share of housing price increases was associated with regulations, which added about \$203,000 to housing prices in Seattle. In Kent and Everett the regulatory environments are associated with \$125,000 to \$113,000 increases in housing prices, respectively. Statewide regulatory measures seem to have been particularly important in affecting Seattle's housing prices, and the local approval delays contributed about \$30,000. None of the four other cities ranked as high as Seattle in terms of approval delays. In fact in Tacoma the permit and rezoning effect is estimated to be just about negligible. By far the greatest impact is generated by statewide restrictions imposed by the level of activity in the executive and legislative branches over the past ten years in Washington State, while growth management contributed about \$10,000 in Vancouver and \$50,000 in Seattle.

### **6.1 Costs of Regulations Implied by Previous Studies**

These estimated costs of regulations may seem extraordinarily large, but they are surprisingly close to previous estimates in studies that use smaller samples. Glaeser and Gyourko (2002) examine the effects of zoning on land values in forty major US cities. Their results circulated widely in the popular press after the *Atlantic Monthly* (Postrel, 2007) reported the study's implied price increases due to regulations in major cities. For Seattle, Glaeser and Gyourko (2002) report a \$201,000 price increase due to regulations.<sup>25</sup> Not all of the price increases in Glaeser and Gyourko (2002) coincide identically with the results predicted by the regression in column 3 of Table 5, but the overall correlation is an astonishing 0.91.<sup>26</sup>

A thorough review of the previous literature on housing prices and regulations highlights that not all studies report statistically significant results. This could be due to methodological problems, or regulatory indicators being combined into a single indices, insufficient objective and comparable regulatory data, or the absence of an effect.<sup>27</sup> Comparative studies that do find

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<sup>24</sup> Note that the regression accounts for both population growth and density (population per area (in sq. miles)), which is particularly important in Vancouver, WA, which grew substantially in both dimensions over the period.

<sup>25</sup> Glaeser and Gyourko (2002) report only the cost increase per square foot. O'Tool (2002) then calculates quarter acre lot prices based on the difference between Glaeser and Gyourko's imputed land cost and their estimated price of land specification. Kent, Vancouver, Everett and Tacoma were not in their sample.

<sup>26</sup> Recall that a perfect correlation of the result in the two studies would imply a correlation coefficient of 1.

<sup>27</sup> See Lillydahl and Singell (1987), Pogodzinski and Sass, 1991, Ihlanfeldt (2004), Xing et al. (2006), Landis et al. (2002), and especially Quigley and Rosenthal (2005).

statistical significant associations between regulations and housing prices are nevertheless numerous, and always document that regulations are associated with higher housing prices. As the survey in Table A.3.1 in Appendix 3 indicates, there are about two dozen studies in the past decades that show significant increases due to regulatory/growth controls – many suggest similar dollar costs as shown in the results above and in the Glaeser Gyourko study.

Mark Twain is at times credited with having coined the term “there are three types of lies: lies, damn lies, and statistics.” The reported association between regulations and housing prices may simply seem implausible to some. Skeptics best turn their attention to the primary data to conduct the ultimate reality check: *were regulations in cities where the regressions report high costs of regulations truly unusually restrictive? Was Washington State/Seattle truly as different from the average city as their dollar cost of regulations suggests?* The regulation data in appendix 2, which as we recall was reported to Wharton by the cities’ planning directors themselves (!), indicates that Seattle is actually one of the most restrictive cities in terms of land use regulations in the entire sample. Table 3 had already shown that Washington State ranked 7<sup>th</sup> in the nation in terms of overall regulatory stringency. The appendix splits the rankings in Table 4 and Table 3 into the Wharton Index subcomponents that are relevant for these cities. Here it becomes apparent that the city of Seattle (not the Seattle metropolitan area reported in Table 4), ranks in the 98<sup>th</sup> percentile for the overall Wharton Index. That is, only 2 percent of the cities in the sample reported to Wharton that they have more restrictive residential land use regulations.

This overall Wharton Index ranking evaluates the stringency of a large number of individual land use regulations. Seattle ranks in the 90 percentile or higher in more than 16 key indicators. Several of the indicators (shaded) are related to approval delays. Other variables in the table are key regressors in the statistical model (the state court effect, the growth management effect and the legislative involvement index). Note that Kent especially is ranked almost as restrictive as Seattle; while Everett’s regulatory stringency places it in the 71<sup>st</sup> percentile. Vancouver is the counter example; its regulatory structure is about average (the 51<sup>st</sup> percentile), which explains why so much of its increase in housing prices was driven by demand.

## **7. What are the Effects of Statewide Regulations?**

Why are the effects of *statewide* regulations associated with such strong increases in housing prices in these 5 major cities in Washington State? The answer lies in examining the

land use restrictions of all Washington cities in the Wharton sample. Appendix 2 clearly reports that each city is affected differently by statewide land use measures. The most prominent statewide land use measure in the state is Washington's Growth Management Act (GMA), enacted by the Washington Legislature in 1990. In 1995, the State Legislature added a requirement to review and update policies and regulations by 2004 on the basis of "Best Available Science."<sup>28</sup>

Statewide growth management affects all jurisdictions identically in terms of the letter of the law.<sup>29</sup> However, to adhere to the letter of the law, individual jurisdictions may have to pass their own land use regulations to accommodate the growth targets. If statewide land use restrictions limit sprawl to create distinct low density peripheries and high density urban cores, each city is affected differently, depending on its individual supply and demand for housing. This is shown in the large variation of the *Stateleg* variable in Appendix 2. The effects of limits on growth are greater in metropolitan areas whose agglomeration pressures are stronger (see Duranton and Puga, 2004 for a review of agglomeration pressures). Statewide regulations limit growth in the periphery and redirect demand (and price pressures) to the metropolitan core. In the absence of such land use restrictions, cities such as New York or Las Vegas have been documented to easily accommodate great population growth (housing demand) without price pressures (see Glaeser, Gyourko and Sachs, 2005) presumably through increases in building heights and/or sprawl.

Statewide regulations may act as catalysts of agglomeration, but courts may also play a crucial role in complementing statewide growth management plans. For example, some argue that under Washington's growth management plan, King County had few options but to require landowners in Seattle's rural periphery to keep 50 to 65 percent of their property in its "natural state" (see Langston, 2004). This forced greater density in the urban core and it is difficult to see why such supply restrictions would not be accompanied by price responses.

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<sup>28</sup> The "GMA requires state and local governments to manage Washington's growth by identifying and protecting critical areas and natural resource lands, designating urban growth areas, preparing comprehensive plans and implementing them through capital investments and development regulations" (see <http://www.gmhb.wa.gov/gma/index.html>)

<sup>29</sup> All cities that are covered by a GMA, that is. In Washington, for example, the GMA was a state mandate that local governments had to follow - where it applied. Originally only 18 counties were required to plan and 11 more opted in. The remaining counties were exempted from portions of the GMA.

It was important, however, that a challenge to the constitutionality of King County's land use regulations was rejected by the Washington State Supreme court. The court clearly stated that *state law required* local governments to provide land use restrictions of the type imposed in King County in order to adhere to the statewide growth management plan. The state's Supreme Court therefore rejected the validity of a King County referendum to repeal local regulations that were put into place explicitly to adhere to the statewide growth management plan (Ervin 2006). Charles Johnson, the Associate Chief Justice of the Supreme Court of the State of Washington, summarized the majority opinion succinctly: "where the state law requires local government to perform specific acts, those local actions are not subject to local referendum." If the dissenting justices had been in the majority, the teeth may well have been taken out of the implementation of the growth management plan in King County. This would have stopped the imposition of local regulations, and therefore mitigated the upward pressure on housing prices.

Note the importance of the interaction between state legislature and courts: state law forced local land use regulations, and the state court upheld local land use regulations because they were mandated by state law. The Seattle metropolitan area responded to the GMA mandate by instituting a Growth Management Planning Council (GMPC). A search of the council's agendas and communications with the managers of the comprehensive plan update and King County's housing and community development program indicates that their review of the GMA effects includes only one study that examines the historic change in housing prices.<sup>30</sup> This study graphs *annual* changes in housing prices against employment (a proxy for population growth) and housing supply. The factors associated with changes in the long term housing supply have not been studied. By correlating employment and housing supply with *annual* changes in housing prices, the GMPC study mixes short and long term effects. In the short run (year to year), the supply of housing is fixed; therefore, annual changes in housing prices can hardly exhibit a significant correlation with housing supply.

While Washington planners especially in Seattle and King County seem to have carefully monitored housing demand and its effect on prices, the above data indicates that housing supply (regulations) has also been associated with significant increases in housing prices. The analysis also highlights that any policy intervention at the municipal, county, or statewide level must be

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<sup>30</sup> See Figures 14 and 15 in the staff report presented to the GMPC on March 28<sup>th</sup>, 2001. [http://www.metrokc.gov/ddes/gmpc/ag\\_rpts2001.shtm](http://www.metrokc.gov/ddes/gmpc/ag_rpts2001.shtm)

accompanied by strong follow up analyses regarding its impacts on housing prices. In addition, studies should be *comparative* so that the impact of regulations on Seattle can be evaluated by comparing results across cities with similar housing demand pressures in order to have a clear metric of evaluation.

As discussed in Figure 1, the optimal policy may be aimed at increasing or decreasing the price of housing. Growth management is often advocated because it allows for designed natural states in urban peripheries and increases construction/density in the urban core. Whether these incentives were sufficient to generate the required increase in housing is an empirical question that is answered by the speed of rising housing prices. Nearly two dozen studies in the past 2 decades associate rising prices with regulations (see Appendix 3).

## **7. Summary and Policy Implications**

Using new, consistent, and comparable land use regulation data reveals that land use regulations are correlated with housing price increases across 250 major US cities. The data indicate that aside from demand effects, statewide regulations and growth management are associated with increases in housing prices. In addition, when courts reject challenges to municipal land use restrictions (which may have been created to adhere to statewide laws), the effects of regulations on housing prices are amplified. Finally, cost-increasing regulations at the municipal level are also found to impact housing prices.

The restrictiveness and the effects of land use regulations vary substantially across five cities in Washington State, ranging from an estimated increase of \$203,000 in Seattle to \$73,000 in Vancouver, WA. The largest share of this increase is not due to municipal regulations, but due to the effects of statewide regulations. When statewide regulations negate sprawl or limit building heights, they exacerbate agglomeration pressures at the city centers. Ultimately these dynamics are reflected in the increase in housing prices in the time period examined above.

Dollar cost estimates of regulations in terms of increased housing prices are derived by examining the change in housing prices from 1989 to 2006. This long term view is different from short term fluctuations that are often the focus of public debates. In the short run (a year or so), the supply of housing is fixed, so that short term analyses are *by design* unlikely to find a meaningful correlation between housing prices and supply over this time frame. The above



results highlight that only a fraction of the change in housing prices is explained when supply side is ignored.

The analysis does not address whether more regulations are better, worse, or misguided. This would be a value judgment that requires the documentation of both costs *and benefits* of regulations. Ultimately, the increase in housing prices may be below or above citizens' valuation of the absence of sprawl. To elicit a benefit valuation of regulations is beyond the scope of this research project. Economic methods to study the contingent valuation<sup>31</sup> are widespread in environmental economics, but they are time intensive (and costly) and infrequently used in the housing regulation literature to establish the benefits of regulations.<sup>32</sup> The alternative is to rely on the electorate. After being informed about the costs of regulations, voters can decide whether to support further regulations, or whether to abolish existing ones.

While this study details the private costs of regulations (the increased cost of housing), it does not include the social cost of regulations, since costs for changed commuting, parking and pollution patterns are not available. Also, while higher housing prices represent a windfall for sellers, they also constitute a redistribution from buyers to sellers as well as a reduction in housing affordability.<sup>33</sup> Land use regulations that increase housing prices also have a time dimension: current owners are the beneficiaries of such regulations, but their children and future migrants to the area bear the costs. This represents redistribution over time and generations, which may affect the location decisions of individuals and companies to limit productivity growth.<sup>34</sup> The design of land use policy is hampered by the complexity of the urban housing market that is difficult to model and predict (for economists and policy makers alike). It is therefore imperative to evaluate whether policies designed to maximize the citizens' welfare actually achieve the policy goal without unintended side effects.

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<sup>31</sup> Contingent valuation is a survey-based method to assign monetary valuations to goods and services (in this case land use regulations) that cannot be bought and sold in the marketplace.

<sup>32</sup> See, for example, Beasley et al. (1986), Breffle et al. (1998), Ready et al. (1997) and Geoghegan (2002)

<sup>33</sup> Housing is generally classified as affordable when renters or owners pay less than 30% of their income in rent or mortgage. For evidence on changes in affordable housing see Crellin (2006), King County (2004) and National Low Income Housing Coalition (2007). Quigley and Raphael (2005) survey the literature and cite one paper that examines the effects of land use regulations on affordable housing (Malpezzi and Green, 1996).

<sup>34</sup> See van Nieuwerburgh and Weill (2007)

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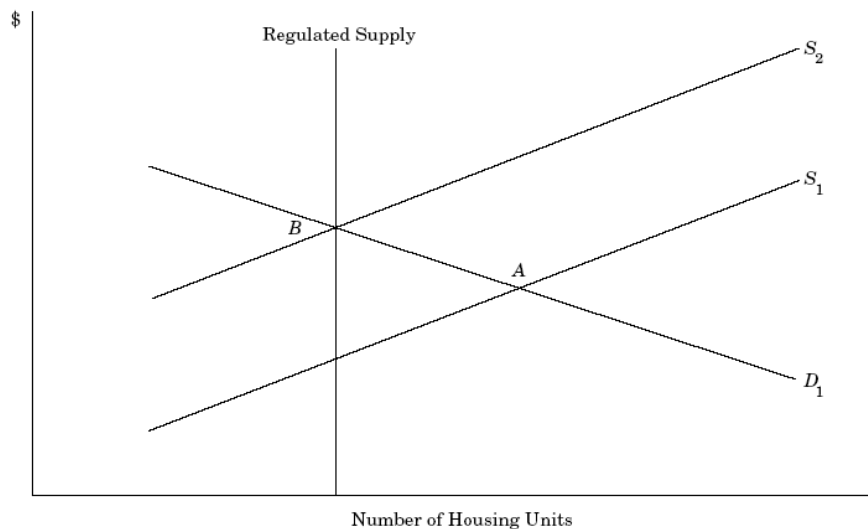
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Figure 1. Case 1: Cost Externalities Exist; Optimal Regulation Is Imposed



Number of Housing Units  
Source Malpezzi 1996

**Table 1: Prices of Housing Units Relative to Their New Construction Costs**

	1989	1999	1989	1999
	Housing valued 90% ≤ construction cost	Housing valued 90% ≤ construction cost	Housing valued ≥ 140% construction cost	Housing valued ≥ 140% construction cost
San Francisco Suburbs, Calif.	1%	2%	98%	97%
San Francisco, Calif.	0%	4%	97%	96%
Anaheim Suburbs, Calif.	25%	3%	96%	96%
Anaheim, Calif.	0%	0%	100%	93%
San Diego, Calif.	7%	3%	88%	93%
Oxnard Suburbs, Calif.	0%	4%	100%	93%
<b>Seattle Suburbs, Wash.</b>	<b>2%</b>	<b>1%</b>	<b>72%</b>	<b>90%</b>
Los Angeles, Calif.	2%	4%	93%	89%
Los Angeles Suburbs, Calif.	4%	4%	91%	89%
San Diego Suburbs, Calif.	4%	5%	92%	88%
Denver, Colo.	4%	8%	60%	86%
<b>Seattle, Wash.</b>	<b>6%</b>	<b>2%</b>	<b>49%</b>	<b>86%</b>
Boston Suburbs, Mass.	1%	2%	87%	86%
Salt Lake City Suburbs, Utah	10%	2%	22%	86%
Fort Lauderdale Suburbs, Fla.	0%	0%	76%	85%
Albuquerque, N.M.	2%	3%	82%	83%
Raleigh, N.C.	6%	2%	81%	81%
New York Suburbs, N.Y.	3%	9%	85%	78%
Phoenix Suburbs, Ariz.	2%	0%	65%	76%
Riverside Suburbs, Calif.	5%	2%	87%	76%
Chicago Suburbs, Ill.	6%	5%	67%	74%
Miami Suburbs, Fla.	5%	0%	72%	73%
Sacramento, Calif.	0%	3%	55%	72%
Newark Suburbs, N.J.	1%	1%	96%	72%
Sacramento Suburbs, Calif.	3%	5%	83%	72%
Austin, Tex.	0%	6%	46%	71%
Greensboro, N.C.	13%	0%	59%	69%
Norfolk, Va.	1%	2%	87%	66%
Tampa Suburbs, Fla.	3%	5%	57%	66%
Phoenix, Ariz.	2%	5%	69%	65%
Tucson, Ariz.	6%	4%	43%	61%
Baltimore Suburbs, Md.	5%	1%	66%	61%
Columbus Suburbs, Ohio	12%	3%	47%	61%
New Orleans Suburbs, La.	10%	6%	53%	61%
Orlando Suburbs, Fla.	3%	4%	70%	61%
Atlanta Suburbs, Ga.	3%	6%	67%	58%
Cleveland Suburbs, Ohio	15%	5%	23%	58%
Detroit Suburbs, Mich.	24%	8%	26%	58%
New Orleans, La.	2%	3%	49%	57%
Nashville-Davidson, Tenn.	2%	5%	69%	56%
New York, N.Y.	4%	11%	81%	56%
Birmingham Suburbs, Ala.	10%	12%	56%	53%
Milwaukee Suburbs, Wis.	5%	8%	39%	53%
Dallas Suburbs, Tex.	3%	6%	58%	52%
Tampa, Fla.	9%	13%	43%	49%
Fort Worth Suburbs, Tex.	9%	9%	59%	49%
Wichita, Kans.	18%	13%	21%	48%
Dallas, Tex.	6%	13%	56%	47%
Cincinnati Suburbs, Ohio	10%	10%	29%	47%
Philadelphia Suburbs, Pa.	3%	11%	78%	47%
Las Vegas, Nev.	0%	3%	29%	45%
Chicago, Ill.	20%	16%	28%	44%
Jacksonville, Fla.	8%	11%	55%	43%
Minneapolis Suburbs, Minn.	8%	5%	29%	43%
Oklahoma City, Okla.	13%	16%	30%	41%
Little Rock, Ark.	9%	8%	36%	40%
Albany Suburbs, N.Y.	6%	0%	63%	40%
Tulsa, Okla.	7%	8%	36%	38%
St. Louis Suburbs, Mo.	11%	21%	34%	34%
Kansas City Suburbs, Mo.	15%	5%	22%	33%
Houston Suburbs, Tex.	23%	8%	24%	31%
Minneapolis, Minn.	22%	20%	21%	30%
Columbus, Ohio	33%	12%	18%	29%
Fort Worth, Tex.	12%	26%	40%	29%
El Paso, Tex.	5%	2%	34%	28%
Rochester Suburbs, N.Y.	1%	9%	63%	28%
Baltimore, Md.	18%	30%	41%	27%
Houston, Tex.	25%	25%	40%	27%
San Antonio, Tex.	12%	30%	48%	26%
Toledo, Ohio	27%	40%	16%	23%

Source: Glaeser and Gyourko (2002)

**Table 2: Land Use Variables Collected in the Wharton Land Use Database**

	Variable Name	Value Explanation
1	Local	local council involvement in regulation (1-not at all, 5-very)
2	pressure	community pressure involvement in regulation (1-not at all, 5-very)
3	countyleg	county legislature involvement in regulation (1-not at all, 5-very)
4	Stateleg	state legislature involvement in regulation (1-not at all, 5-very)
5	localcourts	local courts involvement in regulation (1-not at all, 5-very)
6	statecourts	state courts involvement in regulation (1-not at all, 5-very)
7	commission	planning commission approval required for rezoning, 0=no, 1=yes, 2=yes by superm
8	loczoning	local zoning board approval required for rezoning, 0=no, 1=yes, 2=yes by superma
9	Council	local council approval required for rezoning, 0=no, 1=yes, 2=yes by supermajorit
10	cntyboard	county board approval required for rezoning, 0=no, 1=yes, 2=yes by supermajority
11	cntyzoning	county zoning board approval required for rezoning, 0=no, 1=yes, 2=yes by superm
12	envboard	environmental review board approval required for rezoning, 0=no, 1=yes, 2=yes by
13	commission_n0~z	planning commission approval required (norezoning), 0=no, 1=yes, 2=yes by superm
14	Council_norez	local council approval required (norezoning), 0=no, 1=yes, 2=yes by supermajorit
15	cntyboard_norez	county board approval required (norezoning), 0=no, 1=yes, 2=yes by supermajority
16	envboard_norez	environ review board approval required (norezoning), 0=no, 1=yes, 2=yes by super
17	publlhth_norez	public health off approval required (norezoning), 0=no, 1=yes, 2=yes by supermaj
18	dsgnrev_norez	design review board approval required (norezoning), 0=no, 1=yes, 2=yes by superm
19	sfandsupply	supply of land importance (single family) 1-not at all, 5-very
20	mfulandsupply	supply of land importance (multi family) 1-not at all, 5-very
21	sfudensrestr	density restrictions importance (single family) 1-not at all, 5-very
22	mfuldensrestr	density restrictions importance (multi family) 1-not at all, 5-very
23	sfuimpact	impact fees/exactions importance (single family) 1-not at all, 5-very
24	mfuimpact	impact fees/exactions importance (multi family) 1-not at all, 5-very
25	sfucouncil	council opposition importance (single family) 1-not at all, 5-very
26	mfulcouncil	council opposition importance (multi family) 1-not at all, 5-very
27	sfucitizen	citizen opposition importance (single family) 1-not at all, 5-very
28	mfulcitizen	citizen opposition importance (multi family) 1-not at all, 5-very
29	sfulelengthzoning	length zoning process importance (single family) 1-not at all, 5-very
30	mfulengthzoning	length zoning process importance (multi family) 1-not at all, 5-very
31	sfulelengthpermit	length permit process importance (single family) 1-not at all, 5-very
32	mfulengthpermit	length permit process importance (multi family) 1-not at all, 5-very
33	sfulelengthdvp	length development process importance (single family) 1-not at all, 5-very
34	mfulengthdvp	length development process importance (multi family) 1-not at all, 5-very
35	sfupermitlimit	sf annual permit limit, 0=no, 1=yes
36	mfulupermitlimit	mf annual permit limit, 0=no, 1=yes
37	Sfuconstrlimit	sf annual construction units limit, 0=no, 1=yes
38	mfulconstrlimit	mf annual construction units limit, 0=no, 1=yes
39	mfuldwelllimit	mf dwelling limit, 0=no, 1=yes
40	mfuldwellunitl-t	num. of units in mf dwelling limit, 0=no, 1=yes
41	minlotsize	min lot size requirement, 0=no, 1=yes
42	minlotsize_lh~e	<=0.5 acre minlotsize requirement, 0=no, 1=yes
43	minlotsize_mh~e	>0.5 acre minlotsize requirement, 0=no, 1=yes
44	minlotsize_on~e	>1 acre minlotsize requirement, 0=no, 1=yes
45	minlotsize_tw~s	>2 acres minlotsize requirement, 0=no, 1=yes
46	affordable	affordable housing requirement, 0=no, 1=yes
47	sfusupply	sf zoned land supply compared to demand, 1=far more, 5=far less
48	mfulsupply	mf zoned land supply compared to demand, 1=far more, 5=far less
49	commsupply	commercially zoned land supply compared to demand, 1=far more, 5=far less
50	indsupply	industrially zoned land supply compared to demand, 1=far more, 5=far less
51	lotdevcostinc~e	lot development cost increase (last 10 years)
52	sflotdevcosti~e	single family lot development cost increase (last 10 years)
53	time_sfu	review time for single family units (months)
54	time_mfu	review time for multi family units (months)
55	timechg_sfu	change in review/appr time for sf projects over decade, 0=none, 1=longer, 2=much
56	timechg_mfu	change in review/appr time for mf projects over decade, 0=none, 1=longer, 2=much
57	time1_150sfu	permit lag for rezoning, <50 sf units, mths-midpoint
58	time1_m50sfu	permit lag for rezoning, >50 sf units, mths-midpoint
59	time1_mfu	permit lag for rezoning, mf project, mths-midpoint
60	time2_150sfu	permit lag for subdivision appr (norezoning), <50 sf units, mths-midpoint
61	time2_m50sfu	permit lag for subdivision appr (norezoning), >50 sf units, mths-midpoint
62	time2_mfu	permit lag for subdivision appr (norezoning), mf project, mths-midpoint
63	submitted	# applications for zoning changes submitted (last 12 months)
64	approved	# applications for zoning changes approved (last 12 months)
65	execrating	State Legislative Profile (Foster and Summers)
66	judicialrating	State Judicial Profile (Foster and Summers)
67	town_meet	Town Meeting for of Government
68	zonvote	Town Meeting Approves Zoning Changes
69	zonvote_super	Town Meeting Approves Zoning Changes by a Super-Majority
70	totinitatives	Total number of initiatives from 1996-2005
71	LPPI	Local Political Pressure Index
72	SPII	State Political Involvement Index
73	SCII	State Court Involvement Index
74	LZAI	Local Zoning Approval Index
75	LPAI	Local Project Approval Index
76	LAI	Local Assembly Index
77	DRI	Density Restrictions Index
78	OSI	Open Space Index
79	EI	Exactions Index
80	SRI	Supply Restrictions Index
81	ADI	Approval Delay Index
82	WRLURI	Wharton Residential Land Use Regulation Index

Source Gyourko et al. (2008). Note: SF and MF are single and multi family units, respectively



**Table 3:  
Average Wharton Residential Land Use Regulation Index Values by State**

State	Wharton Index	Number of Observations
1. Hawaii	2.32	1
2. Rhode Island	1.58	17
3. Massachusetts	1.56	79
4. New Hampshire	1.36	32
5. New Jersey	0.88	104
6. Maryland	0.79	18
<b>7. Washington</b>	<b>0.74</b>	<b>49</b>
8. Maine	0.68	44
9. California	0.59	182
10. Arizona	0.58	40
11. Colorado	0.48	48
12. Delaware	0.48	5
13. Connecticut	0.38	65
14. Pennsylvania	0.37	182
15. Florida	0.37	97
16. Vermont	0.35	24
17. Minnesota	0.08	80
18. Oregon	0.08	42
19. Wisconsin	0.07	93
20. Michigan	0.02	111
21. New York	-0.01	93
22. Utah	-0.07	41
23. New Mexico	-0.11	16
24. Illinois	-0.19	139
25. Virginia	-0.19	35
26. Georgia	-0.21	56
27. North Carolina	-0.35	64
28. Montana	-0.36	6
29. Ohio	-0.36	135
30. Texas	-0.45	165
31. Nevada	-0.45	7
32. Wyoming	-0.45	7
33. North Dakota	-0.54	8
34. Kentucky	-0.57	28
35. Idaho	-0.63	19
36. Tennessee	-0.68	41
37. Nebraska	-0.68	22
38. Oklahoma	-0.7	36
39. South Carolina	-0.76	30
40. Mississippi	-0.82	21
41. Arkansas	-0.86	23
42. West Virginia	-0.9	15
43. Alabama	-0.94	37
44. Iowa	-0.99	59
45. Indiana	-1.01	47
46. Missouri	-1.03	67
47. South Dakota	-1.04	11
48. Louisiana	-1.06	19
49. Alaska	-1.07	7
50. Kansas	-1.13	46

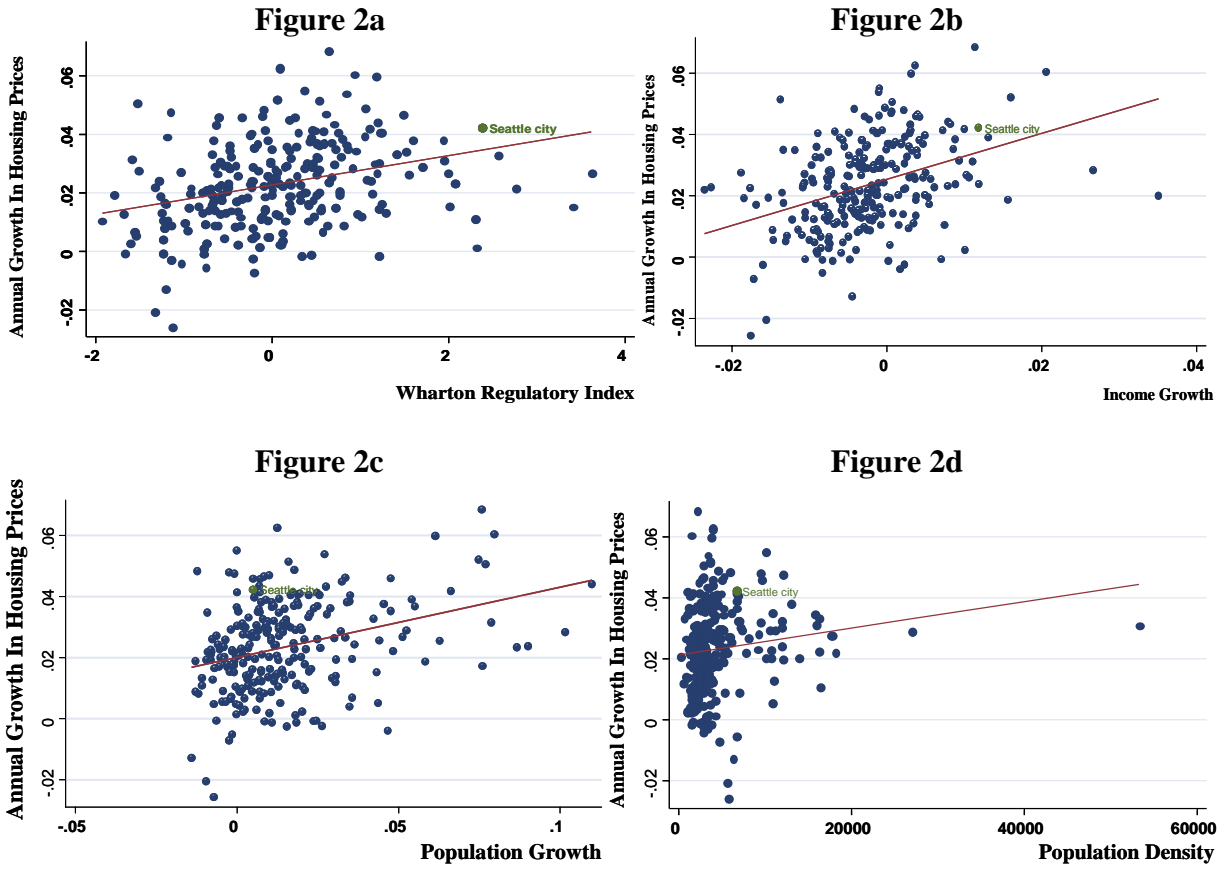
Source Gyourko et al. (2008)

**Table 4:**  
**Wharton Residential Land Use Regulation Index Averages For Major Metropolitan Areas**

	<b>Metropolitan Area</b>	<b>Wharton Index</b>	<b>Number of Observations</b>
1	Providence-Fall River-Warwick	1.79	16
2	Boston	1.54	41
3	Monmouth-Ocean	1.21	15
4	Philadelphia	1.03	55
<b>5</b>	<b>Seattle-Bellevue-Everett</b>	<b>1.01</b>	<b>21</b>
6	San Francisco	0.9	13
7	Denver	0.85	13
8	Nassau-Suffolk	0.8	14
9	Bergen-Passaic	0.71	21
10	Fort Lauderdale	0.7	16
11	Phoenix-Mesa	0.7	18
12	New York	0.63	19
13	Riverside-San Bernardino	0.61	20
14	Newark	0.6	25
15	Springfield	0.58	13
16	Harrisburg-Lebanon-Carlisle	0.55	15
17	Oakland	0.52	12
18	Los Angeles-Long Beach	0.51	32
19	Hartford	0.5	28
20	San Diego	0.48	11
21	Orange County	0.39	14
22	Minneapolis-St	0.34	48
23	Washington DC	0.33	12
24	Portland-Vancouver	0.29	20
25	Milwaukee	0.25	21
26	Akron	0.15	11
27	Detroit	0.12	46
28	Allentown-Bethlehem-Easton	0.1	14
29	Chicago	0.06	95
30	Pittsburgh	0.06	44
31	Atlanta	0.04	26
32	Scranton-Wilkes-Barre-Hazleton	0.03	11
33	Salt Lake City-Ogden	-0.1	19
34	Grand Rapids-Muskegon-Holland	-0.15	16
35	Cleveland-Lorain-Elyria	-0.16	31
36	San Antonio	-0.17	12
37	Tampa-St. Petersburg-Clearwater	-0.17	12
38	Houston	-0.19	13
39	San Antonio	-0.24	12
40	Fort Worth-Arlington	-0.27	15
41	Dallas	-0.35	31
42	Oklahoma City	-0.41	12
43	Dayton-Springfield	-0.5	17
44	Cincinnati OH-KY-IN	-0.56	27
45	St. Louis MO-IL	-0.72	27
46	Indianapolis IN	-0.76	12
47	Kansas City MO-KS	-0.8	29

Source Gyourko et al. (2008)

**Figure 2**  
Simple Correlations between Housing Prices and Explanatory Variables



**Table 5: Regression Analysis Results**

	Dependent Variable: Real Median Owner Occupied Housing Price Growth, 1989-2007		
	(1)	(2)	(3)
<b>Median Real Income Growth</b>	0.549 (4.33)***	0.455 (3.62)***	0.489 (4.00)***
<b>Population Growth</b>	0.172 (3.74)***	0.166 (3.65)***	0.149 (3.45)***
<b>Density</b>	6.66E-07 (3.72)***	6.19E-07 (3.52)***	4.81E-07 (2.73)***
<b>Wharton Land Use Index</b>		0.004 (3.95)***	
<b>Permit Approval Delays</b>			0.00037 (1.6)*
<b>Statewide Regulations</b>			0.005 (3.85)***
<b>Courts</b>			0.004 (2.98)***
<b>State Involvement in Local Land use and Growth Management</b>			0.002 (2.54)**
<b>Constant</b>	0.019 (12.48)***	0.019 (12.34)***	-0.007 (1.62)
Observations	253	246	246
Adj. R-squared	0.21	0.25	0.33
Root MSE	0.0132	0.01288	0.01217

Variable definitions see Appendix 2; t statistics in parentheses; \*, \*\*, \*\*\* are 10%, 5%, 1% significance levels

**Table 6: Sources of Real Housing Price Increase in Washington State**

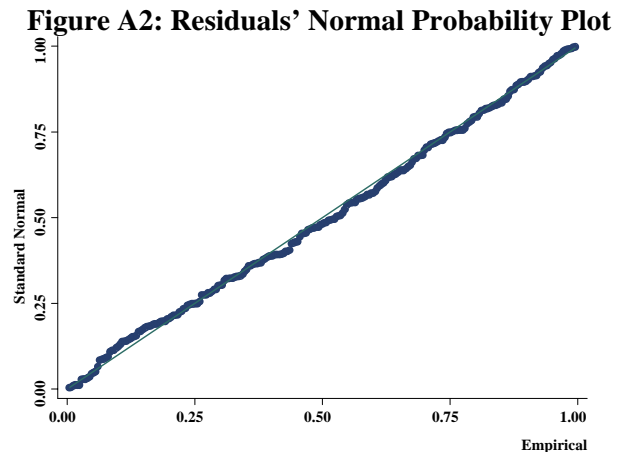
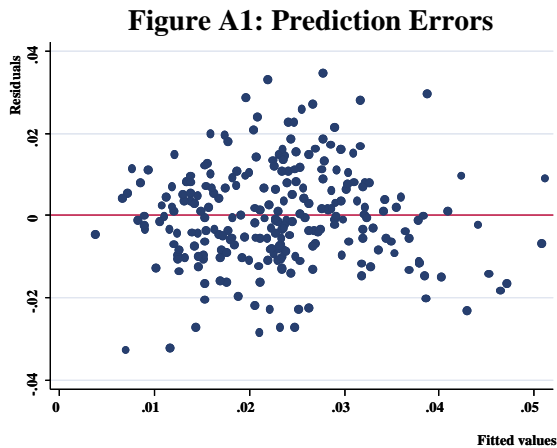
	Seattle	Tacoma	Vancouver	Everett	Kent
<b>Housing Price in 2006<sup>1</sup></b>	\$447,800	\$228,300	\$233,600	\$258,000	\$281,600
<b>Real Housing Price Change 1989-06</b>	102%	114%	137%	62%	62%
<b>INCREASE IN HOUSING PRICES DUE TO:</b>					
<b>I) Common Factors Across Cities<sup>6</sup></b>	-\$36,472	-\$18,099	-\$17,651	-\$23,322	-\$25,474
<b>II) Income &amp; Population Growth</b>	\$35,075	\$8,382	\$49,185	\$7,343	\$24,068
<b>III) Population Density</b>	\$17,271	\$5,099	\$4,609	\$4,968	\$5,810
<b>IV) Land Use Restrictions/Regulations</b>	\$203,525	\$83,265	\$73,086	\$113,477	\$124,614
<b>IVa) Statewide Land Use Restrictions Imposed by Executive &amp; Legislature<sup>2</sup></b>	\$79,106	\$39,256	\$38,284	\$50,584	\$55,253
<b>IVb) Municipal Land Use Restrictions Upheld by Courts<sup>3</sup></b>	\$43,796	\$21,733	\$21,195	2800491%	\$30,589
<b>IVc) Statewide Growth Management and Residential Building Restrictions<sup>4</sup></b>	\$50,274	\$19,958	\$9,732	\$25,718	\$21,068
<b>IVd) Approval Delay<sup>5</sup></b>	\$30,350	\$2,317	\$3,874	\$9,170	\$17,704
<b>Regulation % of 2006 Housing Price</b>	45%	36%	31%	44%	44%

1) For data sources see Appendix 2. 2) The level of activity in the Executive and Legislative branches over the past ten years that is directed toward enacting greater statewide land use restrictions. Source: Foster and Summers (2005) (execrating). 3) The tendency of appellate courts to uphold or restrain municipal land use regulation. Source: Foster and Summers (2005). 4) Involvement of state legislature in affecting residential building activities and/or growth management procedures Source: Gyourko et al. (2008) (stateleg). 5) Approval delay is the average time lag (in months) for a) relatively small, single-family projects involving fewer than 50 units; b) larger single-family developments with more than 50 units, and c) multifamily projects of indeterminate size. Lag times are due to the average duration of the review process, the time between application for rezoning and issuance of a building permit and the time between application for subdivision approval and the issuance of a building permit conditional on proper zoning being in place. Source: Gyourko et al. (2008). 6) Regression constant.

## Appendix 1 Regression Diagnostics

If the regression model in equation (4) and its empirical implementation in Table 5 is missing vital explanatory variables, the coefficient estimates may be biased. Diagnostic tests exist to examine whether an explanatory variable may have been omitted, although it is systematically related to the variable of interest. Visual inspection of the residuals in Figure A1 shows a largely random pattern and provides no indication of an omitted explanatory variable (the  $R^2$  associated with Figure A1 is 0.0000). A more stringent test than the visual examination of the errors is to examine the normal probability plot for the residuals in Figure A2, to see whether the residuals are approximately normally distributed (e. g., random). Given Figure A2, it seems hard to argue that the residuals are not normally distributed.

After ascertaining that there is no obvious evidence for omitted variable bias, it is important to examine the validity of the assumed functional form. Malpezzi (1996) proposes a nonlinear relationship between housing prices and regulations, which is suggested by the visual inspection of his data. Having extended his sample from about 50 to 250 major cities seems to have removed the apparent nonlinearity – at least according to a visual inspection of Figures 2a-d, which seem to indicate linear rather than nonlinear relationships. The STATA *ovtest* routine tests for omitted variables by examining alternative specifications of the baseline model that also feature polynomials. Adding polynomials for regulations does not improve the regression. The STATA *reset* test for regression specification errors (Ramsey 1969) also shows no evidence for nonlinearities in regulations in the sample of 250 cities. Malpezzi (1996) also used the log of housing price, presumably to address heteroskedasticity in his sample. The *Breusch-Pagan* tests for the constancy of the error variance; the obtained critical value indicates that the null hypothesis of homoskedasticity cannot be rejected.



The Residuals' Normal Probability Plot compares the empirical cumulative distribution function of the Residuals with a theoretical standard normal distribution).

## Appendix 2: Summary Statistics

Variable	Description/Source	Variable ID	Observations	Mean	Std. Dev.	Min	Max
<b>Approval Delay Index</b>	Permit and Zoning Approval Delay Index. See also Gyourko et al. (2008)	adi	250	5.993556	3.784825	1.333333	29.38889
<b>Executive and Legislative Rating</b>	The level of activity in the executive and legislative branches over the past ten years that is directed toward enacting greater statewide land use restrictions. See Gyourko et al. (2008)	execrating	253	2.304348	.6888143	1	3
<b>Real Housing Price</b>	1989 housing prices (median owner occupied, 2006 dollars. Census)	medval89_r	253	168220.2	105956	41132.74	570818.4
<b>Housing Price</b>	2006 housing prices (median owner occupied, 2006 dollars. Census)	medval06	253	259140.3	169130.6	60900	806700
<b>Real income growth</b>	Average annual compound growth of real median household income 1989-2006 (Census, 2006 dollars)	mi_gr	253	-.0024926	.0075162	-.0235441	.0350843
<b>Real Housing Price Growth</b>	Average annual compound growth of the real price of the median owner occupied house 1989-2006 (2006 dollars, Census).	mv_gr	253	.0234268	.0148009	-.0256737	.0683899
<b>Density</b>	2006 Population (Census) / 2000 Land area (Census)	person_sqm06	253	4521.534	4765.727	164.2102	53347.4
<b>Population growth</b>	Average annual compound growth of the population 1989-2006. (Census)	pop_gr	253	.0150111	.0210629	-.0140978	.1097826
<b>State Court Involvement Index</b>	Judicial land use environment. Tendency of courts to uphold or restrain municipal land-use regulations See Gyourko et al. (2008)	scii	253	2.245059	.593638	1	3
<b>State Legislature Involvement</b>	The degree of involvement of the state legislature in affecting the residential building activities and/or growth management procedures of a jurisdiction. See Gyourko et al. (2008)	stateleg	247	2.194332	1.068149	1	5
<b>Wharton Residential Land Use Regulatory Index (“Wharton Index”)</b>	See Gyourko et al. (2008)	wrluri	246	.0779213	.9386766	-1.9241	3.625351

The dataset is the Wharton Dataset (Gyourko et al., 2008, downloaded 07/02/07) merged with the 1990 Census data (1990 census place data for entire nation (nation file), which contains places of 10,000+ inhabitants obtained from the UW Center for Social Science Computation and Research (CSSCR)) and 2006 Census Data (Public Use Microdata Sample (PUMS), downloaded from AmericanFactfinder.com). Land Area was obtained from the 2000 Census Tiger Gazetteer database. Real variables are adjusted for inflation (and expressed in 2006 dollars) using the consumer price index, <http://www.bls.gov/cpi/>. “Appleton WI” was deleted in the Wharton data; the city of ~70000 inhabitants was found to have two entries in the Wharton database with different land use restrictions (this explains slightly different results as in the previous version of the paper. Cost estimates = (regressor\* coef)/mv\_gr \* (medval06-medval89\_r).



**Appendix 3  
Table A3.1**

**Results From Comparative Studies of Land Use Restrictions and Housing Prices**

	<b>Study Authors</b>	<b>Year</b>	<b>Cities/Regions</b>	<b>Effects</b>
1	Anthony	2006	FL	Increase in prices attributable to statewide growth management.
2	Glaeser, Schuetz, Ward	2006	187 Communities in Eastern MA	23-36 percent increase in prices (about \$156,000) due to regulations.
3	Somerville / Meyer	2006	44 Metro Areas	20% higher price elasticities and 45% lower housing starts in more regulated areas.
4	Xing et al.	2006	54 Metro Areas	Increase in prices due to growth management and development restrictiveness. Seattle: 15% increase in prices due to growth management tools
5	Chan	2004	97 Metro Areas	44.8% to -3.9% increases in price in cities with urban growth boundaries.
6	Downs	2002	86 Metro Areas	Increase in prices 1990-2000, 1990-94, 1990-96 due to Urban Growth Boundary. Not significant 1994-2000, 1996-2000, so UGB increases housing prices combined with stimulated housing demand.
7	Glaeser/Gyourko	2002	40 Metro Areas	\$50-\$700,000 increase in prices due to zoning restrictions. (Seattle: +\$200,000)
8	Malpezzi	2002	55 Metro Areas	Increase in prices due to regulations, controlling for High Tech Locations
9	Staley/Gilroy	2001	OR, FL, WA	15% increase in prices attributed to growth management.
10	Luger/Temkin	2000	NC, NJ	\$40-80,000 increase in prices of new homes due to regulations
11	Phillips et al	2000	37 Metro Areas	Increase in prices due to regulation index and weak evidence for urban growth boundary effect. But impact is low (less than \$10,000 per unit).
12	Green	1999	Waukesha, WI	8% increase in prices due to zoning and permitting restrictions
13	Malpezzi, et al.	1998	55 Metro Areas	9-46% increase in prices due to regulations
14	Malpezzi	1996	60 Metro Areas	51% increase in prices due to regulations
15	Thorson	1996	10 Metro Areas	Increase in prices due to “zoning monopolies”
16	Cho/Linneman	1993	Fairfax, VA	Increase in prices due to minimum lot sizes. No increase in prices due to residential restrictions
17	Downs	1992	San Diego, CA	54% increase in prices due to growth management
18	Pollakowski/Wachter	1990	Montgomery, MD	27% increase in prices (price elasticity: 0.275) due to regulatory restrictiveness
19	Katz/Rosen	1987/1	63 CA Metros	17-38% increase in prices due to growth management
20	Landis	1986	CA	35-45% increase in prices in growth controlled areas
21	Schwartz et al.	1986	Sacramento, Davis	9% increase in prices due to growth controls
22	Segal/ Srinivasan	1985	51 Metro Areas	20% increase in prices in growth restricted areas

Sources: Original sources, Lillydahl and Singell (1987), Pogodzinski and Sass, 1991, Ihlanfeldt (2004), Xing et al.(2006), Landis et al.(2002), and Quigley and Rosenthal (2005). Table surveys studies that included a substantial number of cities or metropolitan areas with significant effects.



**Table A3.2**  
**Empirical Studies on the Impact of Growth Regulation on Housing Prices**  
**Surveyed by Nelson et al. (2004)**

<b>Study Authors</b>	<b>Year</b>	<b>Cities/Regions</b>	<b>Impact?</b>
Luger and Temkin	2000	New Jersey, North Carolina	Yes
Green	1999	Suburban Wisconsin	Yes
Porter et al.	1996	Montgomery County, Maryland	Yes
Beaton and Pollock	1992	Chesapeake Bay, Maryland	Yes
Downs	1992	San Diego County	Yes
Parsons	1992	Chesapeake Bay, Maryland	Yes
Beaton	1991	New Jersey Pinelands	Yes
Guidry, Shilling, and Sirmans	1991	National	Yes
Shilling	1991	National	Yes
Dale-Johnson and Kim	1990	California Coast	Yes
Pollakowski and Wachter	1990	Montgomery County, Maryland	Yes
Rose	1989	National	Yes
Chambers and Diamond	1988	National	Yes
Nelson	1988	Washington County, Oregon	Yes
Katz and Rosen	1987	San Francisco Bay Area	Yes
Landis	1986	Sacramento, Fresno, San Jose, California	Yes
Nelson	1986	Salem, Oregon	Yes
Zorn et al.	1986	Davis, California	Yes
Black and Hoben	1985	National	Yes
Knaap	1985	Portland, Oregon	Yes
Segal and Srinivasan	1985	National	Yes
Dowall	1984	Santa Rosa, Napa, California	Yes
Frech and Lafferty	1984	California Coast	Yes
Dowall and Landis	1982	San Francisco Bay Area	Yes
Mercer and Morgan	1982	Santa Barbara County, California	Yes
Schwartz et al.	1981, 84	Petaluma, Santa Rosa, Rohnert Park, CA	Yes
Elliot	1981	California	Yes
Correll, Lillydahl, and Singell	1978	Boulder, Colorado	Yes
Real Estate Research Corp	1978	St. Louis County, Missouri	Yes
Urban Land Institute	1977	National	Yes
Richardson	1976	Dover Township, New Jersey	Yes
Peterson	1973	Fairfax County, Virginia	Yes
Phillips and Goodstein	2000	Portland, Oregon	No
Glickfield and Levine	1992	California	No
Knaap and Nelson	1992	Portland, Oregon	No
Landis	1992	California	No
Downs	2002	Portland, Oregon	Mixed
Lowry and Ferguson	1992	Sacramento, Orlando, Nashville	Mixed
Miller	1986	Boulder, Colorado	Mixed
Gleeson	1978	Brooklyn Park, Minnesota	Mixed

Source: Connerly (2004), see the original paper for full citations.

# The Effect of Land Use Regulation on Housing Prices: Theory and Evidence from California \*

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April 4, 2019

## Abstract

Land use regulation may affect housing prices through housing supply and demand, but the empirical literature conflates both effects and finds wide variation in the estimated impact. We disentangle three channels through which regulation may affect housing prices: the production channel through housing supply, the amenity channel through housing demand, and the general equilibrium (GE) channel that captures price feedback effects on location choice. We develop a GE model with households' choices on consumption and location and with housing developers' choice on housing production. Our theoretical model delivers a closed-form solution to the equilibrium prices and a simple form of the estimation equations. Using property transaction-assessment data from 1993 to 2017 in California and a regulatory index compiled from the Wharton Residential Land Use Survey (Gyourko, Saiz and Summers, 2008), we structurally estimate and disentangle the supply and demand-side effects. We find that the regulatory impact on housing prices through the production channel is much stronger than the amenity channel (4.38% vs 0.32% if referenced to the average city in California) and is heterogeneous across cities. The relationship still holds, even when the GE effects are included in the two channels (3.24% vs 0.27%). The total effect of regulation will be 4 times larger, if referenced to the average regulation in the US. Our estimations point out the key roles of structural characteristics of housing and macroeconomic conditions in the prediction of housing prices. Estimations without quality adjustment underestimate land regulation's impact on prices. Additionally, we examine the within-MSA regulatory interdependence and find significant and positive spillover effects of regulation on housing prices. Estimations without spillover consideration underestimate the regulatory impact on prices.

**Keywords:** housing prices, land use regulation, general equilibrium, spillover effect, California

**JEL:** R10, R13, R31, R52, R58

\* We thank Joe Gyourko, David E Rappoport for constructive advice and comments. Susan Wachter acknowledges financial support from the Zell-Lurie Real Estate Center at The Wharton School of the University of Pennsylvania. We thank the Zillow Group for sharing data. All errors are our own.

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## 1. Introduction

Since the US Supreme case of *Euclid v. Ambler* (1926), land use regulation has been central to the debates of housing affordability and economic growth.<sup>1</sup> While land use regulation makes housing less affordable by tightening supply constraints (Glaeser, Gyourko and Saks, 2005a, 2005b; Saiz, 2010), it may also increase environmental amenities and thereby raise housing demand (Hamilton, 1975; Fischel, 1990; Gyourko and Molloy, 2015). Land use regulation may even go beyond localities and exert impacts on multiple jurisdictions (Pollakowski and Wachter, 1990). The empirical literature finds a wide variation in the estimated impacts of land use regulation on housing prices (Quigley and Rosenthal, 2005). In part, the variation in estimated impacts is due to conflating supply and demand-side effects.

We contribute to the literature on land use regulation's impact on housing prices in several ways. First, we base our empirical analysis in a general equilibrium framework with household mobility across geographical markets. We include households' decisions over consumption and location together with developers' housing production decisions. We incorporate multiple transmission channels of regulation on prices that result from this general equilibrium framework. Land use regulation and per capita income are key pricing factors, with the quadratic and interactive effects micro-founded in the model. Our theoretical model delivers a closed-form solution to the equilibrium prices and a simple form of the estimation equations.

We characterize and disentangle three channels through which land use regulation may affect housing prices. The first channel of the regulatory impact goes through housing supply and the effect is local. We call it the *production channel*, because regulation increases the cost of housing supply and the local housing prices. The second channel goes through housing demand and the effect is also local. We call this the *amenity channel*, because regulation boosts amenity values and the housing demand, leading to an increase in the local housing prices. There is a third channel related to the household location choice. We call it the *general equilibrium (GE) channel*, because it captures the price feedback by taking household mobility into account. Tighter regulation that makes housing more expensive will drive housing demand to the neighboring cities. We also calculate *net production and amenity channels* that incorporate the GE effects.

Our empirical analysis is based on structural estimations using Generalized Method of Moments (Hansen, 1982). We use the structural estimates to quantify how different channels respond to the regulatory change by city level over the period 1993 through 2017. We base our measure of regulatory constraint using the Wharton Residential Land Use Survey (Gyourko, Saiz, and Summers, 2008). We estimate city-level land use regulation effects after controlling for individual property-based housing characteristics, metro level per capita income and national credit supply. The average marginal effect of

<sup>1</sup> The case of *Village of Euclid, Ohio v. Ambler Realty Co.* set the precedent of new zoning practice and served to bolster local zoning ordinances nationwide. For the details of *Euclid v. Ambler*, see Fluck (1986).

regulation on housing prices through all channels is about 3% in California (with the average California city as the regulatory reference point) which consists of 4.38%, 0.32% and -1.73% from the production, the amenity and the GE channels respectively (or 3.24% and 0.27% from the net production and amenity channels). The housing price responses through the amenity and the GE channels to a unit increase in regulation are small (0.32% and -1.73% respectively). If referenced to the average level of regulation in the US, the total regulatory effect will be 4 times larger. The heterogeneous regulatory impacts across MSAs are mainly driven by the response through the production channel. San Francisco, San Jose, Los Angeles and San Diego MSAs have the largest production effect, more than 50% larger than the MSA average response through the production channel (3.22%). The net production and amenity channels that incorporate the GE effects are smaller. The price responses through the net production channel of San Francisco, San Jose, Los Angeles and San Diego MSAs are 4.58%, 4.57%, 3.55% and 3.29% respectively, while the response through the net amenity channel is 0.27%. Among the studies with standardized regulatory measures, our estimates of the net production effect are larger than those of Quigley, Raphael and Rosenthal (2008) on the regulatory impact on prices in San Francisco Area (1.2%-2.2% in OLS and 3.8%-5.3% in IV estimations).

Our empirical estimations point out the key roles of structural characteristics of housing and macroeconomic conditions in the prediction of housing prices. Instead of hedonic price indices, we use property transaction data together with housing characteristics in the empirical analysis for housing quality adjustment. Our method has smaller standard errors in estimation than the index approach. We show that aggregate analysis using the housing prices without quality adjustment underestimates the marginal impact of land use regulation by about 33%. We find macro variables are empirically important to predicting time-series movement of housing prices. For example, a one percentage point increase in real GDP per capita is associated with 1.3% increase in housing prices and a one percentage point increase in the growth of household mortgage debt and the 30-year fixed rate mortgage rate leads to 2.88% and -2.59% change in housing prices respectively.

In addition to identifying and measuring regulatory effects decomposed into supply and demand effects for metro areas, we take a more granular view to explicitly examine the within-MSA interdependence of land use regulation among cities. We define the difference between neighboring and home regulatory indices as a relative restrictiveness index, whose marginal contribution to the housing prices measures the spillover effect of regulation. We examine 4 major MSAs selected for their data coverage. We show a robust finding that the regulatory and the spillover effects on housing prices are significant and positive. For the relative restrictiveness indices that weigh the neighboring regulatory impacts in different model specifications, leaving the spillover effect out of the analysis tends to underestimate the regulatory effect on housing prices in the home city.

We aim to establish a direct mapping from the theoretical model to the empirical estimates. We use multiple data sources for the data counterparts in our theory. We obtain residential property transaction

data in California based on a property-level transaction-assessment dataset from the Zillow Group. We control a comprehensive set of housing characteristics (the number of bedrooms/bathrooms, distance to CBD, indicator of single family residential/condominium, square foot, property age). The data on GDP per capita is calculated based on the regional/MSA dataset from Moody's Analytics. To deal with the endogeneity issue of the GDP per capita, we construct demographic variables from American Community Survey as instruments, including mean household age, share of high education and share of high-tech jobs. In addition to the housing characteristics, we control macro variables including the growth of household mortgage debt and the real 30-year fixed rate mortgage rate for goodness of fit along the time-series dimension.

We examine 179 cities in the metro areas from 185 cities surveyed in California in the Wharton Residential Land Use Survey (Gyourko, Saiz and Summers, 2008). We use principal factor analysis to quantify the intensity of land use regulation by creating a unidimensional index of regulation intensity, and to quantify the factorial contribution of the underlying sub-indices. The housing sample matched to the Wharton survey include more than 5 million transactions, ranging from 1993 to 2017 in 25 MSAs.

The organization of the paper is as follows. Section 2 reviews the literature. Section 3 sets up a spatial equilibrium model of land use regulation with endogenous housing prices. Section 4 describes the data and summary statistics. Section 5 maps the model to the structural estimation. Section 6 discusses the decomposition of the regulatory effects through the production and the amenity channels. Section 7 estimates the city-level spillover effects, followed by the conclusion in Section 8.

## **2. Literature Review**

Spatial equilibrium models in urban economics date back to the pioneering work by Rosen (1979) and Roback (1982) and is enriched by Glaeser and Gottlieb (2009). There are two types of theoretical models related to the impact of land use regulation on housing prices, Brueckner (1990) and Engle, Navarro and Carson (1992) propose amenity models with negative population externality in the utility. Regulation mitigates negative externalities and boosts housing prices. The analysis holds only under the small-city assumption, with no role of the supply constraint of land. On the other hand, Brueckner (1995) does propose a supply-restriction model that puts constraints on the developable land and emphasizes supply constraints in housing price determination. Our theoretical model has both demand- and supply-side regulatory implications on housing prices.

In the discussion of the geographical interdependence of land use regulation and housing prices across regions, Pollakowski and Wachter (1990) first introduce the concept of the spillover effect in the housing market. Tighter growth controls in the neighboring area will increase the home housing prices through housing demand. Our theoretical model formalizes the idea by means of the location choices of

households.<sup>2</sup> Our empirical method improves the estimations of Pollakowski and Wachter (1990), in the sense that we use a more comprehensive regulatory measure and make housing quality adjustment in the estimation that is infeasible in the construction of the price indices in previous study.<sup>3</sup> <sup>4</sup> We show that the city-level spillover effect is strong but the regulatory implications are quite heterogeneous across metro areas.

Empirical models vary greatly in their data and methods and their results are not directly comparable as pointed out by Quigley and Rosenthal (2005). The regulatory factors used in empirical analyses vary across studies with different linear or non-linear scales, making the evaluation of the marginal effects of regulation on housing prices more case-by-case.

Most studies develop a regulatory index and find positive and significant regulatory impact on housing prices. Pollakowski and Wachter (1990) construct a regulatory index as the weighted sum of land in various zoning categories. Jackson (2016, 2018) apply the same method to California Land Use Survey (Mawhorter and Reid, 2018). Quigley and Raphael (2005), Ihlanfeldt (2007) and Glaeser and Ward (2009) focus on California, Florida and the Great Boston respectively and define the city regulation index as the total number of adopted regulatory controls. Kok, Monkkonen and Quigley (2014) study the San Francisco Bay Area and use a normalized regulatory index in their analysis. Glaeser, Gyourko and Saks (2005b) examine define a regulatory tax measure as the markup of the housing price over the marginal cost for NYC. Malpezzi (1996) and Malpezzi, Chun and Green (1998) use the Wharton survey of Planning and Policy (Linneman, Summers, Brooks, and Buist, 1990; Buist, 1991) to construct a simple sum of standardized sub-indices as the regulatory measure.<sup>5</sup> Gyourko, Saiz and Summers (2008) update the original Wharton survey. They conduct a national survey with responses from 2,649 jurisdictions and use a principal factor analysis to construct a single regulatory index. Many subsequent studies use the Wharton Land Use Survey and study the regulatory impact in housing and land markets. Saiz (2010) estimates the housing supply elasticity as a function of physical constraints

<sup>2</sup> Consistent with Pollakowski and Wachter (1990), our empirical result echoes the finding on the significant and positive impact of the relative regulatory restrictiveness on the housing prices.

<sup>3</sup> Pollakowski and Wachter (1990) use the transaction prices as the dependent variable and control the real per capita income, distance to Federal Triangle, Gravity Employment Index, real mortgage rate, real construction cost index and percentage of vacant land. They conduct a pooled cross-section time-series regression with 17 areas and 24 quarters to construct the real housing price indices. In comparison, we match the property transactions with the structural characteristics of housing and take into account the property-level heterogeneity that we find crucial to the estimates of the regulatory impacts.

<sup>4</sup> Our regulatory index and the measure of relative regulatory measures are more comprehensive than Pollakowski and Wachter (1990). 3 of the 8 underlying factors, the open space index and the supply restriction index and the local zoning approval index are close to 3 regulatory measures in the previous studies (the percent of vacant land, the development ceiling, the zoning index respectively), although the mapping is not identical. We use multiple measures of the spillover effects to confirm the robustness of our results.

<sup>5</sup> Malpezzi (1996) tries factor analysis as an alternative data reduction method. Because the aggregate score by the simple sum and by factor analysis are highly correlated, Malpezzi (1996) reports the results using the simple sum. Jackson (2016, 2018) do the same as Malpezzi (1996) on a different dataset.

and regulatory measures from the Wharton survey. Turner, Haughwout and Van Der Klaauw (2014) use the Wharton survey to identify the local regulatory effect on the land transaction prices at the boundaries of adjacent jurisdictions with different regulation. Quigley, Raphael and Rosenthal (2008) uses the Wharton survey instruments that are adapted to California to study the housing markets in the San Francisco Bay Area.

Our methodology is close to Gyourko, Saiz and Summers (2008) and Quigley, Raphael and Rosenthal (2008) that use principal factor analysis to define the first common factor as the regulatory index, achieving data reduction of multiple sub-indices. Because we focus on property sales in California, we use the sub-indices with within-state variation in the Wharton Residential Land Use Regulation Index (WRLURI) (Gyourko, Saiz and Summers, 2008) to construct the regulatory measure.<sup>6</sup>

### 3. Model

#### 3.1 Household Problem

Consider an economy with a unit mass of households. Household  $i$  values the non-durable consumption  $c$  and housing consumption  $h$ . We assume that the household's preference has a Cobb-Douglas form. A household makes two sets of choices on consumption and the location. Given staying in city  $j$  and housing rent  $r_j$ , Household  $i$  solves the standard consumption choice problem.<sup>7</sup>

$$v_j^i(r_j) = \max_{c,h} (1 - \alpha) \ln c + \alpha \ln h + \beta_{ij} \quad \text{s.t.} \quad r_j h + c \leq Y_i Z_j A_j, \quad \text{where } A_j = Z_j^{\phi-1} \tau_j^\eta \quad (1)$$

The indirect utility of household  $i$  in city  $j$  can be written as a function of housing rent,  $r_j$ . We assume that the household income consists of three components: an idiosyncratic household income  $Y_i$ , a city-specific income  $Z_j$ , and amenity value  $A_j$ .<sup>8</sup> We assume that two income components,  $Y_i$  and  $Z_j$ , are independently distributed and are multiplicative for tractability of analysis.

We assume amenity value  $A_j$  is a function of city income  $Z_j$  and the regulation intensity  $\tau_j$ . The value  $\phi-1$  controls the income elasticity of amenity demand. If  $\phi > 1$ , the amenity value increases with

<sup>6</sup> For the discussion on WRLURI, see Gyourko, Saiz and Summers (2008) and Gyourko and Molloy (2015).

<sup>7</sup> We assume that the expenditure on housing consumption is linear in the housing rent. There are models in the literature with non-linear pricing to take into account housing quality (Landvoigt, Piazzesi and Schneider, 2015). We make the assumption not only because linear pricing is simple and tractable for analysis, but also because we are able to use the housing transaction-assessment matched data with detailed structural characteristics to control housing quality in the model estimation.

<sup>8</sup> Glaeser and Gyourko (2006) point out the importance of spatial heterogeneity of amenities in housing price dynamics. Similar to their work, we incorporate the impact of amenities in the household utility. We incorporate the amenity in the model as a multiplier of the household income. With log preference, it is mathematically equivalent to a model where amenity creates an additive utility flow  $\ln(A_j)$ .

city income. The parameter  $\eta$  control the regulation elasticity of amenity demand. Amenities in the model serve as the demand shifter of both non-durable and housing consumption.<sup>9</sup>

The parameter  $\alpha$  measures the share of housing consumption relative to non-durable consumption in total expenditure.  $B_{ij}$  denotes the city utility flow to an individual household; this captures personal preference of location and any hidden benefit unobservable to econometricians. Conditional on living in city  $j$ , the optimal housing consumption choice and the indirect utility function are

$$h_i^* = \frac{\alpha Y_i Z_j^\phi \tau_j^\eta}{r_j} \quad (2)$$

$$v_j^i(r_j) = \alpha \ln \alpha + (1 - \alpha) \ln(1 - \alpha) - \alpha \ln r_j + y_i + \phi z_j + \eta \ln \tau_j + \beta_{ij} \quad (3)$$

where  $y_i = \ln(Y_i)$  and  $z_j = \ln(Z_j)$ . summarizes the city-specific value. The location choice of household  $i$  is thus a discrete choice problem. If household  $i$  moves to the city  $j$  among a set of cities  $S$  instead of an alternative city  $k$  in the choice set. Then, the utility given city  $j$  must yield the highest value.

$$v_j^i(r_j) \geq \max_{k \neq j} v_k^i(r_k) \Leftrightarrow \phi z_j + \eta \ln \tau_j - \alpha \ln r_j + \beta_{ij} \geq \phi z_k + \eta \ln \tau_k - \alpha \ln r_k + \beta_{ik}, \text{ for all } k \neq j \quad (4)$$

We assume that  $\beta_{ij}$  is unobservable to econometricians and it is identically and independently Type-I Extreme-Value distributed across cities. That is, when a household makes a location choice, they can make decisions based on the realization of the city income, the growth controls relevant to amenity value, the housing price and a private signal  $\beta_{ij}$  about the utility flow from city  $j$ .<sup>10</sup> The difference  $\beta_{ij} - \beta_{ik}$  has a Logit distribution, because the private signal is Type-I Extreme-Value distributed. The share of households located in city  $j$  is thus as follows.

$$q_j(r) = \frac{Z_j^\phi \tau_j^\eta r_j^{-\alpha}}{\sum_{k \in S} Z_k^\phi \tau_k^\eta r_k^{-\alpha}}, \quad r = \{r_k\}_{k \in S} \quad (5)$$

We can interpret the share as a standardized city index that households create to make location choices based on observables. As we normalize the mass of household to unity, the share of household living in city  $j$  coincides with the moving probability of a household to city  $j$ .

<sup>9</sup> Glaeser, Kolko and Saiz (2001) regress the log housing price on the log per capita income and define the residuals as the amenity indices. Our modeling of the amenities inherits similar idea and define the non-linear piece of city income after taking out the linear component as the amenity value.

<sup>10</sup> In estimation, we will use the log GDP per capita of the MSA where city  $j$  is located as the data counterpart of  $z_j$ . Quigley and Rosenthal (2005) says that although land use regulation is local, growth is regional. As a result, we only allow income variation across MSAs in the empirical analysis.



### 3.2 Housing Developer Problem

The production of housing service needs land  $L$  as the input. In each city, we assume there is a local housing developer, operating a production technology with decreasing return to scale. The assumption motivates an upward sloping housing supply curve. The housing developer pays a license fee  $F_j$  charged by the local government to operate the business and pays the city-specific marginal cost  $c_j$  for each unit of land.  $c_j$  captures both the construction cost of materials and labors, and the shadow cost tied to local land use regulation. We assume that the housing produced each period is fully depreciated. The housing developer in city  $j$  solves the profit maximization problem.

$$\max_{L,H} r_j H - c_j L - F_j \quad s.t. \quad H = A_0 L^\theta, \quad c_j = \tau_j c_0 \quad (6)$$

where  $A_0 > 0$  is the aggregate productivity and  $\theta < 1$  controls the curvature of production technology.  $c_0$  is the construction cost associated with materials and labor, identical across cities.<sup>11</sup>

The parameter  $\tau_j > 0$  is the intensity of land use regulation. The concept is similar to Glaeser, Gyourko and Saks (2005b). The more regulated the land market in city  $j$  is, the higher  $\tau_j$  will be. Concretely, the parameter is a reduced-form index of regulation, taking into account the shadow costs of land supply elasticity, time length of permit approval, density and supply restriction etc. The regulation intensity  $\tau_j$  can be interpreted as an aggregate of multiple measures of land use regulation.

$$\tau_j = \prod_s (\tau_j^s)^{\rho_s} \quad (7)$$

where  $\tau_j^s$  is an underlying regulation factor and  $\rho_s > 0$  is the corresponding factor weight.<sup>12</sup> The profit maximization of a local housing developer leads to a land supply curve with a positive slope in city  $j$ .

$$H_j(r_j) = A_0^{\frac{1}{1-\theta}} \left( \frac{\theta r_j}{c_j} \right)^{\frac{\theta}{1-\theta}} \quad (8)$$

Housing supply is thus increasing the productivity and housing rent but is decreasing in the cost of land. The local government will set the license fee  $F_j$  to charge away any positive profit, so in equilibrium, the local housing developer has zero profit.

<sup>11</sup> This assumption is without loss of generality. We think the assumption is reasonable, because the construction industry is extremely competitive (Saiz, 2010). Gyourko and Molloy (2015) in their Figure 1 shows that the real construction cost is stable compared with the strong movement of the real housing prices. We can relax the assumption to allow for time-varying construction cost. What is essential is that the construction cost is that there is no cross-sectional variation among cities and that it is exogenous to local changes in housing demand over time.

<sup>12</sup> We assume the relationship between the unidimensional measure and the underlying factors of land use regulation follows a product form. The log form of equation (7) will correspond to the predicted score regression in the principal factor analysis that we use to construct a unidimensional index from multiple measures of land use regulation.

### 3.3 Exogenous Processes

To bridge the housing price with housing rent, we assume that the conventional user cost relationship between housing price  $p_j$  and housing rent  $r_j$  in city  $j$  holds.

$$\ln p_j = \ln r_j - \ln u_j \quad (9)$$

where  $u_j$  is the user cost. In the model, we take the log city income  $z_j$ , and the log user cost  $\ln(u_j)$  as exogenous and time-varying. We assume that the log income  $z_{jt}$  and the log user cost at time  $t$  have independent normal distributions.

$$z_{jt} \sim N(\mu_z, \sigma_z^2), \ln u_{jt} \sim N(\mu_u, \sigma_u^2), \forall j, t \quad (10)$$

### 3.4 Equilibrium Conditions and Housing Prices

There are two equilibrium conditions needed to satisfy to close the model. First, each household with random utility flow unobservable to econometricians should move to the city delivering the highest utility. The optimal consumption and location choices have been encoded into the moving probability  $q_j(r)$ . Second, the housing price of each city is an endogenous object. We clear the housing markets in all cities and solve the prices simultaneously. The market clearing condition (11) demand that we equate the housing demand by aggregating the individual demand (2) and the housing supply (8) in each city.

$$q_j(r) \frac{\alpha Y_0}{r_j} Z_j^\phi \tau_j^\eta = H_j(r_j) \text{ for all } j \in S \quad (11)$$

where  $Y_0 = E(Y_i)$  is the expected household income. The house demand in city  $j$  is thus the product of the share  $q_j$  of households moving to city  $j$  and the aggregated house demand in city  $j$ .<sup>13</sup> As is shown in the equilibrium condition, the housing markets are inter-linked. The market clearing condition of city  $j$  depends on the housing prices in other cities. Households have freedom to move and will choose their location depending on city-specific income and private utility flow. The impact of local land use regulation will spill over to the other cities through the location choice of households.

We prove in the appendix that for an arbitrary number of cities  $n \geq 2$ , there exists a unique set of moving probabilities and housing prices that clear the housing markets in  $n$  cities. In the following analysis, we focus on the location choice with binary options ( $n = 2$ ), cities  $j$  and  $k$ . We examine the price determinants of a particular city  $j$ , and the city  $k$  is interpreted as the outside moving option of city  $j$ . It simplifies the mapping from the model to the data and makes the illustration of mechanism straightforward.

<sup>13</sup> Because  $Y_i$  and  $Z_j$  are assumed independently distributed, we can integrate over the household demand and get the housing demand in city  $j$ . Because the individual housing demand is linear in  $Y_i$ , only the first moment is needed for aggregation.

$$\ln p_j = (1 - \theta)(\ln q_j - \ln b_j) - \ln u_j$$

$$\text{where } q_j = \frac{(Z_j^\phi \tau_j^\eta)^{1-\lambda} b_j^\lambda}{(Z_j^\phi \tau_j^\eta)^{1-\lambda} b_j^\lambda + (Z_k^\phi \tau_k^\eta)^{1-\lambda} b_k^\lambda}, \lambda = \frac{\alpha(1-\theta)}{\alpha(1-\theta)+1}, b_j = \frac{A_0^{\frac{1}{1-\theta}}}{\alpha Y_0 Z_j^\phi \tau_j^\eta} \left( \frac{\theta}{c_j} \right)^{\frac{\theta}{1-\theta}} \quad (12)$$

To understand the determinants of the housing price in city  $j$ , we express  $\ln(p_j)$  explicitly as follows.

$$\ln p_j = \{ \theta \ln c_0 + [\theta + \eta(1 - \theta)] \ln \tau_j \} - (1 - \theta) \ln \left[ 1 + e^{(2\lambda-1)\phi(z_j-z_k)+[\frac{\theta}{1-\theta}\lambda+\eta(2\lambda-1)](\ln \tau_j - \ln \tau_k)} \right] + [(1 - \theta)(\ln Y_0 + \phi z_j) - \ln A_0 - \ln u_j] + [(1 - \theta) \ln \alpha - \theta \ln \theta] \quad (13)$$

There are four terms that determines the log housing price. The first two terms are associated with the land use regulation through the cost of land. The first term summarizes the production channel that show that a higher local housing price reflects higher marginal cost of land due to tighter land use regulation. The second term shows the general equilibrium effect of the housing markets. Regulatory change may induce households to make new location choices. Leading to reallocation of housing demand and price adjustment of multiple cities. The first two terms indicate two opposite forces of regulation intensity on the housing price. If we apply first-order Taylor approximation to the second term,

$$(1 - \theta) \ln \left[ 1 + e^{(2\lambda-1)\phi(z_j-z_k)+[\frac{\theta}{1-\theta}\lambda+\eta(2\lambda-1)](\ln \tau_j - \ln \tau_k)} \right] \approx \frac{1}{2} \{ (1 - \theta)(2\lambda - 1)\phi(z_j - z_k) + [\theta\lambda + \eta(1 - \theta)(2\lambda - 1)](\ln \tau_j - \ln \tau_k) \} + (1 - \theta) \ln 2 \quad (14)$$

Combining the first and the second terms, we find that the effect of regulation intensity through the production channel is dominant, leading to a positive relationship between regulation intensity and housing price in aggregate.

The third term,  $(1-\theta)(\ln Y_0 + \phi z_j) - \ln(A_0) - \ln(u_j)$ , summarizes the expected household income, the productivity of housing production, and the local user cost. Higher income will increase housing demand and increase the housing price in city  $j$ , while higher productivity will increase the housing supply and decrease the housing price. Given the rent in city  $j$ , higher user cost implies a lower housing price.

For the first part of the last term,  $(1-\theta)\ln(\alpha)$ , determines the marginal rate of substitution between housing and non-durable consumption. A higher marginal value from housing increases demand, and thus the housing price. The last term,  $\theta\ln(\theta)$ , characterizes the production technology. When  $\theta$  is smaller, the retained profit of the housing developer will be higher, which is consistent with a higher equilibrium housing price.

Besides using the Taylor approximation in (14) to simplify the log housing price equation (13), we make a normalization assumption on city  $k$  which is the outside moving option of city  $j$ . We normalize  $\tau_k = 1$ , indicating constant regulation intensity of outside moving option for any city.<sup>14</sup> To be

<sup>14</sup> As is shown in (13), the normalized value will only affect the level of log housing price.

consistent, we do the same normalization when we measure regulation intensity in the data. For the city income of the outside moving option, we assume it is the mean income of all cities.

$$z_k = \frac{1}{n} \sum_{l \in S} z_l \quad (15)$$

Because  $z_k$  is constant for each cross-section, it plays a role similar to the year fixed effect in the log housing price equation. Together with (13), we can use the Taylor approximation and the normalization to determine the housing price differential across cities. For two cities  $j$  and  $j'$ ,

$$\begin{aligned} \ln p_j - \ln p_{j'} &\approx [\theta(1 - \frac{1}{2}\lambda) + \eta(1 - \theta)(\frac{3}{2} - \lambda)](\ln \tau_j - \ln \tau_{j'}) \\ &+ (1 - \theta)(\frac{3}{2} - \lambda)\phi(z_j - z_{j'}) - (\ln u_j - \ln u_{j'}) \end{aligned} \quad (16)$$

The cross-city price differential consists of three terms. The first term indicates that the regulation intensity differential between cities  $j$  and  $j'$  and has a positive impact on the cross-city housing price differential. The second term emphasizes a positive correlation between city income differential and cross-city housing price differential. The general equilibrium effect mitigates the first and the second term by a fraction  $\lambda$ . The last term captures the differential of user costs across cities and has a negative impact on the housing price differential.

#### 4. Data

We use multiple sources of data. The land use regulation data are derived from the Wharton residential land use regulation survey. The housing data come from the Zillow Transaction and Assessment Dataset. The regional data is based on the dataset compiled by Moody Analytics and American Community Survey.

##### 4.1 Land Use Regulation Data

To measure the land use regulation intensity in the data, we rely on the sub-indices underlying the Wharton Residential Land Use Regulation Index (WRLURI) compiled by Gyourko, Saiz and Summers (2008).<sup>15</sup> WRLURI is a cross-sectional survey and is estimated at the jurisdiction levels (cities hereafter). We focus on the cities in California state that are covered by WRLURI, because the quality of land use regulation data and the housing data in California is better than that in other states.<sup>16</sup> Moreover, jurisdictions in California enjoy remarkable autonomy of land use regulation, creating

<sup>15</sup> Data on WRLURI is available online (<http://real.wharton.upenn.edu/~gyourko/landusesurvey.html>).

<sup>16</sup> The number of cities covered by the land use regulation survey in California is the second highest among all states, only 2 cities fewer than Pennsylvania. The housing data discussed below has more comprehensive coverage and longer time length in California than in other states.

geographical variations of policies (Fischel and Fischel, 1995). Throughout our analysis, we assume that the land use regulation is constant over time.<sup>17</sup>

There are 185 cities in California that responded to the Wharton Land Use Survey. While WRLURI covers only a limited number of jurisdictions (Turner, Haughwout and Van Der Klaauw, 2014), the survey data covers 43 out of 103 principal cities marked by the Census Bureau, including the top 6 cities with the highest population in California (Los Angeles, San Diego, San Jose, San Francisco, Long Beach and Fresno).<sup>18</sup> The survey topics range from zoning and project approval to supply and density restriction that are aggregated into 11 sub-indices as the bases of WRLURI. Not all sub-indices are city-dependent with a state. We thus use only 8 sub-indices that vary across jurisdictions to construct a unidimensional measure of regulation intensity, including the local political pressure index (LPPI), local zoning approval index (LZAI), local project approval index (LPAI), density restriction index (DRI), open space index (OSI), exactions index (EI), supply restriction index (SRI), approval delay index (ADI).<sup>19</sup>

Similar to Gyourko et al (2008), we apply the principal factor analysis to the 8 sub-indices above and define the predicted score of the first factor as the measure of land use regulation intensity. We use the regression method to derive the score. We normalize the score to zero mean and unit variance and define the standardized value as the California Land Use Regulation Index (CALURI). The model counterparts are  $\ln(\tau_j)$  for CALURI and  $\ln(\tau_j^s)$  for the sub-index  $s$ .

In Figure 1, we show the spatial distribution of regulation intensity in California across 185 cities. Noticeably, several cities within Los Angeles-Long Beach-Anaheim Metropolitan Statistical Area are highly ranked in terms of regulation intensity. In Figure 2, we show the kernel density of CALURI. Compared with the standard normal density, the distribution of CALURI is more concentrated near the mean. CALURI has a fat right tail, indicating a non-trivial number of highly land use regulated cities. In the appendix, we list the estimated CALURI by MSA and city. In Figure 3, we compare CALURI with WRLURI. We show that CALURI is highly positively correlated with WRLURI and the simple sum of the 8 sub-indices underlying CALURI, so the method of constructing the index is not driving the unidimensional measure of regulation intensity.

<sup>17</sup> We recognize how stringent the assumption of constant regulation intensity is but given the cross-sectional nature of the Wharton Land Use Survey and the slow-moving nature of the land use regulation reform, we believe our results will not be driven by the assumption.

<sup>18</sup> The principal cities within metropolitan and micropolitan statistical areas uses the 2006 US Census definition to align with the survey year. The ranking of the city population in California comes from US Census. For the number of principal cities covered by each metro area, see the appendix Table A2.

<sup>19</sup> The three sub-indices for dropout are the state political involvement index (SPII), the state court involvement index (SCII), and local assembly index (LAI) that is available only in New England. For the definitions of the sub-indices, see Gyourko et al (2008).

#### **4.2 Housing Data**

For the housing data, we rely on the Zillow Transaction and Assessment Dataset (ZTRAX).<sup>20</sup> The entire ZTRAX dataset contains more than 370 million public records from across the US and includes information on deed transfers, mortgages, property characteristics, and geographic information for residential and commercial properties (Graham, 2018).

Particularly, we are interested in the transaction prices in the deed transfers and the housing characteristics in the property assessment in California. We restrict the data to observations with non-foreclosed sales of residential properties that have detailed documentation of housing characteristics. We use the following housing characteristics: the transaction date, the property use, the number of bedrooms, the number of bathrooms, the age of the property, the property size and the distance to the nearest core cities. We encode the age of the property, the property size and the distance to the nearest core cities that are not directly observable in ZTRAX. The age of the property is calculated as the difference of the transaction year and the built year. There are multiple fields measuring different aspects of the size of a property, so we define the maximum value in those fields as the property size. For properties located in a city in a Core-Based Statistical Area (CBSA), we calculate the great-circle distance in miles to the center of the leading principal city listed in the name of a CBSA. If there are multiple leading principal cities in the CBSA title, we use the distance to the center of the nearest leading principal cities. Other housing characteristics are available in ZTRAX, but they are either optionally reported or sparsely populated. The details of data filtering and construction of variables are documented in the appendix. We use the city name of a sales transaction as the key to match ZTRAX to the land use data. 184 out of 185 cities responded to the Wharton Land Use Survey have at least one transaction record in ZTRAX (with Crescent City as the only exception).

#### **4.3 Regional data**

We calculate gross domestic products (GDP) per capita based on the city income data comes from Moody's Analytics. Moody Analytics compile GDP of 402 US metropolitan statistical areas or metropolitan divisions from Current Employment Statistics, Bureau of Economic Analysis and County Business Patterns, and collect data on the metropolitan population from US Census Bureau. Both the GDP and the population are annual basis. Ideally, we would use city-level income and population, but we use the MSA-level data instead city-level data are not available in general or long enough.<sup>21</sup> Although land use regulation is local, growth is regional (Glickfeld and Levine, 1992; Quigley and

<sup>20</sup> More information on accessing the data can be found at <http://www.zillow.com/ztrax>. ZTRAX database is provided by the Zillow Group. The results and opinions are those of the author(s) and do not reflect the position of Zillow Group or any of its affiliates.

<sup>21</sup> Moody's data at the MSA level traces back to 1990 and allow us to use observations from all sample years in ZTRAX. Also those metropolitan statistical areas, by definition, are socioeconomically tied to the principal cities by commuting.

Rosenthal, 2005; Quigley and Swoboda, 2007). Assuming the city income component of a household to be constant within an MSA sounds reasonable, while we still allow for city-specific characteristics to determine the location choice of households.<sup>22</sup> Moody Analytics only covers the city income and the population in the metropolitan statistical areas instead of micropolitan statistical areas. 179 out of 185 cities responded to the Wharton Land Use Survey are matched to an MSA in Moody's data.<sup>23</sup>

To account for possible endogenous concerns of GDP per capita, we additionally collect other regional data as instrumental variables. The lag term of the log GDP per capita is a natural instrumental variable. In addition, we have 3 candidate instrumental variables on MSA demographics: the share of high education including college and graduate education for at least 1 year, the age of the population, and the share of high-tech jobs. Data on the share of high education and the average age of the population come from the American Community Survey (ACS) Micro data from IPUMS USA. Because ACS data starts from 2000, we fit the time trend and extrapolate the data for each MSA before 2000. Data on the share of high-tech jobs from 1990 to 2017 is compiled by Moody's Analytics, based on Bureau of Labor Statistics and Bureau of Economic Analysis.<sup>24</sup>

#### **4.4 Macroeconomic data**

In addition, we control for variables related to macroeconomic conditions. The data covers the period that witnesses the strong boom and bust in residential mortgage and housing prices from 2001 to 2007 in California (Choi, Hong, Kubik, and Thompson, 2016). The time series variation of housing prices may heavily depend on lending conditions. We take this concern into account by introducing two macro variables: the growth rate of household mortgages in the US and the US 30-year average fixed-rate mortgage rate. Higher growth rate of mortgage lending is expected to increase housing demand by easing household borrowing, while a lower mortgage rate achieves the same effect by making borrowing cheaper. The macro variables serve to improve the goodness of fit along the time dimension.

<sup>22</sup> Note that using MSA-level income from the data to proxy the regional component  $z_j$  in the model doesn't mean that city-specific feature is not important in households' decisions. The data counterpart of a city  $j$  is mapped to a city or a town in the data. In the model, the utility of a household depends on city-specific utility flow and house prices.

<sup>23</sup> 6 cities we drop in the analysis fall into 6 micropolitan statistical areas. They are: Fortuna city in Eureka-Arcata-Fortuna,  $\mu$ MSA; Lakeport City in Clearlake,  $\mu$ MSA; Susanville City in Susanville,  $\mu$ MSA; Ukiah City in Ukiah,  $\mu$ MSA; Corning City in Red Bluff,  $\mu$ MSA; Crescent City in Crescent City,  $\mu$ MSA.

<sup>24</sup> High-tech jobs are defined from the following NAICS industries (NAICS code): Pharmaceutical and Medicine Manufacturing (3254), Computer and Peripheral Equipment Manufacturing (3341), Communications Equipment Manufacturing (3342), Semiconductor and Other Electronic Component Manufacturing (3344), Navigational, Measuring, Electromedical, and Control Instruments Manufacturing (3345), Medical Equipment and Supplies Manufacturing (3391), Software Publishers (5112), Wired Telecommunications Carriers (5171), Wireless Telecommunications Carriers (except Satellite) (5172), Satellite Telecommunications (5174), Other Telecommunications (5179), Other Information Services (5191), Data Processing, Hosting, and Related Services (5182), Computer Systems Design and Related Services (5415), Scientific Research and Development Services (5417), Other Professional, Scientific, and Technical Services (5419), Medical and Diagnostic Laboratories (6215)

In Figure 4, we show the time paths of the macro variables. We collect the data on the US household mortgage debt from Z.1 Financial Account Table from the Board of Governor of Federal Reserves and calculate the annual growth rate. The data on US 30-Year average fixed-rate mortgage rate comes from Primary Mortgage Market Survey by Freddie Mac.

#### **4.5 Summary Statistics**

In Table 1, we show the geographical coverage of our matched land use sample of property transactions in 179 cities. Property sales in 963 cities are not matched to a city in the land use regulation data, but our matched sample covers 5.3 million residential transactions in 39 out of 58 California counties and 25 out of 26 metropolitan statistical areas in California from 1993 to 2017 in ZTRAX.

In Table 2, we report the summary statistics of CALURI, together with the 8 underlying sub-indices and WRLURI originally estimated by Gyourko, Saiz and Summers (2008). The city-level regulation indices are weighted by the number of property transactions in the cities. CALURI has a positive mean 0.27, a median -0.01, and a standard deviation 1.23. Because CALURI is normalized to zero mean and unit variance, the weighted statistics are consequences of the property transactions concentrated in more regulated and more populated cities in our sample.

In Table 3, we show the distribution of residential property uses. 76% of the property transactions are single-family residential, followed by 21% of condominium transactions. Compared with the distribution of the unmatched sample, we have a lower share of single-family units and a higher share of condominiums in the land use sample (84% and 13% in the unmatched sample respectively).

In Table 4, we report the summary statistics of the housing characteristics we control in the empirical analysis. The sales prices have been inflation adjusted to 2006. The average sales price is \$370,000 dollars. The average size of a residential property is 1,700 square feet. We also show the sales price per square foot mean and median as \$221 and \$181. The average age of a residential property is 30 years. There are 2 bathrooms and 3 bedrooms on average in a residential property. The mean and the median distance of a property to the nearest core city in a metropolitan statistical area is 28 miles and 8 miles, respectively.<sup>25</sup>

In Table 5, we show summary statistics of the instrumental variables. The average share of high education is 36% in an MSA, while 6.84% of the total employment are high-tech jobs. The average age of an individual is 35 years ago. In Table 6, we report the correlation of the real GDP per capita with its lag term and 3 demographic instrumental variables, 0.99, while its correlation with the share of the share of high education, the population age, and the share of high-tech job 0.823, 0.753 and 0.651, respectively.

<sup>25</sup> Compared with the unmatched sample, the average property in the land use sample is more expensive in terms of the sales price per square foot and is smaller in size. It has slightly older age and a shorter distance to the nearest core cities. The number of bath rooms and bedrooms are close in the matched and unmatched samples.



## 5. Structural Estimation and Results

### 5.1 Estimation Method

We apply a first-order Taylor approximation to the equilibrium condition of housing price (13) and express it in a linear form for estimation.

$$\begin{aligned} \ln p_{ijmt} = & \beta_0 + [\theta(1 - \frac{1}{2}\lambda) + \eta(1 - \theta)(\frac{3}{2} - \lambda)]CALURI_j \\ & + (1 - \theta)(\frac{3}{2} - \lambda)\phi z_{mt} + \frac{1}{2}(1 - \theta)(2\lambda - 1)\phi z_{0t} + X_{ijmt}\gamma + M_t v + \varepsilon_{ijmt} \quad (17) \end{aligned}$$

where  $z_{0t} = \sum_m g_{mt} z_{mt}$ ,  $\sum_m g_{mt} = 1$ ,  $\lambda = \frac{\alpha(1-\theta)}{\alpha(1-\theta)+1}$

The log real housing price as the dependent variable has 4 subscripts that uniquely identify an observation of property transaction: property  $i$ , city  $j$ , MSA  $m$ , and year  $t$ .  $\beta_0$  is the constant term.  $z_{mt}$  is the log real GDP per capita of MSA  $m$  where property  $i$  is located.  $z_{0t}$  is the log of population-weighted mean GDP per capita of California, with  $g_{mt}$  to be the population share of MSA  $m$  in year  $t$ . To take into account the structural characteristics of residential properties, we control a vector of housing characteristics  $X_{ijmt}$ .<sup>26</sup> To control for the time-varying macro conditions, we use a set of macro variables  $M_t$ , with the vector of the corresponding coefficients stored in  $v$ .

The number of parameters is more than that of the moment conditions. We need one more condition to achieve the just identification of the model. We thus exogenously estimate a relationship between  $\eta$  and  $\phi$ , using the correlation of regulation and the log per capita income. We log-linearize the identity of the amenity demand in (1) and transform it into the following auxiliary regression.

$$z_m = -\frac{\eta}{\phi - 1} \ln \tau_j + cons + controls_m + residuals_{jm} \quad (18)$$

where amenity is treated as the residuals.<sup>27</sup>

<sup>26</sup> The housing characteristics include the property use, the number of bedrooms, the number of bathrooms, the property age, the log property size, and the log miles to the nearest core cities. We recode the property use into three main categories: single-family residential, condominium and others. The number of bedrooms and the number bathrooms are recoded into 5 levels (0, 1, 2, 3, 4+), while the age of property is divided into 8 levels (0, 1-5, 6-10, 11-20, 21-30, 31-40, 41-50, > 50). Recoding the numbers and the age into the discrete bins allows us to control the non-linear effects on the housing price.

<sup>27</sup> In the auxiliary regression, we use the MSA-level data from year 2006. The regulation intensity is aggregated to the MSA level using the probability weight from Gyourko, Saiz and Summers (2008). We add demographic variables as controls. The demographic controls include the tech-job share, the mean age of MSA, the college share, the minority share, the net migration, the employment, the index of cost of doing business and the population. We show the definition of the controls, the model specification and the result of the auxiliary regression in the appendix. We use logarithmic transformations to the property size and the distance to the core cities. The details of the auxiliary model are reported in the appendix. We find the estimated coefficient of  $\ln(\tau_j)$  to be -0.0033, leading to an additional condition for the main estimation:  $\eta = 0.0033(\phi - 1)$ . For robustness, we also use the city-level income data aggregated from the tract-level income in 2009-2014 5-year ACS. We find the estimated coefficient is 10 times bigger but statistically insignificant and still economically small. Our estimations won't qualitatively change, when we use the condition with the alternative estimate.

Besides the coefficients of housing characteristics and macro variables, we need to estimate 3 structural parameters ( $\theta, \lambda, \phi$ ) using 3 instruments ( $CALURI_j, z_{mt}, z_{0t}$ ). It is more convenient here to treat  $\lambda$  instead of  $\alpha$  as a primitive parameter. Our estimation strategy is to use Generalized Method of Moments (GMM) to estimate the structural parameters (Hansen, 1982). GMM won't improve the estimation of the just-identified model, but the estimation method can be naturally extended to the models with additional instrumental variables to deal with endogeneity of per capita income.

## 5.2 Estimation Results

In Table 7, we report the estimation results. The estimation of the coefficients is based on GMM or GMM-IV estimations. In the appendix, we report the estimation of the structural parameters ( $\theta, \lambda, \phi, \alpha$ ).

### 5.2.1 GMM Estimators

Estimations of Model 1 and Model 2 are based on the model specification without and with the vector of housing characteristics, respectively. When housing characteristics are controlled, Model 2 shows that a unit increase (a standard deviation increase) in the regulation intensity (CALURI) increases the housing price by 2.93%. A 1% increase in per capita income increases the local housing price by 1.326%, while a 1% increase in the population-weighted mean per capita income of California increases the local housing price by 0.352%. Model 1 underestimates the marginal effect of regulation intensity by 33%. The reason is that housing characteristics are correlated with the regressors in Model 1. In our data, regulation intensity is negatively correlated with the property size, the number of bedrooms and the number of bathrooms, and positively correlated with the property age.

One caveat at interpreting the marginal effect of regulation is that the regulatory reference point is the average California city, instead of the average city in the US. As we show in Table 2, the frequency-weighted mean and median of WRLURI are 0.8 and 0.55 respectively, much higher than the weighted mean and median of CALURI (0.27 and -0.01 respectively). The regulation of the average California city is much tighter than that of the average city in the US (see Figure 3). If we mistake the regulatory reference point in Table 7 for the average regulation in the US and improperly extend the California estimates to other US cities, we are going to underestimate the national regulatory impact on housing prices.<sup>28</sup> In Table A5 in the appendix, we replicate our estimations in Table 7, but instead use WALURI

<sup>28</sup> There are two sources of underestimating the national level regulatory impact by using the estimates with CALURI and the California sample. The first source is due to the greater standard deviation of CALURI than WRLURI (1.23 vs 0.79 respectively from Table 2). All else equal, if we scale down a regulatory index (e.g. CALURI) by multiplying a factor  $x < 1$ , we will equivalently scale up the regulatory impact by a factor of  $1/x > 1$  in estimation. The second source is related to the non-linear relationship between CALURI and WALURI. In Figure 3, WALURI roughly increases in CALURI at an increasing rate. The convex relationship indicates that specifications with WALURI will yield a higher estimate of the regulatory impact than those with CALURI.

as the regulatory measure. We show that the estimated regulatory impact with the national average as the reference point is 4 times larger (11.7% vs 2.93%) than the California-based regulatory impact.

### 5.2.2 GMM-IV Estimators

The city income  $Z_j$  in the structural model is exogenous, but the per capita income which is its data counterpart can be endogenous. To deal with the endogeneity, we use the lag terms of GDP per capita and the population-weighted mean GDP per capita in California to instrument the contemporaneous variables in Model 3. In Model 4, we build on Model 3 to include 3 demographic variables (the share of high education, the population age, and the share of high-tech jobs) as additional instrumental variables. The GMM-IV estimators of the regulation intensity, the log GDP per capita and the population-weighted mean GDP per capita of California are not substantially different across Model 3 and Model 4 (0.0290, 1.311 and 0.369 for Model 3; 0.0297, 1.291 and 0.432 for Model 4).<sup>29</sup>

By comparing Model 2 and Model 4, we see the difference between GMM and GMM-IV estimators. Treating per capita income as exogenous in Model 2 also underestimates the marginal effect of land use regulation intensity, albeit by a small amount. In Model 4, a unit increase in the regulation intensity increases the housing price by 2.97%, compared with 2.93% in Model 2.<sup>30</sup> If we use the average US regulation as the reference point, we show in Appendix Table A5 that the regulatory impact on housing price is 12.4%. In Appendix, we report the structural parameter estimates of the models in Table 7.

### 5.2.3 Factorial Contribution of Land Use Regulation to Housing Prices

Our analysis relies on CALURI as a unidimensional measure of land use regulation intensity, but we can also quantify the marginal contribution of an underlying factor to the housing prices with one more step. Note that CALURI is the predicted score of the first common factor of 8 sub-indices, derived from the regression method of the principal factor analysis. We can recover the contribution of the sub-indices by regressing CALURI on the standardized sub-indices without a constant term.<sup>31</sup>

$$\begin{aligned}
 CALURI_j = & 0.418 * LPPI_j^{std} + 0.351 * LZAI_j^{std} + 0.412 * LPAI_j^{std} + 0.118 * DRI_j^{std} \\
 & + 0.255 * OSI_j^{std} + 0.151 * EI_j^{std} + 0.147 * SRI_j^{std} + 0.133 * ADI_j^{std}
 \end{aligned}
 \tag{19}$$

<sup>29</sup> We also test the model specifications by including one of the three, or two of the three demographic variables as additional instrumental variables. The estimations results are quantitatively similar. The results are available upon request.

<sup>30</sup> For other marginal effects, Model 2 will underestimate the mean per capita income of California on housing price and will overestimate the marginal impact of the log per capita income. A 1% increase in per capita income increases the local housing price by 1.291% in Model 4, compared with 1.326% in Model 2. A 1% increase in the population-weighted mean per capita income of California increases the local housing price by 0.432% in Model 4, compared with 0.352% in Model 2.

<sup>31</sup> A constant term is not needed because both CALURI and the sub-indices have been standardized to zero mean.

where the superscript *std* means that a sub-index is normalized to zero mean and unit variance. The relationship is exact without an error term, because CALURI, by definition, is a rescaled fitted value of the predicted score regression. The factor weights do not sum to one, because CALURI as the predicted score does not necessarily yield unit variance and we have normalized CALURI in the analysis.

The marginal contribution of sub-indices on the housing prices is the product of the marginal effect of CALURI reported in Table 7 and the factor weights in the predicted score regression (19). The factor weights in (19) are mapped to the estimated parameters of  $\{\rho_s\}$  in (7). In Table 8, we report the marginal effects of the sub-indices for the model specifications in Table 7.

Local political pressure, local project approval and local zoning approval are the leading factors contributing 21.06%, 20.76% and 17.68% respectively to CALURI. In aggregate, CALURI attaches almost 60% of weight to these three factors. In terms of the marginal effect on housing prices, a unit increase (1 standard deviation increase) in these three sub-indices leads to an increase in the housing price by 1.24%, 1.22% and 1.04% respectively. The availability of open space contributes 12.85% to CALURI, and a unit increase leads to an increase in the housing price by 0.76%. Exactions, supply restriction, approval delay and density restriction consist of the remainder of the contribution (7.61%, 7.41%, 6.70% and 5.94%) and lead to a price increase respectively of 0.45%, 0.44%, 0.40% and 0.35%.

### ***5.3 Foundation and Estimation of the Non-Linear Effects on the Log Housing Prices***

We show that land use regulation and the log per capita income have positive impacts on the log housing price. Our estimations yield the average marginal effects. It is natural to ask whether the constant marginal effect is only local, and whether the model ignores any non-constant linear or non-linear effect consideration. Model 4 in Table 7 is treated as the benchmark model in this section where we address this question.

We micro-found the impact of non-constant marginal effects by extending the benchmark to the model that (1) the cost of housing supply may vary with the amenity level; (2) the income elasticity of amenity demand is not a constant. These two extensions represent the supply and demand channels through which amenity and city income can affect the local housing prices.

#### ***5.3.1 Foundation of the Interactive Effect***

We establish how our estimation equation relies on the assumption that the measured impact of regulation on housing production is correlated with the amenity level. Motivated by the finding in the

literature, we generalize the log marginal cost of housing production with the following multiplicative form.<sup>32 33</sup>

$$\ln c_j = (\delta_1 z_j + \delta_0) \ln \tau_j + \ln c_0 \quad (20)$$

The parameters  $\delta_1$  and  $\delta_0$  control the sensitivity of the marginal cost. With  $\delta_0 = 1$  and  $\delta_1 = 0$ , we go back to the benchmark case. When  $\delta_1 > 0$  (we show it is the case), the housing supply exhibits a higher price impact in cities with high income and amenity demand. In estimation, we impose a parametric restriction to focus on the following class of the models that include the benchmark model as a special case.

$$\delta_1 E_i(z_{0i}) + \delta_0 = 1 \quad (21)$$

The relationship indicates that the term in the parenthesis in (20) is unity on average. For a property located in an MSA with the log per capita income equal to  $E_i(z_{0i})$ , *ceteris paribus*, the marginal effect of regulation intensity will be identical in the estimation equations with and without an interactive term. For computation, there are two parameters with one degree of freedom. The new estimation equation will be similar to (17), but with an additional interactive term of CALURI and the log per capita income.

### 5.3.2 Foundations of the Quadratic Effect

We extend the assumption of constant income elasticity of amenity. The extension results in the quadratic term of the log per capita income in estimation.<sup>34</sup>

The power term  $\phi-1$  in the benchmark model has the interpretation of the income elasticity of amenity. The amenity adjusted household income can be written as  $\exp(\phi z)$ . We extend the linear form to the quadratic form in the power term.<sup>35</sup>

$$\exp(\phi_0 + \phi_1 z + \phi_2 z^2) = Z \exp(\phi_0) Z^{\phi_2 z + \phi_1 - 1} \quad (22)$$

where the last term on the right side is the amenity value and  $2\phi_2 z + \phi_1 - 1$  will be the income elasticity of amenity demand. With  $\phi_0 = 0$  and  $\phi_2 = 0$ , we go back to the benchmark case. When  $\phi_2 > 0$  (we show it is the case), the income elasticity of amenity demand is higher for wealthier cities.

<sup>32</sup> Glaeser, Gyourko and Saks (2005a) find that the likelihood to build new housing units, an inverse measure of time cost, is lower in wealthier communities. Homeowners in the wealthy communities may use time to influence local planning (Gyourko and Molloy, 2015). Fischel (2001) brings about the homevoter hypothesis that homeowners in wealthy communities have stronger incentive to protect local amenities capitalized in housing values.

<sup>33</sup> If the impact of the log amenity comes into the marginal cost in an additive form. The parameters  $\delta_1$  and  $\delta_0$  will remain unidentified in estimation.

<sup>34</sup> We leave out the quadratic effect of the regulation intensity in the section, because we don't find the quantitatively important quadratic effect along the dimension. Moreover, the regulation intensity is an index we construct from sub-indices. We take the stand that the index construction should pick up the high-order effects, if there is any.

<sup>35</sup> The extension of the amenity demand captures two things, the residual linear effect after taking out the unity linear impact of the per capita income, and any non-linear effect of per capita income.

In the estimation, we impose two parametric restrictions to focus on the following class of models that include the benchmark model as a special case.

$$\begin{aligned}\phi_{avg} - 1 &= 2\phi_2 E_t(z_{0t}) + \phi_1 - 1 \\ \phi_{avg} E_t(z_{0t}) &= \phi_0 + \phi_1 E_t(z_{0t}) + \phi_2 [E_t(z_{0t})]^2\end{aligned}\tag{23}$$

The value  $\phi_{avg} - 1$  captures the average income elasticity of amenity demand according to the first restriction. The second restriction indicates that when the city income is equal to  $E_t(z_{0t})$ , the elasticity of amenity demand is identical in the benchmark and the extended model.

To focus on the marginal effect of regulation and per capita income on housing prices, we further make an assumption that a household uses the average elasticity  $\phi_{avg}-1$  in the location choice problem, which is the same as the benchmark case. The assumption allows us to focus on the quadratic term of the log per capita income as an additional term in the estimation equation (17).<sup>36</sup>

### 5.3.3 Estimation of the Non-Linear Effects on the Log Housing Prices

Our extended estimation equation with the interactive and quadratic effects takes the following form.

$$\begin{aligned}\ln p_{ijmt} &= \beta_0 + [\theta(\delta_0 - \frac{1}{2}\lambda) + \eta(1-\theta)(\frac{3}{2} - \lambda)]CALURI_j + \theta\delta_1 z_{mt} \cdot CALURI_j \\ &+ (1-\theta)[\phi_1 - \frac{1}{2}(2\lambda - 1)\phi_{avg}]z_{mt} + (1-\theta)\phi_2 z_{mt}^2 + \frac{1}{2}(1-\theta)(2\lambda - 1)\phi_{avg} z_{0t} \\ &+ X_{ijmt}\gamma + \varepsilon_{ijmt}\end{aligned}\tag{24}$$

We report the estimation of four model specifications in Table 9 and the parameter estimates in the appendix. Model 4 is the benchmark case ( $\delta_0 = 1$  and  $\delta_1 = 0$ ;  $\phi_0 = 0$  and  $\phi_2 = 0$ ). Model 5 builds on Model 4 with the interactive effect ( $\phi_0 = 0$  and  $\phi_2 = 0$ ), while Model 6 builds on Model 4 with the quadratic effect ( $\delta_0 = 1$  and  $\delta_1 = 0$ ). Model 7 incorporates both effects in the benchmark model.

In Model 5, we find the interactive term has a positive coefficient, so the marginal effect of regulation on the log housing prices is not constant. For an average property in year 2006 located in an MSA whose log per capita income is one standard deviation above (below) the mean, a unit increase in the regulation leads to 3.47% (2.57%) increase in the housing price in Model 5, compared with a uniform 2.97% increase in Model 4. The significant impact of the interactive term supports the hypothesis that there is a direct and positive impact of the city income on the marginal cost of housing production.

The way we model the interactive effect by allowing the cost to housing production to vary with amenity and city income provides one explanation for the positive interactive effect, but there are alternative explanations. Wealthier and bigger cities may have more complex sets of the growth control policies that cannot be fully incorporated in the survey with limited dimensions. If the omitted growth control policies are positively correlated with our regulatory measure and the omitted variable bias is

<sup>36</sup> What the approximation assumption leaves out is the interactive effect of the GDP per capita and the mean GDP per capita of California, and the quadratic effect of the latter term.

more severe in the wealthier and bigger cities, then we will see a larger upward bias of the regulatory effect for the wealthier and bigger cities.

In Model 6, we find the quadratic effect of the log per capita income is positive; the marginal effect of the log per capita income has a positive and increasing impact on the log housing prices. For an average property in year 2006 located in an MSA whose log per capita income is one standard deviation above (below) the mean, 1% increase in the per capita income leads to 1.99% (1.17%) increase in the housing price in Model 6, compared with a uniform 1.29% increase in Model 4. The significant impact of the quadratic term supports the hypothesis that the income elasticity of amenity demand is not constant but positively correlated with the income.

Model 7 reports the coefficients with the interactive and quadratic effects that are both significant. The marginal effect of land use regulation is thus corrected for the quadratic effect of the log per capita income. For an average property in year 2006 located in an MSA whose log per capita income is one standard deviation above (below) the mean, a unit increase in the regulation intensity leads to 5.08% (1.98%) increase in the housing price in Model 7, compared with a uniform 2.97% increase in Model 4. With the quadratic effect considered, the marginal effect of land use regulation is found more disperse geographically in Model 7 than in Model 5.

In Figure 5(a), we visualize the relationship of the log housing price, CALURI and the log GDP per capita in the benchmark model.<sup>37</sup> The tighter the regulation is or the higher the per capita income is, the higher the housing price.<sup>38</sup> In Figure 5(b), we show the same relationship with the interactive and quadratic effects. There is wide dispersion of the marginal effect of land use regulation by city income. When we approach the corner where the land use regulation is tight and the log GDP per capita is high, the increasing steepness shows the importance of the non-linear effect.

We use the top 6 most populated MSAs in California as an example to show the price dynamics.<sup>39</sup> The leading principal cities of these MSAs are Los Angeles, San Francisco, Riverside, San Diego, San Jose and Fresno. Figure 6 compares the dynamics of the actual price and the estimated price based on

<sup>37</sup> We simulate the grid points of CALURI and the log GDP per capita that are normal distributed with the mean and the standard deviation estimated from the data. The grid of each dimension is truncated at  $1.64\sigma$  above and below the variable mean, so the grid points fall into the 90% confidence intervals along each dimension. We thus look at the space where a majority of the grid points lie.

<sup>38</sup> To construct Figure 5(a), we evaluate the parameters of CALURI and the log GDP per capita at the parameters estimated from the linearized Model 4 in the exact model solution (13). We find that the surface in Figure 5(a) is very close to a hyperplane, indicating that the estimation equation (17) based on the first-order Taylor approximation is precise enough to capture the marginal impact of land use regulation and the per capita income on the housing prices in the benchmark model.

<sup>39</sup> The population ranking is based on the Moody's data in 2006. We exclude Sacramento--Roseville--Arden-Arcade MSA, because the land use data from Gyourko, Saiz and Summers (2008) is not available from the leading principal city (Sacramento). As a result, our choice of the top 6 most populated MSAs are Los Angeles-Long Beach-Anaheim MSA, San Francisco-Oakland-Hayward MSA, Riverside-San Bernardino-Ontario MSA, San Diego-Carlsbad MSA, San Jose-Sunnyvale-Santa Clara MSA, Fresno MSA.

the structural estimates from Model 7. The subplots are sorted by the MSA population in 2006 in descending order. The estimated prices from our empirical model trace the actual prices closely.<sup>40</sup>

## 6. Decomposing the Regulatory Effects: Production and Amenity Channels

### 6.1 Measuring Production and Amenity Channels

The effect of land use regulation on housing prices can be decomposed into three channels. The first channel goes through the housing supply. We call this the production channel. The second channel goes through the housing demand. We call it the amenity channel, because the regulation protects the amenity value and increases housing demand, leading to an increase in the local housing prices. There is a third channel related to the household location choice; this is the general equilibrium (GE) channel associated with the feedback effect of housing prices on housing choice. Tighter regulation that makes housing more expensive will drive housing demand to neighboring cities.

We disentangle these three channels using our structural estimates. We decompose the responses of housing prices through these different channels to a land use regulatory change. We can rewrite the estimation equation (24) by separating the impacts of regulation as follows.

$$\begin{aligned}
 \ln p_{ijmt} &= \text{prod}_{jmt} + \text{amen}_{jmt} + \text{ge}_{jmt} + [\text{other terms}]_{ijmt} \\
 \text{prod}_{jmt} &= \theta(\delta_0 + \delta_1 z_{jmt}) \cdot \text{CALURI}_j \\
 \text{amen}_{jmt} &= \eta(1 - \theta) \cdot \text{CALURI}_j \\
 \text{ge}_{jmt} &= -\frac{1}{2}[\theta\lambda + \eta(1 - \theta)(2\lambda - 1)] \cdot (\text{CALURI}_j - \text{CALURI}_k)
 \end{aligned} \tag{25}$$

where *prod*, *amen* and *ge* stand for the production, the amenity and the GE channels respectively.<sup>41</sup> We define three channels in this way, because they achieve the normalization with zero mean; if the land use regulatory measure and the per capita income is evaluated at their means ( $\text{CALURI}_j = \text{CALURI}_k = 0$ ), *prod*, *amen* and *ge* will yield zero values.

The GE channel is closely related to the spillover effect in Pollakowski and Wachter (1990) which emphasizes the interdependence of land use regulation and housing prices across regions. Our structural model picks up the effect as part of the GE channel. Pollakowski and Wachter (1990) and our model predict that tighter land use regulation in the neighboring regions increases local housing prices, as

<sup>40</sup> The housing boom and bust in the 2000s in the Los Angeles, San Francisco and San Jose MSAs are very well captured by our structural model. Note that the estimated prices of Fresno MSA are not as good as those in other MSAs. Our estimated price dynamics in Fresno MSA capture the shape along the time dimension, but not the level. We think the main reason is that our GMM-IV structural estimates based on cross-sectional time-series data are not indexed by MSA and year, so more weights will be assigned to bigger MSAs including Los Angeles and San Francisco MSAs.

<sup>41</sup> Note that *ge* is not identical to the Taylor approximated term (14); only the effect related to CALURI in (14) is included in the empirical measure of the GE channel.



regulation intensity of neighboring cities  $CALUR I_k$  is positively correlated with the GE channel and housing prices.

The production and the amenity channels do not include the second-order effects due to the price feedback, but separately identifies them in the GE effect. We thus conduct another decomposition that adds back the price feedback effects to construct the net production and the net amenity channels.

$$\begin{aligned} \ln p_{ijmt} &= prod_{jmt,ge} + amen_{jmt,ge} + [other\ terms]_{ijmt} \\ prod_{jmt,ge} &= \theta(\delta_0 + \delta_1 z_{mt}) \cdot CALUR I_j - \frac{1}{2}\theta\lambda \cdot (CALUR I_j - CALUR I_k) \\ amen_{jmt,ge} &= \eta(1 - \theta) \cdot CALUR I_j - \frac{1}{2}\eta(1 - \theta)(2\lambda - 1) \cdot (CALUR I_j - CALUR I_k) \end{aligned} \quad (26)$$

In Figure 7, we provide a graphical illustration of the housing price responses to the regulation increase through the (net) production and amenity channels. The housing supply curve will shift to the left through the production channel, while the housing demand curve will shift to the right through the amenity channel. The response through the net production (amenity) channel is the price response through the production (amenity) channel net of the GE effect.

## 6.2 Responses of Production and Amenity Channels to Land Use Regulation

Table 10 reports the responses of housing prices through each channel in response to one unit increase in land use regulation. We construct the counterfactual prices that only one channel in (25) or (26) responds to the regulatory change. The response is measured by the percentage deviation of the counterfactual price from the estimated price. We report the result by MSA, because our measure of the per capita income only varies at the MSA level.<sup>42</sup>

From Columns 1-3 in Table 10, the response of housing prices through the production channel is in general larger than the responses through the amenity or the GE channel. Tight regulation has the first-order effect to increase housing prices directly through the housing supply (3.22% on average). In comparison, the response through the GE channel is much smaller (-1.73%), because the effect comes from the demand feedback of housing prices. The response through the amenity channel has in general the smallest impact on housing prices (0.32%). If the production and the amenity channels take the GE effects into account, we see in Columns 4-5 in Table 10 that both effects become smaller.

The total response of housing prices to a unit increase in CALURI combines the responses of all channels. San Francisco area (4.84%), San Jose area (4.84%), Los Angeles area (3.82%) and San Diego area (3.53%) show the largest response of housing prices to a unit increase of regulation. These 4 MSAs have higher per capita income than the average MSA in California. The strong response of the housing prices in these MSAs is mainly attributed to the production channel. In these 4 MSAs, the responses

<sup>42</sup> We aggregate the city regulatory measure to the MSA level using the probability weight provided by Gyourko, Saiz and Summers (2008) as before.

through the net production channel are more than 50% larger than the MSA average response through the net production channel (1.55%). The price will increase through the net production channel by 4.58% in San Francisco, 4.57% in San Jose, 3.55% in Los Angeles, and 3.26% in San Diego. Our estimated response of the net amenity channel is constant by construction across MSAs. A unit increase in CALURI lead to 0.27% increase through the net amenity channel.

We can also use these results to simulate the impact of changes in regulatory regimes. Our regulatory index at the city level ranges from to -3.23 to 3.38. Los Angeles City scores the highest, while Hillsborough town scores the lowest in terms of CALURI in our sample. Using these measures to set up a counterfactual: If Los Angeles City were to relax its land use regulation to the lowest level among cities, *ceteris paribus*, housing prices could be as much as 25% lower. The production, the amenity and the GE channels contribute to -34.60%, -2.12% and 11.44% respectively.<sup>43 44</sup>

Our estimated effects in San Francisco MSA are comparable to the estimated marginal effects in Quigley, Raphael and Rosenthal (2008) (QRR), because both works have a single standardized regulatory index and the questionnaire are similar. More importantly, the local survey conducted by QRR is based on the questionnaires of Qyourko, Saiz and Summers (2008) but is adapted to California jurisdictions. Table 11 shows the comparison of QRR's analysis in several aspects to ours.<sup>45</sup> QRR's OLS estimates of the marginal effect of regulation on housing prices range from 1.2% to 2.2% and their IV estimates range from 3.8% to 5.3%. Our GMM-IV estimators are close to QRR's IV estimators. The marginal effect through the production, the amenity, and GE channels are 6.25%, 0.32% and -1.73% respectively. If the we factor the GE effects into the first two channels, we find 4.58% and 0.27% for the production and amenity channels. We find that the total marginal effect of regulation on prices in San Francisco MSA is 4.84%.

## 7. The Spillover Effect of Land Use Regulation on Housing Prices

Pollakowski and Wachter (1990) using a database for a single county, Montgomery, Maryland find that the relative restrictiveness of regulation between neighboring and home cities has a positive spillover effect on the housing prices in the home city. Our dataset is larger. We use a more granular sample from California to confirm the existence and the positive impact of the city-level spillover effects. We find

<sup>43</sup> For the net channels incorporated with GE effects, the contributions to the price decrease are -23.48% and -1.79% for the net production and amenity effects.

<sup>44</sup> To calculate these price change through different channels, we use the estimated responses of Los Angeles MSA in Table 10. We multiply the responses by the size of regulatory change, 3.38 - (-3.23), to estimate the decline of housing prices attributed to different channels.

<sup>45</sup> QRR focus on the pricing data from the cross-section data of 2000 Census from 86 cities in San Francisco Bay area, while we have transaction cross-section time-series data from 25 cities in San Francisco MSA from 1997 to 2017. There are 10 sub-indices underlying the single index in QRR, compared to 8 sub-indices behind CALURI in our work.

that the home regulatory impact on home housing prices is stronger, once the neighboring regulatory impact is controlled. Consistent with Pollakowski and Wachter (1990), we show the previous finding holds in more recent data and more widely in the metro areas.

### 7.1 *Measuring the Spillover Effect*

While the spillover effect establishes the price interdependence of neighboring housing markets through regulation, it is different from the home regulatory effect through the general equilibrium channel in the previous analysis. The latter captures the second-order price feedback effect through the production or the amenity channels due to the spatial reallocation of housing demand. The spillover effect may capture any direct regulatory impact from the neighboring cities, in addition to the price feedback channel.

We define the relative restrictiveness index (RRI) as the difference between neighboring and home regulatory indices whose marginal effect measures the spillover effect in the section.

$$RRI_j = CALURI_{-j} - CALURI_j \quad (27)$$

We specify the functional form of the neighboring regulatory index of city  $j$  as the weighted average of the regulatory indices in California and consider 2 weighting measures of the neighboring indices that weigh on the city proximities.

$$CALURI_{-j} = \sum_{k \neq j} weight_{jk} \cdot CALURI_k \quad (28)$$

$$\text{inv. sq. distance: } weight_{jk} = x_{invdist2} / d_{jk}^2 \quad (29)$$

$$\text{gravity: } weight_{jk} = x_{gravity} z_j z_k / d_{jk}^2$$

where  $x_{invdist2}$ , and  $x_{gravity}$  are constants to make sure that the sum of the weights is equal to 1.<sup>46</sup> The second case generalizes the first one and takes a gravitational form. The gravity model puts weight on the per capita income of the home and neighboring cities, adjusted by the distance.

### 7.2 *Additional Data*

Our estimations in the previous sections exclude the discussion of the spillover effect due to limited data availability.<sup>47</sup> As the spillover effect is local among the neighboring cities that are geographically close,

<sup>46</sup> Alternatively, we also test the inverse distance to weigh the neighboring indices. Compared with the case of inverse squared distance, the alternative case puts less weight on the neighboring cities closer to the home city.

<sup>47</sup> We make the decision to use more data to produce more precise estimates and to exclude the spillover effect in the estimations in the previous sections where the per capita income varies only at the metro level. The choice may raise the concern of downward bias of the home regulatory impact. As will be shown in this section, we find a negative correlation between the regulatory index and the relative restrictiveness index. However, we find the issue is minor in the previous estimates for the following reason.

The decomposition of the regulatory effects in (25) shows that the negation of the GE channel takes a form similar to our definition of the spillover effect, so previous estimates do partially take into account the effect of relative restrictiveness index. The difference is that the neighboring regulatory index  $CALURI_k$  is not varying by city but

one needs to control city-level variation of the per capita income to identify the spillover effect in the metro areas. There is no series of per capita income that covers the whole sample period from 1993 to 2017 at such granular level. An additional data issue is the low response rate of the Wharton Land Use Survey in some MSAs. Among the most populated MSAs, only San Diego-Carlsbad MSA has a response rate of jurisdictions that exceeds 50% (11 out of 18 cities).<sup>48</sup> The construction of RRI which relies on geo-spatial information may be severely biased towards the cities responding to the Survey.

To overcome the data issue, we additionally collect census tract data from the tract-block Summary File of the 2014 American Community Survey (ACS) 5-year estimates. The 5-year survey spans from 2010 to 2014 but the estimates do not represent any single year in the range.<sup>49</sup> We calculate the city-level per capita income by averaging the tract-level median income per capita and using the tract population as the weight.

To match the time frame of the income data, the empirical analysis in the section will use the property transactions in California in 2014. We thus exclude the variables that don't exhibit cross-sectional variations to prevent collinearity problem.<sup>50</sup> The independent variables include the first and second order terms of the log per capita income and structural characteristics of housing in the benchmark estimation (Model 4 in Table 7). We select four major MSAs that are the least likely to suffer the data issue of low response rates in the Survey and have not too small numbers of cities within the metro area (Los Angeles-Long Beach-Anaheim MSA, San Francisco-Oakland-Hayward MSA, San Diego-Carlsbad MSA, Oxnard-Thousand Oaks-Ventura MSA, with LA, SF, SD and VT respectively for short notations).<sup>51</sup>

In Figure 8, we show the distribution of the CALURI and RRI. RRI under different weight measures in (29) show similar distributional patterns, with the bell shapes and the two-sided fat tails. In Figure 9, we show the scatter diagrams of CALURI and RRI by city. There is a strong negative

normalized to 0 for all cities. Because the mean of CALURI is zero by construction, the assumption of zero neighboring regulatory index is thus a special case where equal weight is assigned to all cities, regardless of the distance. The assumption turns out to make the regulatory estimates more robust for MSAs with low survey response rates.

<sup>48</sup> In the appendix, we report the response rate of cities by CBSA (MSA and  $\mu$ MSA) in the Wharton Land Use Survey.

<sup>49</sup> The first wave of the tract level data is 2009 ACS 5-year estimates, but we use the wave of 2014 ACS 5-year estimates to exclude any unobservable consequence of the Great Recession on the housing market. 2014 ACS 5-year estimates is the wave that is closest to the time of the Wharton Land Use Survey with no single year falling into the Great Recession.

<sup>50</sup> The excluded independent variables in the section are the growth rate of the household mortgage debt, the real 30-year fixed-rate mortgage rate, and the log of population-weighted mean GDP per capita of California.

<sup>51</sup> To choose MSAs, we set the following criteria: (1) there are at least 10 cities in an MSA covered by the Wharton Land Use Survey; (2) an MSA has more than 1 principal city based on the definition in the historical delineation files of metropolitan and micropolitan statistical areas (2006) from the Census Bureau; (3) more than 50% of the leading principal cities (listed in the name of an MSA) are covered by the Survey. Three MSAs survive the criteria: Los Angeles-Long Beach-Anaheim MSA, San Francisco-Oakland-Hayward MSA, and San Diego-Carlsbad MSA (For San Francisco MSA, it is long known as San Francisco-Oakland-Fremont MSA until 2013). We additionally add Oxnard-Thousand Oaks-Ventura MSA as another case. Based on the appendix Table A2, the share of cities and the share of principal cities covered by the Survey are both high among MSAs.

correlation between CALURI and RRI and the negative relationship is robust under different weighting measures (-0.92, -0.93 respectively). We separately mark the cities in the four selected MSAs (LA, SF, SD, VT) and show that the negative correlation still holds within each metro area.

### **7.3 Estimation of the Spillover Effect**

In Tables 12a-d, we report the estimated home and neighboring regulatory effects for the four selected metro areas (Los Angeles MSA, San Francisco MSA, San Diego MSA, Oxnard MSA respectively). We report three model specifications in each table. Similar to the method adopted by Pollakowski and Wachter (1990), we use Ordinary Least Square in the estimations.<sup>52</sup> Model 1 in Table 12 includes the home regulatory impact but excludes the spillover term in the estimations, while Models 2 and 3 add the relative restrictiveness indices under 2 different weighting measures in (29). Our cross-sectional estimations can explain 43%-61% of the log price variations, depending on the model specifications and the MSAs.

By estimating the regulatory impacts using the city-level per capita income, we find in Model 1 that the marginal effect of regulation on housing prices are qualitatively similar to the estimated regulatory effects shown in Table 10. This specification has the interpretation of equal weights assigned to all cities available in the Wharton Land Use Survey, regardless of the geographical distance (see footnote 47).

Models 2 and 3 build on Model 1 by considering the neighboring regulatory impact and apply the inverse squared distance and the gravity weight respectively as the weighting measures to the neighboring cities. General results hold for all models. The home and neighboring regulatory effects will be both significantly positive for all of the 4 selected MSAs.

The comparison of Model 2 to Model 1 shows that the marginal impacts of land use regulation will be bigger if the relative restrictiveness index is controlled in the log housing price equations. The result follows naturally from the fact that CALURI and RRI are negatively correlated and omitting RRI in the estimation in Model 1 will downward bias the estimated coefficients of CALURI. We see large spatial variation in the estimated regulatory and spillover impacts. In Model 2, the home and neighboring regulatory effects on the log housing prices (referenced to the average city in the metro area) are 14.7% and 8.78% in Los Angeles MSA, 6.00% and 4.10% in San Francisco MSA, 25.7% and 10.3% in San Diego MSA, and 6.07% and 8.05% in Oxnard MSA.

If we build on Model 2 and further take the per capita income of the neighboring cities into account in Model 3, the estimated regulatory and spillover effects are both larger in all of 4 selected MSAs. In

<sup>52</sup> Instrumenting the per capita income with city-level demographic variables (using the mean population age and share of high education aggregated from the tract level) won't qualitatively change the estimated regulatory and spillover effect of the selected MSAs.

Model 3, the regulatory and the spillover effects on the log housing prices are 18.2% and 12.4% in Los Angeles MSA, 7.15% and 5.12% in San Francisco MSA, 26.2% and 10.6% in San Diego MSA, and 6.79% and 8.79% in Oxnard MSA.

## **8. Conclusion**

In this paper, we develop a general equilibrium framework to determine the impact of land use regulation on housing prices in cities in California over the years 1993 to 2017. We use housing transaction prices and housing characteristics along with data on macro credit supply and regional per capita income together with the Wharton Residential Land Use Survey (Gyourko, Saiz and Summer, 2008) to identify the impacts of land use regulation on housing prices.

We identify the separate channels through which land use regulation can impact housing prices. Specifically, we characterize the production channel which measures the increasing cost of housing production and the amenity channel which measures the increase in environmental attractiveness of communities with greater land use regulation. While the empirical literature discusses these channels, the literature does not measure these effects in a general equilibrium framework. In addition, we show the general equilibrium effects of mitigating housing price impacts through households' location choice response to higher prices. Our estimated effects show that Los Angeles is the city whose housing prices are most impacted by regulation. In our calculations, if land use regulation in LA were to be decreased to the level observed in the least regulated cities, housing prices would decline by approximately 25%. Besides, we take a more granular view to examine the regulatory interdependence among cities and to estimate the spillover effects of regulation. We define the relative restrictiveness indices as the difference between the neighboring and home regulatory effects and report robust finding on the significant and positive spillover effects on housing prices.

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**Tables**

**Table 1. Sample Coverage by Geographical Cities**

	City	County	CBSA	Count
Land Use Sample	179	39	25	5,318,379
Unmatched Sample	963	47	25	7,403,052

**Table 2: Summary Statistics of Land Use Regulation Indices**

	Mean	Median	Std.Dev	Pct.25	Pct.75
LPPI	0.47	0.11	1.08	-0.31	1.09
LZAI	1.87	2	0.61	1	2
LPAI	1.69	1	0.98	1	2
DRI	0.15	0	0.35	0	0
OSI	0.87	1	0.33	1	1
EI	0.93	1	0.26	1	1
SRI	0.19	0	0.77	0	0
ADI	9.04	8.06	4.51	5.67	12.13
CALURI	0.27	-0.01	1.23	-0.41	0.6
WRLURI	0.8	0.55	0.79	0.16	1.5

Note: local political pressure index (LPPI), local zoning approval index (LZAI), local project approval index (LPAI), density restriction index (DRI), open space index (OSI), exactions index (EI), supply restriction index (SRI), approval delay index (ADI). California Land Use Regulation Index (CALURI), Wharton Residential Land Use Regulation Index (WRLURI). Frequency weights of the property transactions are used. Source: Gyourko, Saiz and Summer (2008) and authors' calculation.

**Table 3. Distribution of Residential Property Use**

Property Type	Land Use Sample		Unmatched Sample	
	Frequency	Percent	Frequency	Percent
Single Family Residential	4,045,001	31.80	6,200,178	48.74
Townhouse	13,401	0.11	31,418	0.25
Cluster Home	39,918	0.31	45,049	0.35
Condominium	1,133,241	8.91	951,460	7.48
Cooperative	859	0.01	323	0.00
Row House	336	0.00	702	0.01
Planned Unit Development	84,951	0.67	159,699	1.26
Inferred Single Family Residential	672	0.01	14,223	0.11
Total	5,318,379	100.00	7,403,052	100.00

Note: the total sample is the non-foreclosed residential sales transactions in California from 1993 to 2017. Source: ZTRAX and authors' calculation. ZTRAX database is provided by Zillow Group. The results and opinions are those of the author(s) and do not reflect the position of Zillow Group or any of its affiliates.

**Table 4. Summary Statistics of Property Characteristics**

	Mean	Median	Std.Dev	Pct.25	Pct.75
<b>Land Use Sample</b>					
Sales Price	369,615	282,102	620,425	169,943	453,920
Sq.Ft.	1,699.40	1,503.00	858.78	1,162.00	2,011.00
Price/Sq.Ft	221.27	181.26	518.6	115.82	283.93
Age of Property	30	26	24.56	9	46
No.of Bathroom	2	2	0.81	2	2
No.of Bedrooms	3.03	3	1.04	2	4
Miles to Core Cities	28.08	8.14	240.19	4.44	14.5
<b>Unmatched Sample</b>					
Sales Price	352,330	270,609	643,300	165,749	427,337
Sq.Ft.	1,778.34	1,574.00	1,048.22	1,217.00	2,128.00
Price/Sq.Ft	199.64	164.88	761.11	108.91	250.08
Age of Property	27.8	24	23.13	8	44
No.of Bathroom	2.05	2	0.8	2	2
No.of Bedrooms	3.16	3	0.95	3	4
Miles to Core Cities	52.34	10.99	362.95	5.83	20.65

Note: Sales Price and Price/Sq.Ft are inflation adjusted to Jan. 2006 US dollars, using the Consumer Price Index for All Urban Consumers: Housing (FRED: CPIHOSNS). Source: ZTRAX and authors' calculation. ZTRAX database is provided by Zillow Group. The results and opinions are those of the author(s) and do not reflect the position of Zillow Group or any of its affiliates.

**Table 5. Summary Statistics of Instrumental Variables**

	Mean	Median	Std.Dev	Pct.25	Pct.75
share of high education (%)	35.92	35.2	8.02	29.12	42.10
population age	34.48	34.3	2.22	32.72	36.27
share of high-tech jobs (%)	6.84	5.37	5.90	2.94	8.11

Note: variables are weighted by the MSA population. Source: American Community Survey, Moody's Analytics.

**Table 6. Correlation Matrix: Instrumental Variables**

	GDP pca	L.GDP pca	high educ %	high-tech %	pop. age
GDP pca	1.000				
L.GDP pca	0.992	1.000			
high educ %	0.823	0.820	1.000		
high-tech %	0.651	0.627	0.706	1.000	
pop. age	0.753	0.762	0.905	0.405	1.000

Note: all variables are in log form. Correlation is weighted by the MSA population. Source: American Community Survey, Moody's Analytics.

**Table 7. Benchmark Estimation: Coefficients**

	Model 1 GMM	Model 2 GMM	Model 3 GMM-IV	Model 4 GMM-IV
CALURI	0.0195*** (0.000)	0.0293*** (0.000)	0.0290*** (0.000)	0.0297*** (0.000)
log GDP per capita	1.231*** (0.001)	1.326*** (0.001)	1.311*** (0.001)	1.291*** (0.001)
log Avg. GDP per cap	0.496*** (0.005)	0.352*** (0.004)	0.369*** (0.004)	0.432*** (0.004)
Bedroom: 1		-0.120*** (0.003)	-0.120*** (0.003)	-0.129*** (0.003)
Bedroom: 2		-0.291*** (0.003)	-0.293*** (0.003)	-0.300*** (0.003)
Bedroom: 3		-0.389*** (0.003)	-0.391*** (0.003)	-0.405*** (0.003)
Bedroom: 4+		-0.453*** (0.003)	-0.455*** (0.003)	-0.471*** (0.003)
Bathroom: 1		0.134*** (0.006)	0.135*** (0.006)	0.107*** (0.006)
Bathroom: 2		0.209*** (0.006)	0.211*** (0.006)	0.169*** (0.006)
Bathroom: 3		0.161*** (0.006)	0.165*** (0.006)	0.115*** (0.006)
Bathroom: 4+		0.303*** (0.007)	0.308*** (0.007)	0.264*** (0.007)
log sq.feet		1.084*** (0.001)	1.084*** (0.001)	1.107*** (0.001)
log miles to core cities		-0.0262*** (0.000)	-0.0261*** (0.000)	-0.0314*** (0.000)
SFR		-0.0576*** (0.001)	-0.0595*** (0.001)	-0.0709*** (0.001)
condominium		0.0217*** (0.001)	0.0219*** (0.001)	0.0233*** (0.001)
Age: 1-5		0.132*** (0.001)	0.133*** (0.001)	0.115*** (0.001)
Age: 6-10		0.0847*** (0.001)	0.0848*** (0.001)	0.0695*** (0.001)
Age: 11-20		0.0652*** (0.001)	0.0656*** (0.001)	0.0530*** (0.001)
Age: 21-30		0.0576*** (0.001)	0.0585*** (0.001)	0.0413*** (0.001)
Age: 31-40		0.108*** (0.001)	0.110*** (0.001)	0.0937*** (0.001)
Age: 41-50		0.127*** (0.001)	0.129*** (0.001)	0.117*** (0.001)
Age: > 50		0.143*** (0.001)	0.147*** (0.001)	0.137*** (0.001)
growth rate of mortgage debt	3.072*** (0.008)	3.025*** (0.006)	3.024*** (0.006)	2.881*** (0.006)
30-year FRM rate	-4.003*** (0.049)	-3.190*** (0.040)	-3.153*** (0.042)	-2.591*** (0.042)
Constant	5.806*** (0.021)	-1.825*** (0.021)	-1.830*** (0.022)	-2.115*** (0.022)
Observations	5,259,215	5,259,215	5,259,215	5,259,215

Note: robust standard errors in the parentheses. \* p<0.10, \*\* p<0.05, \*\*\* p<0.010. The base levels of the factor variables are: no bedroom, no bathroom, property use other than single-family and condominium, new property (age is zero). The lag terms of log real GDP per capita and log real GDP per capita in California are used as IVs of their contemporaneous terms in Models 3-4; the share of high education, the population age and the share of high-jobs are additional IVs of Model 4.

**Table 8. Marginal Effect of Sub-indices on log Housing Price**

	Model 1	Model 2	Model 3	Model 4	Contribution (%)
	GMM	GMM	GMM-IV	GMM-IV	sum to 100%
LPPI	0.0082	0.0122	0.0121	0.0124	21.06
LZAI	0.0068	0.0103	0.0102	0.0104	17.68
LPAI	0.0080	0.0121	0.0119	0.0122	20.76
DRI	0.0023	0.0035	0.0034	0.0035	5.94
OSI	0.0050	0.0075	0.0074	0.0076	12.85
EI	0.0029	0.0044	0.0044	0.0045	7.61
SRI	0.0029	0.0043	0.0043	0.0044	7.41
ADI	0.0026	0.0039	0.0039	0.0040	6.70

Note: local political pressure index (LPPI), local zoning approval index (LZAI), local project approval index (LPAI), density restriction index (DRI), open space index (OSI), exactions index (EI), supply restriction index (SRI), approval delay index (ADI). All sub-indices have been standardized to zero mean and unit variance. The marginal effect of a sub-index is the marginal effect of CALURI on the log housing prices multiplied by the sub-index weight in the predicted score regression. The control variables and the estimation method can be found in Table 7.

**Table 9. Estimation with Non-Linear Effects: Coefficients**

	Model 4	Model 5	Model 6	Model 7
	GMM-IV	GMM-IV	GMM-IV	GMM-IV
CALURI	0.0297*** (0.000)	-0.0577*** (0.004)	0.0341*** (0.000)	-0.267*** (0.004)
log GDP per capita	1.291*** (0.001)	1.293*** (0.001)	-6.440*** (0.030)	-6.758*** (0.031)
Avg.log GDP per capita	0.432*** (0.004)	0.426*** (0.004)	0.356*** (0.004)	0.343*** (0.004)
CALURI*log GDP per capita		0.0221*** (0.001)		0.0760*** (0.001)
log GDP per Capita squared			1.008*** (0.004)	1.049*** (0.004)
Observations	5,259,215	5,259,215	5,259,215	5,259,215

Note: robust standard errors in the parentheses. \* p<0.10, \*\* p<0.05, \*\*\* p<0.010. The lag terms of the log real GDP per capita and log mean GDP per capita in California are used as IVs of their contemporaneous terms; the share of high education, the population age and the share of high-jobs are additional IVs of Models 4-7. The control variables and the estimation method can be found in Table 7.

**Table 10. Counterfactual Experiments: Responses to +SD CALURI (% deviation)**

	production	amenity	GE	production with GE	amenity with GE	total
Bakersfield	3.22	0.32	-1.73	1.55	0.27	1.81
Chico	3.23	0.32	-1.73	1.56	0.27	1.82
<b>Fresno</b>	3.12	0.32	-1.73	1.45	0.27	1.72
Hanford-Corcoran	0.04	0.32	-1.73	-1.63	0.27	-1.37
<b>Los Angeles- Long Beach-Anaheim</b>	5.23	0.32	-1.73	3.55	0.27	3.82
Madera	1.64	0.32	-1.73	-0.04	0.27	0.23
Merced	0.35	0.32	-1.73	-1.32	0.27	-1.06
Modesto	2.02	0.32	-1.73	0.34	0.27	0.61
Napa	4.74	0.32	-1.73	3.07	0.27	3.33
Oxnard-Thousand Oaks- Ventura	3.37	0.32	-1.73	1.70	0.27	1.96
Redding	4.20	0.32	-1.73	2.52	0.27	2.79
<b>Riverside- San Bernardino-Ontario</b>	1.67	0.32	-1.73	0.00	0.27	0.27
Sacramento-Roseville- Arden-Arcade	4.89	0.32	-1.73	3.21	0.27	3.48
Salinas	2.99	0.32	-1.73	1.32	0.27	1.58
<b>San Diego-Carlsbad</b>	4.94	0.32	-1.73	3.26	0.27	3.53
<b>San Francisco- Oakland-Hayward</b>	6.25	0.32	-1.73	4.58	0.27	4.84
<b>San Jose-Sunnyvale- Santa Clara</b>	6.25	0.32	-1.73	4.57	0.27	4.84
San Luis Obispo- Paso Robles-Arroyo Grande	4.26	0.32	-1.73	2.59	0.27	2.86
Santa Cruz- Watsonville	3.57	0.32	-1.73	1.90	0.27	2.16
Santa Maria- Santa Barbara	4.52	0.32	-1.73	2.85	0.27	3.11
Santa Rosa	3.91	0.32	-1.73	2.23	0.27	2.50
Stockton-Lodi	2.04	0.32	-1.73	0.37	0.27	0.64
Vallejo-Fairfield	2.14	0.32	-1.73	0.47	0.27	0.73
Visalia-Porterville	0.80	0.32	-1.73	-0.87	0.27	-0.60
Yuba City	1.12	0.32	-1.73	-0.55	0.27	-0.29
mean	3.22	0.32	-1.73	1.55	0.27	1.81

Note: the numbers reported by MSA are the time average percentage deviations of the counterfactual prices from the estimated prices, for the period from 1993 to 2017. The estimated parameters from Model 7 are used to construct the counterfactual prices. The price dynamics of MSAs in bold type (most populated MSAs in 2006 with leading principal cities available in the Wharton Survey) are plotted in Figure 6.

**Table 11. Comparison with Quigley, Raphael and Rosenthal (2008)**

Quigley, Raphael and Rosenthal (2008)				
Location	San Francisco Bay Area			
Number of cities	86			
Source of Price data	2000 US Census			
Regulatory Index	BLURI (from Berkeley Land Use Survey)			
Number of sub-indices	10			
Estimation method	OLS and IV			
Results	OLS		IV	
Marginal effect of regulation	1.2%-2.2%		3.8%-5.3%	
This paper				
Location	San Francisco-Oakland-Hayward, MSA			
Number of cities	25			
Source of Price data	ZTRAX, 1993-2017			
Regulatory Index	CALURI (from Wharton Residential Land Use Survey)			
Number of sub-indices	8			
Estimation method	GMM-IV			
Results (GE separated)	production	amenity	GE	total
Marginal effect of regulation	6.25%	0.32%	-1.73%	4.84%
Results (GE incorporated)	production with GE	Amenity with GE		total
Marginal effect of regulation	4.58%	0.27%		4.84%

**Table 12a. Spillover Effect: Los Angeles-Long Beach-Anaheim, MSA**

Variable	(1) Benchmark	(2) Inv.dist2	(3) Gravity
CALURI	0.0595*** (0.0015)	0.147*** (0.0093)	0.182*** (0.0100)
RRI		0.0878*** (0.0091)	0.124*** (0.0099)
Adjusted R <sup>2</sup>	0.563	0.564	0.565
N	52,102	52,102	52,102

Note: robust standard errors in the parentheses. \* p<0.10, \*\* p<0.05, \*\*\* p<0.010. CALURI = California Land Use Regulation Index; RRI = Relative Restrictiveness Index. *Inv.dist2* uses the inverse distance squared to weigh neighboring CALURI. Gravity indicates the specification with the city-level income per capita divided by the squared distance as the weight. Omitted control variables in all specifications include log city-level per capita income where a property is located and its squared term, the number of bedrooms, the number of bathrooms, the log distance to the Central Business District (centroid of the nearest core city of an MSA), the log size of a property, the property use (single-family, condominium) and the property age. We use the housing transactions in 2014 from ZTRAX. The data of the city-level per capita income is aggregated from the census tract data from the Summary File of the 5-year American Community Survey 2010-2014.

**Table 12b. Spillover Effect: San Francisco-Oakland-Hayward, MSA**

Variable	(1) Benchmark	(2) Inv.dist2	(3) gravity
CALURI	0.0158* (0.0081)	0.0600*** (0.017)	0.0715*** (0.016)
RRI		0.0410*** (0.014)	0.0512*** (0.013)
Adjusted R <sup>2</sup>	0.510	0.511	0.511
N	19,137	19,137	19,137

Note: robust standard errors in the parentheses. \* p<0.10, \*\* p<0.05, \*\*\* p<0.010. CALURI = California Land Use Regulation Index; RRI = Relative Restrictiveness Index. *Inv.dist2* uses the inverse distance squared to weigh neighboring CALURI. Gravity indicates the specification with the city-level income per capita divided by the squared distance as the weight. Omitted control variables in all specifications include log city-level per capita income where a property is located and its squared term, the number of bedrooms, the number of bathrooms, the log distance to the Central Business District (centroid of the nearest core city of an MSA), the log size of a property, the property use (single-family, condominium) and the property age. We use the housing transactions in 2014 from ZTRAX. The data of the city-level per capita income is aggregated from the census tract data from the Summary File of the 5-year American Community Survey 2010-2014.

**Table 12c. Spillover Effect: San Diego-Carlsbad, MSA**

Variable	(1) Benchmark	(2) Inv.dist2	(3) Gravity
CALURI	0.125*** (0.0076)	0.257*** (0.023)	0.262*** (0.021)
RRI		0.103*** (0.018)	0.106*** (0.016)
Adjusted R <sup>2</sup>	0.604	0.605	0.605
N	21,985	21,985	21,985

Note: robust standard errors in the parentheses. \* p<0.10, \*\* p<0.05, \*\*\* p<0.010. CALURI = California Land Use Regulation Index; RRI = Relative Restrictiveness Index. *Inv.dist2* uses the inverse distance squared to weigh neighboring CALURI. Gravity indicates the specification with the city-level income per capita divided by the squared distance as the weight. Omitted control variables in all specifications include log city-level per capita income where a property is located and its squared term, the number of bedrooms, the number of bathrooms, the log distance to the Central Business District (centroid of the nearest core city of an MSA), the log size of a property, the property use (single-family, condominium) and the property age. We use the housing transactions in 2014 from ZTRAX. The data of the city-level per capita income is aggregated from the census tract data from the Summary File of the 5-year American Community Survey 2010-2014.

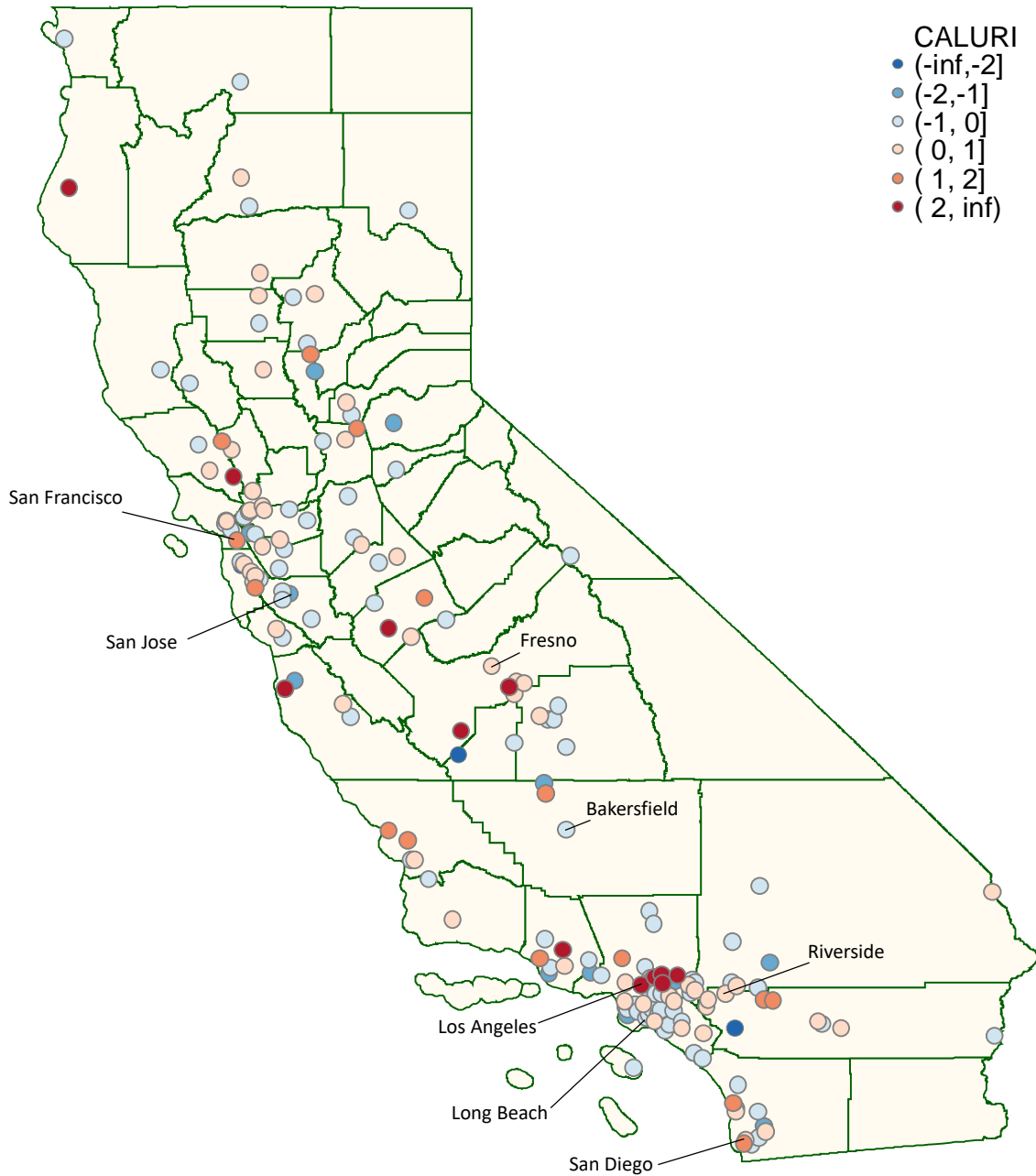


**Table 12d. Spillover Effect: Oxnard-Thousand Oaks-Ventura, MSA**

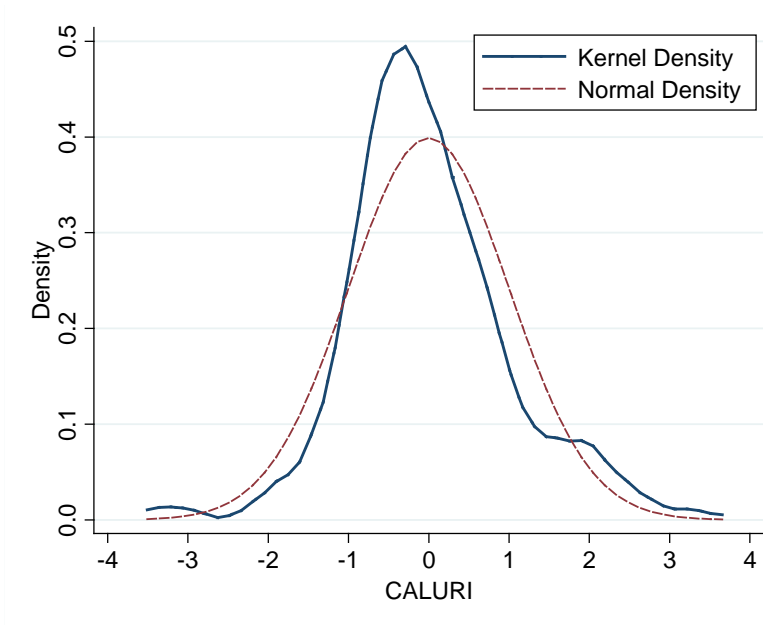
Variable	(1) Benchmark	(2) Inv.dist2	(3) Gravity
CALURI	-0.0191** (0.0089)	0.0607*** (0.022)	0.0679*** (0.022)
RRI		0.0805*** (0.018)	0.0879*** (0.019)
Adjusted R <sup>2</sup>	0.429	0.431	0.431
N	6,272	6,272	6,272

Note: robust standard errors in the parentheses. \* p<0.10, \*\* p<0.05, \*\*\* p<0.010. CALURI = California Land Use Regulation Index; RRI = Relative Restrictiveness Index. *Inv.dist2* uses the inverse distance squared to weigh neighboring CALURI. Gravity indicates the specification with the city-level income per capita divided by the squared distance as the weight. Omitted control variables in all specifications include log city-level per capita income where a property is located and its squared term, the number of bedrooms, the number of bathrooms, the log distance to the Central Business District (centroid of the nearest core city of an MSA), the log size of a property, the property use (single-family, condominium) and the property age. We use the housing transactions in 2014 from ZTRAX. The data of the city-level per capita income is aggregated from the census tract data from the Summary File of the 5-year American Community Survey 2010-2014.

## Figures

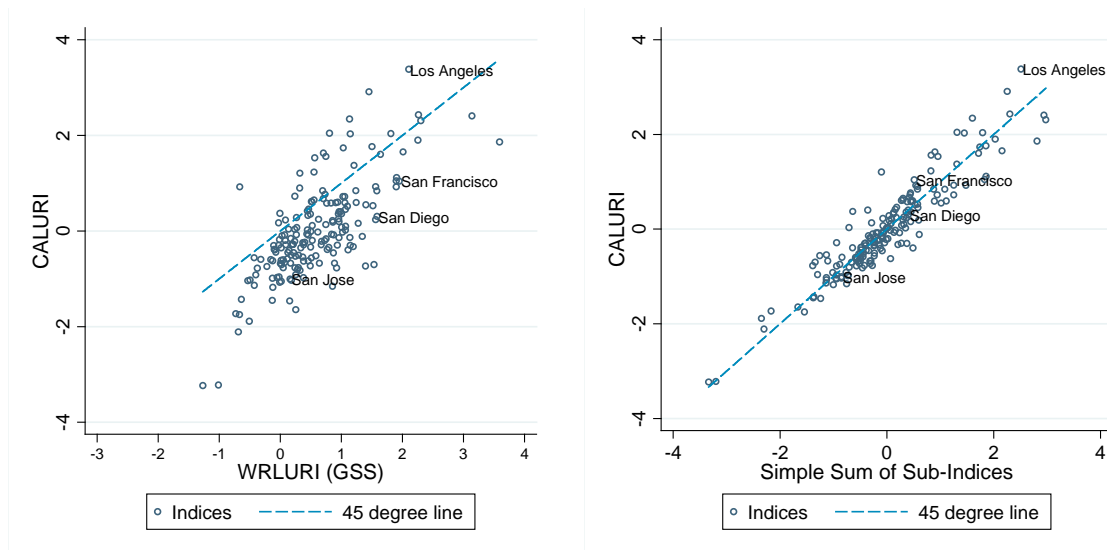


**Figure 1:** spatial distribution of land use regulation intensity in California. California Land Use Regulation Index (CALURI) is based on the sub-indices from WRLURI. A higher index value indicates higher regulation intensity. There are 185 jurisdictions in total. Source: Gyourko, Saiz and Summers (2008) and authors' calculation.



**Figure 2:** comparison of the kernel density of California Land Use Regulation Index (CALURI) and the normal density. CALURI is based on the sub-indices from WRLURI. A higher index value indicates higher regulation intensity.

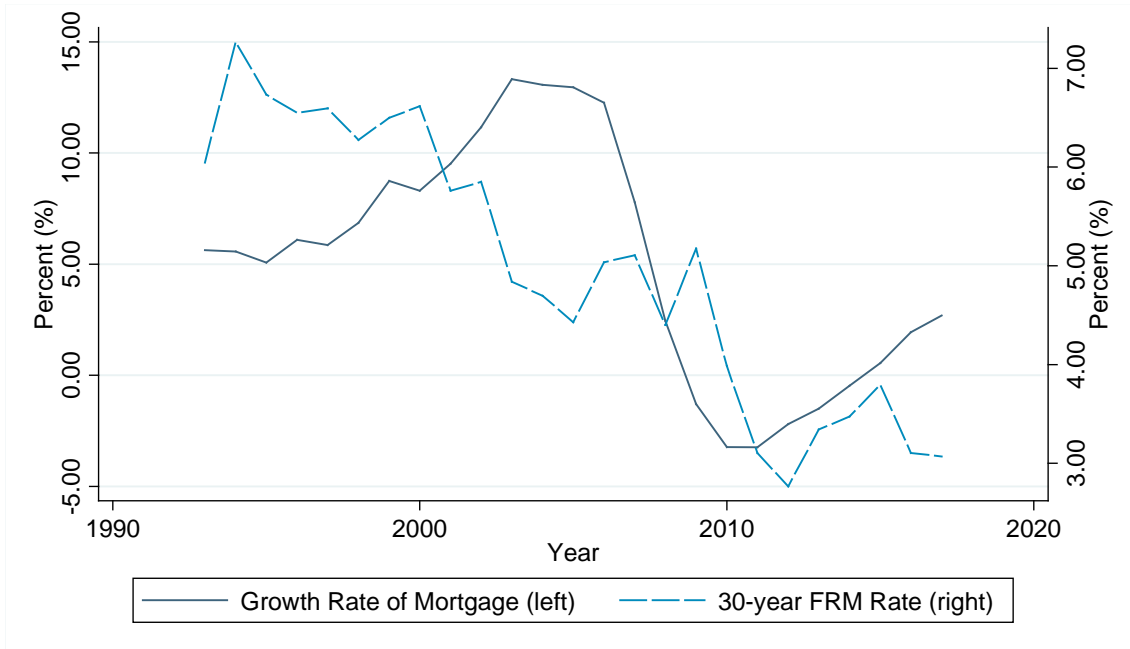
Source: Gyourko, Saiz and Summers (2008) and authors' calculation.



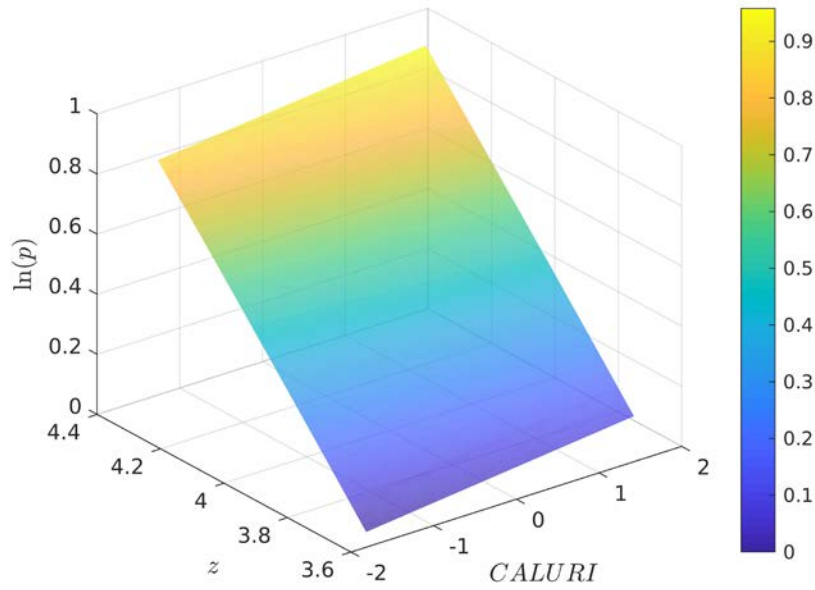
(a) CALURI vs WRLURI

(b) CALURI vs Simple Sum of Sub-indices

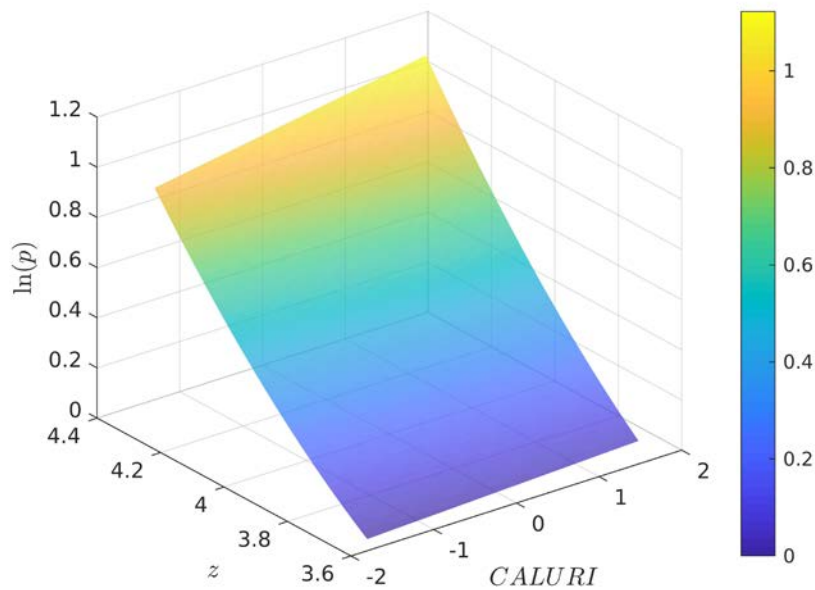
**Figure 3:** quantile-quantile plots of WRLURI, CALURI and Simple Sum of Sub-indices. We compare the index based on the first factor of the principal factor analysis with the simple sum of the 8 sub-indices underlying CALURI. For comparability, we normalize the sub-indices and their sum, so all indices in comparison have zero mean and unit variance.



**Figure 4:** Annual growth rate of the residential mortgage debt of US households and 30-year US average fixed-rate mortgage rate. The mortgage rate has been adjusted for inflation. Source: Z.1 Financial Account Table from the Board of Governors of Federal Reserves and Freddie Mac.



Panel (a): no interactive or quadratic term

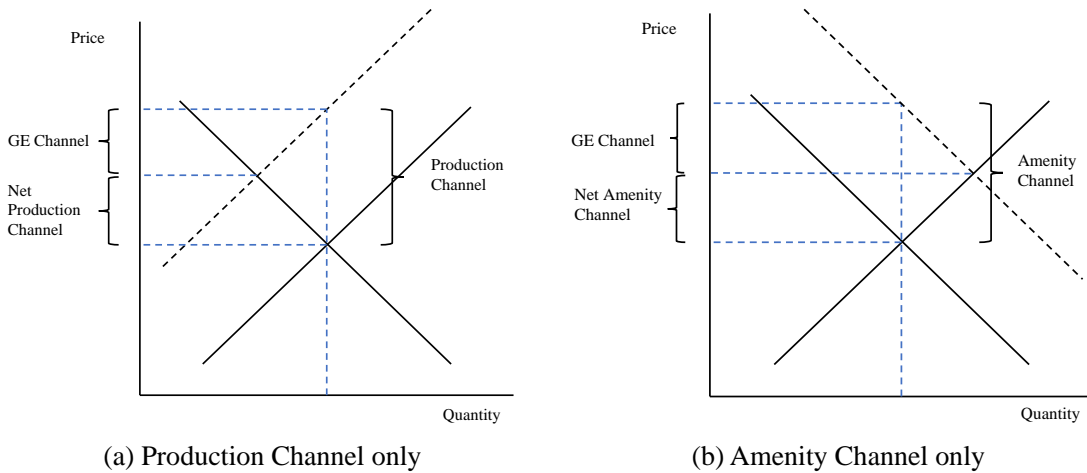


Panel (b) with the interactive term and the quadratic term of the log GDP per capita

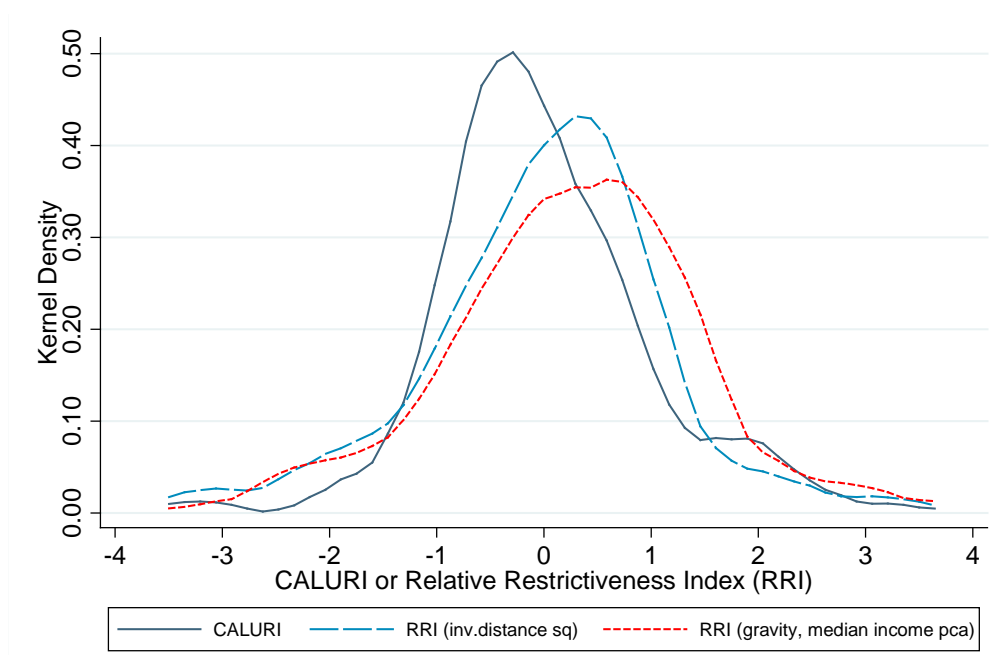
**Figure 5:** the log housing price as the function of the log GDP per capita ( $z$ ) and land use regulation intensity ( $CALURI$ ). The grid of each dimension is simulated using normal distribution, with the mean and the standard deviation estimated from the data. Grid points within 90% confidence intervals along each dimension are plotted. The parameters are evaluated at the estimated values of Model 4 in panel (a) and Model 7 in panel (b). The min value along the  $z$ -axis is normalized to 0.



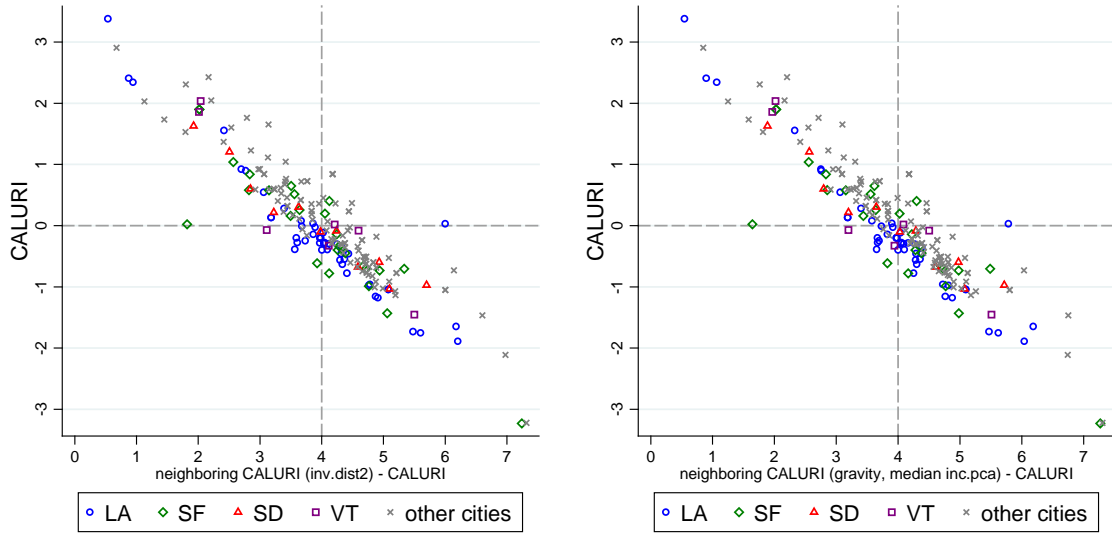
**Figure 6:** housing price dynamics of 6 MSAs in California: actual price vs estimated price. The estimation is based on Model 7. The prices are aggregated by year and MSA.



**Figure 7:** graphical illustration of the (net) production and amenity channels. The shift of the housing supply or the demand curve is triggered by an increase in land use regulation.



**Figure 8:** kernel density of CALURI and relative restrictiveness indices (RRI). RRI is defined as the difference between the neighboring regulatory index and CALURI of the city. We report three ways of constructing the neighboring regulatory index, with the weight indicated in the parentheses.



(a) weight: inverse distance sq.

(b) weight: gravity (per capita income\*inv. distance sq.)

**Figure 9:** CALURI vs relative restrictiveness index. Panels (a) and (b) show the scatter plots using different weights in the construction of the neighboring regulatory index. The relative restrictiveness index (RRI) of a city is defined as the difference between the neighboring regulatory index and CALURI of the city. We rescale RRI to the positive real line with the same mean (4) for comparability. We separately mark 4 MSAs (LA = Los Angeles-Long Beach-Anaheim MSA; SF = San Francisco-Oakland-Hayward MSA; SD = San Diego-Carlsbad MSA; VT = Oxnard-Thousand Oaks-Ventura MSA) that are large in terms of and population and the number of cities, and that have high survey response rates in the Wharton Residential Land Use survey (Gyourko, Saiz and Summers, 2008).



## Appendix

### A.1 Proof of Uniqueness of the Equilibrium

First, rewrite the market clearing condition of city  $j$  as follows.

$$q_j = b_j r_j (q_j)^{\frac{1}{1-\theta}}, \text{ where } b_j = \frac{A_0^{\frac{1}{1-\theta}}}{\alpha Y_0 Z_j^\phi \tau_j^\eta} \left( \frac{\theta}{c_j} \right)^{\frac{\theta}{1-\theta}} \quad (30)$$

We express  $r_j$  as a function of  $q_j$ . The equilibrium condition of location choices (5) can be written as

$$q_j x = Z_j^\phi \tau_j^\eta r_j (q_j)^{-\alpha}, \text{ where } x = \sum_{k \in S} Z_k^\phi \tau_k^\eta r_k^{-\alpha} \quad (31)$$

Combine two equations and eliminate  $r_j$ .

$$q_j(x) = Z_j^{\frac{\phi}{\alpha(1-\theta)+1}} \tau_j^{\frac{\eta}{\alpha(1-\theta)+1}} b_j^{\frac{\alpha(1-\theta)}{\alpha(1-\theta)+1}} x^{-\frac{1}{\alpha(1-\theta)+1}} \quad (32)$$

For an arbitrary  $n$ , we can prove that there is a unique set of moving probabilities that solve the system of equations. We can solve  $x$  from the following equation.

$$\sum_{k \in S} q_j(x) = 1 \quad (33)$$

LHS of (33) is a strictly decreasing function of  $x$ , while RHS is a weakly decreasing function of  $x$ . There is a unique solution to the equation. Given  $x$ , we can use (33) to fully solve the set of moving probabilities.

For the special case of  $n = 2$ , we can solve the model. With  $q_j + q_k = 1$  and  $S = \{j, k\}$ ,

$$q_j = \frac{(Z_j^\phi \tau_j^\eta)^{1-\lambda} b_j^\lambda}{(Z_j^\phi \tau_j^\eta)^{1-\lambda} b_j^\lambda + (Z_k^\phi \tau_k^\eta)^{1-\lambda} b_k^\lambda}, \text{ where } \lambda = \frac{\alpha(1-\theta)}{\alpha(1-\theta)+1} \quad (34)$$

Combined with (30), the log housing price can be expressed in the linear form (13).

A.2 CALURI by MSA and City

**Table A1. City and CALURI**

MSA and City	CALURI	MSA and City	CALURI
<b>Bakersfield</b>	0.291	Signal Hill city	-0.203
McFarland city	1.735	Redondo Beach city	-0.245
Bakersfield city	-0.308	Pico Rivera city	-0.279
Delano city	-1.052	Lakewood city	-0.279
<b>Chico</b>	0.190	Tustin city	-0.284
Orland city	0.721	La Palma city	-0.289
Paradise town	0.527	Palmdale city	-0.297
Willows city	-0.163	Claremont city	-0.302
Gridley city	-0.288	Los Alamitos city	-0.351
Chico city	-0.343	Commerce city	-0.385
<b>Fresno</b>	1.032	Whittier city	-0.389
Huron city	2.908	South Pasadena city	-0.396
Selma city	2.429	Lancaster city	-0.455
Kingsburg city	0.841	La Canada Flintridge city	-0.459
Fresno city	0.452	Avalon city	-0.544
Parlier city	0.369	Hermosa Beach city	-0.561
Reedley city	0.236	Alhambra city	-0.631
<b>Hanford-Corcoran</b>	-1.280	Calabasas city	-0.775
Corcoran city	-0.508	Carson city	-0.962
Avenal city	-2.112	Huntington Beach city	-0.975
<b>Los Angeles-Long Beach-Anaheim</b>	-0.195	La Habra city	-1.042
Los Angeles city	3.382	Agoura Hills city	-1.157
Glendora city	2.408	Palos Verdes Estates city	-1.178
El Monte city	2.342	Covina city	-1.648
San Fernando city	1.558	Montebello city	-1.730
Irvine city	0.924	Santa Ana city	-1.751
Seal Beach city	0.897	Baldwin Park city	-1.889
Brea city	0.546	Arcadia city	NA
Pomona city	0.322	San Marino city	NA
Compton city	0.280	<b>Madera</b>	-0.772
La Habra Heights city	0.131	Mammoth Lakes town	-0.623
El Segundo city	0.077	Chowchilla city	-0.772
Rancho Santa Margarita city	0.037	<b>Merced</b>	0.830
Beverly Hills city	0.032	Los Banos city	2.046
Anaheim city	-0.008	Merced city	1.231
Dana Point city	-0.025	Dos Palos city	0.728
San Clemente city	-0.115	Gustine city	-0.081
Gardena city	-0.142	<b>Modesto</b>	-0.036
Fountain Valley city	-0.198	Waterford city	0.458
Long Beach city	-0.198	Ceres city	-0.684

**Table A1. City and CALURI (continued)**

MSA and City	CALURI	MSA and City	CALURI
<b>Napa</b>	0.414	Rancho Cordova city	0.070
Calistoga city	1.114	West Sacramento city	-0.353
St. Helena city	0.363	Rocklin city	-0.510
American Canyon city	0.242	Placerville city	-1.072
<b>Oxnard-Thousand Oaks-Ventura</b>	0.254	<b>Salinas</b>	-0.294
Santa Paula city	2.037	Carmel-by-the-Sea city	2.031
San Buenaventura (Ventura) city	1.861	Soledad city	0.226
Camarillo city	0.020	Greenfield city	-0.914
Oxnard city	-0.071	Seaside city	-1.466
Ojai city	-0.081	<b>San Diego-Carlsbad</b>	-0.253
Simi Valley city	-0.327	Encinitas city	1.630
Port Hueneme city	-1.453	Coronado city	1.207
<b>Redding</b>	-0.307	Del Mar city	0.599
Shasta Lake city	0.173	San Diego city	0.303
Anderson city	-0.584	El Cajon city	0.217
Weed city	-0.768	Vista city	-0.086
<b>Riverside-San Bernardino-Ontario</b>	-0.081	Lemon Grove city	-0.102
Beaumont city	1.761	National city	-0.596
Banning city	1.654	Poway city	-0.676
Rancho Mirage city	0.921	Solana Beach city	-0.972
Riverside city	0.842	Santee city	-1.035
Coachella city	0.675	<b>San Francisco-Oakland-Hayward</b>	-0.219
Needles city	0.617	Portola Valley town	1.899
Chino city	0.590	San Francisco city	1.040
Corona city	0.419	Belmont city	0.839
Loma Linda city	0.402	Redwood city	0.648
Norco city	0.353	Hercules city	0.582
Palm Desert city	-0.180	San Leandro city	0.578
Yucaipa city	-0.236	Larkspur city	0.515
Chino Hills city	-0.287	Woodside town	0.402
Blythe city	-0.299	Martinez city	0.256
Colton city	-0.599	Corte Madera town	0.196
Montclair city	-0.625	San Ramon city	0.159
Barstow city	-0.674	Burlingame city	0.022
Hesperia city	-0.745	Mill Valley city	-0.139
Big Bear Lake city	-1.136	Fremont city	-0.338
Canyon Lake city	-3.222	Brentwood city	-0.397
<b>Sacramento-Roseville-Arden-Arcade</b>	-0.001	Pittsburg city	-0.450
Folsom city	1.370	Millbrae city	-0.614
Lincoln city	0.112	Dublin city	-0.664

**Table A1. City and CALURI (continued)**

MSA and City	CALURI	MSA and City	CALURI
Sausalito city	-0.700	Santa Maria city	-0.519
Menlo Park city	-0.703	<b>Santa Rosa</b>	0.653
Pinole city	-0.732	Sonoma city	2.309
Piedmont city	-0.778	Rohnert Park city	0.719
San Pablo city	-0.987	Windsor town	-0.027
Emeryville city	-1.430	<b>Stockton-Lodi</b>	-0.110
Hillsborough town	-3.232	Ripon city	0.592
<b>San Jose-Sunnyvale-Santa Clara</b>	-0.657	Jackson city	-0.219
Campbell city	-0.158	Manteca city	-0.407
Santa Clara city	-0.605	Lodi city	-0.769
Morgan Hill city	-0.824	<b>Vallejo-Fairfield</b>	0.187
San Jose city	-1.007	Benicia city	0.187
<b>San Luis Obispo-Paso Robles-Arroyo Grande</b>	0.531	<b>Visalia-Porterville</b>	-0.292
San Luis Obispo city	1.603	Visalia city	0.606
Morro Bay city	1.046	Exeter city	-0.060
Arroyo Grande city	0.590	Woodlake city	-0.079
Grover Beach city	-0.526	Farmersville city	-0.674
<b>Santa Cruz-Watsonville</b>	-0.036	Porterville city	-0.806
Scotts Valley city	0.358	<b>Yuba City</b>	0.849
Capitola city	-0.731	Live Oak city	1.532
<b>Santa Maria-Santa Barbara</b>	-0.158	Williams city	0.922
Buellton city	0.098	Yuba city	-1.026

Note: MSAs are sorted in alphabetic order. Within each MSA, cities are sorted by CALURI in descending order. CALURI is defined as the first factor using the principal factor analysis. 8 sub-indices that have city-level variations from the Wharton Residential Land Use Survey are used: local political pressure index (LPPI), local zoning approval index (LZAI), local project approval index (LPAI), density restriction index (DRI), open space index (OSI), exactions index (EI), supply restriction index (SRI), approval delay index (ADI). Source: Gyourko, Saiz and Summer (2008) and authors' calculation.

**Table A2. Survey Response Rates by CBSA in California**

CBSA (MSA/μMSA)	City and Town			Principal City		
	CA	GSS	%	CA	GSS	%
Bakersfield	11	3	27	1	1	100
Chico	5	3	60	1	1	100
Clearlake	2	1	50	1	0	0
Crescent City	1	1	100	1	1	100
El Centro	7	0	0	1	0	0
Eureka-Arcata-Fortuna	7	1	14	3	1	33
Fresno	15	6	40	1	1	100
Hanford-Corcoran	4	2	50	2	1	50
Los Angeles-Long Beach-Anaheim	122	48	39	25	13	52
Madera	2	1	50	1	0	0
Merced	6	4	67	1	1	100
Modesto	9	2	22	1	0	0
Napa	5	3	60	1	0	0
Oxnard-Thousand Oaks-Ventura	10	7	70	4	3	75
Red Bluff	3	1	33	1	0	0
Redding	3	2	67	1	0	0
Riverside-San Bernardino-Ontario	52	20	38	9	3	33
Sacramento--Roseville--Arden-Arcade	19	6	32	5	2	40
Salinas	12	4	33	1	0	0
San Diego-Carlsbad	18	11	61	4	2	50
San Francisco-Oakland-Hayward	65	25	38	12	4	33
San Jose-Sunnyvale-Santa Clara	17	4	24	7	2	29
San Luis Obispo-Paso Robles-Arroyo Grande	7	4	57	2	1	50
Santa Cruz-Watsonville	4	2	50	2	0	0
Santa Maria-Santa Barbara	8	2	25	3	1	33
Santa Rosa	9	3	33	2	0	0
Sonora	1	0	0	0	0	0
Stockton-Lodi	7	3	43	1	0	0
Susanville	1	1	100	1	1	100
Truckee-Grass Valley	3	0	0	2	0	0
Ukiah	4	1	25	1	1	100
Vallejo-Fairfield	7	1	14	2	0	0
Visalia-Porterville	8	5	63	2	2	100
Yuba City	4	2	50	1	1	100
Total	458	179	39	103	43	42

Note: the list of Core Based Statistical Areas (CBSA) includes both MSAs and μMSAs. There are 482 jurisdictions in California, with 458 tied to the CBSA codes in California. “CA” and “GSS” counts the total number of cities and towns in California (CA) and in the sample of Gyourko, Saiz and Summers (2008) (GSS) respectively. The columns with “%” calculate the city share of GSS sample in California. The definition of the principal cities is based on the historical delineation files of the Principal cities of metropolitan and micropolitan statistical areas (2006) from the Census Bureau. The definition of CBSA is based on 2010 Geographic Terms and Concepts from the Census Bureau.

### *A.3 Data Filtering and Construction of ZTRAX Variables*

The Whole ZTRAX database consists of two parts: ZTrans (transaction data) and ZAsmt (assessment data) that can be linked by a unique parcel ID. For most states, the sample prior to 2005 are scarce; for California, the database can trace back to transactions as early as 1993. I first restrict the sample to the transaction with the sales prices more than 5,000 US dollars in California. California data before 1993 (inclusive) is extremely sparse, so our ZTRAX data starts from 1993:M1 and ends in 2017:M6. For the other US states, the quality of data before 2005 is generally worse than that after the 2005. California data allows us to examine the housing prices and property characteristics in a much longer horizon.

We keep residential properties only and drop any commercials, manufactural, and foreclosure sales. Based on the Property Use Standard Code and Assessment Land Use Standard Code, we identify and focus on the residential types including single family residentials, townhouses, cluster homes, condominiums, cooperatives, planned unit developments and those inferred as single family residentials by Zillow. A transaction can involve multiple parcels, we focus on transactions with a single parcel only. We only keep the transactions that can be linked to the housing properties in the assessment data. About 89% of the transactions are matched to the assessment files.

The data fields we use from the housing data include: transaction date, geographic location (county, city, CBSA, address longitude and latitude), the sales prices, the number of bedrooms, the number of bathrooms, the year a property was built, the square foot of a property and the miles to the nearest core cities. There are other housing characteristics available in the database, but they are in general not commonly populated.

There is no separate field to directly observe the size of a property, so we construct the field as follows. We are able to observe the following fields relevant to the size of a property: building area living, building area finished, effective building area, gross building area, building area adjusted, building area total, building area finished living, base building area, heated building area. To take the maximum of the fields above and define it as the square footage of a property.

The miles of a property to the nearest core cities is constructed as follows. We first identify the CBSA where a property is located. We use the leading principal cities listed in the name of an MSA and geocode the city centers using the application program interface (API) of Google Map. We calculate the great-circle distance in miles from each property to the center of each leading principal city in the CBSA and define the minimum as the distance to the principal city. A small number of cities are not assigned to any CBSA. We thus geocode the distance from the properties in each of the cities to the nearest leading principal cities in all CBSAs in California using the API of Google Map.<sup>53</sup> We assign these cities to the nearest MSAs, so they don't fall out of sample in the analysis.

<sup>53</sup> 6 cities whose fips county codes don't fall in any MSA in California are assigned to the nearest metropolitan statistical area. They are Jackson City, Williams City, Orland City, Willows City, Mammoth Lakes Town, and Weed City.

The number of annual transactions in California ranges from 100,000 to 600,000, depending on the year. There are about 13 million transactions in total from about 1,400 cities available to be matched to the Wharton Land Use Survey data.

#### ***A.4 Auxiliary Regression***

We log-linearize the definition identity of amenity demand as follows.

$$A_j = Z_j^{\phi-1} \tau_j^\eta \Leftrightarrow z_j = -\frac{\eta}{\phi-1} \ln \tau_j + \ln A_j \quad (35)$$

We exogenously estimate the elasticity of per capita income  $Z_j$  with respect to  $\tau_j$  for an additional moment condition in the estimation. Amenity is unobservable, so it is treated as the error plus a constant term. Our data points are 25 MSAs in year 2006 and the regression analysis is cross-sectional. In Table A2, we report three specifications. Model 1 include CALURI as the only independent variable. Model 2 add three more variables: the share of high-tech jobs from the regional dataset of Moody's Analytics collected from BLS and BEA, the mean household age from American Community Survey (ACS) Public Use microdata, and the share of high education (college + graduate study) from ACS microdata. These three factors are highly correlated with per capita income. We show their correlation in Table 6.

Model 3 include more controls based on Model 2. Data on the net migrants (in thousand) and total population (in thousand) come from the regional data set of Moody's Analytics collected from the Census Bureau. Data on employment (in thousand) comes from Moody's Analytics collected from BLS (CES and QCEW). The minority share is the fraction of non-white individuals surveyed in ACS microdata. The cost-of-doing-business index is provided by Moody's Analytics. The index is the weighted average of unit labor costs, energy costs, tax burden and office rents. It is an index that standardizes the US average to 100.

We find that the coefficients of CALURI is close to zero. The insignificance of the coefficient is probably due to the small size of the MSAs. We use the estimate from Model 3 to construct the following condition for estimation.

$$\eta = 0.00331 \cdot (\phi - 1) \quad (36)$$

**Table A3. Auxiliary Regression of log GDP per capita**

	Model 1	Model 2	Model 3
CALURI	0.0176 (0.097)	0.0131 (0.055)	-0.00331 (0.028)
share of high-tech job		0.00747 (0.008)	-0.00167 (0.005)
log household age		-0.190 (0.949)	0.313 (0.576)
share of high education		2.275** (0.808)	-0.0173 (0.470)
net migrant			0.000664 (0.002)
log population			-1.001*** (0.189)
log employment			1.012*** (0.177)
business cost index			-0.00128 (0.004)
minority share			0.166 (0.202)
Constant	3.855*** (0.050)	3.728 (3.148)	3.837 (2.350)
Observations	25	25	25

Note: robust standard errors in the parentheses. \* p<0.10, \*\* p<0.05, \*\*\* p<0.010.



### A.5 Structural Parameter Estimates

In Table A4, we report the estimation of the structural parameters. Without housing characteristics properly controlled in Model 1, we tend to underestimate  $\theta$  by 33%, but to overestimate  $\alpha$  and  $\phi$  by 49% and 1.5% respectively, compared to the estimated values in Model 2. GMM-IV estimations produce comparable estimated parameters in Models 3 and 4. Compared with Model 2, Model 4 which treats contemporaneous per capita income as endogenous yield bigger estimated values of  $\phi$  and  $\theta$ . We find that  $\theta = 0.045$  and  $\phi = 1.803$  in Model 4, while  $\theta = 0.043$  and  $\phi = 1.753$  in Model 2. The estimation in Model 4 indicates that the income elasticity of amenity demand is 0.803 (or  $1.803 - 1$ ). That is, 1% increase in the per capita income increases the amenity demand by 0.803% on average.<sup>54</sup>

**Table A4. Benchmark Estimation: Structural Parameters**

	Model 1 GMM	Model 2 GMM	Model 3 GMM-IV	Model 4 GMM-IV
$\theta$	0.029*** (0.000)	0.043*** (0.000)	0.042*** (0.000)	0.045*** (0.000)
$\lambda$	0.787*** (0.002)	0.710*** (0.002)	0.720*** (0.002)	0.751*** (0.002)
$\phi$	1.779*** (0.005)	1.753*** (0.004)	1.754*** (0.004)	1.803*** (0.004)
$\alpha$	3.811*** (0.048)	2.554*** (0.040)	2.681*** (0.042)	3.152*** (0.042)
$\eta$	0.003*** (0.000)	0.002*** (0.000)	0.002*** (0.000)	0.003*** (0.000)

Note: robust standard errors in the parentheses. \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.010$ . The lag terms of log real GDP per capita and log mean GDP per capita in California are used as IVs of their contemporaneous terms in Models 3-4; the share of high education, the population age and the share of high-jobs are additional IVs of Model 4.

In Table A5, we replicate the GMM estimations in Table 5, but instead use WALURI as the regulatory index instead. Compared to CALURI constructed only from the subsample of California cities, WALURI is estimated nationally from more than 2,000 jurisdictions.

In Table A6, we report the estimates of the structural parameters under four model specifications. The average income elasticity of amenity demand is adjusted upward from 0.803 in the benchmark to the 1.030 in the fully extended model. The coefficient of the quadratic term  $\phi_2$  is positive, indicating that the income elasticity of amenity demand increases with income.

<sup>54</sup> In the model, the parameters are not free to take any value on the real line. In the GMM or GMM-IV estimations, we solve the minimization problems without parameter constraints, so our estimations of  $\alpha$  may fall out of the unit interval.

**Table A5. Estimation with WRLURI**

	Model 1	Model 2	Model 3	Model 4
	GMM	GMM	GMM-IV	GMM-IV
WRLURI	0.109*** (0.000)	0.117*** (0.000)	0.117*** (0.000)	0.124*** (0.000)
log GDP per capita	1.185*** (0.001)	1.295*** (0.001)	1.280*** (0.001)	1.265*** (0.001)
log Avg. GDP per cap	0.556*** (0.005)	0.405*** (0.004)	0.427*** (0.004)	0.482*** (0.004)
Bedroom: 1		-0.0670*** (0.003)	-0.0677*** (0.003)	-0.0639*** (0.003)
Bedroom: 2		-0.230*** (0.003)	-0.231*** (0.003)	-0.223*** (0.003)
Bedroom: 3		-0.318*** (0.003)	-0.320*** (0.003)	-0.315*** (0.003)
Bedroom: 4+		-0.381*** (0.003)	-0.383*** (0.003)	-0.380*** (0.003)
Bathroom: 1		0.107*** (0.006)	0.107*** (0.006)	0.0712*** (0.006)
Bathroom: 2		0.185*** (0.006)	0.187*** (0.006)	0.138*** (0.006)
Bathroom: 3		0.136*** (0.006)	0.139*** (0.006)	0.0843*** (0.006)
Bathroom: 4+		0.272*** (0.006)	0.277*** (0.006)	0.229*** (0.006)
log sq.feet		1.066*** (0.001)	1.065*** (0.001)	1.082*** (0.001)
log miles to core cities		-0.0236*** (0.000)	-0.0235*** (0.000)	-0.0292*** (0.000)
SFR		-0.0402*** (0.001)	-0.0420*** (0.001)	-0.0555*** (0.001)
condominium		0.0118*** (0.001)	0.0118*** (0.001)	0.00944*** (0.001)
Age: 1-5		0.134*** (0.001)	0.134*** (0.001)	0.120*** (0.001)
Age: 6-10		0.0858*** (0.001)	0.0860*** (0.001)	0.0740*** (0.001)
Age: 11-20		0.0645*** (0.001)	0.0649*** (0.001)	0.0556*** (0.001)
Age: 21-30		0.0544*** (0.001)	0.0553*** (0.001)	0.0408*** (0.001)
Age: 31-40		0.103*** (0.001)	0.104*** (0.001)	0.0898*** (0.001)
Age: 41-50		0.122*** (0.001)	0.124*** (0.001)	0.114*** (0.001)
Age: > 50		0.124*** (0.001)	0.127*** (0.001)	0.118*** (0.001)
growth rate of mortgage debt	3.057*** (0.008)	3.006*** (0.006)	3.000*** (0.006)	2.865*** (0.006)
30-year FRM rate	-3.894*** (0.049)	-3.150*** (0.040)	-3.064*** (0.041)	-2.553*** (0.041)
Constant	5.658*** (0.021)	-1.916*** (0.021)	-1.945*** (0.021)	-2.178*** (0.021)
Observations	5,259,215	5,259,215	5,259,215	5,259,215

Note: robust standard errors in the parentheses. \* p<0.10, \*\* p<0.05, \*\*\* p<0.010. The base levels of the factor variables are: no bedroom, no bathroom, property use other than single-family and condominium, new property (age is zero). The lag terms of log real GDP per capita and log mean GDP per capita in California are used as IVs of their contemporaneous terms in Models 3-4; the share of high education, the population age and the share of high-jobs are additional IVs of Model 4.

**Table A6. Estimation with Non-Linear Effects: Structural Parameters**

	Model 4 GMM-IV	Model 5 GMM-IV	Model 6 GMM-IV	Model 7 GMM-IV
$\theta$	0.045*** (0.000)	0.045*** (0.028)	0.048*** (0.000)	0.049*** (0.000)
$\lambda$	0.751*** (0.002)	0.748*** (0.001)	0.684*** (0.002)	0.678*** (0.002)
$\alpha$	3.152*** (0.033)	3.106*** (0.092)	2.273*** (0.033)	2.212*** (0.033)
$\delta_0$	1	-0.944*** (0.385)	1	-5.124*** (0.097)
$\delta_1$	0	0.489*** (0.097)	(0.000)	1.540*** (0.024)
$\phi_0$	0	0	16.748*** (0.066)	17.458*** (0.067)
$\phi_1$	1.803*** (0.005)	1.800*** (0.053)	-6.389*** (0.032)	-6.748*** (0.033)
$\phi_2$	0	0	1.059*** (0.004)	1.104*** (0.004)
$\phi_{avg}$	1.803*** (0.005)	1.800*** (0.053)	2.032*** (0.005)	2.030*** (0.005)
$\eta$	0.003*** (0.000)	0.003*** (0.000)	0.003*** (0.000)	0.003*** (0.000)

Note: robust standard errors in the parentheses. \* p<0.10, \*\* p<0.05, \*\*\* p<0.010.

### A.6 Quantifying the Contribution of Production and Amenity Channel to Housing Prices

We evaluate the contribution of the production, the amenity, and the general equilibrium channels at the MSA level, because our measure of the per capita income only varies by MSA. We aggregate the city-level regulatory measure using the probability weight provided by Gyourko, Saiz and Summers (2008). For any MSA-year combination, we calculate the levels of the estimated housing prices  $P_{mt}$  and the counterfactual prices that exclude the production, the amenity or the GE channels  $P_{mt,-prod}$ ,  $P_{mt,-amen}$  and  $P_{mt,-ge}$  as follows.

$$\begin{aligned}
 P_{mt} &= \exp[E_{ij}(\ln p_{ijmt})] \\
 P_{mt,-prod} &= \exp[E_{ij}(\ln p_{ijmt}) - E_j(prod_{jmt})] \\
 P_{mt,-amen} &= \exp[E_{ij}(\ln p_{ijmt}) - E_j(amen_{jmt})] \\
 P_{mt,-ge} &= \exp[E_{ij}(\ln p_{ijmt}) - E_j(ge_{jmt})]
 \end{aligned}
 \tag{37}$$

$E_{ij}$  denotes the empirical mean aggregating households and cities. For the counterfactual price excluding the production channel (hereafter, counterfactual production price), we interpret it as the price that normalizes the production effect to the mean but keeps everything else constant. For the counterfactual price excluding the amenity channel (hereafter, counterfactual amenity price), we interpret it as the price that normalizes the amenity effect to the mean but keeps everything else constant. For the counterfactual price excluding the GE channel (hereafter, counterfactual GE price), we can interpret it as the price that normalizes the GE effect to the mean but keeps everything else constant.

To evaluate the production effect of regulation, we conduct the experiments that exclude the production channel. The result by MSA is reported in Column 1 of Table A7. The percentage deviation of an MSA measures the size of the production effect. For an MSA with the average per capita income, a positive (negative) deviation indicates how much the price will increase (decrease) due to the production effect if the cost of housing supply counterfactually increases (decreases) from a below-mean (above-mean) level to the mean.

To evaluate the amenity effect of regulation, we conduct the experiments that exclude the amenity channel. The result by MSA is reported in Column 2 of Table A7. The percentage deviation of an MSA measures the size of amenity effect. For an MSA with the average per capita income, a positive (negative) deviation indicates how much the price will increase (decrease) due to the amenity effect if the amenity level increases (decreases) from a below-mean (above-mean) level to the mean.

To evaluate the GE effect of regulation, we conduct the experiments that exclude the GE channel. The result by MSA is reported in Column 3 of Table A7. The percentage deviation of an MSA measures the size of GE effect. For an MSA with average per capita income, a positive (negative) deviation indicates how much the price will increase (decrease) due to the GE effect if households are counterfactually not moving out (in) for higher utility.

Similarly, we also calculate the levels of the counterfactual prices that exclude the production with GE effect  $P_{mt,-prod,ge}$ , and the amenity channel with GE effect  $P_{mt,-amen,ge}$  as follows.

$$\begin{aligned}
 P_{mt,-prod,ge} &= \exp[E_{ij}(\ln p_{ijmt}) - E_j(prod_{jmt,ge})] \\
 P_{mt,-amen,ge} &= \exp[E_{ij}(\ln p_{ijmt}) - E_j(amen_{jmt,ge})]
 \end{aligned}
 \tag{38}$$

The production and the amenity channels with GE effects are reported in Columns 4-5 in Table A7.

**Table A7. Counterfactual Experiments: Size of the Channels**

MSA	Prices excluding			Prices excluding	
	production	amenity	GE	production with GE	amenity with GE
Bakersfield	1.02	0.10	-0.55	0.49	0.08
Chico	0.33	0.03	-0.18	0.16	0.03
Fresno	-1.61	-0.17	0.90	-0.75	-0.14
Hanford-Corcoran	-0.01	0.33	-1.73	-1.69	0.27
Los Angeles-Long Beach-Anaheim	-3.78	-0.24	1.27	-2.60	-0.19
Madera	1.07	0.23	-1.23	-0.13	0.19
Merced	-0.50	-0.46	2.51	1.91	-0.38
Modesto	0.86	0.14	-0.73	0.14	0.11
Napa	-1.72	-0.12	0.66	-1.10	-0.10
Oxnard-Thousand Oaks-Ventura	-0.74	-0.07	0.39	-0.36	-0.06
Redding	1.50	0.11	-0.60	0.90	0.09
Riverside-San Bernardino-Ontario	-0.43	-0.07	0.39	-0.06	-0.06
Sacramento-Roseville-Arden-Arcade	-0.76	-0.05	0.28	-0.49	-0.04
Salinas	-0.30	-0.04	0.20	-0.11	-0.03
San Diego-Carlsbad	-1.10	-0.07	0.39	-0.73	-0.06
San Francisco-Oakland-Hayward	-0.95	-0.05	0.26	-0.69	-0.04
San Jose-Sunnyvale-Santa Clara	6.02	0.30	-1.60	4.37	0.25
San Luis Obispo-Paso Robles-Arroyo Grande	-3.76	-0.29	1.57	-2.30	-0.24
Santa Cruz-Watsonville	0.35	0.03	-0.16	0.20	0.02
Santa Maria-Santa Barbara	2.25	0.16	-0.85	1.41	0.13
Santa Rosa	-3.70	-0.31	1.66	-2.16	-0.25
Stockton-Lodi	0.87	0.14	-0.74	0.15	0.11
Vallejo-Fairfield	-0.40	-0.06	0.32	-0.09	-0.05
Visalia-Porterville	-0.19	-0.06	0.33	0.12	-0.05
Yuba City	0.78	0.22	-1.19	-0.38	0.18