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Further Empirical Evidence on Property Taxation and the Occurrence of Urban Sprawl

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Abstract

How does the effective rate of property taxation in a United States urbanized area influence the occurrence of urban sprawl (measured as greater land used for a given population) observed there? Economic theory indicates that the portion of property taxation assessed on the non-land components of a residential parcel exerts opposite influences on the intensity of capital (building and machinery) use on the parcel through a negative Improvement Effect and a positive Dwelling Size Effect. An empirical assessment of this issue is therefore necessary; however, methodological concerns in earlier empirical analyses cast doubt on the reliability of what previously reported. The use here of years 2000 and 2010 panel data from 370 comparable, single-state United States urbanized areas, coupled with a more fully specified set of explanatory variables and fixed-effects regression methodology, results in greater confidence that the estimated influences of effective rates of commercial, industrial, single family residential, and multifamily residential property taxation on land use is valid.

Research Highlights

- Regression results indicate that a higher rate of effective commercial property taxation decreases the amount of land used for a given population (reduced sprawl), while a higher rate of effective multifamily residential property taxation raises the amount of land used for a given population (increased sprawl).

- After controlling for urbanized area fixed effects, the rates of effective property taxation on single family residential and industrial property taxation revealed no measurable influences on amount of land used for a given population.

- The findings for the effective rates of commercial and multifamily residential property taxation confirm Henry George's premise that the use of traditional property taxation assessed on both the land and improvement components of a parcel distorts the intensity of land use.

The policy implications of these findings are that an increase (decrease) in the rate of effective property taxation applied to commercial (multifamily residential) properties could be used to decrease the amount of land used for a given population in a United States urbanized area. To yield the same decrease in land usage for a given population, the decrease in the effective rate of multifamily housing property taxation could be about half of the increase in the effective rate of commercial property taxation.

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Professor Wassmer directs the Sacramento State Master's Program in Urban Land Development and teaches master's level courses in applied microeconomics and public policy, urban economics and public policy, benefit/cost analysis, regression analysis, and state and local public finance. In 2011, Rob earned the Sacrament State Outstanding Scholarly Achievement Award. His research on topics relating to state/local public finance and urban economic development has appeared in academic journals like *Land Economics, Urban Studies, Public Finance Review, Public Budgeting and Finance, Regional Science and Urban Economics, National Tax Journal, Journal of Housing Economics, Economic Development Quarterly, Journal of Policy Analysis and Management, and the Journal of Urban Economics.* Professor Wassmer (coauthored with John Anderson) has a book *Bidding for Business: The Efficacy of Local Economic Development Incentives* (2000) published by the Upjohn Institute for Employment Research. He also has produced an edited collection of previously published articles on *Readings in Urban Economics: Issues and Public Policy* (2000) published by Blackwell. Recently he has placed chapters in books produced by the Lincoln Institute of Land Policy, Urban Institute, and the Brookings Institution. He also serves an associate editor of the academic journal *Economic Development Quarterly*.

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Introduction

The objective of this research is answers to the twofold question: Does the effective rate of property taxation in a United States urban area (UA) influence its occurrence of urban sprawl as measured by greater land used for a given population? If so, then what is the direction and magnitude of the influence?

As primarily practiced in the United States, property taxation falls upon both the land and improvement portions of the taxed parcel. The portion of the property tax falling upon land value is one of the *best* taxes—a result stemming from its inability to distort the supply of raw land. The portion falling upon the improvements (buildings and other fixtures) to the land is one of the *worst* taxes—per its discouragement of improvements to unimproved land (Vickrey 1999; Oates and Schwab 2009). This line of thought was the basis for George's (1879) advocacy for a single tax on land value assessed on its highest and best use, and more contemporary arguments for limiting the rate of traditional property taxation on mobile business activity (Kenyon, Langley, and Paquin 2012).

Most jurisdictions in the United States levy a property tax that does not distinguish between the land and improvement components of the property taxed. Instead, a single rate of taxation applies to the combined market value of a parcel's land and improvements in their current use. In 2012, this form of property taxation raised nearly one quarter of all own source state and local revenue in the United States, while the state and local governments of New Hampshire, New Jersey, Illinois, and Texas respectively garnered about 45, 37, 30, and 28 percent of their own source revenues from property taxation.[1] Given the likelihood that traditional property taxation distorts the capital intensity of land use, the question of the magnitude's distortion remains; chiefly, how does it translate into a policy-relevant outcome like the degree of urban sprawl (as measured by land used for a fixed population) occurring in a United States urbanized area. The degree of population density in an urbanized area is policy relevant since some have noted a link between it and a greater emission of greenhouse gases per resident and greater economic segregation.[2]

Evidence in support of the beneficial effects of traditional property taxation justifies its continued use. Alternatively, evidence of the negative effects of traditional property taxation supports the desirability of its discontinuation and possible replacement with a property tax assessed on only the market value of land in a parcel. A possible negative effect of traditional property taxation, in theory, is its encouragement of urban land development at a lower level of population density. However, theoretical explorations of this relationship remain inconclusive,

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[1]These percentages derived from 2012 values available at the State and Local Government Finance page of the U.S. Census Bureau's website (http://www.census.gov/govs/local).

[2]See Bart (2010) for an example of empirical research tying urban sprawl to climate change. Yang and Jargowsky (2006) offer empirical evidence on a positive link between the degree of suburbanization in a U.S. metropolitan area and increase in its economic segregation.

while methodological concerns in earlier empirical analyses cast doubt on the reliability of what was previously reported.

The remainder of this paper first summarizes the inconclusive nature of the previous theoretical findings. It then offers a brief description of the methods and findings from the previous empirical work on this question. Next, I offer the objectives of this research resulting from my assessment of these previous lines of inquiry, and cover the data and research methods employed to reach these objectives. The paper concludes with a discussion of findings and policy implications.

Inconclusive Nature of Previous Theoretical Findings

Theories regarding the influence of the rate of traditional property taxation on population density (land used for a given amount of population) in a UA account for the difference between the land and improvements components of this form of tax. Oates and Schwab (2009) explain that it is theoretically conclusive that a property tax levied only on land values based on highest and best use exert no influence as to when it is most profitable to develop a parcel of vacant land. However, with only a few exceptions, the value of land for tax purposes in the United States relies not on its highest and best use, but on its market value in actual use.[3] Since unimproved land in a UA occurs most likely at the fringe between urban and agricultural best use, the land component of traditional property taxation (since it relies on use value) is likely to yield lower population density (greater sprawl) the greater the rate of property taxation imposed upon it**.** But as Arnott (2005) shows, this non-neutrality of the land portion of the traditional property tax can be overcome by applying lower property tax rates to agricultural lands at the fringe (e.g., preferential treatment of farmland) and lower rates of property taxation to improvements at the urban core (e.g., directed property tax abatement).

Brueckner (2000) was the first to consider the theoretical influence of the improvement portion of the traditional property tax on an urban area's population density using the simplifying assumption that the urban area accommodates a static population in which each household only desires a fixed-size dwelling. The traditional property tax discourages real additions to land in the form of greater use of high-rise structures that stack fixed dwelling size units upon each other. If fewer multiple story dwellings exist in an urban area due to a greater rate of property taxation, an urban area with a greater average rate of property taxation likely exhibits less population density (greater sprawl). Brueckner also uses his model to demonstrate that urban sprawl arises from an underpricing of public infrastructure at the urban periphery due to average cost pricing on lower valued housing units—a consequence of using traditional property taxation used to finance it. Mitigation of this occurs if user/impact fees replace traditional property taxation.

Brueckner and Kim's (2003) extension of Brueckner (2000), allows for the possibility that the dwelling size of a household is no longer fixed and as likely, varies with the rate of property

[3]Bentick (1979), Anderson (1986), and others also use theory to model the expected result of using actual use value assessment in a land value tax and have shown that it results in an earlier development of raw land than if value assessment for property taxation based upon best use.

taxation. This introduces the possibility that if a portion of the property tax is born by consumers in the form of a higher price per unit of dwelling space, they may then desire a smaller dwelling size. A static urban population will accordingly live at a higher population density (decreased sprawl).[4] Thus, the portion of the traditional property tax assessed on real capital improvements results in two theoretically possible, but distinctly opposite, influences on population density in an urban area. Based on Brueckner and Kim's model, the influence that dominates depends on the relative responsiveness of the supply and demand of housing in an urban area to property taxation. If the consumer demand response for housing is rather insensitive to property tax rates, and if the housing supply of improvements is more sensitive to property tax rates, then a higher rate of property taxation will lead to greater sprawl. Brueckner and Kim (2003) believe this is very likely the case due to empirical evidence showing the greater mobility of housing producers relative to housing consumers. Nonetheless, Brueckner and Kim concede a degree of uncertainty in the dominance of one countervailing response to the other; suggesting the need for an empirical investigation to resolve this issue.

Sullivan (1984 and 1985) and Mills (1998) represent earlier theoretical approaches to determining the expected impact of traditional property taxation on urban population density. Sullivan employs a general equilibrium model of a small open urban area with residential and business sectors, and simulates the replacement of a pure land tax assessed on the highest and best use of land values with a traditional residential property tax. He reports that this increase in traditional property taxation reliance reduces population density (greater sprawl). Alternatively, Mills' theoretical approach uses a business-based model of a monocentric and open urban area where labor, capital improvements, and land generate a single output. Counter to the theoretical findings previously described, Mills reports that in his model a greater reliance on a conventional real estate tax results in a smaller urban area (less sprawl). He finds that the addition of a housing sector would not affect the basic insights from the model.

Inspired by Brueckner and Kim (2003), Song and Zenou (2006) adopt a similar model of suppliers (housing based land developers) and demanders (housing consumers) interacting in a closed and monocentric urban area to determine the direction of expected influence of the improvements component of traditional property taxation on population density. Instead of Brueckner and Kim's use of a constant elasticity of substitution utility function for dwelling size, Song and Zenou use a log-linear utility function that assumes the more reasonable variable elasticity of substitution utility function. Contrary to Brueckner and Kim's ambiguous finding regarding the relationship between the degree of urban property taxation and urban population density, Song and Zenou derive a certain negative relationship. Furthermore, Song and Zenou (2009) expand their earlier theoretical model of an urban area to be duo centric (with central and suburban jurisdictions) where housing developers and consumers enter each of the jurisdictions,

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[4]A theoretical debate still exists among economists as to whether a portion of the property tax rate is passed onto property consumers (*Traditional View*), absorbed by property owners (*Capital View*), or best viewed as irrelevant due to the non-distortionary result that housing consumers view property tax payments as payments for local government services that they desire (*Benefit View*). Brueckner and Kim's (2003) assumption is that consumers pay at least a portion of the local property tax and this reduces their demand for the size of a dwelling. The same result would occur if a portion of the property tax is born by producers of housing and this decrease in price received per unit of housing results in them offering smaller units for sale. The assumption of a traditional property tax resulting in a smaller dwelling, through its improvement portion, is only invalid if a pure Benefits View of property taxation applies. Wassmer (1993) and Zodrow (2001) note this as unlikely through reviews of the economic literature on property tax incidence.

resulting in equilibrium levels of housing investment and housing consumption.[5] The equilibrium in Song and Zenou's expanded theoretical model indicates that the ratio of the traditional property tax in the suburban jurisdiction to the central city jurisdiction exerts an ambiguous influence on the population density of the urban area.

England and Ravichandran (2010) and England, Zhao, and Huang (2014) offer variations on the previous theoretical models. They also find that the property tax rate levied on newly constructed buildings could affect the density of real estate development in an urban area. Through a theoretical examination of a developer's decision of how much capital to place on a vacant lot of a given size, the 2010 article shows that a higher rate of effective property taxation favors houses with fewer stories and a smaller foundation (lower density) while the 2014 article offers an extension of the previous theoretical model, allowing lot size as a choice and accounting for its acquisition cost. Property tax rates still affect residential lot sizes and the size of new homes, but the direction of this theoretical influence is uncertain.

This brief summary of the previous theoretical investigations indicates that greater reliance on traditional property taxation in an urban area exerts some influence on its population density (land used for a given population). When considering the collective theories just described, the overall direction of the expected influence points toward greater rates of property taxation generating greater population density. Nevertheless, most of the theories previously discussed leave open the possibility of realistic ways to invalidate this finding. The determination of this relationship, therefore, can only occur through a well-crafted empirical study. Before turning to a summary of the earlier empirical studies of this type, I first consider some of the insights gained from these previous theoretical inquiries relevant to my design of this appropriate empirical inquiry.

All of the previous theoretical models use greater land area after controlling for population (or population density) as a positive proxy for greater sprawl. An important insight from Arnott (2005) on what can alter the theoretical influence of traditional property taxation on an urbanized area's (UAs) population density is differences in the preferential tax treatment of property across United States UAs. This could come in the form of the favored tax treatment of farmland at the urban fringe and/or the reductions of property taxes paid on improvements at the urban core (property tax abatements). Importantly, the key difference between Brueckner's (2000) finding that greater property tax reliance yields greater sprawl, and Brueckner and Kim's (2003) and Song and Zenou's (2006) findings to the contrary, is the possibility of residents altering their size of residential dwelling due to the rate of property taxation. The assumptions made in Brueckner's earlier model did not allow for the existence of a *Dwelling-Size Effect* and thus, the result of a greater rate of property taxation being only the *Improvement Effect* that causes developers to construct shorter buildings with less fixed-size housing units (lower population density). Once the later models allows for the possibility of a property tax increase generating both shorter buildings and smaller dwelling sizes, the determination of this change to population density is dependent on whether the Improvement Effect or Dwelling-Size Effect dominates.

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[5]Song and Zenou received funding from a David C. Lincoln Fellowship in Land Value Taxation in year 2005 through a proposal titled *Property Tax or Land Tax as the Possible Cure for Urban Sprawl: Theory and Empirical Tests on Property Tax and City Sizes in the U.S.* (http://www.lincolninst.edu/pubs/993_Fellowships).

Consequently, it is crucial for empirical studies to control for differences across UAs in factors that influence the magnitudes of these two effects.

For the Improvement Effect, this would include measures of zoning or land use controls that restrict building height or size. While the Dwelling-Size Effect would include consumer characteristics that cause them to be less willing to alter their residential size (e.g., age, education, race/ethnicity, married, children present, etc.). Finally, Song and Zenou's (2009) theoretical model, which allowed for a more realistic polycentric UA, demonstrates the need to control both for differences in fiscal structures across the UA and in the rate of property taxation in the UA's central place(s) and suburban areas. In the empirical analysis offered here of what causes differences in population density across United States urbanized areas, I attempt to control for as many of these previously identified possible influences as the available data allows.

Table 1 offers a summary of the four theoretical models discussed. The summary focuses on differences in expectations of how higher property tax rates influence land area after controlling for population (population density). Following this, Table 2 includes a review of the few empirical studies that have attempted to do this. Table 3 consists of a synopsis of the empirical studies utilizing population density (or a similar measure of sprawl) as the dependent variable, but not including property taxation as an explanatory variable.

Table 1: Relevant Insights from Theoretical Work on the Influence of Property Taxation on Population Density

Author(s)	Prediction for Greater Property Tax Reliance	New (from Previous Model) Relevant Assumptions Made in Theoretical Model	New (from Previous Models) Implications for Regression Controls
Brueckner (2000)	**Less population density (increase in sprawl)**	Closed urban area with fixed population, Absentee land owners, Model of residential housing produced under constant returns to scale with capital and land, All residents identical, Fixed size of a one-family residential dwelling, Mono-centric employment, Constant-elasticity-substitution (CES) between housing and non-housing good in utility function, Infrastructure financed with general property tax	Population, Zoning or land use controls, User/impact fees infrastructure financing, Employment centrality, Commuting cost
Bruecker and Kim (2003)	**Less population density (increase in sprawl) if improvements effect dominates** (less capital-intensive land use through greater low-rise buildings): **Greater population density (decrease in sprawl) if dwelling-size effect dominates** (smaller single-family homes when excise tax effect of property tax raises housing price)	Variable size of residential dwelling	Factors influencing the supply sensitivity of land improvement intensity (high-rise buildings) and demand for size (square feet) of single-family to changes in property tax rate
Song and Zenou (2006)	**Greater population density (decrease in sprawl)**	Log-linear (variable-elasticity-substitution > 1) utility function	
Song and Zenou (2009)	*Prediction if Greater Property Tax Rate in Central City Relative to Suburban City* **Ambiguous**	Duo-centric employment (central city and suburban city), Different central city and suburban property tax rate	Ratio of central city to suburban city's property tax rate

Table 2: Previous Regression-Based Studies of Sprawl that Used Property Taxation as an Explanatory Variable

Author(s)	Dependent Variable	Other Explanatory Variables Included (unless noted, based on dependent variable measurement unit)	Measure of Property Taxation [Influence Derived on Sprawl]
Wassmer (2002)	Real value of *big box* sales (measured separately as retail, building material, and auto) in non-central places in 54 western U.S. metropolitan areas for years 1977, 1987, and 1997	Real median household income, Population, Previous ten-year population growth, percent population <18 years old, percent population >64 years old, Real value of agricultural products per acre in metro area, Closed-region urban containment (CRC) dummy, Years CRC in place, Isolated urban containment (IC) dummy, Years IC in place, Open-region urban containment (ORC) dummy, Years ORC in place, percent statewide municipal revenue from general sales taxes, percent statewide municipal revenue from other taxes (year and metropolitan area fixed effects)	Percent statewide municipal revenue from property taxes [**not statistically significant**]
Hettler (2002)	Suburban population as % metropolitan statistical area (MSA) population in 289 MSAs from 1960, 1970, 1980, and 1990	MSA population change in last 10 years, Central city (CC) per-capita taxes, CC percent spending on education, CC percent spending on highways, Suburban (SUB) per-capita taxes, SUB percent spending on education, SUB percent spending on highways (year and metropolitan area fixed effects)	CC percent tax revenue from property [10% increase yields a 1.2% **decrease in sprawl** (SUB % MSA pop)] SUB percent tax revenue from property [10% increase yields a 0.2**% decrease in sprawl** (SUB % MSA pop)]
Wassmer (2003)	Real value of retail sales in non-central places in 54 western U.S. metropolitan areas for years 1977, 1987, and 1997	Real median household income, Population, Previous ten-year population growth, percent population <18 years old, percent population >64 years old, Real value of agricultural products per acre in metro area, Closed-region urban containment (CRC) dummy, Years CRC in place, Isolated urban containment (IC) dummy, Years IC in place, Open-region urban containment (ORC) dummy, Years ORC in place, percent statewide municipal revenue from general sales taxes, percent statewide municipal revenue from other taxes (year and metropolitan area fixed effects)	Percent statewide municipal revenue from property taxes [**not statistically significant**]

Song and Zenou (2006)	Square mile size of 448 U.S. urbanized areas (UAs) for year 2000	Median household income, Population, Median agricultural land value per acre, Per-capita state and local government transportation expenditure	Weighted average of local property tax millage rates [10% increase yields a 4.0% **decrease in sprawl** (square miles)]
Wassmer (2006)	Square mile size of 452 U.S. urbanized areas (UAs) for year 2000	Median household income, Population, Percent population <18 years old, percent population >64 years old, Percent population born in state, Average household size, Agricultural land price per acre, Percent employed in wholesale/transportation/warehousing, Percent employed in management/finance/insurance/real estate, Percent employed in construction, Central places (CP) percent population poor, CP percent population Asian, CP percent population African America, CP percent population Latino, CP crime rate, CP median age home, Number of CPs, Number of counties, percent statewide municipal revenue from general sales taxes, percent statewide municipal revenue from other sales taxes, percent statewide municipal revenue from local income taxes, percent statewide municipal revenue from other taxes, Urban containment present and years in existence (various measures), Statewide urban growth management present and years in existence	Percent statewide municipal revenue from property taxes [**not statistically significant**]
Marshall (2008)	Calculated Gini coefficient (GC), index of dissimilarity (ID), and sprawl index (SI) that all positively measure the degree of sprawl occurring among Census tracts in 306 U.S. metropolitan statistical areas in 1990 and 2000	Real total personal income, Population, Previous ten-year population growth, Real value of agricultural products per acre in metro area, Real average home price, Percent eligible population attending public K-12 school, Central City (CC) percent MSA non-white population, Total municipalities, Statewide subnational taxes divided state personal income (year fixed effects)	Effective property tax rate (EPTR) measured as aggregate household specific property taxes paid divided by aggregate market value of home reported on Census long form [10% increase yields a 0.7% **decrease in sprawl** using GC, 1.4% **decrease in sprawl** using ID, and 2.8% **decrease in sprawl** using SI] Standard Deviation of EPTR [10% increase yields a 0.01% **increase in sprawl** using GC; not statistically significant for ID and SI]

Wassmer (2008)	Square miles (SM) or population density (PD) of 452 U.S. urbanized areas for year 2000	Per capita income, Percent households earning > $100K, Population (excluded when population density used as dependent variable), percent population <18 years old, percent population >64 years old, Percent households married, Agricultural land price per acre, Percent employed in wholesale/warehousing, Percent employed in management/finance/insurance/real estate, Percent employed in public administration, Percent households earning one or more autos, Central places (CP) percent population poor, CP percent population Asian, CP percent population African America, CP percent population Latino, CP crime rate, CP median age home, Percent CP housing two or less rooms, Number of counties, percent statewide municipal revenue from general sales taxes, percent statewide county revenue from general sales taxes, State dummies to account for state institutions and land use regulations	Percent statewide municipal revenue from property taxes [**not statistically significant** for SM, 10% increase yields a 1.4% **increase in sprawl*** using PD] Percentage statewide county revenue from property taxes [**not statistically significant** for SM and PD]
Song and Zenou (2009)	Acres, population density gradient (lower represents greater sprawl), and employment density gradient (lower represents greater sprawl) of 445 U.S. urbanized areas for year 2000	Simulated income, Population, Median agricultural land value per acre, Highway lane miles, Number commuters using public transit, Climate dummies, Percent employed in service, CP crime rate	Ratio of weighted average property tax millage rates of suburbs to central city [10% increase yields a 0.005 **decrease in sprawl**** using acres, 0.52% **decrease in sprawl** using population density, and 0.56% **decrease in sprawl** using employment density]
Woo and Guldmann (2011)	Population density gradient (lower represents greater sprawl), and employment density gradient (lower represents greater sprawl) of 135 U.S. metropolitan statistical areas for year 2000	Per capita income, Percent population rural, Percent population own home, Percent employed in manufacturing, Percent employed in wholesale, Percent employed in retail, Percent employed in finance/insurance/real estate, Percent households earning one or more autos, Central business district (CBD) population density, CBD employment density, Central city (CC) Percent households earning > $100K, CC housing vacancy rate, CC age since incorporation, CC homeownership rate, CC total federal expenditure per capita, Federal expenditure per capita on housing, Federal expenditure per capita on transport, Number of cities, State planning legislation for land use elements dummy, State adoption of local comprehensive plans dummy	Percent statewide municipal revenue from property tax [10% increase yields a 1.3% **increase in sprawl*** using population density gradient, **not statistically significant** using employment density] Percentage statewide county revenue from property tax [10% increase yields a 0.8% **decrease in sprawl** using population density gradient, **not statistically significant** using employment density]

Gomez-Antonio, Hortas-Rico, and Li (2014)	Percentage of undeveloped land around residential land within immediate neighborhood for 1,194 subsample of 3,895 possible municipalities with Spain's urban areas in 2000	Percent in poverty, Population growth 1930 to 1990, percent population 25-45 years old, percent population >65 years old, Average number children in household, Percent with college degree in 1991, Percent population not from EU, Automobiles per household in 1991, Distance from CBD to nearest highway, Highway density, Percent employed in wholesale/transportation/warehousing, Percent employed in manufacturing, Percent employed in retail, Distance to urban area's central city, Percent local revenues intergovernmental, Dummy if political majority from 1991 to 1994 belong to "Left" party, Mean maximum temperature, Mean minimum temperature, Average precipitation, Percent land open space, Percent land devoted to leisure/sports, Percent land classified as "wetland", Percent land covered by water, Index terrain ruggedness, Elevation range	Percent municipal revenue from local property taxation [one standard deviation increase yields a 1.44 unit **increase in sprawl*****]

*This influence is statistically significant at an 89 percent confidence level in a two-tailed test.

**Song and Zenou (2009, 826) report a -0.27 arc elasticity with respect to the property tax ratio, but offer no explanation for how they derived this. I choose to thus report the value of 0.005 derived from their reported property tax ratio regression coefficient of -45.7 multiplied by the reported mean of this explanatory variable (0.91), divided by the reported mean of the dependent variable measured in acres (90,424), multiplied by ten.

***The authors offer too little information to translate this finding to an elasticity value. In addition, these results not included in the cited working paper and obtained from Miriam Hortas-Rico by email (*miriamhortas@ccee.ucm.es*).

Table 3: Previous Regression-Based Studies of Sprawl Not Using Property Taxation as an Explanatory Variable

Author(s)	Dependent Variable (size, year(s), & source)	Explanatory Variable Categories (measures used)	Regression Specifics
Brueckner and Fansler (1983)	Square miles of urbanized land area 40 U.S. urbanized areas from 1970 (U.S. Census Bureau)	Muth-Mills Models of urban spatial size **Population** **Income** (Household) **Agricultural rent** (Median agricultural land value in UA county) **Commuting cost** (% commuters using transit, % households own auto)	Linear-Linear specification
McGrath (2005)	Distance to urban fringe = (square miles of urbanized land / $\pi)^{0.5}$ 33 largest U.S. metropolitan statistical areas from 1950, 1960, 1970, 1980, and 1990 (U.S. Census Bureau)	Muth-Mills Models of urban spatial size **Population** **Income** (Real personal income) **Agricultural rent** (Real state average per acre agricultural land value) **Commuting cost** (Regionally adjusted private transportation CPI)	Log-Mixed Log specification Year fixed effects
Burchfield, Overman, Puga, and Turner (2006)	Percentage of square kilometer of land surrounding average urban dwelling left undeveloped 275 metropolitan areas for new dwellings between 1976 and 1996 (High altitude and satellite images)	***Ad hoc* Muth-Mills Models of urban spatial size** (Central employment, 1902 streetcar passengers, 1920 to 1970 mean decennial population growth, Bars/restaurants per thousand, Urban fringe road density) **Geography** (Percentage urban fringe over aquifer, Elevation range in urban fringe, Index of urban fringe terrain ruggedness, Mean cooling degree days, Mean heating degree days, 1970 to 1990 percent population growth) **Political Institutions** (Percentage urban fringe incorporated, 1967 percent intergovernmental transfers of local revenue, Herfindahl index of incorporated places size)	Linear-Linear specification

Ke, Song, and He (2009)	Distance to urban fringe = (square miles of urbanized land / π)$^{0.5}$ 650 Chinese cities from 1994 (Chinese Statistical Yearbook for Cities)	Muth-Mills Models of urban spatial size **Population** (Permanent population, Temporary population) **Income** (Average salary) **Agricultural rent** (Value of product per unit agricultural land) **Commuting cost** (Length paved city road per resident, Number highways passing center district, Rail station in city, Commercial airport in city) **Control dummies** (National capital, County capital, Resource center, Central region, Western region)	Log-Log specification
Zenou and Patacchini (2009)	Population density growth rate 30 European towns and cities between 1991 and 2001 (European Urban Audit Dataset)	Muth-Mills Models of urban spatial size **Population** **Income** (Income per capita) **Commuting cost** (Auto ownership per capita, Employment rate) **Flight from blight** (Percentage population not from European Union country, Crime rate)	
Deng, Huang, Rozelle, and Uchida (2010)	Hectare size of urban core 2063 county sampling units in 1995 (Scientific Data Center, Chinese Academy of Sciences)	Muth-Mills Models of urban spatial size **Population** **Income** (Gross domestic product (GDP), Percent GDP from industry, percent GDP from service) **Agricultural rent** (Public investment to agriculture) **Commuting cost** (Highway density) **Geography** (Distance to port, Distance to capital, Share of land flat, Average slope of land, Average elevation. Average annual rainfall, Average annual temperature)	Log-Mixed Log specification Includes lagged (1988) dependent variable Spatial autocorrelation accounted for
Fallah, Partridge, and Olfert (2012)	Index (0 to 1) where one represents all Census Block Groups at population density below overall U.S. metropolitan median value U.S. metropolitan statistical areas (MSAs) from 1980, 1990, and 2000 (U.S. Census Bureau)	Muth-Mills Models of urban spatial size **Population** (Average value of previous population changes, Standard deviation of previous population changes) **Income** (Log per-capita income, Gini coefficient of income) **Agricultural rent** (Share of undeveloped land) **Flight from blight** (Central city poverty rate)	Lin-Mixed Log specification Year and MSA fixed effects Residuals assumed to be correlated with a geographic cluster All explanatory variables lagged one period

Geshkov and DeSalvo (2012)	Square miles of urbanized land area Subsample of 182 U.S. urbanized areas within a single county and a single metropolitan area from 2000 (U.S. Census Bureau)	Muth-Mills Models of urban spatial size **Population** (Household number) **Income** (Mean household income) **Agricultural rent** (Mean market value of agricultural land per acre in county) **Commuting cost** (State annual highway expenditures divided by "users") **Land use controls** (Minimum lot size zoning dummy, Maximum lot size zoning dummy, Urban growth boundary dummy. Maximum FAR restriction dummy, Minimum square footage limitation dummy, Maximum building permits dummy, Minimum number of persons per room dummy, Impact fee dummy)	Lin-Lin specification
Paulsen (2012)	(1) Change in amount of developed land Between 1992 and 2001 for 329 U.S. metropolitan area (National Land Cover Database) (2) Square miles of urbanized land area Apply the year 2000 definition of 329 urbanized area to calculate comparable areas for years 1980, 1990 and 2000 (U.S. Census Bureau)	Muth-Mills Models of urban spatial size **Population** (Household number) **Income** (Median household income) **Agricultural rent** (Mean market value of agricultural land per acre in county)	Lin-Lin specification MSA fixed effects
Tanguay and Gingras (2012)	(1) percent of population living in metropolitan area center (2) percent of low-density density housing in metropolitan area (3) Median distance travelled to reach work in metropolitan area Subsample 12 Canadian metropolitan statistical areas from years 1986, 1991, 1996, 2001, and 2006	Muth-Mills Models of urban spatial size **Population** **Income** (Median household income) **Commuting cost** (Gas price, Consumer price index of urban public transportation)	Lin-Lin specification MSA fixed or random effects

DeSalvo and Su (2013a)	(1) percent of square kilometer of land surrounding average urban dwelling left undeveloped 275 metropolitan areas for new dwellings between 1976 and 1996 (High altitude and satellite images) [same as Burchfield et al. (2006)] (2) Square miles of urbanized land area Subsample of 277 U.S. urbanized areas from 1980 which match the metropolitan areas used by Burchfield et al. (2006) (U.S. Census Bureau)	Muth-Mills Models of urban spatial size **Population** (Number households) **Income** (Median household income) **Agricultural rent** (Average value of farmland per acre) **Commuting cost** (Gasoline price) ***Ad hoc* Muth-Mills Models of urban spatial size** (Central employment, 1902 streetcar passengers, 1920 to 1970 mean decennial population growth, Bars/restaurants per thousand, Urban fringe road density) **Geography** (Percentage urban fringe over aquifer, Elevation range in urban fringe, Index of urban fringe terrain ruggedness, Mean cooling degree days, Mean heating degree days, 1970 to 1990 percent population growth) **Political Institutions** (Percentage urban fringe incorporated, 1967 percent intergovernmental transfers of local revenue, Herfindahl index of incorporated places size)	Linear-Mixed Log specification
DeSalvo and Su (2013b)	Square miles of urbanized land area Subsample of 552 U.S. urbanized areas (UAs) from 1990, 2000, and 2010 (U.S. Census Bureau)	Muth-Mills Models of urban spatial size **Population** (Population) **Income** (Median household income, Median household income squared) **Agricultural rent** (Average value of farmland per acre) **Commuting cost** (Gasoline price) ***Ad hoc* Muth-Mills Models of urban spatial size** (Bars/restaurants per thousand) **Geography** (Percentage urban fringe over aquifer, Elevation range in urban fringe, Index of urban fringe terrain ruggedness)	Linear-Mixed Log specification Year and UA fixed effects
Paulsen (2013a)	Square miles of urbanized land area Apply the year 2000 definition of 329 urbanized area to calculate comparable areas for years 1980, 1990, and 2000 (U.S. Census Bureau)	Muth-Mills Models of urban spatial size **Population** **Income** (Median household income) **Agricultural rent** (Mean market value of agricultural land per acre in county) **Land use controls** (State growth management program dummy; or Nonlocal urban containment program dummy; or Significant state planning constraint dummy; or Wharton index of regulatory restrictions on residential development dummy)	Lin-Lin specification MSA fixed effects

Paulsen (2013b)	Change in urban housing density; or change in marginal land consumption per new urban household, change in housing unit density in newly urbanized areas, change in percent of new housing units located in previously developed areas) Apply the year 2000 definition of 329 urbanized area to calculate comparable areas for years 1980 and 2000 (U.S. Census Bureau)	Muth-Mills Models of urban spatial size **Income** (1980 Median household income) **Agricultural rent** (1980 Mean market value of agricultural land per acre in county) **Flight from blight** (1980 urban housing density, 1980 metropolitan percent minority, Percent of housing units built before 1950) **Political Institutions** (1980 general purpose governments per capita) **Land use controls** (1980 metropolitan land area, Percent land undevelopable, Urban containment dummy, Significant state planning constraint dummy or Wharton index of regulatory restrictions on residential development dummy)	Lin-Lin specification
Su and DeSalvo (2013)	Square miles of urbanized area (UA) land, sprawl index from Burchfield et al. (2006), square miles of UA per capita, and vehicle miles travelled Subsample of 552 U.S. urbanized areas (UAs) from 2000 (U.S. Census Bureau)	**Muth-Mills Models of urban spatial size** **Population (Household number)** **Income (Median household income, Median household income squared)** **Agricultural rent (Average value of farmland per acre in county)** **Commuting cost (State highway expenditure per user)** *Ad hoc* **Muth-Mills Models of urban spatial size** (1977 central city employment) **Geography** (Percentage urban fringe over aquifer) **Flight from blight** (Violent crime in central city) **Political Institutions** (1967 intergovernmental transfers as a percent of revenues) **Land use controls** (Minimum lot size zoning dummy, Urban growth boundary dummy, Minimum number of person per room dummy)	Linear-Mixed Log specification Three-stage-least squares simultaneous regression model

Methods and Findings from the Previous Empirical Work

Five previous empirical studies offer insight on whether reliance on traditional property taxation in a United States urban area exerts a measurable influence on its population density. The research of Song and Zenou (2006 and 2009) sought to test the theoretical assertions of Brueckner (2000), and Brueckner and Kim (2003). The investigation of different hypotheses regarding what generates urban sprawl guided Wassmer (2002, 2006, and 2008); however, my studies are relevant for the investigation at hand because they did control for the possible influence of property taxation.

The need to control for the multiple influences that determine an urban area's population density, to isolate the influence of key factors under investigation, necessitates that these empirical studies employ multiple regression analysis. Four of the five studies use year 2000 data from the nearly 460 urbanized areas (UAs) in the United States, while Wassmer (2002) uses data from 54 Western United States Metropolitan Statistical Areas (MSAs) drawn from 1977, 1987, and 1997. Rather than a MSA based on politically established county boundaries, a UA is the more appropriate measure of what constitutes an urban area due to its use of minimum population density Census Blocks surrounding a central place(s) to define its border.

Song and Zenou (2006, 525) empirically test their theoretical finding that the rate of property taxation reduces the spatial extent of urbanized areas. Using the dependent variable of acres in 448 United States urbanized areas in 2000, they control for the additional causal factors of population, income, agricultural land rent, and public transportation expenditures. They find that **a one percent increase in a UA's property tax rate results in about a 0.40 percent decrease in a UA's land area, holding population constant (diminished sprawl).** Their property tax variable is a GIS calculated, weighted by area, aggregate measure of city, county, and school statutory property tax rates in a UA.[6] They appropriately recognize that this measure of property taxation is endogenous to the UA's population density—through less population density requiring greater infrastructure and higher rates of property taxation—and use instrumental variable (IV) estimation. Such an IV must help predict the differences in property tax rates across urban areas, but also be unrelated to changes in the size of urban areas. Song and Zenou's IV choice is the magnitude of state aid given to K–12 schools in an urban area.

Song and Zenou (2009) employs the same data set and dependent variable used in the 2006 analysis. Furthermore, they add population or employment density gradients (a lower value indicating greater sprawl) as two additional dependent variables in their regression analyses. Based upon their duo-centric urban model described earlier, they alter the measure of urban area property taxation used as an explanatory variable to be a weighted average of suburban (non-central places in the UA) to central place property tax rates. They again recognize the endogeneity of this key explanatory variable. Unfortunately, they fail to find suitable instruments for it and consequently do not correct for this concern. Besides the group of explanatory variables employed in their previous study, they add climate, service-sector employment share,

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[6]An effective property tax rate (EFT) equals actual property taxes paid for a parcel divided by its market value—and not the statutory property tax millage rate used by Song and Zenou (2006)—is the most appropriate measure of the burden of the property tax. An EFT accounts for differences in assessed value percentages and implementation practices across UAs, which the property tax millage rate alone does not. I use effective property tax rate measures in the empirical analysis included here. In addition, Song and Zenou (2006) only use a cross section of data and cannot control for UA-specific fixed effects.

and central-place crime rate measures. For their previously used measure of county-weighted transportation expenditures, they also substitute measures of highway miles (considered endogenous and instrumented with 1947 values), auto use, and public transit use. They find that **a one percent increase in the ratio of suburban to central place property tax rates reduces the size of the urban area, holding population constant, by -0.27 percent (less sprawl), and that an increase in this property tax ratio raises population and employment densities (less sprawl) in an urban area.** However, when considering this, note the finding's basis on: (1) a ratio of statutory property tax rates, (2) a biased endogenous regression estimate, and (3) no UA-specific controls for fixed effects since only one cross section of data is used.

The empirical analyses of Wassmer (2006 and 2008) are similar to Song and Zenou in that I use regression analysis to examine the grounds for differences in the land size of United States urbanized areas in 2000. The primary focus is a measurement of the influence of urban containment/statewide growth management in Wassmer (2006) and auto reliance in Wassmer (2008), rather than a detection of the influence of the property taxation rate. Nevertheless, both studies include measures of statewide reliance on the property tax to raise local own-source revenue. Although reliance on property taxation to raise local own-source revenue is not the same as the desired measure on an effective property tax rate, there correlation in value is likely positive. This inclusion is based on the theoretical expectation that difference in UA land sizes are driven by *fiscalization of land use* causal factors along with *natural evolution*, *flight from blight*, and unaccounted for statewide or regional factors. Wassmer's (2006) property tax measure is the 1997 percent of the statewide, own-source local revenue derived from property taxation in the UA's state. For a UA in multiple states, this value is a weighted average based on the percentages of a UA's land area in different states. Wassmer (2008) refines this measure by allowing its separate calculation by county and municipality. Contrary to Song and Zenou (2006 and 2009), Wassmer (2006 and 2008) finds that **statewide measures of local reliance on property taxation exert no influence on an urban area's population density**. Also contrary to Song and Zenou, Wassmer (2008) reports that a **one percent increase in a state's municipal reliance on property taxation decreased population density (greater sprawl).**

Also worth considering is the earlier regression work by Wassmer (2002) that examined the influence of local sales tax reliance in a state on the degree of retail sprawl in the state's urbanized areas by using the Metropolitan Statistical Area (MSA) as the unit of analysis. The percentage of the MSA's retail sales occurring in non-central places for 54 MSAs in the western United States in years 1977, 1987, and 1997 acts as a positive proxy for the degree of retail urban sprawl occurring in these MSAs. I used a fixed effect regression technique, and a group of explanatory variables derived from the same theory used in Wassmer (2006 and 2008), to find that a **statewide measure of municipal reliance on local sales taxation generates greater retail sprawl, but a similar statewide measure for property tax reliance does not.** Note that although the use of municipal reliance on property taxation is positively correlated with the rate of property taxation, a direct measure of the rate of property taxation is preferred based on its specific use in the earlier described theories.

The regression analyses contained in England, Zhao, and Huang (2013) that utilized a sample of over 36,000 New Hampshire homes built between 1985 and 2005 are also relevant. These analyses found that the effective rate of local property taxation exerted a negative influence on lot size, square feet, and height. Translating these house specific findings to a macro determination of how differences in the effective rate of property taxation across urban areas influences differences in population density is no easy task. The negative influence on lot size works in favor of greater density, while the negative influence on capital usage does the opposite.

The previous empirical findings on the influence of the rate of property taxation in an urban area on population density are not entirely conclusive. What these previous studies do offer is a base of relevant ideas and methods upon which to build a better study. I summarize these as:

- Census calculated urbanized areas (UAs) are the appropriate unit of analysis;
- The variable relevant to testing the theory of property taxation's influence on population density is the effective rate of property taxation;
- A contemporaneous measure of a UA's average property tax rate is endogenously determined with UA size; and
- A well-specified regression model, that tries to control for major factors expected to determine differences in land used for a given population across United States urbanized areas, is necessary to identify the true independent influence of the property tax rate.

Research Plan

A principal innovation of the research described here is the use of data from single-state comparable United States urbanized areas from 2000 and 2010. Previous empirical work did not have the option to use data from more than one cross section of United States urbanized areas because the Census chose to alter the method used to calculate the land area of a United States UA after each decennial census before year 2000.[7] In year 2000, the Census committed to use the same method in all future decennial censuses to define the geographical footprint of a UA:[8] this being an urbanized area consisting of a central core (city or place) or cores, which are expanded outward to define the spatial footprint of a UA as long as adjacent Census Blocks have a population density of at least 1,000 people per square mile. The minimum total population for the UA must be at least 50,000. Specific rules are also in place regarding when to jump over lower population density Census Blocks to incorporate a neighboring higher density Census Block (of at least 1,000 per square mile) into the UA's total spatial footprint. Thus, a change in the square miles of a UA between 2000 and 2010 is the result of forces like the effective rate of

[7]Paulson (2012), using GIS methods to overcome the Census definition of what counts as an urbanized area being different in each decade prior to year 2000, creates a panel of three-years of comparable United States urbanized areas using the 2000 definition applied to Census Block data from 1980 and 1990. He then runs a regression with UA land area as the dependent variable, but unfortunately does not include the UA's rate of property taxation as an explanatory variable. Paulson chooses instead to include only the *natural evolution* influences of UA population, income, and agricultural land value.

[8]See the Department of Commerce (August 24, 2011), urbanized area criteria for the 2010 Census, *Federal register* (76)164, at https://www.census.gov/geo/reference/pdfs/fedreg/fedregv76n164.pdf for details. FAQs about Census defined UAs are at https://www.census.gov/geo/reference/ua/uafaq.html .

property taxation in the UA acting upon land use decisions, and not corrupted by a definitional change as could have been the case in decennial censuses prior to year 2000.

I use the square miles of land area of a United States UA as the dependent variable in the regression analysis.[9] See Figure 1 for the strong linear relationship that exists between the natural logs of square miles and population in the 435 comparable (single and multistate) UAs in 2000 and 2010. Variation in the natural log of these urbanized areas' populations explains nearly 90 percent of the natural log variation of their land areas (square miles) around its mean. A simple regression indicates that a one percent increase in population (holding nothing else constant) leads to about a 0.86 percent increase in land area. Nevertheless, as also indicated in Figure 1, there are urbanized areas that fall above this simple prediction (greater land area per population, equaling less population density, and more sprawl), and below it (less land area per population, equaling greater population density, and decreased sprawl). After controlling for other factors previously mentioned as possible causes of variation in square miles or population density in United States UAs, the purpose of this study is to account for differences in the effective rates of property taxation across these areas as a cause for being off this fitted line.

This study also uses a different measure of a United States urbanized area's rate of property taxation as the key explanatory variables of interest. As described earlier, this variable must be some measure of the typical rate of effective property taxation experienced in a UA. Song and Zenou (2006 and 2009) chose to use an elaborate GIS-based calculation of these values. Unfortunately, after all their efforts, the calculations could not be included directly in their regression analyses because of the endogenous determination with population density. In their 2006 research, Song and Zenou account for this through the appropriate two-stage regression analysis. However, they were unable to find a reasonable instrumental variable to do this in their 2009 analysis. I avoid this endogeneity concern by using the effective tax rate (EFT) values that the Minnesota Taxpayers Association (2001 and 2011) calculates for the largest city in each of the 50 states for the desired years of 2000 and 2010.[10] These EFTs are derived separately for a typical: (1) median value single family home; (2) one million dollar (with $200,000 in fixtures) market value commercial property; (3) one million dollar (with $500,000 in machinery and equipment, $400,000 in inventory, and $100,000 in fixtures) market value industrial property; and (4) $600,000 market value rental (multifamily) apartment (with $30,000 in fixtures) property.[11] EFTs indicate the percentage of the property's market value paid in state and local

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[9] In future work I plan to explore the reasonableness of using other measures of urban sprawl proposed in the literature. As Galster et al. (2001) note, these include a lack of continuity, concentration, clustering, centrality, nuclearity, mixed uses, and proximity. Because the Census designation of year 2000 urbanized areas included a listing of central places (CPs) for each UA, it is possible to account for these additional dimensions by gathering population density data from these central places for the years 2000 and 2010. A greater concentration of a UA's population in its CPs should point to a more continuous, concentrated, clustered, central, mixed use, and proximate development pattern in the UA and thus less urban sprawl. Thus, I will compute the additional dependent variable measures of CP population density, non-CP population density, and the ratio of CP to non-CP population densities to check if the influence that the UA's rate of property taxation varies in its influence on these measures in regression analyses. Furthermore, I will consider using Ewing and Hamidi's (2014) sprawl index of development density already calculated for the 162 largest and comparable United States UAs in 2000 and 2010.

[10] The Lincoln Institute of Land Policy now collaborates with the Minnesota Taxpayers Association to offer future values of EFTs (*https://www.lincolninst.edu/subcenters/significant-features-property-tax/resources.aspx*).

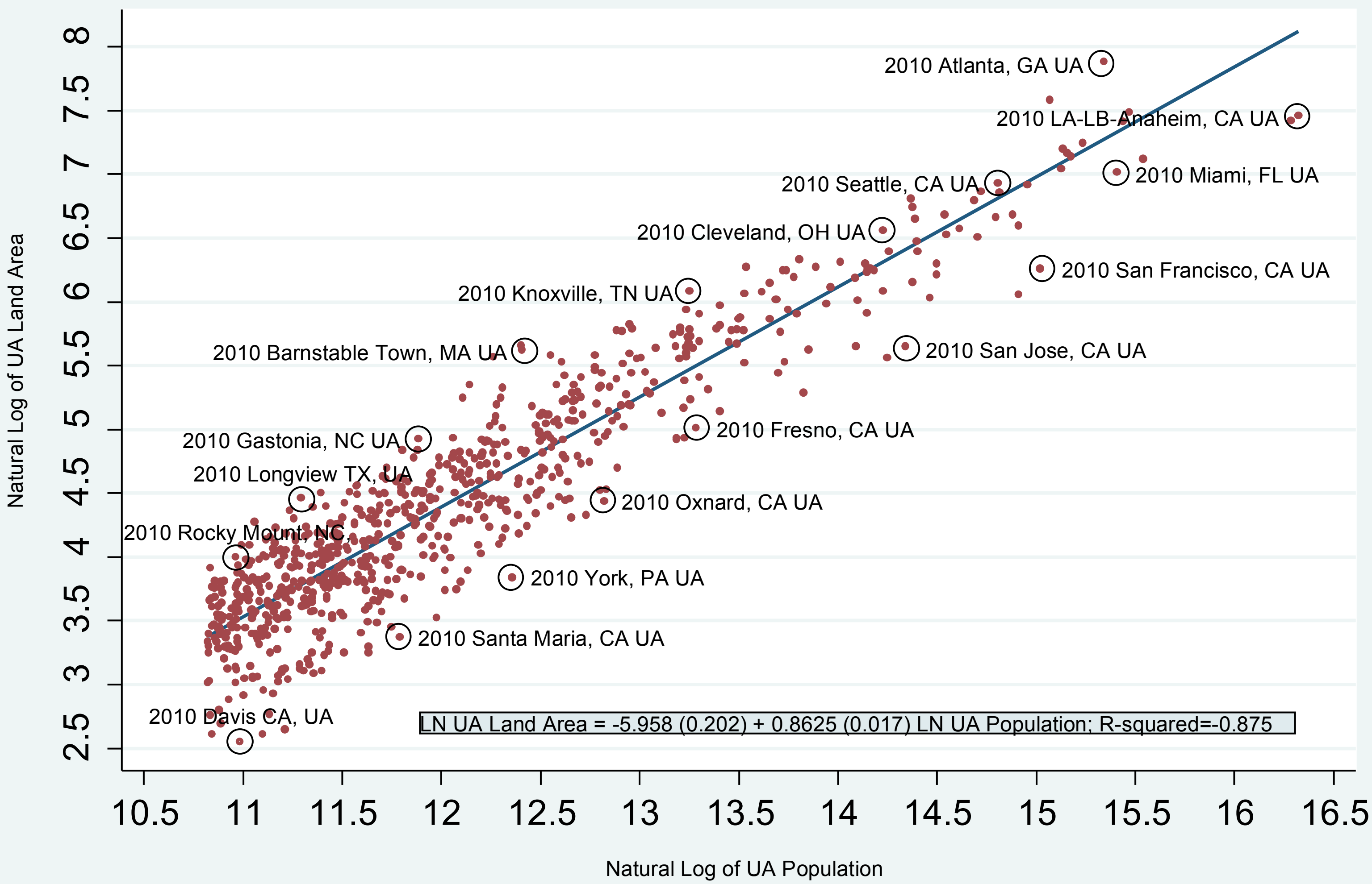
[11] The Minnesota Taxpayers Association also calculates EFTs in these same four categories for a typical rural city in each state. These are not suburban cities contained in UAs. Still, an argument exists that these may contain information relevant to measuring the rate of effective property taxation in a UA beyond just using large city EFTs. I will therefore run a regression that includes these four types of synonymous EFTs calculated for a typical rural city in the urbanized area's state. This inclusion is

property taxes after accounting for sales to market value ratios, classification rates, property tax rates, and property tax credits that differ across jurisdictions. Since I use the Minnesota Taxpayer's Association value (calculated for the largest city in a state) as a representative proxy of the relative degree of property taxation between different states, it is likely appropriate to consider these as exogenous to a specific urban area's population density.[12] Unfortunately, the use of these measures precludes the use of multistate UAs; I use only the comparable UAs from 2000 and 2010 that are fully contained in a single state.

similar to what Song and Zenou (2009) did when they included a measure of the ratio of suburban to central place property taxation in their empirical estimation of what causes differences in population density gradients in 445 United States UAs in 2000.

[12]It is possible that the Minnesota Taxpayer Association's calculated EFT for a central place, if used as a proxy for the effective tax rate for the UA containing that central place, is endogenously determined. (For example, using the City of Detroit's EFT for the Detroit UA could be a concern, but it should not be if using the same EFT for all other UAs in Michigan.) To test this concern, I run a regression that excludes the 31 UAs where the central place is the same as the one calculate by the Minnesota Taxpayer's Association.

Figure 1: The Linear Relationship between the Natural Logs of UA Land Area and Population in 2000 and 2010



The Effective Property Tax rates (EFTs) used here are not the weighted average statutory property tax rate that Song and Zenou (2006 and 2009) derived through GIS methods. However, I believe these EFTs offer more reasonable proxies for the burden of this taxation imposed upon real property than what Song and Zenou used in both of their previous analyses. In 2006 and 2009, they did not use effective rates, and in 2009, they did not even control for the endogenous nature of the rate of property taxation measured used. Since the Minnesota Taxpayer Association EFTs exists for four different classes of property, I measure a separate influence using each available EFT.

The gathering of the proposed data set allows for the use of regression estimation techniques (fixed or random effects) that control for UA-specific influences over time. With the exceptions of Wassmer (2006) and Marshall (2008), such influences were unaccounted for in previous empirical work. Doing so here results in greater confidence that the estimated influence of an urbanized area's effective rates of property taxation does not suffer from omitted variable bias. I next offer a causal model of the various factors expected to influence differences in urban land areas by drawing upon previous theories of how property tax rate can influence this. I also draw upon other theories offered by urban economists on what influences the spatial footprint of an urban area.

Regression Specification

The dependent variable used in the regression analysis discussed next is the natural log of land area in square miles that makes up the Census-calculated footprint of single-state United States urbanized areas that are comparable in years 2000 and 2010. The natural log of the UA's population is included as an explanatory variable. Measurements of the influences of different effective rates of property taxation on this dependent variable are the key results sought in this regression analysis. To detect these independent influences, it is necessary to include other causal factors expected to influence differences in population density across UAs. From the earlier discussion of theory and related previous empirical work, I model the desired regression specification as:

(1) **Natural Log Land Area**$_{i,t}$ = f (Natural Log Population$_{i,t}$, *Effective Property Tax Rates*$_{i,t}$, *Resident Housing Preference*$_{i,t}$, *Development Constraints*$_{i,t}$, *Commuting Cost*$_{i,t}$, *Urban Fringe Land Cost*$_{i,t}$, *Flight From Blight*$_{i,t}$, *Economic Factors*$_{i,t}$, *Local Fiscal Structure*$_{i,t}$, *Local Political Institutions*$_{i,t}$, *Preferential Property Tax Treatment*$_{i,t}$, *Historic Housing Stock*$_{i,t}$, *Geography*$_{i,t}$);

where;

i = 1,2,3, …370 (one state, comparable United States urbanized areas);
t = 2000 or 2010;

and;

Effective Property Tax Rates$_{i,t,}$ = f(Single-Family Residential Effective Property Tax Rate$_{i,t}$, Commercial Effective Property Tax Rate$_{i,t}$, Industrial Effective Property Tax Rate$_{i,t}$, Multifamily Residential Effective Property Tax Rate$_{i,t}$);

Resident Housing Preference$_{i,t}$ = f (Owner Occupied Percentage$_{i,t}$, Real Median Household Income$_{i,t}$, Poverty Percentage$_{i,t}$, Real Household Income Greater 200K$_{i,t}$, Bachelor Degree Percentage$_{i,t}$, Master/Professional Degree Percentage$_{i,t}$, Doctorate Degree Percentage$_{i,t}$, Age 17 Less Percentage$_{i,t}$, Age 75 Plus Percentage$_{i,t}$, Latino Percentage$_{i,t}$, African American Percentage$_{i,t}$, Asian Percentage$_{i,t}$, Pacific Islander Percentage$_{i,t}$, Native American Percentage$_{i,t}$, Other Race Percentage$_{i,t}$, Two Race Percentage$_{i,t}$, Foreign Born Percentage$_{i,t}$, Male Head Family Household Percentage$_{i,t}$, Female Head Family Household Percentage$_{i,t}$);

Development Constraints$_{i,t}$ = f (State Growth Management$_i$, State Growth Management Years$_i$, Regional Urban Containment$_i$, Regional Urban Containment Years$_i$, Local Urban Containment$_i$, Regional Urban Containment Years$_i$, Wharton Res Land Use Extreme Regulation$_i$);

Commuting Cost$_{i,t}$ = f (Local Highway Miles Per OneK Capita$_{i,t}$, Labor Force Percentage$_{i,t,}$);

Urban Fringe Land Cost$_{i,t}$ = f(Real Agric Prod Per Acre$_{i,t}$, State Farm Preservation Years$_i$, State Farm Preservation Dev Penalty$_i$);

Flight From Blight$_{i,t}$ = f(Central Place Murder Manslaughter Rate Per 100K$_{i,t}$);

Economic Factors$_{i,t}$ = f(Housing Occupied Percentage$_{i,t}$, Finance Insurance Employed Percentage$_{i,t}$, Manufacturing Employed Percentage$_{i,t}$, Retail Employed Percentage$_{i,t}$)

Local Fiscal Structure$_{i,t}$ = f (Percent Own Source Local Revenue Fees$_{i,t}$);

Preferential Property Tax Treatment$_{i,t}$ = f (State Enterprise Zone$_{i,t}$, State Enterprise Zone Years$_{i,t}$, Manufacturing Prop Abate$_{i,t}$, Manufacturing Prop Abate Years$_{i,t}$, Commercial Prop Abate$_{i,t}$, Commercial Prop Abate Years$_{i,t}$, Housing Prop Abate$_i$, Housing Prop Abate Years$_{i,t}$, Tax Increment Finance$_{i,t}$, Tax Increment Finance Years$_{i,t}$);

Local Political Institutions$_{i,t}$ = f (County Gov Per 100K Capita$_{i,t}$, Municipal Gov Per 100K Capita$_{i,t}$);

Historic Housing Stock$_{i,t}$ = f(Years Old Median Housing Stock$_{i,t}$);

Geography$_{i,t}$ = f(Percent Area Water$_{i,t}$).

Brueckner (2000), Brueckner and Kim (2003), and Song and Zenou (2006, 2009) find that the expected theoretical influence of the *Effective Rates of Property Taxation* on an urban area's usage of land for a given population depends on the: willingness of residents (or businesses as I will later describe in a feasible extension) to alter the size of their residence (production facility), and the ability of developers to alter building height and/or size. Thus, to determine the influence of the various forms of effective property taxation on population density, Equation (1) accounts for both *Resident Housing Preferences* and *Development Constraints*. Specifically, observable characteristics expected to influence a housing consumer's strength of preference for a particular size and type of house include measures representing differences across UAs in ownership verses tenant desire, income and poverty, education, age ranges where housing demand expected to change, and race/ethnicity or family structures that may account for differences in housing preferences. Developers' ability to affect building height or size depends on the restrictiveness of land use and building controls present in a UA. In Wassmer (2006), I use various sources of previously gathered data and my own inquiries to offer information on the states with a statewide growth management program in place and the year it began. I also listed the UAs that had a form of local (municipal or county specific) and regional urban containment in place and the year it began.[13] These translate into dummy explanatory variables representing the presence of these development constraints in 2000 and 2010, and for each type, the number of years since their inception. In addition, I include a dummy variable that accounts for a UA in a state that scored at least two standard deviations above the mean Wharton Residential Land Use Regulatory Index calculated by Gyourko, Saiz, and Summers (2008) for the mid-2000s. I assign the respective state value of this dummy (equal to one for Hawaii, Rhode Island, Massachusetts, and New Hampshire) to each UA, in both 2000 and 2010, because an earlier comparable index does not exist. This accounts for a more restrictive regulatory environment for home construction in these states—a factor that Brueckner and Kim (2003) note as important to control for when determining the influence of the rate of property taxation on population density.

The classic Muth-Mills model serves as the basis for much of the previous research on the determinants of the size of an urban area. Besides population and income, this model notes the importance of *Commuting Cost* and *Urban Fringe Land Cost*. Previous researchers argue that if measured by the specific presence of highways or mass transit in a UA, the inclusion of commuting cost must be considered endogenously determined. I, like Geskov and DeSalvo (2012), overcome this problem by using the 1999 and 2009 values of local highway miles in the UA's state divided by the state's urban population (assuming this is a reasonable proxy for the greater presence of highways in a UA, less costly commuting, and thus greater sprawl). Also included is the percentage of the UA's adult population participating in the labor force to control for differences in the percentages of the population who would even consider commuting costs (due to employment) as relevant to a housing decision. Brueckner and Fansler (1983), McGrath (2005), Ke, Song, and He (2009), and Paulsen (2012) all used the value of agricultural production in a county divided by the acres in production as a positive proxy measure of land cost at the urban fringe. I do the same here, with the 1997 and 2007 values translated into real

[13] A statewide growth management plan mandates the coordination of land use planning decisions across local jurisdictions in a region that in part seeks more compact urban growth patterns. Urban containment policies are in place to limit the occurrence of new development outside a specific boundary. The regional urban containment dummy variable only receives a one if such a policy is in place for the region that makes up the UA.

values using the 2009 base year GDP Deflator. For multi-county UAs, the value used for a UA is land-area weighted values across the counties encompassing this form of UA. However, in using this I must note that it is not an ideal measure of the cost of land at the urban fringe because its value is for the entire county.

As noted by Arnott (2005), the non-neutrality of the rate of property taxation in a UA could be overcome using farmland preservation programs that granted a preferential (lower) rate of property taxation for land kept in agriculture. The causal category of Urban Fringe Land Cost thus includes a continuous variable representing the number of years that a UA's state had a farm preservation program in place and a second dummy accounting for if the state's farm preservation program imposes a penalty if the farmer develops the property.[14] The expectation here is that such a penalty will discourage farmers holding land at the urban fringe from using the preservation program; making the program less effective at raising UA property density.[15]

Previous empirical research on this topic has appropriately included the causal category of *Flight from Blight* as being necessary to account for when modelling differences in the spatial footprint of United States UAs. Greater pressure exists to expand the size of an urbanized area if there are greater reasons for existing residents to flee the UA's central place(s), or for new residents to avoid them. I roughly approximate this repellant with the inclusion of the rate of reported murders/manslaughters per 100,000 recorded in the FBI's Uniform Crime Report.[16]

The theoretical work of Sullivan (1984 and 1985) and Mills (1998) serve as a reminder that the size of an urban area is not only determined by factors acting on housing choices, but other causes exist driven by the business sectors that employ the residents seeking shelter in the UA. The broad *Economic Factors* included in the regression model account for these differences across time and urbanized areas. These include differences in the degree and type of economic activity that exist across UAs as measured by the percentage of the existing occupied housing stock. Measures of percent employment in relevant industries, consistently measured by the Census in 2000 and 2010, also serve this purpose and as well accounts for differences in agglomeration benefits that may push a certain industry's location preference to be more or less central. These industries include finance/insurance/real estate, manufacturing, and retail.

Some of the previous empirical investigations of what drives differences in UA population density account for *Local Fiscal Structure*. As noted by Brueckner (2000), a greater reliance on traditional property taxation to fund a UA's infrastructure through average cost pricing underprices this infrastructure relative to new development likely occurring at the urban fringe; thus, encouraging such fringe development, usually at a lower rate of population density. An

[14]There is no explanatory variable in the regressions for the presence of a farmland preservation program because all of the included states had in both 2000 and 2010.

[15]Data from 2006 (the earliest year available) on the existence of a statewide program for the preferential property tax treatment of agricultural property is from the Lincoln Institute of Land Policy (A), and confirmed to be the same in the early 1990s using Malme (1993). The year each state's farm preservation program is from Anderson, Giertz, and Shimul (2014).

[16]Unfortunately, many of the necessary values for specific cities named as central places for the included UAs were missing for 2000. Reporting was better for 2010, but still incomplete. The sources are available at *https://www.fbi.gov/about-us/cjis/ucr/crime-in-the-u.s/2000* and *https://www.fbi.gov/about-us/cjis/ucr/crime-in-the-u.s/2010/crime-in-the-u.s.-2010/tables/10tbl08.xls/view* . For the needed number of murders and manslaughters per 100,000 for an included UA's central place that was unreported, I substituted the value always available for the entire state. This introduction of error may explain the later statistical insignificance of this explanatory variable in the regression findings.

alternative that avoids this is a greater reliance on user charges/fees and the motivation for including 1997 and 2007 reliance of the state and local government in the UA's state to raise own-source funds. A statewide value for this avoids the likely endogenous nature of this measure if instead a UA-specific value used.

On a related point, the theoretical work of Arnott (2005) indicates the importance of accounting for differences in *Preferential Property Tax Treatment* when trying to tease out the influence of the effective rate of property taxation on property and land use decisions in an urban area. Kenyon, Langley, and Paquin (2012) have produced a nationwide accounting of the presence of state programs that allow for: (1) the reduction of the rate of property taxation in an enterprise zone; (2) the presence statewide of property tax abatement programs for either manufacturing, commercial, or housing; and/or (3) the capability to use tax increment financing to divert the revenue from a municipality's general property taxation to bond obligations issued for capital improvements in only a designated area. I confirmed the presence of these programs prior to the year 2000 through an email exchange with Langley in which he provided the dates that each program began. The regression analysis thus includes variables representing whether an incentive program was in existence in the cross sections of 2000 and 2010, and for each, the number of years in existence.

The degree of competition among jurisdictions for mobile residential and business property in an urbanized area influences the degree of use of preferential property tax programs used there. Since the number of jurisdictions in a UA influences the degree of this competition, I include the number of county governments and number of municipal governments, both per 100,000 residents, as two separate explanatory variables under the causal category of *Local Political Institution*. Because in 1997 the United States Census of Governments chose to gather no information on government organization, the values are from 1992 for the year 2000 sample of UAs, and from 2002 for the year 2010.

Finally, the regression specification offered in equation (1) controls for differences in the *Historic Housing Stock* and *Geography* of UAs in the sample. These measures include the median age of the housing stock and percentage of a UA's total area (land and water) that is water. The older the vintage of an UA's existing housing stock, the more likely it was built when commuting and transportation reliance was less auto centric and thus perhaps the higher the population density. A UA with a larger percentage of its overall land area consisting of undevelopable water will likely exhibit different development patterns and a different value of population per square mile of usable land.

Data and Regression Results

Table 4 offers a list of all the variables used in the regression analysis and the respective descriptive statistics and sources for each one of them. The final sample of 740 observations was drawn from the 486 urbanized areas (UAs) designated by the Census in 2010 and the 452 UAs in 2000. Once I eliminated multistate UAs due to effective property rates (and other relevant explanatory variables) only being available at the state level, and retained only comparable UA designations (as distinguished by a unique UACE number) , the number of UAs in each cross section fell to 377. This was further reduced by the seven UAs where the necessary information to calculate the value of agriculture production per acre was not reported. The final sample used here consists of 2000 and 2010 cross sections of 370 UAs each.

Table 5 summarizes the results derived from the regression analyses that reports robust standard errors for the calculated regression coefficients. I list two different results. Each of these results includes the addition of a dummy variable for the year 2010 cross section. This accounts for the possibility of an overall time trend, separate from the other causal factors, that can cause differences in UA population density. Regression (PA) is a population-averaged panel data analysis that pools the 2000 and 2010 cross sections of UA data together. As noted in Cameron and Trivedi (2010, 266), this model is only relevant if the expected error of the regression for each UA is uncorrelated over time—an assumption tested using the appropriate Hausman test and rejected with 99 percent confidence. Thus, the coefficients recorded in regression (PA) are not *consistent* (or in repeated samples produce estimates that have an average value that converges to the true population parameter).

Striving for consistency, I use a fixed-effect (FE) panel data estimation that includes a constant term for each of the 370 separate UAs. This curtails the estimate of a regression coefficient for the presence of state growth management program, local urban containment, and residential property tax abatement program because there was no variation in the use of these interventions across the 370 UAs in 2000 and 2010. The 370 UA specific constant terms estimated in the FE panel data estimation subsume the effects of these excluded explanatory variables. The same holds for the calculation of the effect of housing regulations given the availability of only one index value for both cross sections. I include the PA results to reveal the estimated regression coefficient for explanatory variable that do vary across the cross sections; though remember, reported PA regression coefficients are inconsistent.

The dependent variable of UA land area is in natural log form and only the explanatory variable of UA population is in natural log form (as deemed appropriate through Figure 1). The regression coefficient on natural log of population represents the percentage change in land area from a one-percentage change in population. To interpret the other regression coefficients, take their exponent, subtract one, and multiply by 100 to yield the expected percentage increase in population density after a one-unit increase. Table 5 employs a system of asterisks to indicate the statistical significance of each regression coefficient. In this type of regression analysis, the likelihood exists of correlations among the explanatory variables. The greater this *multicollinearity*, the greater the upward bias expected on the regression coefficients' standard errors, causing the t-test for statistical significance to not reject the null hypothesis that an explanatory variable exerts a zero influence on the dependent variable. To test for this possibility, I also calculate the *variance inflation factors* (VIFs) for each regression coefficient in the PA estimation and record the values in the proceeding column. A VIF value of greater than five indicates the distinct possibility of such multicollinearity, and the finding of statistically insignificance that may be due to it.

In the remainder of this section, I discuss the FE regression results due to their consistency, but also point out some PA results when relevant to interpreting the FE findings. Support for the validity of the FE regression model comes from its high degree of overall explanatory power (an

R-squared of 0.957) and the statistical significance/expected signs exhibited by many of its explanatory variables (and the likelihood of the non-statistical significance exhibited by many others due to multicollinearity). Begin by noting the regression coefficient value of 97.4 on the natural log of population explanatory variable in the FE regression. This indicates that after controlling for other explanatory variables in the regression, including UA-specific fixed effects, a one percent rise in population yielded nearly a unitary (0.97) elastic response in land area. Also, note the finding for the 2010-year dummy explanatory variable that land area in United States UAs was on average, after controlling for other factors expected to influence it, about 64 greater in 2010 than in 2000. Urban sprawl, as measured by greater land area for the same population, grew as a phenomenon over this decade.

The influence of Resident Housing Preferences on the land area of a United States UA is clearly present with increases in the following percentages of these UA values found to decrease land area: (1) real median household income; (2) master's or professional degrees; (3) Latinos; (4) African Americans; and (5) single parent households with a female as the head. For example, a $10,000 increase in real median household income (or about a one-standard deviation increase from an average of about $35,000) results in about a six percent decrease in UA's land area. An increase in the percentages of the following exerts a positive influence on a UA's land area: (1) those desiring home ownership over renting; (2) children; (3) other races; and (4) single parent households headed by a male. A one percentage point increase in the percentage of a UA's population that live in single adult households headed by a male (from an average of 4.3 percent) results in about a 3 percent increase in land area. Based on Brueckner's (2000) theory, it is reasonable that these characteristics describe households that desire different housing and/or lot sizes, and this changes the amount of land used for a given population. When further considering the results recorded for the Resident Housing Preference category, it is important to note that the statistical insignificance of other explanatory variables (except for Native American percentage) may be the result of the high degree of multicollinearity exhibited by other variables in this category.

The Development Constraint that exerts a statistically significant influence on UA land area is years that a statewide growth management requirement in place. Although this influence is positive, consider its sign within the context of a dummy variable for the presence of this development constraint in the PA regression, but dropped in the FE regression because of no variation between years 2000 and 2010. In the PA regression, the presence of this development constraint exhibited the expected positive influence on population density, but the presence of a high VIF (13.4) recorded for is likely the reason for its statistical insignificance. Thus, it is reasonable to conclude that growth management containment for urban areas at the state level lowers a UA's land area, but the effect of this negative influence at reducing sprawl diminishes over time. Given the high similar signs observed on the regional urban containment dummy and number of years in place, and the high VIFs also exhibited for these, the same holds true for the effect of a region-wide approach to development constraints and UA land area. As expected in the PA regression, if a UA exists in a state that was found—in a classification scheme developed by Gyouroko, Saiz, and Summers (2008)—to exhibit extreme residential building and land use controls in the mid-2000s, its land area rose by over 18 percent. Though an inconsistent estimate, it does indicate the relevance of Bruecker and Kim's (2003) theoretical need for controlling for variation in the supply elasticity of housing across UAs when trying to determine the influence of property taxation on population density.

Arnott (2005) offered the insight that programs that raise the return of agricultural production at the fringe between urban and agricultural land use in an urban area and could mitigate the influence of property taxation on urban spatial size/density. I control for this through the inclusion in the regression of an explanatory variable that measure the real value of agricultural production per acre in a UA, the number of years a farmland preservation program in existence in the UA's state, and whether the program penalized farmers who pulled their land from such a program. In the FE regression, only the real value of agricultural production per acre exerted a statistically significant influence on UA land area and the direction was positive. That is, a higher the value of agricultural production per acre is associated with greater land use. This is likely due to the endogenous nature of this variable. UAs using more land are absorbing the less productive farmland first and leaving farmland with a higher value production per acre. Nevertheless, as shown in the PA regression, for every year a farmland preservation program present in a state containing a particular UA, the UA's land area fell around a half percent. As also shown in the PA regression, if a farmer at the fringe of a UA could enroll their property in such a program, and then be able pull it out without penalty when urban development become favorable, the negative influence on UA land area based upon the years program in existence is diminished by about a 10 percent increase in land area.

The greater the percentage of housing occupied in a UA (a positive proxy for a strong local economy), and the greater the percentage of the population employed in finance/insurance/real estate or manufacturing related professions (more likely to benefit from urban agglomeration), the less the UA's footprint in square miles.

Arnott (2005) called for the need to account for the use of preferential programs for reducing property taxes in an urban area when attempting to assess the overall influence of effective property tax rates on population density. These programs often offer as their goal the favorable tax treatment of property existing or locating in more centralized, and thus higher density, locations in an urbanized area. The regression model accomplishes this through controls on whether the state containing the UA allowed in years 2000 and 2010: (1) state enterprise zones; (2) manufacturing; (3) commercial; or (4) housing property tax abatement programs; and/or (5) a tax increment finance (TIF) program. I also include separate measures for the years in existence if they did. With the exception of the measures accounting for presence of TIF, the high multicollinearity exhibited among these variables may account for the statistical insignificance of all these regression coefficients. The statistically significant finding here being that if a UA exists in a state that allows the use of tax increment finance districts—which are often used to rejuvenate central place business districts—the UA's land area is about six percent smaller for the same amount of population (diminished sprawl). The previous literature further concluded the need to control for Local Political Institutions, Historic Housing Stock, and Geography. There is no VIF-based evidence that multicollinearity may be the reason for the statistical insignificance of these measures.

Most relevant to the questions motivating this research are the regression findings regarding the four different types of effective property tax rates. First, consider the non-findings in the FE regression for residential and industrial effective property tax rates. Though the residential rate exhibited a significant influence in the PA regression, this disappeared when accounting for UA specific effects in the FE regression. With a VIF less than five, the loss of this significance was not due to multicollinearity. Alternatively, the effective rate of industrial property taxation never demonstrated a statistically significant influence on UA density in either the PA or FE regression, but did produce a VIF greater than seven. Moreover, industrial/commercial property tax rates across UAs indicate a simple correlation coefficient of 0.83. This finding of industrial tax rate insignificance could be due to multicollinearity biasing the robust standard errors upward. I checked for this possibility by rerunning the FE effect regression after dropping the measure of commercial effective property tax rate, and after dropping the two other measures of property tax rates. The industrial effective property tax rate never indicated a statistically significant influence on population density. It is reasonable to conclude that the effective rates of property taxation on residential and industrial property in a UA exerts no influence on its population density.

Table 4: Descriptive Statistics for Regression Analysis Variables from Cross Section Years 2000 and 2010 for the 370 Single State and Comparable United States Urbanized Areas

Name	Mean	Standard Deviation	Minimum	Maximum	Source
Land Area	150.91	248.96	12.77	2,645.35	Social Explorer*
Population	380,866	910,263.20	50,058	12,300,000	Social Explorer
Single-Family Residential Effective Property	1.31	0.64	0.11	3.26	MN Tax Association**
Commercial Effective Property Tax Rate	2.14	1.02	0.65	6.92	MN Tax Association
Industrial Effective Property Tax Rate	1.69	0.73	0.44	3.94	MN Tax Association
Multifamily Residential Effective PTR	1.91	0.91	0.33	4.31	MN Tax Association
Owner Occupied Percent	62.10	7.85	35.38	89.79	Social Explorer
Real (2009) Median Household Income $10K	3.466	9.829	18.383	79.614	Social Explorer
Poverty Percentage	10.94	4.47	2.6	33.2	Social Explorer
Real (2009) Household Income Greater 200K	1.79	1.18	0.16	9.28	Social Explorer
Bachelor Degree Percentage	16.79	5.49	6.09	36.31	Social Explorer
Master/Professional Degree Percentage	8.47	3.81	2.14	28.48	Social Explorer
Doctorate Degree Percentage	1.38	1.63	0.12	13.98	Social Explorer
Age 17 Less Percentage	24.51	3.99	8.73	35.55	Social Explorer
Age 75 Plus Percentage	6.16	2.21	0.81	21.24	Social Explorer
Latino Percentage	13.58	16.37	0.41	95.37	Social Explorer
African American Percentage	12.04	12.30	0.19	70.05	Social Explorer
Asian Percentage	3.18	3.75	0.25	34.34	Social Explorer
Pacific Islander Percentage	0.15	0.55	0.00	11.24	Social Explorer
Native American Percentage	0.74	1.14	0.01	12.12	Social Explorer
Other Race Percentage	4.50	5.73	0.11	43.92	Social Explorer
Two Race Percentage	2.75	1.93	0.63	29.3	Social Explorer
Foreign Born Percentage	8.85	7.17	0.64	43.34	Social Explorer
Male Head Family Household Percentage	4.33	0.99	1.13	9.49	Social Explorer
Female Head Family Household Percentage	13.12	3.20	4.23	24.47	Social Explorer
State Growth Management	0.13	0.34	0	1	Wassmer (2006)

State Growth Management Years	2.65	7.34	0	49	Wassmer (2006)
Regional Urban Containment	0.15	0.35	0	1	Wassmer (2006)
Regional Urban Containment Years	3.00	7.96	0	47	Wassmer (2006)
Local Urban Containment	0.10	0.30	0	1	Wassmer (2006)
Local Urban Containment Years	2.02	7.03	0	52	Wassmer (2006)
Wharton Res Land Use Extreme Regulation	0.02	0.13	0	1	Gyourko, Saiz, … (2008)
Local Highway Miles Per OneK Capita	14.93	117.39	2.16	191.25	Statistical Abstract of U.S.
Labor Force Percentage	78.86	15.50	28.54	97.28	Social Explorer
Real (2009) Agric Prod Per Acre $1K	0.856	1.101	0.00176	11.211	Census of Agriculture
State Farm Preservation Years	33.33	9.37	5	50	Anderson *et al.* (2015)
State Farm Preservation Dev Penalty	0.69	0.46	0	1	Anderson & England (2014)
Central Place Murder Manslaughter Per 100K	6.83	7.35	0	90.3	FBI Uniform Crime
Housing Occupied Percentage	91.05	5.17	55.49	98.13	Social Explorer
Finance Insurance Employed Percentage	9.49	4.18	2.38	25.14	Social Explorer
Manufacturing Employed Percentage	9.94	6.65	1.52	45.73	Social Explorer
Retail Employment Percentage	11.97	1.67	6.47	18.49	Social Explorer
Percent Own Source Local Revenue Fees	18.28	4.28	6.50	29.18	Census of Governments
State Enterprise Zone	0.93	0.2	0	1	Turner and Cassell
State Enterprise Zone Years	18.24	8.13	0	30	Turner and Cassell (2007)
Manufacturing Prop Abate	0.66	0.47	0	1	Kenyon *et al.* (2012)*****
Manufacturing Prop Abate Years	14.04	15.75	0	74	Kenyon *et al.* (2012)
Commercial Prop Abate	0.39	0.49	0	1	Kenyon *et al.* (2012)
Commercial Prop Abate Years	10.67	16.52	0	74	Kenyon *et al.* (2012)
Housing Prop Abate	0.15	0.35	0	1	Kenyon *et al.* (2012)
Housing Prop Abate Years	3.71	9.90	0	53	Kenyon *et al.* (2012)
Tax Increment Finance	0.93	0.26	0	1	Kenyon *et al.* (2012)
Tax Increment Finance Years	27.44	16.09	0	65	Kenyon *et al.* (2012)
County Gov Per 100K Capita	1.37	1.09	0.03	7.89	Census of Governments
Municipal Gov Per 100K Capita	12.77	17.29	0	137.84	Census of Governments
Years Old Median Housing Stock	31.26	10.27	7	65	Social Explorer
Percent Area Water	1.31	2.21	0.00	18.82	Social Explorer

*Social Explorer refers to an internet application described at *http://www.socialexplorer.com/about* that allows the access of U.S. Census data. Year 2000 data based on information reported in the 2000 Decennial Census. Year 2010 data based on information reported in the Five-Year (2009–2013) American Community Service. I chose this most recently available compilation to better guarantee accuracy in values calculated from the Census definition of a 2010 Urbanized Area based on the aggregation of information calculated for Census Tracts. These values will be more precise if using a five-year compilation in which the desired year of observation is in the middle of the period under observation.

**MN Tax Assoc refers to the Minnesota Taxpayers Association, which for years 2000 and 2010, released *50-State Property Tax Comparison Study Executive Summary* publications with the four desired effective property tax rates. See *https://www.fiscalexcellence.org/our-studies/how-does-mn-compare.html* to download data and description of methods used in calculations. More recent is now available through a partnership with the Lincoln Institute of Land Policy and is available at *https://www.lincolninst.edu/subcenters/significant-features-property-tax/resources.aspx* .

***FBI Uniform Crime Report for 2000 and 2010 available at https://www.fbi.gov/about-us/cjis/ucr/crime-in-the-u.s/2000 and https://www.fbi.gov/about-us/cjis/ucr/crime-in-the-u.s/2010/crime-in-the-u.s.-2010/tables/10tbl08.xls/view .

****Turner and Cassell (2007) use this data, but did not publicly report its value. Cassell provided the data based upon a 9/2/2015 email request.

*****Kenyon, Langley, and Paquin (2012) record the 2010 presence of a manufacturing, commercial, or residential property tax abatement program in a state, but not when these programs began. Langley provided these start years based upon a 9/2/2015 email request.

Table 5: Population Averaged and Fixed Effects^ Panel Data Regression Results Using Natural Log of UA Land Area as Dependent Variable (Clustered on UA Robust Standard Errors^^)

Explanatory Variable	Panel Population Averaged (PA) Regression	VIFs from PA Regression^^^	Panel Fixed Effects (FE) Regression
Constant	-5.764*** (0.405)	not relevant	-6.327*** (1.106)
2010 Year Dummy	**19.4** 0.177* (0.096)	51.26	**63.7** 0.493* (0.276)
Natural Log of Population	0.926*** (0.0128)	2.84	0.974*** (0.0686)
Single-Family Residential Effective Property Tax Rate	**-2.8** -0.0281** (0.0119)	3.42	-0.00226 (0.0129)
Commercial Effective Property Tax Rate	**-2.9** -0.0290** (0.0127)	10.10	**-3.6** -0.0365** (0.0159)
Industrial Effective Property Tax Rate	0.0227 (0.0195)	**7.57**	0.00906 (0.0243)
Multifamily Residential Effective Property Tax Rate	**7.3** 0.0704*** (0.0166)	6.32	**8.3** 0.0799*** (0.0258)
Owner Occupied Percent	**1.2** 0.0118*** (0.00184)	4.96	**0.8** 0.00765*** (0.00323)
Real Median Household Income $10K	**-8.0** -0.0830*** (0.0233)	21.09	**-6.1** -0.0632*** (0.0256)
Poverty Percentage	**0.7** 0.00697** (0.00344)	**11.98**	-0.00233 (0.00353)
Real Household Income Greater 200K	**2.8** 0.0278** (0.0118)	**6.91**	0.0131 (0.0132)
Bachelor Degree Percentage	0.00000319 (0.00341)	**10.68**	0.00342 (0.00518)
Master/Professional Degree Percentage	0.00778 (0.00534)	26.51	**-1.7** -0.0172** (0.00748)
Doctorate Degree Percentage	**-4.2** -0.0428*** (0.0143)	**17.80**	-0.00806 (0.0197)
Age 17 Less Percentage	-0.00690 (0.00447)	7.06	**1.2** 0.0121* (0.00710)

Explanatory Variable	Panel Population Averaged (PA) Regression	VIFs from PA Regression^^^	Panel Fixed Effects (FE) Regression
Age 75 Plus Percentage	**-1.6** -0.0160** (0.00649)	**5.83**	-0.0131 (0.00927)
Latino Percentage	**-0.7** -0.00719*** (0.00159)	10.61	**-1.0** -0.00988*** (0.00312)
African American Percentage	0.00182 (0.00140)	8.39	**-1.0** -0.00986** (0.00445)
Asian Percentage	**-1.3** -0.0130*** (0.00378)	4.56	-0.00926 (0.00655)
Pacific Islander Percentage	**-4.4** -0.0448** (0.0164)	4.58	-0.0451 (0.0296)
Native American Percentage	0.00467 (0.0111)	2.47	-0.0116 (0.0323)
Other Race Percentage	**0.4** 0.00441** (0.00196)	4.97	**0.7** 0.00667*** (0.00236)
Two Race Percentage	-0.00905 (0.00638)	**5.90**	-0.00783 (0.0106)
Foreign Born Percentage	-0.00389 (0.00348)	**9.73**	0.00608 (0.00570)
Male Head Family Household Percentage	0.0172 (0.0108)	4.40	**2.7** 0.0263** (0.0112)
Female Head Family Household Percentage	-0.00700 (0.00559)	14.05	**-1.7** -0.0169** (0.00608)
State Growth Management	-0.0581 (0.0513)	13.36	Dropped
State Growth Management Years	**0.8** 0.00800*** (0.00212)	13.31	**0.4** 0.00437* (0.00218)
Regional Urban Containment	9.7 -0.0716* (0.0400)	7.90	Dropped
Regional Urban Containment Years	**-6.9** -0.000758 (0.00160)	**7.98**	0.000580 (0.00187)
Local Urban Containment	-0.0188 (0.0773)	5.05	Dropped
Local Urban Containment Years	-0.000546 (0.00210)	4.99	0.00297 (0.00211)

Explanatory Variable	Panel Population Averaged (PA) Regression	VIFs from PA Regression^^^	Panel Fixed Effects (FE) Regression
Wharton Res Land Use Extreme Regulation	**18.2** 0.167* (0.0865)	1.92	Dropped
Local Highway Miles Per OneK Capita	**-0.1** -0.00127** (0.000568)	2.79	0.13 -0.00106 (0.00250)
Labor Force Percentage	0.000450 (0.00165)	**36.04**	0.00221 (0.00184)
Real Agric Prod Per Acre $1K	-0.000454 (0.00641)	1.66	**1.46** 0.0145* (0.00848)
State Farm Preservation Years	**-0.4** -0.00409** (0.00171)	4.44	-0.0262 (0.0204)
State Farm Preservation Dev Penalty	**10.2** 0.0974*** (0.0228)	2.37	0.109 (0.204)
Central Place Murder Manslaughter Per 100K	0.0000692 (0.00067)	1.62	0.000549 (0.000703)
Housing Occupied Percentage	**-0.7** -0.00705*** (0.00189)	2.55	**-0.5** -0.00533* (0.00265)
Finance Insurance Employed Percentage	**-1.2** -0.0122*** (0.00247)	8.49	**-1.2** -0.0122*** (0.00280)
Manufacturing Employed Percentage	-0.000383 (0.00140)	3.35	**-0.4** -0.00377*** (0.00146)
Retail Employment Percentage	0.00530 (0.00390)	2.43	0.00696 (0.00456)
Percent Own Source Local Revenue Fees	0.00205 (0.00251)	4.10	0.000120 (0.00339)
State Enterprise Zone	0.0124 (0.0214)	2.43	0.00438 (0.0248)
State Enterprise Zone Years	0.000251 (0.00171)	**5.00**	0.00188 (0.00449)
Manufacturing Prop Abate	**-6.4** -0.0661** (0.0336)	**9.17**	-0.104 (0.207)
Manufacturing Prop Abate Years	**0.3** 0.00331* (0.00180)	**31.18**	0.000622 (0.00268)
Commercial Prop Abate	0.0346 (0.0419)	**14.04**	0.0784 (0.186)

Explanatory Variable	Panel Population Averaged (PA) Regression	VIFs from PA Regression^^^	Panel Fixed Effects (FE) Regression
Commercial Prop Abate Years	**-0.3** -0.00309* (0.00183)	**38.32**	-0.00239 (0.00236)
Housing Prop Abate	0.0144 (0.0632)	11.77	Dropped
Housing Prop Abate Years	0.00203 (0.00173)	**10.79**	0.00284 (0.00194)
Tax Increment Finance	**-5.7** -0.0587*** (0.0203)	1.98	**-5.9** -0.0606* (0.0301)
Tax Increment Finance Years	**-0.4** -0.00443*** (0.000905)	3.41	-0.00545 (0.000426)
County Gov Per 100K Capita	**-3.9** 0.0385*** (0.0106)	2.01	0.0463 (0.0304)
Municipal Gov Per 100K Capita	-0.000832 (0.000620)	2.20	0.000102 (0.000840)
Years Old Median Housing Stock	**-0.6** -0.00555*** (0.00147)	4.47	-0.000161 (0.00335)
Percent Area Water	0.00421 (0.00245)	1.70	0.00391 (0.00275)
R-Squared	***NA***	***NA***	***0.957***

Each entry in the table first contains in **bold** the calculated percentage change in population density from a one-unit change in the respective explanatory found to be statistically significant. The entry below that is the regression coefficient. Below that is the regression coefficient's robust standard error.

^The appropriate Hausman Test indicates that with 99.99% confidence, the fixed effects model is preferred to the PA model.

^^A regression coefficient is defined to be statistically significant from zero in a two-tailed test at the *** (99% or greater confidence level), ** (95% to 99% confidence level), or * (90% to 95% confidence level).

^^^A variance inflation factor (VIF) greater than five indicates the likely presence of multicollinearity between an explanatory variable and all other explanatory variables. Multicollinearity biases the calculated standard error of the regression coefficient downward and may result in an incorrect finding of statistical insignificance when it actually exits. The second-to-last column of this table contains VIFs calculated from a pooled regression. If a VIF is greater than five and the regression coefficient is statistically insignificant, the VIF is highlighted in **bold** to indicate that the finding of insignificance may be invalid due to multicollinearity. Note that the presence of multicollinearity does not bias the regression coefficient.

In both the PA and FE regressions, despite relatively high VIFs, I find that a higher rate of effective commercial property taxation reduces land area when holding population constant (decreasing sprawl), while a higher rate of effective multifamily residential property taxation increases land area when holding population constant (increasing sprawl). The magnitudes of both of these influences increase in the FE regression (after controlling for UA-specific, time-invariant, influences) as compared to the PA regression. The FE regression indicates that a one-percentage point increase in the effective commercial property tax rate in a UA (or about a one standard deviation change from a mean of 2.14) results in a 3.6 percent decrease in land area. While a one percentage point increase in the multifamily residential tax rate (again about a one standard deviation increase from a mean of 1.91) results in the more than double in absolute magnitude, 8.3 percent increase in land area.[17]

Concluding Thoughts

This study sought to determine the independent influence that higher effective rates of property taxation has on the square mile size (or after controlling for population, one way of accounting for urban sprawl) of a United States urbanized area (UA). A review of the previous literature revealed that economic theory predicts an indeterminate influence of a greater rate of property taxation in a UA on the land use of that UA. Though an influence is expected, its direction is only predictable after controlling for UA specific factors that determine how housing consumers and housing developers react to property taxation. Theorists have also studied the influence of property taxation on urbanized area size through non-residential property effects. Similar to with residential property, definitive conclusions can only be made after assuming very specific characteristics of an urban area that are unlikely to remains constant across a single cross section of United States UAs.

Previous empirical researchers—understanding this theoretical ambiguity—have tried to tease out the effect of differences in the rate of property taxation on urban density. This paper included a review of this literature that noted concerns stemming from the use of only a single cross section of UAs (which allowed for no control of unobservable fixed effects that vary across urbanized areas) and likely omitted variable bias due to an incomplete accounting for other factors besides property taxation expected to influence UA square miles. I have tried to overcome these concerns by gathering two cross sections of data from 2000 and 2010 of comparable United States UAs whose spatial footprint, for the first time in consecutive censuses, has been determined by a consistent process. I have also controlled for other factors expected to influence UA size.

I find that a one-percentage point increase in the effective rate of property taxation on commercial property in a United States UA results in about a four percent decrease in land area holding population constant (decreased sprawl). While the same one-percentage point increase in the effective rate of property taxation charged to a multifamily residential property results in an

[17]I chose to not include the results of additional fixed-effect regression runs (described earlier in footnotes 11 and 12)—that account for the influence of rural effective tax rates on the population density of a UA and the possible endogeneity of the central place effective tax rate being used for the same UA for which it is the central place—because they did little to change the findings already described.

approximate eight percent increase in land area holding population constant (increased sprawl). A similar increase in the taxation of single-family residential or industrial property exerted no effect. These findings are most comparable to two earlier regression analyses summarized in Table 2. First, Song and Zenou's (2006) regression analysis of a 448 United States UAs in 2000 found that a 10 percent increase in a weighted average of local property millage rates resulted in about a four percent decrease in square miles holding population constant. Second, Marshall's (2008) regression analysis of 306 United States metropolitan statistical areas from 1990 and 2000 found that a 10 percent increase in the effective residential property tax rate (measured as aggregate household specific property taxes paid divided by market value of home as reported on Census long form) resulted in about four percent less sprawl (as measured by a sprawl index she created). These findings match my own regarding effective commercial property taxation, but differ for single family residential and industrial effective property taxation that exhibited no effect, and for multifamily residential that exhibited the opposite effect.

As practiced in the United States, with only a few exceptions, the same statutory rate of taxation falls on both the land and improvement component values of a parcel subject to property taxation. As noted by George (1879), the portion of the property tax on land is non-distortionary, while the property tax on improvements to land distorts the desirability of undertaking these improvements (Oates and Schwab 2009). The regression findings recorded here show that rates of effective property taxation for different classes of property do distort the amount of improvements undertaken on raw land and thus influence the square miles of a United States urbanized area. My thoughts on what may be driving the difference in the property tax results across different classes of property is based on Brueckner's (2000) and Brueckner and Kim's (2003) theoretical identification of two effects of residential property taxation as it applies to improvements to land. In his 2000 article, Brueckner first assumed that each household desires a fixed square-foot size of floor space. It is possible to build this desired floor space on a slightly larger lot for one household in a single-story configuration. It can also exist for certain number (N) of households using the same size lot in an N-story configuration. The N-story options yield increasingly more capital-intensive land use of residential housing, greater population density, and less sprawl. But as the rate of residential property taxation rises, the capital intensive use of a lot for residential housing units through more stories is discouraged through an *Improvement Effect*, and the expected effect is to encourage more one-story units, less population density, and greater sprawl.

In their 2003 article, Brueckner and Kim extend this theory to allow for the possibility of shifting higher rates of property taxation forward, at least in part, to a greater price charged per square foot of floor space. This shift results in a countervailing *Dwelling-Size Effect* where each household desires a smaller square-foot total floor space, resulting in greater population density and less sprawl. The relative magnitude of the Improvement to the Dwelling-Size Effect determines the outcome of greater rates of residential property taxation on population density. Since the single-family residential and multifamily residential effective property tax rates are levied on housing structures, the application of this theoretical model to explaining the regression findings derived here is that for single family residential properties, the Improvement Effect and Dwelling-Size Effect (moving in opposite but equal directions) cancel out and yield the insignificant effect found. While for multifamily residential properties, the Improvement Effect dominates the Dwelling-Size Effect and the result is less population density.

An analogous extension of this theory to non-residential properties would assume that for each unit of output produced by a typical commercial or manufacturing firm, there is a profit-maximizing square footage size of optimal single-story production space. If labor (or another input) cannot replace taxable property in the firm's production, then this optimal square footage of floor space is fixed. Under this restrictive assumption, higher rates of non-residential property taxation yield the *Improvement Effect* of more one-story firms spread out among an urbanized area that subsequently uses more land and encourages workers to live near these spread out firms at a lower population density and greater sprawl. If labor (or another input) can be substituted for taxable real property in the firm's production (as it likely can), then a *Production Size Effect* could also occur of each firm consequently using less square-foot size of production space and less land to put this on, encouraging workers to live near these more closely spaced firms at higher population density and less sprawl. Thus, the positive influence of effective commercial property rates on a UA's population density found here may be due to the Production Size Effect dominating the Improvement Effect. The insignificant influence of effective industrial property tax rates could be a consequence of these two countervailing effects cancelling each other out.

The regression analyses offered here used a panel data set consisting of two comparable cross-sections of United States urbanized areas from years 2000 and 2010 gathered to account meticulously for other measurable factors that may influence UA population density besides the effective rates of property taxation. The result of the regression being a confirmation of George's (1879) premise that the rate of effective property taxation observed in a United States urbanized area does distort its intensity of land use. Importantly, this distortion differs by the type of property taxed as it acts through the relative influences of an Improvement verses Dwelling (or Production) Size Effect.

A feasible policy implication from the results of this analysis is the use of an increase in the rate of effective property taxation applied to commercial properties in a United States UA to increase the population density of that UA. While a decrease in the rate of effective property taxation applied to multifamily residential (apartment) properties would do the same. Based upon the finding that the magnitude of an equal multifamily residential effective property tax rate decrease is expected to be over twice that of an equal commercial effective property tax rate increase, a balanced-budget imposition of this policy that reduces land used for a given population (diminished sprawl) would require less of a cut in the absolute effective rate on commercial property tax rate than an increase in the absolute effective rate on multifamily residential property tax rate.

How does a policymaker go about changing the effective rate of property taxation on a specific class of property? As noted in *Significant Features of the Property Tax*, 33 states in 2013 operated under a classified system of property taxation that allowed for the differential treatment of classes of property (like commercial, industrial, multifamily residential, and single family residential) through differences in assessment to market value ratios and/or differences in statutory rates (Lincoln Institute of Land Policy and George Washington Institute of Public Policy B). Conceivably, localities within urbanized areas in these states that allow for differential property tax treatment by class (either through a change in assessment ratio and/or statutory rate) could directly institute this policy change. Urbanized areas in the12 states in 2012 that do allow for property tax abatement in the residential class of property (Kenyon, Langley, and Paquin 2012) could alternatively use this program to achieve the prescribed reduction in effective multifamily residential property taxation. Urbanized areas in states that do not approve of differences in tax treatment of property by class or abatement would need to lobby their state legislature for such allowances to do this.

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