The Impact of Urban Sprawl on Disaster Relief Spending: An Exploratory Study

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Abstract

Students of public policy have written a lot over the years about the rise of suburbia and development beyond older city boundaries in the United States, whether such development has been called urban, suburban, or ex-urban sprawl. Many writers have focused on various issues concerning sprawl, especially on the unintended consequences that new development has had on (among other issues) municipal finances, neighborhood income and residential segregation, and transportation planning. Over the last decade or so, a new area in the literature on sprawl has focused on how the "built-environment" of residential areas can impact health and emergency services. This research note adds to these latest set of papers on sprawl by trying to empirically estimate the impacts of sprawl in metropolitan regions on United States Federal Emergency Management Agency (FEMA) spending on rehabilitating or rebuilding infrastructure in post-disaster relief efforts. In this exploratory analysis the results indicate that urban sprawl is an important factor in influencing FEMA relief spending in the US.

Keywords: disasters, disaster relief, emergency management, FEMA, infrastructure, United States Federal Emergency Management Agency, urban sprawl

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Introduction

The housing market in the United States saw rapid changes in the post-World War II era. As roads to previously rural and fringe areas were developed and/or expanded, middle and upper income families, mostly white, left older city neighborhoods in favor of newer and less densely settled ones that offered large lot housing units and safer, cleaner public parks, shopping centers, schools and other amenities (Mieskowski and Mills 1993, Barnett 1995, Burchell and Lisotkin 1995, Burchell, et al 1998, Ewing 1997, Ciscel 2001, Glaser and Kahn 2003). These developments were nicknamed “sprawl” or “urban sprawl”, although the terms “suburban sprawl’ and “ex-urban sprawl” have also been used and continue to be used as labels. Sprawl has often been characterized as involving “leapfrog” and unplanned or haphazard development (Ewing, Pendall and Chen 2002). Many claim, however, that negative externalities and/or hidden costs were created in the new and larger metropolitan regions through regional income and racial segregation; divestment from the old urban central business district and neighborhoods which drained municipal coffers; increased pollution from vehicle emissions; and increased traffic congestion (Glaser and Kahn 2003). Additionally, as new communities and municipalities arose, some questioned the cost effectiveness of public sector services provision and infrastructure spending in regions where greater economies of scale possibly could be achieved by having fewer governmental entities and/or more densely settled neighborhoods (Ladd 1992, Carruther and Ulfarsson 2003, Lambert, Srinivasan and Min 2009). Finally, and more recently, concerns over whether suburban life can cause greater health risks and greater fatality rates have been raised by those who claim that there is a connection between neighborhood design and weight problems and obesity (Frumkin 2002), higher incidents of vehicle fatalities per capita (Ewing, et al 2003, Lambert and Meyer 2006), and delays in EMS and fire response to crisis situations (Lambert and Meyer 2006 and 2008; Trowbridge, et al 2009; Katirai 2011, Lambert, Srinivasan and Katirai 2012) in addition to other possible health problems (Lucy 2003).

Hidden costs and negative externalities arise or become issues often because some or many participants in a market act under the conditions of "bounded rationality" or conditions of assymetric information (Simon 1957, Lindblohm 1959, Varian, Ch. 25, 1992). That is, using neoclassical theory, the private costs of residential housing in fringe areas (C) is underpriced or underestimated when compared to social costs (SC) given housing choices and residential choices (h) because expected costs are less than actual costs. This in turn results in too much production of fringe, residential development:

$$\partial C / \partial h < \partial SC / \partial h \qquad (1)$$

Because

$$\sum EV\,(w_i\, x_{j)} < \sum w_i x_j \qquad \text{for all i and j.} \qquad (2)$$

Where EV stands for expected value, w is the probability of an event, and x is a cost of the event.

Actual costs may be higher than expected because the new development brings traffic congestion and delays as well as higher than expected taxes (or inadequate service provision) because of the need for new schools, infrastructure, or greater police and fire or other problems as mentioned above (Ladd 1992, Carruther and Ulfarsson 2002, 2003). As Brueckner and Helsley (2011) write,

> When open-spaced amenities are present or when infrastructure is underpriced, the social cost of suburban land development exceeds the private cost faced by builders, again leading to inefficient urban expansion. (p. 205)

One environmental problem that has been cited in addition to the ones above is that with new and sometimes poorly planned development, wetlands are often destroyed, which often in turn make water run-off and drainage difficult during and after a storm. Sometimes severe flooding may occur (Sierra Club 1998). Such occurrences often trigger more infrastructure spending down the road in order repair damaged infrastructure and to prevent future flooding. This is occurring with current reparations after Hurricane Sandy in New Jersey in 2012 with water system reparations estimated at $2.6 billion (Johnson 2013). Heavy winds, hurricanes, and tornados which accompany such storms may also damage infrastructure that is fragile or vulnerable due perhaps sometimes to its quick or haphazard construction or to its bad location within a community, e.g., poorly planned or designed or located sewers, water lines, bridges, road overpasses, natural gas or electricity lines, etc. (White House 2006, Johnson 2013).

During the course of developing and researching this paper, no scholarly literature was found that explored the potential link between sprawl and spending on post disaster infrastructure rehabilitation and replacement, and so this paper attempts to at least be one of the first to examine the issue. This paper proceeds as follows. In the next section, Research Methods, the methods and variables used to assess an association between sprawl and infrastructure replacement spending post disaster are discussed. After that, the general results of the analysis are discussed, and then a Conclusion section gives an overview of the policy implications of the results and what can be learned, discusses the limitations of the study, and makes suggestions for further research.

Research Methods

This paper uses a double, natural log, least squares regression model to predict the amount of infrastructure relief/restoration expenditures per capita for certain US counties in 2010. A double log regression model takes the following form

$$\text{Ln } \hat{y} = \text{Ln } b_0 + \text{Ln } b_1 x_1 + \text{Ln } b_2 x_2 + \text{Ln } b_3 x_3 + \ldots.. + \text{Ln } b_n x_n \qquad (3)$$

and was used because scatterplots of the data as well as comparisons of different models yielded this one as the best fitting model. It is also the model form used by Ewing et al (2003), Lambert and Meyer (2006, 2008) and Lambert, Srinivasan, and Katirai (2012) in assessing the impact of sprawl on traffic fatalities, emergency services and fire response. Since the main hypothesis was whether urban sprawl has an impact on damage expenditures, only data from counties which were part of a metropolitan area in 2010 according to the US Census Bureau were used so as to insure that each county had at least a minimum level of urban habitation according to the Census. This means that some counties from FEMA's list of counties which received infrastructure aid were not included in the analysis because they were classified as rural, and this delineation also makes the list of counties used more aligned with the list of the counties in the sprawl index described below.[1] Therefore, the following variables below were used in the model.

Dependent variable:

1. Ln of Expenditures per Capita per County on Infrastructure Public Assistance (Source: US FEMA Disaster Declarations for 2010). These were collected for 2010 from the US FEMA website under the preliminary damage assessments for each declared disaster. In 2010, there were 81 major disaster declarations, most of which were for tornados,

[1] Counties and regions of US territories are also not included because they are not on the sprawl index.

hurricanes, heavy rains, and/or flooding. There were also 9 emergency declarations and 28 fire management assistance declarations, but FEMA does not provide data on expenditures per county for these categories. Most of the emergency declarations are part of a disaster declaration. FEMA provides a definition of what constitutes public assistance, which covers most of the repair for damages incurred to public buildings and infrastructure for state and local governments as well as certain non-profit organizations.[2]

Independent Variables:

2. Ln Median Year of all Housing Structures Built per County (Source: US Census Bureau, American Community Survey, 2010, 5 year estimates). This is used as an approximation

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[2] FEMA states, "The Public Assistance Program provides grants to state and local governments and certain non-profit entities to assist them with the response to and recovery from disasters. Specifically, the program provides assistance for debris removal, emergency protective measures, and permanent restoration of infrastructure.
Eligible Applicants: Eligible applicants include state governments, local governments and any other political subdivision of the state, Native American tribes and Alaska Native Villages. Certain private non-profit (PNP) organizations may also receive assistance. Eligible PNPs include educational, utility, emergency, medical, temporary or permanent custodial care facilities (including those for the aged and disabled), irrigation, museums, zoos, community centers, libraries, homeless shelters, senior citizen centers, rehabilitation, shelter workshops and health and safety services and other PNP facilities that provide essential services of a governmental nature to the general public. PNPs that provide "critical services" (power, water - including water provided by an irrigation organization or facility, sewer, wastewater treatment, communications and emergency medical care) may apply directly to FEMA for a disaster grant. All other PNPs must first apply to the Small Business Administration (SBA) for a disaster loan. If the PNP is declined for a SBA loan or the loan does not cover all eligible damages, the applicant may reapply for FEMA assistance.
Public Assistance Process: As soon as practicable after the declaration, the state, assisted by FEMA, conducts the Applicant Briefings for state, local and PNP officials to inform them of the assistance available and how to apply for it. A Request for Public Assistance must be filed with the state within 30 days after the area is designated eligible for assistance. Following the Applicant's Briefing, a Kickoff Meeting is conducted where damages will be discussed, needs assessed, and a plan of action put in place. A combined federal/state/local team proceeds with Project Formulation, which is the process of documenting the eligible facility, the eligible work, and the eligible cost for fixing the damages to every public or PNP facility identified by State or local representatives. The team prepares a Project Worksheet (PW) for each project.
Public Assistance Projects Categories:

- Category A: Debris removal
- Category B: Emergency protective measures
- Category C: Road Systems and Bridges
- Category D: Water control facilities
- Category E: Public buildings and contents
- Category F: Public utilities
- Category G: Parks, recreational, and other Items."

(FEMA Public Assistance Factsheet, https://www.fema.gov/recovery-directorate/public-assistance-fact-sheet) for the median age of a county's infrastructure since infrastructure if often constructed around the time of residential development. It has also been used as measure by Lambert and Meyer (2006, 2008) to assess the impacts of sprawl in that newer residential development is often associated with a greater degree of sprawl in an area all else held constant. The hypothesis is that the more recent is the median year, the more resilient an area's infrastructure should be, on average and all else held constant. Of course, if more recent dates or years are associated with greater sprawl, then the damages could be worse if the sprawled environment makes the infrastructure less resilient.

3. Number of Full Time Equivalent (FTE) Firefighters per Capita per County (Source: US Census Bureau, Census of Governments 2010). This is used as a proxy for the total number of first responders in a county. It is also a control variable in that the greater the number of first responders in an area, the less the expenditures per capita should be, all else held constant, because greater disaster preparedness probably has been undertaken, on average, by local governments. That is, it is hypothesized that a greater number of first responders means greater disaster preparedness, and hence expenditures should be lower on average. Unfortunately the US Census of Governments did not list expenditures per county for emergency management or disaster preparedness programs or personnel explicitly although data was available for policy and firefighters. Not all counties gave police numbers, and since payroll amounts were missing for volunteer firefighter units. The hypothesis is that the greater the number of first responders, the lower the post disaster expenditures for infrastructure repair post disaster on average, *ceteris paribus*.
4. Ln Weather Severity Index (Source: US FEMA Disaster Declarations for 2010 and US National Oceanographic and Atmosphere Association National Climatic Data Center

2010). In order to control for the severity of the disaster and its impact on infrastructure replacement and rehabilitation spending, an index was constructed which consisted of the product of the following: the total expenditures for the disaster (one indicator of its magnitude); maximum wind speed (if given) for thunderstorms, hurricanes, and tornadoes[3]; the level of the tornado (EF0=1, EF1=2, etc.) if given[4]; the sum of the presence (1=yes, 0=no) of the events heavy rain, heavy winds, flooding, or severe snowstorm; and, if an earthquake, the Richter scale value was used to measure intensity. Unfortunately, for storms and flooding, the total depth or amount of flooding in an area was not available as were total inches of rainfall. The hypothesis is that the greater the weather severity, the greater expenditures for infrastructure repair need, all else held constant.

5. Ln Sprawl Index (Source: Ewing, Meakins, and Hamidi 2010). The index measures a wide variety of factors that revolve around how urban sprawl has been defined and updates work done by the authors in 2002 and 2003 on an earlier index. Essentially, they examine population density numbers, employment density numbers, average block size, the portion of census tracts at or above a certain population density threshold as well as those at or below a certain population density threshold, indicators of mixed land use (i.e., a mixture of residential, commercial, and public land uses together in an area), etc. These in turn are combined into an index where a greater score indicates less sprawl, and a lower score indicates more sprawl. The hypothesis is that counties with high scores should have lower expenditures for infrastructure assistance, on average and all else held constant.

[3] If not given, this part of the calculation was skipped.
[4] If not given, this part of the calculation was skipped.

Results

(Insert Tables 1, 2, and 3 around here)

The descriptive statistics for each variable is provided in Table 1. In looking at the least squares results in Table 2, around 42% of the variation in the log of estimated repair expenditures can be explained by the four independent variables with each being statistically significant at $\alpha < 0.05$ except for the variable Median Year Structure Built. There does not appear to be any problems with multicollinearity with none of the variance inflation factors for each variable greater than 2.0. However, there appear to be symptoms of serial correlation at $\alpha < 0.05$ according to the Durbin-Watson statistic, and so the results of least squares regression with Newey-West standard errors are displayed in Table 3. Since the standard errors only slightly change for some of the variables, and since the levels of statistical significance do not change, serial correlation does not appear to be a threat to making inferences about the model (Studenmund 2005).

Examining the statistically significant variables, the model in Table 2 predicts that for a one unit increase in the log of the number of FTE Firefighters per Capita in a county, the log of the expenditures per capita go down 0.003 on average. Or, since both variables are natural logs, the coefficient can be considered an elasticity where a 10% increase in the number of firefighters per capita results in a 0.03% decrease in expenditures, all else held constant. Similarly, a 10% increase in the log of the Weather Severity Index is associated with 4.4% increase in expenditures per capita. Finally, a 10% increase in the Ln Sprawl Index is predicted to cause around a 20% decrease in infrastructure repair expenses per capita on average, *ceteris paribus*. Recall that a greater value for the sprawl index indicates less sprawl whereas a lower score indicates more sprawl.

With regard to the magnitude that each variable has on infrastructure rehabilitation expenses, the betas in Table 3 show that the weather index carries the greatest weight at 0.573, then the sprawl index at -0.465, and lastly the number of firefighters per capita at -0.106.

Conclusion

Given the results of the model, some doubt is cast on whether infrastructure age matters, although the variable used was a proxy, median age of housing structures. Also, depending upon local government expenditures, infrastructure can be upgraded from time to time regardless of its original construction date, and so these limitations of the results must be considered. Future research is needed that would contain data that accurately reflects infrastructure age or infrastructure spending per local government.[5]

However the other hypotheses put forth in this paper are supported given the way the variables were operationalized and the model constructed. The number of first responders per capita seems to matter in mitigating infrastructure damage perhaps due to the fact that the level of first responders per capita may indicate a certain degree of commitment to emergency and disaster preparedness in an area. For example, a greater number of first responders may be able to prevent a greater degree of flooding and sewer damage in an area given the total number of personnel available to erect walls of sand bags, to cover and protect vulnerable facilities, etc. As mentioned earlier, local spending on disaster preparedness was not available for this study, and so this variable was used as a proxy. This is a limitation of this paper, and more research is needed to find a better proxy or to do a survey of the counties impacted by a disaster on their prior disaster preparedness spending levels.

[5] There are state rankings of infrastructure quality but none could be found for the county or metro levels unfortunately.

The weather severity index also works well as a predictor variable. Logically, the greater the degree of weather severity, the greater the rehabilitation expense for infrastructure per capita later, all else held constant. However, to make the variable more precise, data on the volume or depth of flooding in an area would have been useful as well as data for total rainfall amounts for the disaster event. The US NOAA provides the average annual and monthly precipitation amounts for different major US cities in each state, but these average are for the last several decades and do not include data for counties (US Census Bureau 2010 Statistical Abstract). Of course, for this paper, using averages or norms would not be appropriate given the interest in extreme weather circumstances. Further research is needed to refine weather severity measures in future studies. If this variable and the previous two mentioned can be developed into variables with more precision, the perhaps the explanation of the variation in infrastructure expenditures per capita would be higher than the moderate 42% found in the regression results.

Finally, and most importantly for this paper, the hypothesis about greater levels of sprawl being linked to higher expenditures per capita is supported. Again, in the course of doing research for this paper, only a few articles in the popular press or in publications by advocacy groups mentioned or implied a link between urban sprawl and the severity of natural disasters, especially with regard to post-disaster spending (Sierra Club 1998). The publications only mentioned a few specific instances or examples of natural disasters and used circumstantial evidence to link sprawl with the severity. No scholarly literature was found that investigated the topic systematically, even in a preliminary way. The forerunner to the sprawl index used in this paper has been used in a wide range of research by a many authors over the last 12 years or so, with at least 20 scholarly papers employing it (Ewing, Meakins, and Hamidi 2010) and so has some credibility as a predictor variable.

One major limitation of this research note is that it would have been better to have had more specific geographic data other than that at the county level. To have had data that was zip code or census tract specific would have helped perhaps pinpoint more precisely the age of infrastructure through housing age. However, FEMA expenditures per capita data and the sprawl index were available only at the county level. Therefore, the research findings of this paper are submitted as preliminary findings in an exploratory analysis.

However, if sprawl plays some role in making post-disaster infrastructure rehabilitation more costly than what it would be otherwise, then what should be done? Again, the situation can perhaps be likened to one in which there are hidden costs and negative externalities in which taxpayers throughout the country have to help more sprawled communities and areas at greater amounts per capita than others due to underpriced and/or poorly planned or vulnerable infrastructure. If this is so, then remedies include those that try to internalize the externalities through, e.g., higher taxes or "impact fees" on large housing lots and development that are akin to Pigouvian taxes (Varian, Ch. 24, 1992, Nelson and Moody 2003, Turner 2007), subsidies for small lot housing development (Turner 2007), growth boundaries that prevent leap frog development (Carruthers 2002), and buying and protecting wetlands from development. Bento, Franco, and Kaffine (2006) develop a model and argue that development taxes and urban growth boundaries have equivalent effects and are the two best approaches to limiting the external effects of sprawl.

Better and more comprehensive development planning within and across municipal boundaries would also perhaps be a step in the right direction (Atkinson and Oleson 1996, Katz and Bradley 2000). An individual government is limited with regard to how it can address sprawl and its consequences. Regional planning undertaken by a group of cities and counties working together and encouraged by state governments would allow local governments to better allocate and ration land use, although this would probably entail incentives given by state governments to encourage smaller and more rural areas to forego some residential development. Carruthers (2002, 2003) and Carruthers and Ulfarsoon (2002) argue that regional planning can work if done on a consistent basis. In 1997, FEMA launched a program called "Project Impact: Building a Disaster-Resistant Community" which called for more regional planning in order to develop more disaster resilient communities, although sprawl was not mentioned as a topic of the initiative (US FEMA 1997).

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Table 1—Descriptive Statistics

	Mean	Standard Deviation
Expenditures per capita	16.9113	56.6371
Sprawl Index	107.8182	46.4185
Median Yr. Structure Built	1973.5263	11.0187
FTE Firefighters per capita	0.0007	0.0010
Weather Severity Index	6056005.97	49849129.12

Table 2—Least Squares

Predictor	b	SE	T-score	P-value	VIF
Constant	2.1	83.34	0.03	0.98	
Ln Median Year Structure Built	0.42	10.92	0.04	0.969	1.209
Ln FTE Firefighters per Capita	-0.003	0.002	-2.110	0.035	1.143
Ln Weather Severity Index	0.439	0.038	11.470	0.000	1.129
Ln Sprawl Index	-2.042	0.234	-8.720	0.000	1.286

S = 0.906787   R-Sq = 42.5%   R-Sq(adj) = 41.6%

N=265

Durbin-Watson statistic = 1.59791

Table 3—Least Squares with Newey-West Standard Errors

Predictor	b	Robust SE	T-score	P-value	Beta
Constant	2.098	77.932	0.03	0.979	
Ln Median Year Structure Built	0.423	10.196	0.04	0.967	0.002
Ln FTE Firefighters per Capita	-0.003	0.002	-2.11	0.035	-0.106
Ln Weather Severity Index	0.439	0.048	9.13	0.000	0.573
Ln Sprawl Index	-2.042	0.304	-6.71	0.000	-0.465

S = 0.906787   R-Sq = 42.5%   R-Sq(adj) = 41.6%

N=265