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Can Urban Planning Instruments Solve Externalities?
Empirical Analysis of Regulations and Taxes

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Abstract

Urban success depends on the external effects of urbanization, for example, carbon dioxide (CO_2) emissions and crime levels. In addition, there is a connection between urbanization policy and population density. This study contributes to our understanding of indirect linkages from urban policy to external effects. Using Japanese city level data from 1990 to 2007, we find that existing land use regulations such as taxes and command-and-control regulations can alter city density. Increases in population density decrease CO_2 emissions and the costs of waste cleanup but worsen crime, traffic accidents and public finances. Thus, density-increasing urban planning simultaneously generates both positive and negative effects on society.

Keywords: urbanization, urban planning instruments, land use regulations, command-and-control regulations, carbon dioxide emissions, externalities

1. Introduction

Urban success surely depends on economic development (Glaeser, 2012), and the literature on agglomeration tells us that growth of a city has many merits in terms of economies of scale and network effects (Fujita and Thisse, 2013). Recent studies have analyzed external effects of urbanization such as carbon dioxide (CO_2) emissions and changes in crime rates (Glaeser and Sacerdote, 1999; Glaeser and Kahn, 2010; Gaigné et al., 2012). Additionally, urban policy affects urbanization through changes in population or population density (Song and Zenou, 2006).

Half of the world's population currently lives in urban areas (International Herald Tribune, 2008). In the present study, we seek to contribute to our understanding of the indirect linkages from urban policy to external effects through urbanization. External effects include common externalities such as CO_2 emissions and crime. Mitigation of these externalities can be important policy goals of governments.

Environmental and urban economists are closely observing how environmentally friendly urban policies can help counteract CO_2 emissions. The notion of a compact urban city has attracted the attention of international organizations (OECD, 2012). As an urban planning and urban design concept, the compact city is a place of short distances, high residential density (spatial distribution of the population) and mixed land use. Advocates of the compact city argue that such a design encourages low energy consumption and reduced pollution. We therefore expect that CO_2 emissions from vehicles will decrease as cities become increasingly compact and city functions are relocated.[1] In this study, population density (or population per given land area) is used to measure the degree of urbanization.

Glaeser (2012) discusses the need for urban policies, especially land use regulation and

[1] The transportation sector has greatly contributed to increases in CO_2 emissions around the world. Effective environmental policies with respect to this sector are required to reduce CO_2 emissions from vehicles. We therefore apply emissions data for vehicle use.

other economic measures, to address negative externalities such as CO_2 emissions, pollution, crime and congestion. Previous studies have emphasized the effect of urban policy on density (Newman and Kenworthy, 1989; Cervero and Murakami, 2010; Gleaser and Kahn, 2010; Gaigné et al., 2012).

CO_2 emissions may decrease in dense cities, and indeed, empirically, a negative relationship between CO_2 emissions from vehicles and population density is found. Residents in highly urbanized environments may have less need of vehicles, given well-established transportation systems, than people in low density environments. Total vehicle miles traveled in a city may also be low in high density cities. These factors lead to reduced CO_2 emissions from vehicles.

However, city density/agglomeration generates economic growth (Cuberes, 2012) because opportunity costs such as travelling time in densely packed areas are smaller than in sparse areas. If the marginal utility of vehicle ownership is positive, economic growth might provide residents without vehicles incentives to purchase vehicles. This is an income effect of agglomeration. If the positive effects on CO_2 emissions exceed the negative effects, city density leads to increased emissions.

Suppose increases in population/population density indeed led to a decrease in CO_2 emissions. How could we then increase city density (Glaeser, 2012)? Glaeser and Kahn (2010) suggest that the effects of land-use restrictions on people's decisions to move to different locations merit further research. One possible solution is to effectively utilize existing land use regulations, such as taxes and command-and-control mechanisms (CAC). We examine the following research questions: 1) Can land use regulations affect population density? 2) Are CO_2 emissions from vehicles and other external factors such as congestion and crime lower in high density areas than in low density areas? We study Japan, using city level data for the 1970-2007 period. We use data for all Japanese cities because there is wide variation in the population densities of regions in Japan (see Appendix Figure A1). For example, the data include the world's largest super-city, Tokyo-Yokohama, which is larger than New York City, Mexico City, and Delhi (Demographia, 2013).

Using city-level data, this paper examines whether CO_2 emissions from vehicles in cities with high population densities are likely to be small relative to cities with low population densities. Previous studies have investigated the US (see Glaeser and Kahn, 2010; Cervero and Murakami, 2010). Building on this literature, we analyze the effects on population density of several urban policies such as property taxes and urbanization control areas.

Furthermore, we examine other effects of city density, in addition to CO_2 emissions. These include traffic accidents, annual cleaning expenditures, the facility condition index[2] and crime. These other outcomes are important in evaluating urban policy, as they represent social issues that, similarly to CO_2 emissions, must be solved (Glaeser, 2012). If city governments succeed in raising population density, traffic congestion may increase (Glaeser and Gottlieb, 2009), and an increase in congestion will result in an increase in traffic accidents (Wang et al., 2009). In addition, crime will also most likely increase because crime in big cities is higher than in small cities (Glaeser and Sacerdote, 1999). Therefore, the more dense cities become, the higher traffic accidents and crime are expected to be. These are negative impacts on social welfare associated with increased city density.

Not only negative outcomes but also positive outcomes may be generated by raising city density. Due to increased density, areas that city governments must clean and collect waste from may shrink, as development and urban sprawl are reinforced by increased city density and residential neighborhoods concentrate into city centers. City governments can thus save expenditures that may have gone for cleaning and use them to improve their facility condition index. Similarly to reductions of CO_2 emissions, these effects improve social welfare.

The remainder of this paper is organized as follows: Section 2 describes the background of our research and Japanese urban planning. Sections 3 and 4 present our empirical model used to measure the effects of population density and our estimation results, respectively. Section 5 concludes the paper.

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[2] The facility condition index is used to assess the financial resources of local governments. It is calculated as standardized annual revenue divided by standardized annual demand. Therefore, the larger the index is for a given city government, the greater its financial resources.

2. Urban Planning Instruments for Urbanization

2.1. Background

Several empirical studies have directly examined the relationship between population density and vehicle usage (CO_2 emissions from vehicles). The first of these, Newman and Kenworthy (1989), using 1980 data from large cities throughout the world, found that gasoline consumption per capita in cities with high density was lower than that in cities with low density. In addition, Gleaser and Kahn (2010) provided a detailed analysis based on individual data for large cities in the United States (US), finding a negative relationship between population density and automobile emissions. Using data on 370 US regions for 2003, Cervero and Murakami (2010) showed that vehicle mile traveled per capita is negatively correlated with population density, while Brownstone and Golob (2009), employing US household survey data, showed that people in low residential density areas tend to use vehicles more than people in high residential density areas.[3] It is therefore generally expected that policies that increase city density can be effective in achieving emissions reductions.

Figure 1 shows the relationship between population density and per capita CO_2 emissions from automobiles in all cities in Japan. Unlike Newman and Kenworthy (1989), Figure 1 includes small cities and towns. As seen in the figure, even including small scale city data, the relationship is found to be negative, which is consistent with previous studies. In addition, the plot shows a larger variance of per capita CO_2 emissions from automobiles in lower population density areas than in higher population density areas. Therefore, it is crucial to include all city data to gain an overall picture of the relationship between population density and CO_2 emissions.

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[3] Several studies also indirectly support the view that population density is negatively correlated with CO_2 emissions from vehicles. Yamamoto (2009) reveals that population density has a negative effect on vehicle ownership in Japan and Malaysia. Liu et al. (2014) show that there is positive correlation between urban compactness and CO_2 emissions per GDP in China. Additionally, Fang (2008) provides evidence that people in high density areas tend to own small vehicles, which have better fuel economy than large vehicles. These studies imply that CO_2 emissions from vehicles may decrease with increasing population density.

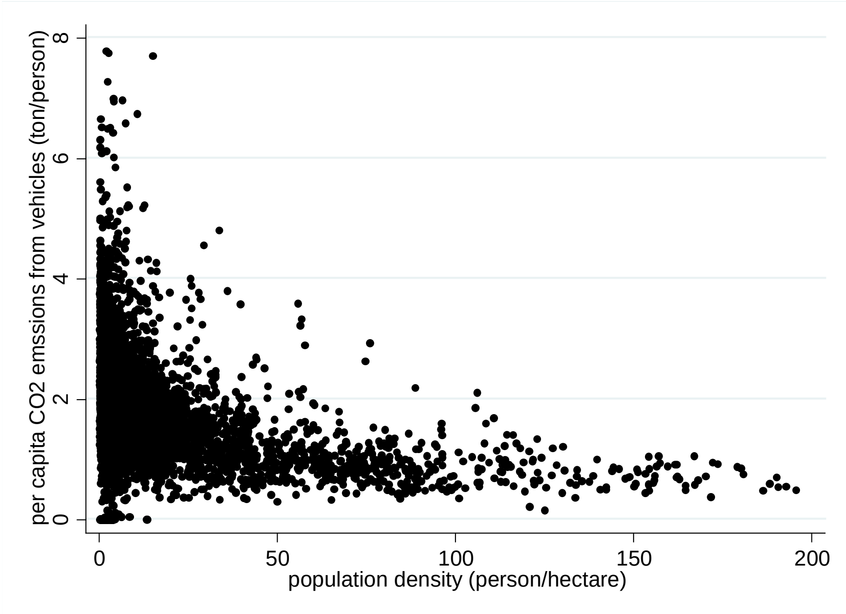

Figure 1. CO_2 and Urbanization: The relationship between population density and per capita CO_2 emissions from 1990 to 2007 in Japan

Note: The number of observations is 6,866. The figure is based on data from 1990, 1999, 2003 and 2007. There are 12 cities in which per capita CO2 emissions are above 8.

If the negative relationship between population density and the CO_2 emissions holds, as Gleaser and Kahn (2010) show, governments can decrease CO_2 emissions by increasing population density. We hypothesize that several land use regulations can potentially increase population density. These include property taxes (Brueckner and Kim, 2003; Song and Zenou, 2006) and urbanization control areas (Sorensen et al., 2004). There is a connection between land use regulations and population growth at the regional level (Glaeser and Ward, 2009). Our study is the first to assess whether and to what extent various land use regulations affect CO_2 emissions and other external factors indirectly through changes in population density. Therefore, using datasets that cover all Japanese cities, we extend previous studies by examining the indirect effects of land use regulations.

Land use regulations such as property taxes and urbanization control areas are implemented to control the scale of cities and constrain urban sprawl. For example, Song and Zenou

(2006) show theoretically that property taxes affect population density, which in turn affects urban sprawl. It is clear that the urbanization control areas influence population density because the policy prohibits residents from living in designated areas. This paper is the first to examine the effects of multiple land use regulations on CO_2 emissions and other external factors via population density. We also note that direct policies, although they are not the focus of our study, affect emissions. For example, Millard-Ball (2012) shows that cities that implement climate plans succeed in reducing greenhouse gas emissions.

2.2 Japanese Urban Planning

Urban policies affect all residential economic activities via land use relocations of city facilities such as city halls, hospitals, roads, railways, and schools, among others. Hence, planning may affect CO_2 emissions from vehicles and have other affects as well. This paper examines five outcome variables: CO_2 emissions, traffic accidents, annual cleaning expenditures, the facility condition index and crime.

Previous studies have shown that CO_2 emissions (gasoline consumption) in cities with relatively high population densities tend to be low (Glaeser and Kahn, 2010). At the same time, Brownstone and Golob (2009) note that it may be difficult for governments to dramatically increase residential density. We contribute to the literature by examining how governments can raise population density.

The purpose of this paper is to examine the effects of urban policy on CO_2 emissions by assessing Japanese city planning instruments designed to raise population density. The types of instruments examined are two CAC regulations and two taxes stipulated by *Japanese Urban Planning Law*. The CAC instruments, known as *urbanization control areas* and *urbanization promoting areas*, have been implemented in certain cities. Under the law, *urbanization control areas* are defined as areas where urbanization is restricted. As a general rule, certain kinds of development, for example, development of home sites by chopping down forests, are prohibited in such areas.[4] In other words, urban sprawl is restricted, and these areas act as buffer zones in protecting the environment. Therefore, city policy planners can control urban sprawl and promote urbanization by implementing *urbanization control areas*.

However, *urbanization promoting areas* are major urban areas where governments decide to preferentially urbanize over a ten-year period in a systematic manner. To this end, city governments actively create infrastructure such as water and sewage, roads and utilities in designated areas. The locations and scale of the infrastructure, including roads, are effectively planned. Well planned roads could lead to reduced gasoline consumption by reducing congestion. Hence, *urbanization promoting areas* could decrease CO_2 emissions from vehicles inside a city.

As for taxes, residents face *urban planning taxes* and *property taxes* imposed by their city governments. Local city governments can change these tax rates because, similarly to the regulations discussed above, they are local policies. Importantly, the two taxes differ significantly. *Urban planning taxes* are exclusively for constructing infrastructure in *urbanization promoting areas*, and city governments cannot use these taxes for other purposes. Therefore, residents in certain areas, for example, in the central business district, are subject to both *urban planning taxes* and *property taxes*, while persons living in an *urbanization control area* are subject only to *property taxes*. All city governments impose a *property tax*, whereas an *urban planning tax* is not imposed by every city government. Also note that tax rates vary across city governments.

Using the characteristics of the two taxes, city governments can incentivize residents living in outer areas to move to central areas, so that population density might rise. To increase city density, it is preferable to increase *property taxes* and reduce *urban planning taxes* (or subsidies) simultaneously. Then the cost of living in an *urbanization promoting area* is lower than the cost of living in an *urbanization control area*.

This projection pertains to internal movements or residents within a city. In addition,

[4] Living in such areas is permitted if certain conditions stipulated in the *Urban Planning Law* are met.

however, residents move externally between cities. That is, people may choose to live in cities where both *urban planning tax* rates and *property tax* rates are low. In this case, the population densities of cities with low tax rates will exceed those of cities with high tax rates. It is thus unclear whether internal movements of a city population will outweigh external movements, or vice versa.

Furthermore, these instruments have the important feature that city governments can implement them without permission from the national government. Implementations can be carried out by passing/revising ordinances. Hence, such rate changes are feasible instruments of urban policy to achieve higher city density, as city governments have the freedom to utilize the four instruments for their own purposes.

Figure 2 presents an intuitive example of the four urban policy instruments in a circular city. The outer of *urbanization promoting area* is set as *urbanization control area*.

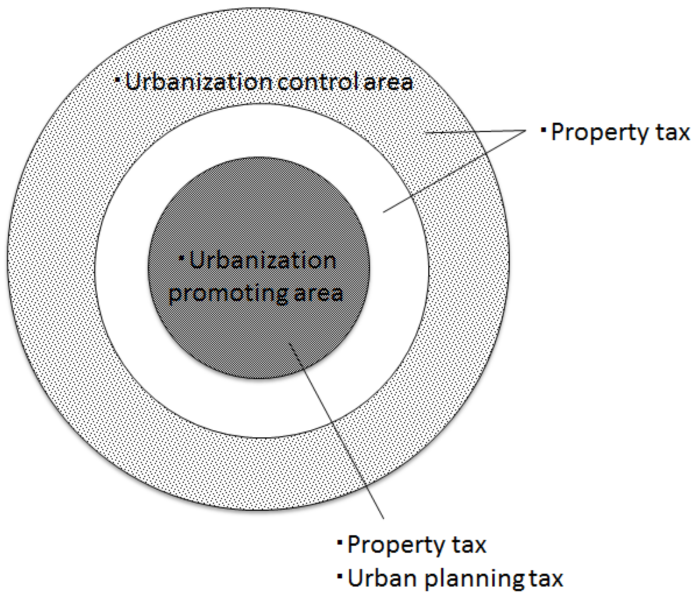

Figure 2. Example for Taxes and Regulations in a Circular City

As of March 2010, there were 1,750 city governments in Japan.[5] Cities can be classified

[5] In Japan, local governments are divided into two types. One is the prefecture, which is nearly equivalent to a state in the United States. There are 47 prefectures in Japan. The other is the city government, defined in this paper.

into four types: special ward, city, town and village. Breaking down these classifications, there are 23 special wards (exclusively in the Tokyo prefecture), 786 cities, 757 towns and 184 villages. Among them, 687 city governments implement an *urban planning tax*. Although the standard *property tax* rate is 1.4 percent, 126 city governments set higher tax rates.

Urbanization promoting areas and *urbanization control areas* have been established by 649 and 626 city governments, respectively. Histograms for tax rates and regulation area rates (regulation area divided by habitable area) in 2007 are presented in Figure 3. Figure 3 shows that the uses of each of these instruments vary. Exploiting these variations in tax rates and regulation area rates, we can empirically identify the effects of the four instruments on population density. Descriptive statistics, such as the means and standard deviations, are presented in section 3.

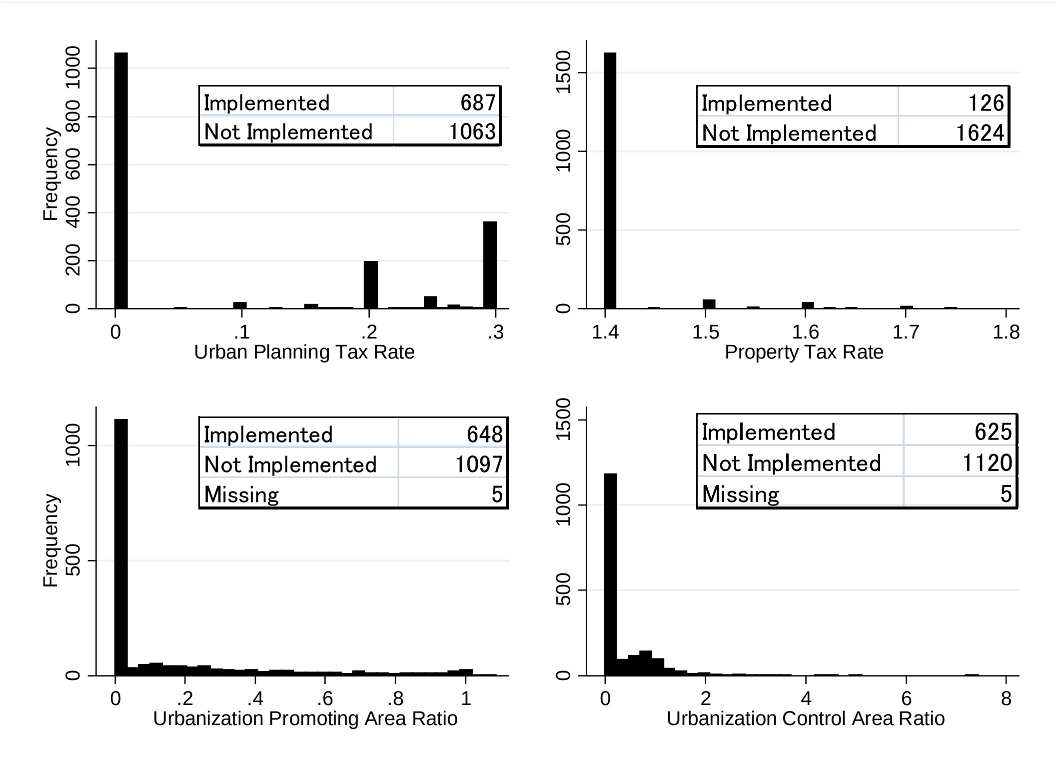

Figure 3. Distributions of Taxes Rates and Regulation Area Rates in 2007 (*Obs*.=1,750)

Note: The vertical and horizontal axes denote frequencies and rates, respectively. The urbanization promoting area ratio is measured as the regulation area divided by habitable area. The urbanization control area ratio is calculated by the same procedure.

3. Model and Data

3.1. Empirical Model

This section discusses the empirical model and data used to examine the relationship between city urbanization/population density, urban planning instruments and CO_2 emissions.

First, the following linear equation model (1) is used to identify the relationship between population density and CO_2 emissions. The dependent variable, $E_{i,t}$, denotes CO_2 emissions from vehicles in city *i* in year *t*. The vector $\mathbf{X}_{i,t}$ on the right-hand side is a vector of explanatory variables capturing city characteristics such as income per capita, road length and so on that affect CO_2 emissions. $POP_{i,t}$ is population density in city *i* in year *t*. $\boldsymbol{\beta}$ and γ are parameters to be estimated. η_i and μ_t are city and time specific effects, respectively. An unobserved idiosyncratic error term is expressed as $\varepsilon_{i,t}$.

$$\ln E_{i,t} = \ln \mathbf{X}_{i,t}\boldsymbol{\beta} + \gamma \cdot \ln POP_{i,t} + \eta_i + \mu_t + \varepsilon_{i,t} \quad (1)$$

If CO_2 emissions from vehicles in a city in which population density is high are lower than those in a sprawled city, the estimated coefficient $\hat{\gamma}$ is negative. Therefore, the sign of $\hat{\gamma}$ is important to our analysis.

In addition to CO_2 emissions, we analyze traffic accidents, crime, annual cleaning expenditures and the facility condition index as dependent variables. As city functions are compacted (city density increases), we expect traffic accidents, crime and the facility condition index to increase and cleaning expenditures to decrease.

City governments may be able to raise their population densities through policy instruments. Four urban planning instruments are considered, namely, *urbanization promoting areas*, *urbanization control areas*, *urban planning taxes* and *property taxes*. Hence, population density in equation (1) must be treated as an endogenous variable. We therefore estimate the following equation (2).

$$\ln POP_{i,t} = \ln \mathbf{X}_{i,t}\boldsymbol{\delta} + \mathbf{UP}_{i,t}\boldsymbol{\theta} + \nu_i + \lambda_t + \varpi_{i,t} \quad (2)$$

where the vector $\mathbf{UP_{i,t}}$ represents the four urban planning instruments that affect population density. The other control variables are contained in vector $\mathbf{X_{i,t}}$. City and time specific fixed effects are expressed as ν_i and λ_t, respectively, unobserved independent and identically distributed error term.

Treatment of population density as an endogenous variable, as in equation (1), is consistent with previous studies of urbanization (Brownstone and Golob, 2009). Therefore, a two-stage estimation method is used to avoid endogeneity. That is, we estimate equation (2) and then estimate equation (1), using estimated values from equation (2). The instrumental variables in equation (2), which only affect population density, are required to ensure consistency of the estimated coefficients in equation (1). The estimated coefficients are biased in equation (1) if population density is treated as an exogenous variable. In our model, $\mathbf{UP_{i,t}}$ works as an instrumental variable vector because urban planning taxes and regulations are not introduced to reduce CO_2 emissions but to control land use and design city characteristics.

3.2. Data

The study employs data for all 1,750 Japanese cities from 1990 to 2007. Table 1 presents descriptive statistics for the variables used in this paper. Data sources for each variable are indicated in the table. If there are no missing values, the number of observations is 31,500 (=1,750×18). Due to a lack of available data on CO_2 emissions from vehicles, the four years of 1990, 1999, 2003 and 2007 are used in our analysis. There are also many missing values for the number of police stations.

City government data on CO_2 emissions are provided in *Statistics for Local Environment*, published by the Coalition of Local Governments for Environment Initiative. The *Basic Resident Register*, which contains population data, is published by the Ministry of Internal Affairs and Communications (MIAC). To convert population into population density, we use habitable area, which is reported by the Geological Information Authority of Japan. The *Annual Report on Fire*

Defense, *Taxation Status of Local Government* and the *Annual Report on Local Public Finance* are also published by MIAC. Both the *Annual Survey on Urban Planning* and the *Annual Report on Road Statistics* are obtained from the Ministry of Land, Infrastructure, Transport and Tourism.

Property tax rates for each city were obtained through telephone surveys conducted in cities with property tax rates above 1.4 percent. A list of these cities (126 city governments) was obtained from MIAC. The list is presented in Figure 3.

Table 1. Descriptive Statistics

Variables	Unit	Obs.	Mean	S.D.	Min	Max	Source
Population Density	person/ha	30923	13.8	23.0	0.12	195.7	Basic Resident Register
CO_2 (Total)	ton-CO_2	6914	110115	226004	0	3758081	Statistics for local environment
CO_2 (Passenger)	ton-CO_2	6921	60746	126105	0	2121385	Statistics for local environment
CO_2 (Truck)	ton-CO_2	6916	49295	103562	0	1675453	Statistics for local environment
Traffic Accident	case	30860	467	1275	0	25712	Annual report on fire defence
Crime	case	29618	1179	4233	0	136454	Annual report on fire defence
Annual Expenditures for Cleaning	1,000 yen	29064	1273080	3674104	0	9.46E+07	Annual report on local public finance
Facility Condition Index	index	28792	0.74	0.64	0	7.34	Annual report on local public finance
Income	1,000 yen	31188	1.06E+08	2.96E+08	239855	7.18E+09	Taxation status of local government
Road Length	kilometer	30553	806	5903	8	550300	Annual report on road statistics
Singuler	place	27961	93.3	233.4	0	4226	Annual report on fire defence
Police Station	place	16823	9.01	15.44	0	259	Annual report on fire defence
Urban Planning Tax Rate	percent	31500	0.10	0.13	0	0.31	Annual survey on urban planning
Property Tax Rate	percent	31500	1.41	0.04	1.4	1.85	Telephone survey
Urbanization Promoting Area Ratio	percent	30720	0.14	0.33	0	37.91	Annual survey on urban planning
Urbanization Control Area Ratio	percent	30720	0.32	0.56	0	7.73	Annual survey on urban planning

In Japan, significant consolidation of city governments began around 2002 (see Figure 4). While there were more than 3,000 city governments before 2002, the total number fell dramatically as a result of these consolidations. To account these consolidations, we created a variable for city government specific effects. Suppose, for example, that city *A* is consolidated with city *B* and that the new city is named city *A*. In this case, we cannot distinguish between the old city *A* and the new city *A* because the two cities' names are the same. Therefore, we cannot precisely account for city *A*'s fixed effects in the estimations.

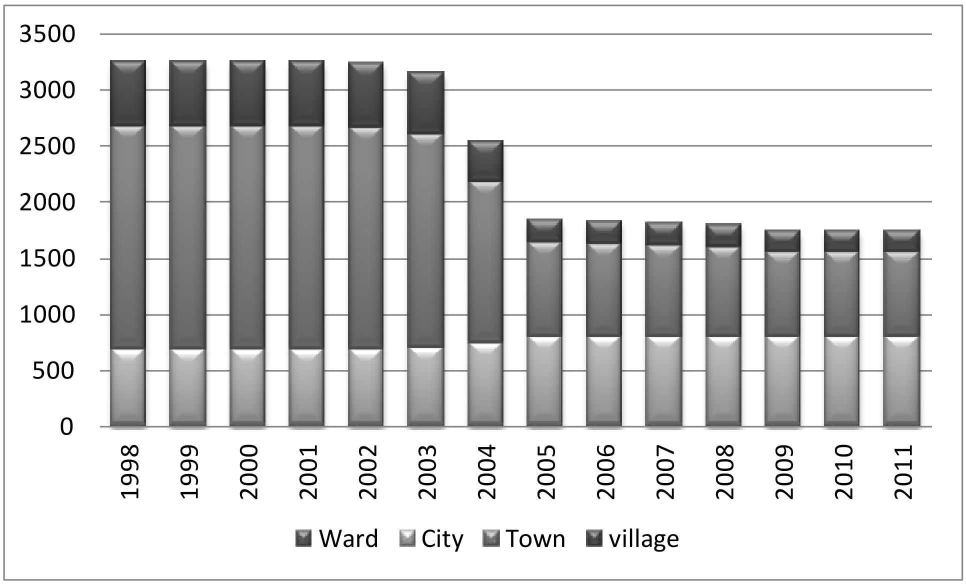

Figure 4. Transition of Number of City Governments in Japan

We construct our database by the following procedure. To avoid incorporating city *A*'s fixed effects, we transform our unbalanced city government data into balanced data. That is, we add the value for city *B* to the value for the old city *A* before consolidation and then treat the created "*B*+old *A*" as a new city *A* in the estimation. Fixed effects without missing values can be obtained by accounting for the decrease in the number of city governments due to consolidation.

4. Results

4.1. Relationship between outcomes and population density

This section discusses the estimation results, using the all-city government panel data from 1990 to 2007. Before estimating equations (1) and (2), we run bivariate regressions in which the five outcomes are dependent variables, and the explanatory variable is logged population density. A plotted graph is presented in Figure 5. Due to missing values, the number of observations for each regression differ. For CO_2 emissions, the number of observations is smaller than for the others because the sample period is only four years.

All relationships between CO_2 emissions (total = passengers + trucks), CO_2 emissions (passengers), CO_2 emissions (trucks) and population density are negative. Hence, population density may lead not only to decreased passenger vehicle usage but also to decreased truck usage. In highly dense cities, accidents and crime increase, and cleaning expenditures and the facility condition index improve. These regression results agree with our expectations.

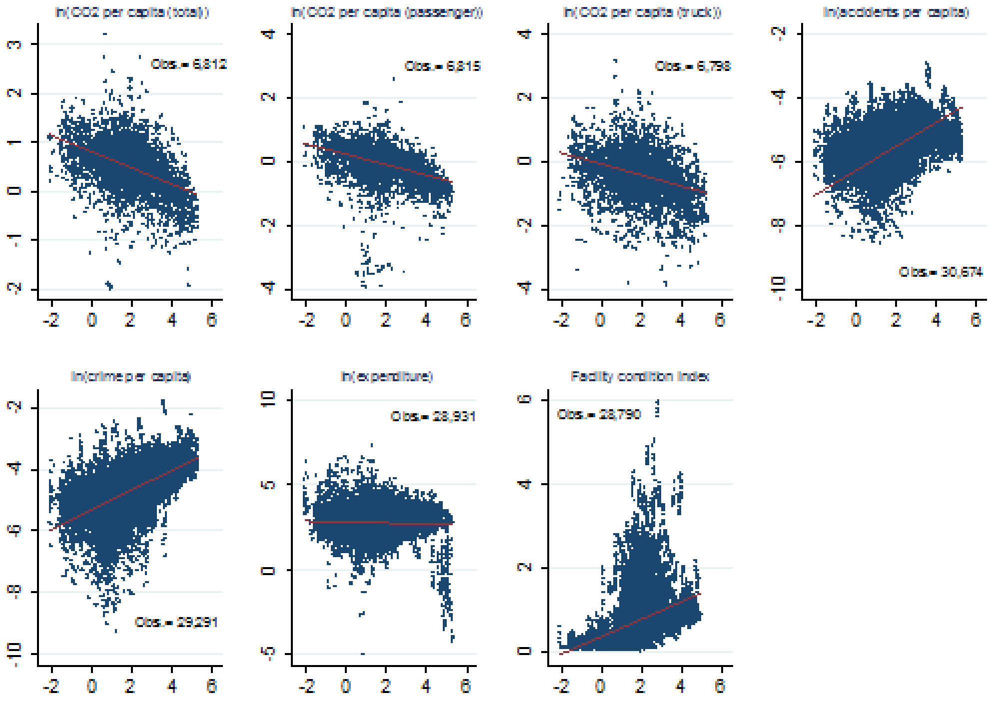

Figure 5. Relationship between Outcomes and Logged Population Density from 1990 to 2007

Note: The vertical axes represent outcomes, and the horizontal axes represent logged population density.

4.2. Effects of urban planning instruments on population density

Population density is associated with income and policy variables. Table 2 shows the results for equation (2). Three of the instruments significantly affect population density in all cases. The exception is the urban planning tax, although the urban planning tax is significant in models 1 and 2. Decreases in both the urban planning tax rate and the property tax rate increase population density—a result that does not support the view that the urban planning tax and the property tax have negative and positive effects on population density, respectively. Instead, our alternative hypothesis of residential external movements between cities appears to be supported, as the coefficient for the urban planning tax rate is insignificant in model 3. Therefore, city governments can attract people living in other cities by reducing property taxes. As for the two CACs, it is robustly revealed that expansion of both urbanization promoting areas and urbanization control areas leads to increased population density, as expected.

Income is used as a proxy for the economic scale in the city. As a growing city is attractive to people in various respects (Glaeser, 2011), the sign of the coefficient is strongly significant and positive. Thus, property taxes and regulations can make a city more compact. This empirical finding is important for urban policy planners.

Table 2. Estimation Results of Population Density on Urban Planning Instruments

	Model 1			Model 2			Model 3		
Variables	Coef.	S.E.		Coef.	S.E.		Coef.	S.E.	
ln(income)	0.458	0.045	***	0.460	0.045	***	0.395	0.019	***
Urban Planning Tax Rate	-0.324	0.088	***	-0.336	0.088	***	-0.004	0.011	
Property Tax Rate	-0.587	0.163	***	-0.587	0.161	***	-0.213	0.031	***
Urbanization Control Area Ratio	0.204	0.044	***	0.203	0.044	***	0.009	0.004	**
Urbanization Promoting Area Ratio	1.082	0.574	*	1.080	0.573	*	0.005	0.001	***
Constant	-5.409	0.549	***	-5.341	0.549	***	-4.470	0.408	***
Time Fixed Effects	No			Yes			Yes		
City Government Fixed Effects	No			No			Yes		
Adj. R-squared	0.62			0.62			0.99		
F-value (P-value)	9030.2 (0.00)			2060.8 (0.00)			44985.9 (0.00)		

Notes: Obs.=30,713. ***, ** and * indicate significance levels of 1%, 5% and 10%, respectively. Robust standard errors are used.

Next, we conduct a quantile regression rather than the usual fixed effects regression (see Koenker (2005) for a review of this method). In the fixed effect model, coefficients are estimated under the condition of variable means. Hence, the model cannot verify a hypothesis that the effects of urban planning instruments on population density in cities with high density are different from those in cities with low density. Quantile regression can clarify this hypothesis. Estimation results for the four urban planning instruments using a quantile regression are presented in Figure 6. The vertical and horizontal axes in each graph denote estimated coefficients and quantiles, respectively. Ninety-five percent confidence intervals are added as dashed lines to each figure. To take computation feasibility into account, city government- and time-specific fixed effects are omitted from the estimations.

We find greater effectiveness for the two CAC regulations in low density cities, with the exception of the coefficient for the urbanization promoting area ratio for the quantile from 0.1 and 0.2. On the contrary, in areas with low population density, the effectiveness of urban planning and property taxes are higher and lower, respectively. In particular, in quantile 0.1 to 0.5, the property tax is statistically insignificant.

There are two important implications. First, the two regulations are less effective in increasing population density in cities that are already dense compared with cities that are less dense. On the other hand, the two regulations are useful in increasing density in low density cities.

Second, the urban planning tax is effective in increasing population density in low density cities. Property taxes, by contrast, are not found to be helpful in increasing density, as the coefficients are insignificant. While the usefulness of urban planning taxes diminishes with higher levels of city density, property taxes are valuable tools for increasing population density in highly dense cities. Therefore, appropriate instruments must be chosen to obtain additional population density.

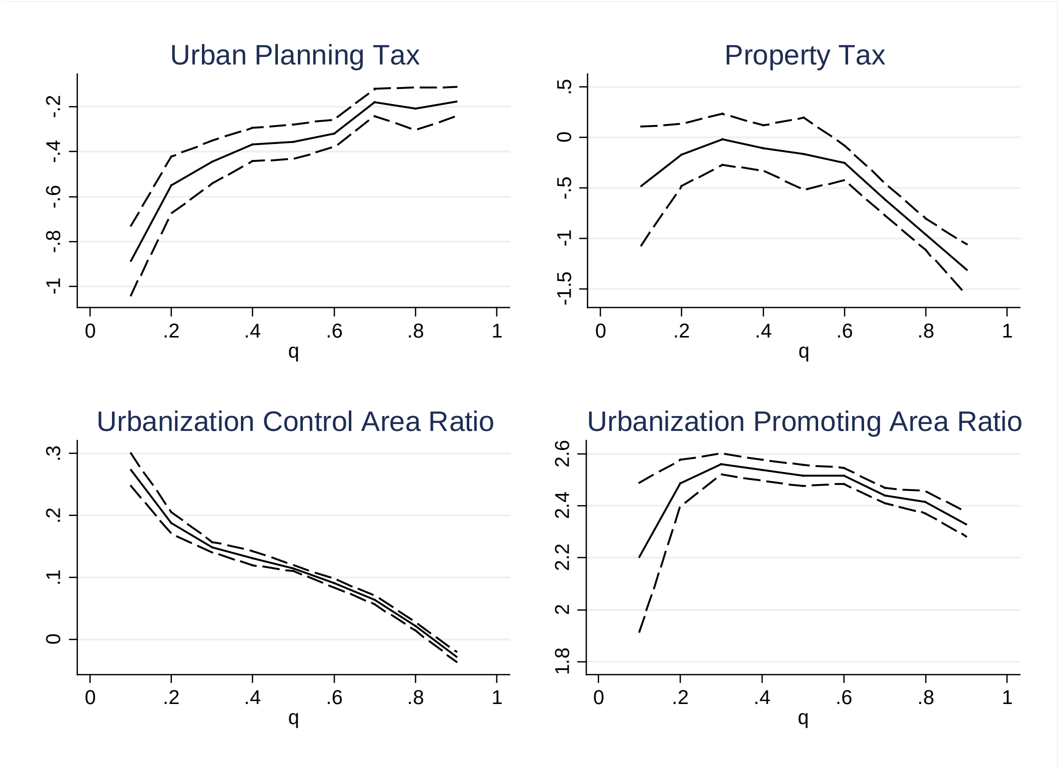

Figure 6. Policy Effects on Population Density: Estimated coefficients for impact of each instrument by quantile of population density

Note: The vertical axis denotes the estimated coefficients, and the horizontal axis denotes quantiles of population density. The coefficients for the property tax rate for quantile 0.1 to 05 are insignificant. The other coefficients plotted are significant at the 1 percent level. Standard errors are calculated through bootstrapping, with 20 repetitions.

4.3. Effects of population density on CO_2 emissions

Population density on the right-hand side of equation (1) is treated as an endogenous variable, determined by the economic scale of the city and the urban planning instruments. We employ two-stage estimation methods, whereby we first estimate equation (2) and then calculate the predicted population density using the estimated coefficients. Next, using the predicted population density, we estimate equation (1). As a robustness check against previous studies, we also estimate specifications in which population density is treated as exogenous.

Table 3 shows the estimation results. In the first step, population density is estimated using model 3 in Table 2. Here we apply prefecture-specific fixed effects instead of city government fixed effects (1,750 city governments belong to 47 prefectures). The adjusted R^2 in Table 3 is quite high, with a value above 0.9.

We evaluate the effects of population density on CO_2 emissions. The coefficients for population density in each model are negative and significant at the 1 percent level. Therefore, increases in population density lead to decreased CO_2 emissions from vehicles. If governments can raise population density by 1 percent, CO_2 emissions would decrease by approximately 0.21 to 0.24 percent, even if we do not consider the endogeneity of population density (model 2). The population density elasticity per vehicle mile traveled (VMT), reported by Cervero and Murakami (2010), is approximately -0.38, which is not far from our estimates.

Table 3. Estimation Results: Regression of logged CO_2 emission on Population Density

	Model 1			Model 2			Model 3		
Variables	Coef.	S.E.					Coef.	S.E.	
ln(population density)	-0.242	0.011	***	-0.240	0.010	***	-0.209	0.011	***
ln(population density)×$Year_{1999}$							-0.015	0.011	
ln(population density)×$Year_{2003}$							-0.028	0.011	**
ln(population density)×$Year_{2007}$							-0.089	0.011	***
ln(income)	0.996	0.006	***	0.996	0.006	***	0.997	0.005	***
road length/habitable area	-0.342	0.210		-0.342	0.210		-0.317	0.128	**
Constant	-6.084	0.103	***	-6.081	0.103	***	-6.160	0.088	***
Endogenous Problem	Yes			No			Yes		
Adj. R-squares	0.92			0.92			0.92		
F-value (P-value)	1471.36 (0.00)			1378.83 (0.00)			1408.04 (0.00)		

Notes: Obs.=6,642. ***, ** and * indicate significance levels at the 1%, 5% and 10% levels, respectively. Prefectural and time fixed effects are included. Robust standard errors are used.

The effects of population density might change over time. We therefore add cross-terms for population density and year dummies to form model 3. In the base year of 1990, the effect of population density on CO_2 emissions is -0.209. The additional effect had no significant influence in 1999. However, the reduction effect increased by -0.028 and -0.089 in 2003 and 2007, respectively.

Therefore, the effect strengthened over time, especially after 1999.

Income (the proxy for the economic scales of cities) positively affects CO_2 emissions. It is through the scale effect that economic scale is associated with CO_2 emissions. Road length per habitable area is significant and negative only in model 3. Expansion of road length may thus reduce traffic congestion, resulting in reduced CO_2 emissions. Therefore, governments may be able to use road construction as a policy to mitigate climate change.

4.4. Effects of population density on the other four outcomes

In this section, we discuss the effects of population density on the other four outcome variables: traffic accidents, crime, cleaning expenditures, and the facility condition index. Similarly to section 4.3, we treat population density as an endogenous variable and employ a two-stage estimation method (see Table 4 for results).

All coefficients are found to be significant at the 1 percent level. An increase in population density is found to generate 1) an increase in traffic accidents, 2) an increase in crime, 3) a decrease in cleaning expenditures and 4) a decrease in the facility condition index. This implies that, while governments can reduce cleaning expenditures by increasing their population density, such an increase also results in negative externalities such as increased traffic accidents and crime. Thus, we find that an increase in population density is not necessarily advisable as urban planning policy.

Among the outcome variables, only the coefficient for the facility condition index has an adverse sign. Although city governments can save on cleaning expenditures by increasing population density, the governmental facility condition index decreases. This might be related to our findings regarding the effects of population density on traffic accidents and crime in that the latter outcomes may instigate increased expenditures on public safety. As a result, reduced cleaning expenditures may be offset by increased expenditures on public safety, causing the facility condition index to rise.

The expected signs are obtained for most of the other variables. Police stations as a proxy for policemen is effective in controlling for traffic accidents and crime. Road expansion is also a useful measure for these outcomes. However, traffic signal installation is positively associated with traffic accidents. Thus, more accidents may occur as more traffic signals are installed; alternatively, the finding may reflect insufficient control for economic scale.

Table 4. Estimation Results: Regression of the other outcomes

	ln(traffic accident)			ln(crime)			ln(expenditure for cleaning)			facility condition index		
Variables	Coef.	S.E.		Coef.	S.E.		Coef.	S.E.		Coef.	S.E.	
ln(population density)	0.195	0.051	***	0.041	0.010	***	-0.081	0.006	***	-0.189	0.005	***
ln(income)	1.233	0.024	***	1.067	0.004	***	0.918	0.004	***	0.329	0.004	***
road length/habitable area	-5.252	1.097	***	-1.166	0.126	***	-0.005	0.003	***	0.003	0.002	***
signal/habitable area	8.526	2.679	***	6.448	0.442							
police station/habitable area	-341.256	52.892	***	-42.498	6.104							
Constant	-16.262	0.402	***	-12.891	0.077	***	-3.091	0.062	***	-4.918	0.071	***
Adj. R-squares	0.56			0.94			0.88			0.53		
F-value (P-value)	338.86 (0.00)			4184.86 (0.00)			3055.08 (0.00)			491.01 (0.00)		
Obs.	15,568			15,499			28,259			28,244		

Notes: ***, ** and * indicate significance at the 1%, 5% and 10% levels, respectively. Robust standard errors are used. Time and prefectural fixed effects are included.

4.5. Overall Effects of Population Density on Externalities

Externalities present significant problems for urban policy planners (Glaeser, 2012). We evaluate the full effects of increased population density on externalities (to the extent possible) and find that urban policy has both negative and positive effects. First, we calculate the marginal effects of population density on CO_2 emissions, traffic accidents, and crime.

Using the results of model 1 in Table 2 (for CO_2 emissions) and Table 3 (for the other outcomes), we calculate the marginal effects. The marginal effect of population density (POP) on CO_2 emissions (E), calculated as the response of the average city, is $\partial E\left[E\,|_{\mathrm{X},POP}\right]/\partial Pop\,|_{\overline{\mathrm{X}},\overline{POP}}$ (see Cameron and Trivedi (2005) for details on the method used).[6] The marginal effects on

[6] The subscripts i and t are omitted. For all outcome variables other than the facility condition index, the marginal

population density on the other outcome variables are determined by the same formula.

The estimated marginal effects are presented in Table 5. The marginal effects on cleaning expenditures and the facility condition index are also indicated as a reference. The sample means for each outcome are shown in the third row. CO_2 emissions decrease by approximately 1,762 tons when population density increases by one person/hectare. The reduction is equivalent to 1.6 percent of CO_2 emissions on average. The reduction generated by increased population density is not negligible because the mean of population density is 13.8 persons/hectare (see Table 1). If average city density were to double, CO_2 emissions would decrease by approximately 22 percent, assuming constant marginal effects.

Traffic accidents and crime, by contrast, would worsen on average by 0.7 and 0.2 percent when population density increases by one unit. Relative to the reduction in CO_2 emissions, the changes in traffic accidents and crime are small.

Table 5. Marginal Effects of Population Density

Outcomes	Marginal effects	Sample mean	Change rate from mean
CO2 emissions from vehicles	-1761.69	110115	-1.6%
Traffic accident	3.48	467	0.7%
Crime	1.82	1179	0.2%
Expenditure for cleaning	-5494.41	1273080	-0.4%
Facility condition index	-0.03	0.74	-4.2%

Notes: Units for CO2 emissions, traffic accidents, crime and cleaning expenditures are CO2-ton, case, case and 1,000 yen, respectively.

The units in which the marginal effects for the different outcome variables are calculated

effects are calculated as $\hat{\gamma} \cdot \overline{POP}^{\hat{\gamma}-1} \cdot \overline{\mathbf{X}}\hat{\boldsymbol{\beta}}$ because the dependent variables are transformed into log variables. $\overline{POP}$ and $\overline{\mathbf{X}}$ are the sample means for population density and other control variables used in the estimations, respectively. $\hat{\gamma}$ and $\hat{\boldsymbol{\beta}}$ are estimated coefficients. Because the facility condition index is not in log form, the marginal effect is computed as $\hat{\gamma} \cdot \frac{1}{\overline{POP}}$.

are not uniform. For the overall evaluation of the effects of increasing population density, therefore, we convert the units of the effects into monetary values using externality costs (shadow prices) estimated in previous studies. Upper and lower bound estimates for sensitivity analysis are also provided in view of the uncertainty of these externalities (e.g., Boardman, et al., 2010).

For the externality cost of CO_2 emissions, we use US$25 and US$345 per CO_2-ton as the upper and lower bounds, following Tol (2009). Converting to yen evaluated in 2007 prices, 2.1 and 28.8 thousand yen represent the lower and upper bounds, respectively.

The National Police Agency reports that the numbers of deaths and injuries caused by traffic accidents are 0.9 and 99.1 percent, respectively, of total victims from 1990 to 2007. The economic damage from one death is approximately 355 million yen (Tsuge et al., 2005), while the economic damage from one injury is 46 to 86 million yen (Cabinet Office Japan, 2009), evaluated in 2007 yen. Using these percentages as weights, we use 49 to 88 million yen per case as bounds for the external costs of traffic accidents.

McCollister et al. (2010) estimates the social costs of 13 types of crime in the United States. Among these, we use the externality cost of larceny/theft because larceny/theft constitutes approximately 77 percent of total crime in Japan.[7] These authors show that the minimum and maximum externality costs of larceny/theft, as assessed in the literature, are US$344 (Cohen, 1988) and US $3,532 (McCollister et al., 2010), respectively, evaluated in 2008 dollars. After converting into 2007 Japanese yen, we employ 35.8 and 368.1 thousand yen as lower and upper bounds of the externality costs of crime.

Using these lower and upper bounds for externality costs, we present the valuations of the marginal effects of population density on each type of externality in Table 6. The lower and upper bounds of the estimated marginal effect of population density on CO_2 emissions are 3.7 to 50.8 million yen, respectively. The lower and upper bounds of the marginal effect of population density

[7] This value is the average from 2003 to 2007 reported by the National Police Agency. Although there are also atrocious crimes, such as murder and arson, these constitute, on average, only 0.5 percent of total crime during this period.

on traffic accidents and crime combined are 160.7 to 291.4 million yen, respectively. Thus, an urban policy of increasing population density is not helpful in mitigating externalities on the whole, both at the lower and upper bounds, whereas it does contribute to reducing CO_2 emissions. In implementing urban policies designed to increase city density, therefore, city planners must carefully consider the linkage between the negative effects of such policies on traffic accidents and crime and the positive effects on CO_2 emissions reduction. We note that there are significant uncertainties in the values of these externalities. For example, Stern (2010) suggests that CO_2 emissions represent the most significant market failure and that public authorities should therefore prioritize it.

Table 6. Valuation of Marginal Effects

Outcomes	lower	upper
CO2 emissions from vehicles	-3.68	-50.77
Traffic accident	160.67	290.71
Crime	0.07	0.67
Total	157.05	240.61

Notes: all units are in millions of yen evaluated in 2007.

We note that there are limitations in our valuations. Our study does not consider other important externalities, such as congestion, air pollution, disaster risk and agglomeration. Agglomeration, for example, is a well-known positive externality associated with city growth through economies of scale and network effects (Fujita and Thisse, 2013). On the other hand, congestion, air pollution and disaster risk are negative externalities. Congestion and air pollution are typically positively correlated with city density via vehicle use. In addition, damage caused by natural disasters may be greater in dense areas than in sparse areas (Kellenberg and Mobarak, 2009). Therefore, further research is needed to assess these untreated externalities: the potentially positive effects of agglomeration and the potentially negative effects of the other three externalities cited.

5. Conclusion

Urbanization is not by itself a solution to the problem of designing an optimal living space. Successful cities are highly sustainable, while unsuccessful cities are plagued by economic, environmental, and social problems. This paper examines what is needed to implement suitable urbanization policies with respect to environmental and social problems.

We examine the relationship between urbanization and city environmental and social problems using data for all Japanese cities from 1990 to 2007. Employing population density as a measure of urbanization, we select CO_2 emissions, traffic accidents, crime, and two measures of city governmental expenditures (cleaning expenditures and the facility condition index) as relevant externalities.

We further enhance our understanding of urbanization by examining how city governments can increase population density. Specifically, the paper draws connections between four urban policy instruments—*urbanization promoting areas*, *urbanization control areas*, *urban planning taxes* and *property taxes*. This is first paper to integrate policies designed to affect population density with the effects of population density on environmental and social problems.

Our results show that governments can increase residential density by changing/implementing the policy instruments identified. Setting and expanding both types of land use regulation, i.e., *urbanization control areas* and *urbanization promoting areas*, increase population density, while decreasing both types of taxes considered similarly generates increased density.

The effects of these instruments vary across cities. Specifically, their effects in low density cities differ from their effects in high density cities. We find that a decrease in the *urban planning tax* rate is more effective in increasing density in sparse cities than in dense cities. By contrast, a decrease in the *property tax* rate is found to be more effective in high density cities. City governments can also increase density through the command-and-control mechanism of an *urbanization promoting area*, whereas city governments with high population density are advised not to utilize this instrument.

City governments in Japan are free to set both of the tax rates considered in this paper, although the Japanese (central) government officially places some limits on city actions, such that it is desirable to set the property tax rate at 1.4% and the urban planning tax rate at less than 0.3%. In view of such social issues as CO_2 emissions and the other outcomes examined in this paper, the Japanese government would be well advised to be more flexible with respect to these limitations.

Next, we examine the influence of population density on CO_2 emissions and the four other outcome variables. Population density is found to have a negative impact on CO_2 emissions. Urban planning policy designed to increase population density can thus play a role in climate change mitigation. Higher density also leads to savings on public cleaning expenditures. On the other hand, such policies lead to increased traffic accidents, increased crime and a decrease in the facility condition index. Therefore, the use of urban planning to raise population density simultaneously generates both positive and negative outcomes for society.

Increases in population density give rise to multiple outcomes. To assess the effects of urban policies designed to increase population density on the external outcomes considered (CO_2 emissions, traffic accidents and crime) as a whole, we calculate the marginal effects of raising density on these outcomes in monetary terms. We find that increases in population density appear to worsen social outcomes on the whole because the negative effects on traffic accidents and crime are large. Therefore, when governments seek to increase population density, it is necessary to introduce complementary policies to address traffic accidents and crime.

There are limitations to our analysis. First, we do not evaluate whether the policy improves social welfare. Second, our model assumes only inter-city population transfer, while inner-city population mobility is not considered. If overall city density in one city is equivalent to that in another city, then both cities are treated the same, even if the density in the center of one city is substantially greater than that of the other city. This implies that our model assumes only inter-city population transfer. Further research should also consider inner-city population mobility.

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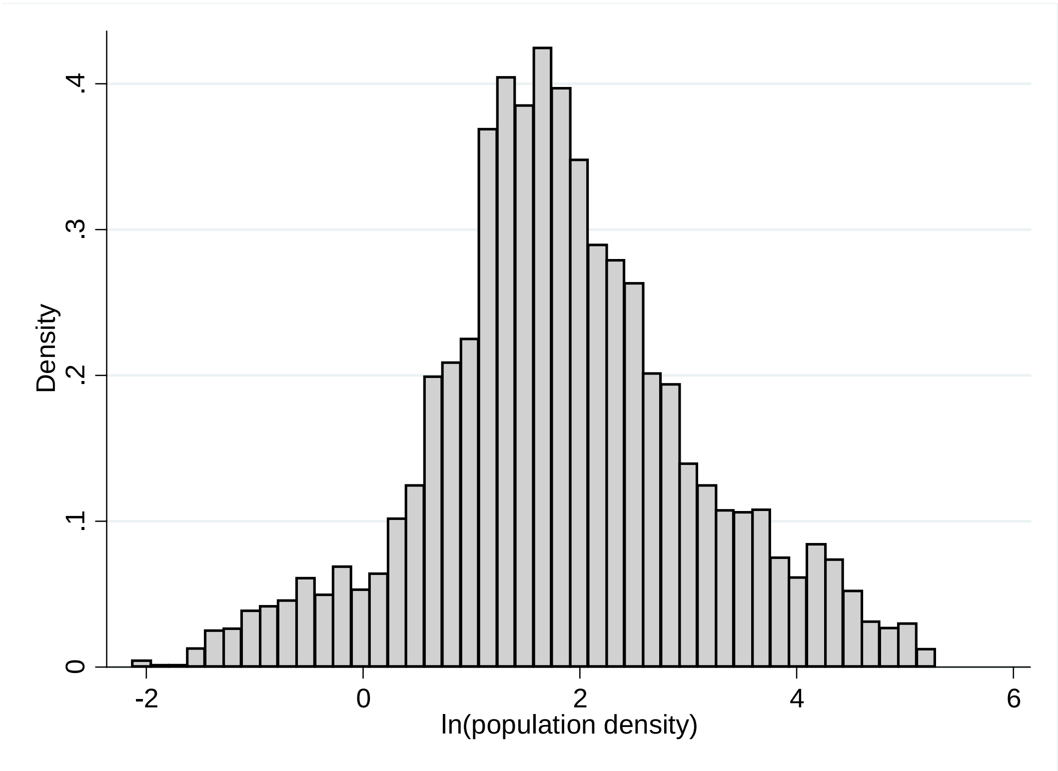
Figure A1: Distribution of City Level Population Density from 1990 to 2007 in Japan



Notes: Obs.=30,923

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