UNIVERSITY OF ALBERTA
FACULTY OF ARTS
Department of Economics

Working Paper No. 2018-04

"Causes of Sprawl": A (Further) Public Finance Extension

Melville L. McMillan
University of Alberta

March 2018

“Causes of Sprawl”: A (Further) Public Finance Extension

by

Melville L. McMillan
Professor Emeritus
Department of Economics
University of Alberta

October 2017

Summary

There are good reasons to expect that attributes of local public finance may impact urban land use and, specifically, sprawl. A detailed and novel investigation of U.S. metropolitan areas (Burchfield et al., 2006) provides substantial insights into the causes of sprawl, but it overlooks the main characteristics of local public finance (taxes and user charges). Using a subset of the data matched to city public finance data, a parallel analysis yielded evidence that greater reliance on local property taxes reduces sprawl and suggested that user charges (primarily for water, sewerage and solid waste services) could have a similar effect (McMillan, 2016). Expansion of the local public finance data set allowed extension of the data analyzed from 83 to 109 observations. The subsequent analysis was expected to enable a refinement of the estimates made in the 2016 paper. However, analysis of the extended data set as reported in this paper indicates more nuanced results. In particular, the impacts of property taxes on sprawl depend upon the population of the metropolitan area.

Introduction

Many have expressed concern about the patterns of land use in metropolitan areas. Often those concerns are focused on development characterized as urban "sprawl" and land "fragmentation." The discussion has ranged across perceived problems, possible causes and potential solutions. The possible impacts of municipal government revenue generation upon sprawl and fragmentation have attracted some attention in the conversation. My previous paper on this topic (McMillan, 2016) extended existing work on the causes of sprawl to explore relationships between municipal finance and metropolitan land-use patterns. Following that paper's publication, it became possible to expand the data set used for the 2016 paper and so refine the analysis. In extending the data set, it is found that a more nuanced interpretation of the results is required. That analysis is reported upon in this further extension of the "causes of sprawl".

The analysis of sprawl and fragmentation requires extensive and accurate data on land use. To assess the determinants of land use and patterns of development, detailed information is required on land uses in the built-up area and on the urban fringe across many urban areas. Satellite imagery is now providing such data and it is expanding the scope and depth of land-use studies. An excellent illustration of such databases is the Lincoln Institute of Land Policy's Atlas of Urban Expansion, which surveys 200 global cities and, in particular, reports on the development between 1990 and 2015 and provides measures of land-use fragmentation (i.e., sprawl) in its latest edition (Shlomo et al., 2016). Associated work illustrates the emerging analyses.[1] While quite recent, the atlas does not provide adequate data suitable for this analysis. Of the 120 cities, only two are in Canada and only 14 are in the United States — too small a number of relatively comparable cities.[2] Instead, data generously provided by Marcy Burchfield on U.S. metropolitan areas that were examined in Burchfield et al. are utilized[3]

In leading work, Burchfield et al. (2006) calculate measures of sprawl and assess the determinants of differences in sprawl across 275 U.S. metropolitan areas. Their land-use data combines that from high-altitude photographs from 1976 with that from satellite images from 1992. The examination of 30 x 30 metre cells allowed land use to be categorized into a variety of uses; most notably, whether land was developed (e.g., residential, commercial/industrial, transportation) or undeveloped /open (e.g., agricultural, wetland, forest). The analysis focused on the percentage of open space in the square kilometre surrounding the average residential development in the metro area. Potential determinants of sprawl (or openness, scatteredness, fragmentation of development) were identified from urban economics (e.g., the monocentric city model), geographical features and political influences. The importance of intergovernmental

[1] See Angel (2012), Angel et al. (2010) and Angel, Parent and Civco (2010).
[2] A new and expanded edition of the atlas is planned. That may allow a more adequate data set to be established.
[3] The data limitations imposed on the empirical analysis of sprawl prior to satellite imagery are reflected in Duranton and Puga's review of empirical studies of land development (Duranton and Puga, 2015). A recent study of the determinants of sprawl using European data is Oueslati, Alvanides and Garrod (2015).

transfers to local governments was included among the political factors. It was the only public finance variable included.

This study is directed towards understanding better the possible contribution of local public finance towards explaining sprawl. That is, do taxes, the type of taxes, and user charges (as well as transfers) matter? Local public finance data are generally not available or easily assembled on a metropolitan level. However, information is available for major cities, but that too is complicated by the fact that many local authorities (most commonly municipal governments and school boards) may be imposing taxes on residents. Fortunately, the Lincoln Land Institute has developed the Fiscally Standardized Cities database that provides information on a collection of revenues and expenditures of cities that are comparable despite differences in the assignments or responsibilities and taxing authority of their composite local governments. That database has recently been expanded from 112 to 150 cities.[4] Cities in that database are matched with the metropolitan areas in the Burchfield et al. data set. The recent expansion has meant that the possible number of observations for which detailed public finance information is available has increased from the 83 analyzed in the McMillan (2016) report to109 observations which are analyzed in this paper. Those 109 observations are analyzed following, or largely following, the approach and methods of Burchfield et al. and as extended by McMillan. As concluded in McMillan (2016), local public finance matters; in particular, greater reliance on property taxation reduces sprawl. However, new from this analysis is that the influence of property taxes appears to vary with the population size of metropolitan areas. The results also suggest that user charges for property services may have a negative impact on sprawl but those results are less robust. Finally, although not a public finance variable, another interesting finding is that the greater the population of the major city population to that of the metropolitan area is found to imply less sprawl.

The paper is organized as follows. The next section highlights the literature and it introduces the Lincoln Land Institute public finance data and the Burchfield et al. (2006) data. The second part presents initial regression results that, in particular, compare the results from McMillan (2016) with 83 observations and those from the extended data set with 109 observations. A brief section examines the data for a three class (population sized) subdivision of the109 observations. The following section presents regression results demonstrating the merits of the three group subdivision and, in particular, the contribution of public finance variables towards explaining the three Burchfield et al. measures of sprawl. The impacts of property taxes, charges and, also, the city to metro population ratio on sprawl are demonstrated in the penultimate section. A conclusion completes the paper.

[4] See http://datatoolkits.lincolninst.edu/subcenters/fiscally-standardized-cities.

Local Public Finance: Implications for Urban Sprawl?

Local public finance matters have not been central in the land-use discussion nor has land use been central in the discussion of local public finance. However, the potential implications of local government finance alternatives have received some attention in the public finance literature. The approach has typically focused on the distorting effects of local taxes and on the merits of user charges to finance certain local government services.

The efficient provision of local public services has long attracted the attention of numerous economists. Much of their work has promoted the advantages of benefit taxation and of user charges (fees, levies) and has generally advocated that local governments rely more upon charges on beneficiaries where possible and less on local taxes. Properly defined, user charges have the advantage of revealing demand to the supplier and of indicating the costs of provision to users and so better guide resource use than if the service were financed by other means such as general taxes. User charges fit well services such as utilities (e.g., water and sewerage services), waste disposal, public transit, parking, recreational and cultural facilities, and opportunities are seen to be emerging for extending them to garbage collection and road services. Most closely related to the questions of land use have been concerns that new land developments have not been paying their way; that is, they have been subsidized because they have not been required to meet the costs that they have imposed on the community. A consequence is that new developments have been underpriced and that is seen to have encouraged sprawl. In turn, that has led to recommendations for and, indeed, the expanded use of development charges, impact fees, dedications, etc. Regardless, many see further potential for expanding the use of benefit charges.[5]

The possible impacts of local property taxes on urban sprawl have not gone unnoticed (although they have received less attention than user charges). Brueckner (2001) provides a detailed theoretical analysis. He concludes the conventional property tax reduces the intensity of land development and encourages urban sprawl and socially inefficient land use. However the situation is complex and he qualifies his conclusion with the caveat that it is probably "roughly correct". Nonetheless, he believes that the property tax may be among various factors contributing to excessive growth of cities.[6] Arnott (2006) provides a more extensive theoretical assessment of the effects of property taxes on land development than Brueckner but also concludes that the conventional property tax distorts land development and may be expected to contribute to sprawl. Arnott proposes potentially feasible changes to the property tax system that

[5] For discussions of the role for user fees and their implications, see (for example), Bazel and Mintz (2014), Kitchen and Tassonyi (2012) and Slack (2002). Yinger (1998) argues that development charges may not be paid entirely by users but shared with the owners of undeveloped land.

[6] Brueckner's arguments about the property tax relate to and are supported by the underpricing of public infrastructure and of traffic congestion costs for which he advocates the expanded use of user fees. A third market failure he identifies is the value of open space.Brueckner also reviews his empirical work (based on 40 small to modest-sized urban areas) on the forces underlying urban expansion, which he identifies as population growth, household income, agricultural land value/rent, and commuting costs.

could reduce the social welfare losses that result from the inferior intensity and timing of land development resulting from the existing property tax.

The analyses of Brueckner and Arnott provide interesting insights but provide limited assistance for empirical analysis. Their starting point or counterfactual alternative tax is the land-rent tax promoted by Henry George. A tax on land rent does not affect land use and development decisions. In contrast, the conventional property tax found in the United States and Canada taxes the value of land and improvements (value usually approximating or related to market value). Taxing land at market value and the capital invested in improvements distorts land-use decisions; in particular, land will be used less intensively (lower capital investment per unit of land) and development timing can be affected. As Brueckner and Arnott demonstrate, the interactions are complicated and the exact consequences for land use difficult to predict. The implication is, however, that distortions could be removed and welfare improved by converting to a tax on land rent. However, as discussions of their papers indicate, such a move may not be entirely appealing nor has it found support in the United States.[7]

The tax options before local governments in the United States are quite different. While the conventional property tax prevails, many local governments also use or have the potential to use sales taxes and even local income taxes. Local governments generate sales tax revenues in almost all states and local income (or payroll) taxes are levied in 14 states. Where utilized, each source generates revenues equivalent to about 22 per cent of the local property taxes (on average).[8, 9] These alternative tax sources exist and are significant. In this environment, more or less reliance on property taxes implies less or more reliance upon sales or income taxes (if tax revenues are to be constant). Thus, it is a tradeoff or balance among two or three sources of local tax revenues in most states. The choice may be a significant determinant of land use. As already discussed, property taxes impose a cost on holding land (real property to be more accurate) — a cost that may be particularly significant for undeveloped land. Where local sales and/or income taxes substitute for property taxes, the cost of holding property is reduced as the cost of financing local services is shifted from property owners to consumers and income earners. The implications of varying reliance on different tax bases for land use are likely to be complicated to sort out but, in this environment, it is reasonable to suspect that a greater reliance on property taxation should discourage sprawl. In this paper, the issue is explored as a purely empirical question.

---

[7] Also see Ladd (1998).

[8] These numbers come from the U.S. *Statistical Abstract*, 2012. For overviews of local government taxes in the United States see Sjoquist, Wallace and Edwards (2004) and Benton (2010).

[9] Canadian local governments rely almost exclusively (i.e., close to 100 per cent) on property taxes. Dahlby and McMillan (2014) examine the need of Alberta cities for alternative sources of tax revenues and assess the merits of alternative sources.

The literature on urban land use has often noted local public finance attributes as possibly having some influence, but relatively few empirical investigations include them, particularly in any comprehensive fashion.[10] This work is intended as another step towards correcting that deficiency by building upon my 2016 paper. Measures of the utilization of user charges and of the reliance on property taxes are variables included in our analysis. Also, following Burchfield et al. (2006) and because transfers are the third major source of local government funds, transfers are also included.

The Public Finance Data

Public finance data used in this analysis comes from the Lincoln Land Institute's Fiscally Standardized Cities database. These data come from the collection of revenue and expenditure data for 150 (predominately large) U.S. cities standardized so as to make the data comparable across cities despite financing and service arrangements differing among cities due to differences in the assignments of responsibilities among municipal and (possibly) overlying counties, school districts and other special districts. In providing "a full picture of revenues raised from city residents and businesses and spending on their behalf," it serves to reflect the public finances of the larger region and is taken as representing the local finances of the metro area.[11] The public finance data are for 1977, the earliest year for which the data are available and the closest to the 1976 base-year metropolitan data of Burchfield et al. (2006).

The available public finance data cover only a subset of the 275 metropolitan areas studied by Burchfield et al. (2006). While there are 150 cities in the Fiscally Standardized data, 109 observations for 1977 are realized. The shrinkage in the numbers is due to some cities being part of a single metropolitan area in the Burchfield et al. data (e.g., Phoenix and Mesa, Ariz.) and a few cities not being included in the data (e.g., Anchorage). Where two or more standardized cities are included within a single metro area, the data are combined into a weighted average reflecting 1977 city populations. Even so, the metro area populations exceed those of the available cities. That is also the case even when the metro area is associated with only a single city. Only for Lincoln, Neb. does the city encompass the full metro area. On average, the standardized city population is 45.8 per cent of the metro area population as reported in Burchfield et al. and the values range from 12.8 per cent to 100 per cent with a standard deviation of 19.2. This means, of course, that the standardized city data, although covering less than the full metro community, is assumed to provide a good approximation or characterization

[10] Overviews discussing, among other factors, the possible roles of local public finance upon land use are Ladd (1998) and McGuire and Sjoquist (2003). Wassmer (2016a) provides a comprehensive review of theoretical and empirical works on the determinants of sprawl with a focus on the role of property taxes and also presents new empirical results. Also see Wassmer (2016b). Further discussion of related work follows presentation of the results of this paper.

[11] See Lincoln Institute of Land Policy website, "Fiscally Standardized Cities," http://www.lincolninst.edu/subcenters/fiscally-standardized-cities/, for information and the data set.

of the public finances of the metro region. Given that the public finances of neighbouring local governments are known to parallel one another fairly closely,[12] especially within states, and that the dominant jurisdiction can have a large influence, the assumption may not be seriously violated. However, this issue needs to be monitored. Regardless, resource limitations make it very difficult to consider further refinements. As it turns out, the empirical results suggest that the data from the Fiscally Standardized Cities database serve well.

Local taxes are a major source of local government revenue and local property taxes are the dominant source of local taxes. Because of their significance and because of the cost property taxes impose on holding land, we are especially interested in the role of property taxes in the local tax structure. To measure this, the property tax variable utilized is: property tax revenues as a percentage of total tax revenues in the metro area. Across the 109 observations, property taxes averaged 75.9 per cent of the total taxes collected in the fiscally standardized cities/metro areas in 1977 (Table 1). Conveniently, for the purposes of this analysis, there is a wide range in the relative contribution of property taxes; from 28.1 to 99.5 per cent of total taxes with a standard deviation of 17.1. The other taxes are primarily sales taxes (of various types), individual income taxes and miscellaneous taxes. Across the 150 standardized cities, sales taxes contributed 14.2 per cent of taxes and income taxes 4.2 per cent.

User charges are an important source of local government revenue and are expected to be a possible determinant of land use. To provide an indicator of their relative magnitude, the charges variable used here is charges as a percentage of total taxes. Charges encompass a long list of possibilities. Those charges most related to land use are chosen, including sewerage charges, water utility revenues, solid waste charges, special assessments (typically used for specific local improvements) and “other” charges. These amount to about less than half of total charges. Major charges that are omitted are hospital charges and electricity revenue (which together exceed the revenue of those selected for inclusion). Electricity (and also gas) utility revenue is excluded because only a minority of the cities report those as revenue sources. Clearly, many cities rely upon private firms to provide and charge for electricity and gas. Almost all cities report each of the charges selected (with solid waste fees being less common). These charges amount to the equivalent of 22.4 per cent of total tax revenue on average and vary widely with a range from 1.9 to 73.7 per cent.

[12] See, for example, Brueckner (2003) and Hauptmeiera, Ferdinand Mittermaierb and Johannes Rinckec (2012).

Table 1. Summary Statistics of the Public Finance Variables, 1977				
	Mean	Minimum	Maximum	Standard Deviation
	Measured as a Percentage of Total Taxes			
Property taxes	75.9	28.1	99.5	17.1
Charges (selected)	22.4	1.9	73.7	14.5
Transfers	116.8	32.4	438.4	54.6
	Measured as a Percentage of Total Revenue			
Property taxes	26.6	7.5	49.5	9.4
Charges (selected)	8.2	0.3	21.9	3.9
Transfers	37.7	15.6	77.9	10.2
Source: Lincoln Land Institute, Fiscally Standardized Cities database.				

Transfers from other governments may be the surprising element here. Intergovernmental grants exceed total taxes and are, on average, the equivalent of 116.8 per cent of total taxes. Again, the variation across the cities/metro areas is large; from 32.4 to 438.4 per cent with a standard deviation of 54.6. The reason for the magnitude of intergovernmental transfers is that the standardized cities data includes school districts and schools are heavily supported by grants, particularly grants from the state governments. On average, school districts obtain 51 per cent of their funding from transfers (and 42 per cent from property taxes). Of the 150 standardized cities, city governments averaged about 33 per cent of their revenues from transfers, essentially the same as revenues from taxes.[13]

Further insight into local finances is provided by the data in the lower panel of Table 1. There, the summary statistics for property taxes, charges and transfers are reported as a percentage of total revenue (rather than of tax revenue). Transfers, at 37.7 per cent, are the single largest source of revenues for the local governments. That implies that own-source revenues amount to 62.3 per cent. Total taxes are about 35 per cent. The specific sources of own-source revenues we analyze are property taxes at 26.6 per cent and the selected charges (as noted above) at 8.2 per cent. All variables report a wide range in the values across the observations. To add a dimension to the magnitude of the local public sector in the city/metro areas, the own-source revenue of the local governments amounted to about 11 per cent of per capita incomes. Hence, local government revenue policies should have a noticeable impact on citizens.[14]

[13] City governments and school districts average 85 per cent of the standardized cities total revenues, with counties and special districts accounting for the remainder.
[14] For overviews of local public finance in the United States, refer to Benton (2010) and Pagano (2010).

The Burchfield et al. Independent Variables

Burchfield et al. (2006) assembled a substantial and detailed file of data with which to evaluate the causes of sprawl as measured in 1976 and 1992. The summary statistics of the independent variables appearing in the regression results reported in their paper are presented in Table 2 for the 109 observations analyzed here. The only notable differences in these data compared to Burchfield et al.'s 275 observations are that the means and standard deviations for streetcar passengers per capita in 1902 and for elevation range on the urban fringe are larger in this data set.[15] The first 11 variables in the table (i.e., those listed down to intergovernmental transfers) plus the percentage population growth 1970–1990 appeared (though not necessarily consistently) with significant coefficients in their regression results. These variables, in addition to the public finance variables, are employed (at least initially) in this analysis.

[15] For streetcar passengers, the mean here of 49.6 contrasts with the Burchfield et al. mean of 21.5, while the elevation range mean here is 726.2 metres as compared to 542.4 metres.

Table 2. Summary Statistics of Burchfield et al. Variables for 109 Observations				
	Mean	Minimum	Maximum	Standard Deviation
Centralized-sector employment 1977	22.8	20.8	26.2	0.96
Streetcar passengers per capita 1902	49.6	0	312.6	90.1
Mean decennial % population growth 1920-1970	26.0	3.9	117.1	18.2
Std. dev. decennial % population growth 1920-1970	13.2	2.1	85.6	12.0
% of urban fringe overlying aquifers	26.9	0	100.0	34.1
Elevation range in urban fringe (m)	726.2	4.0	4048.0	872.5
Terrain ruggedness index in urban fringe (m)	9.44	0.06	56.0	10.0
Mean cooling degree-days	1264.2	108.3	3972.5	853.5
Mean heating degree-days	4740.1	242.6	9549.5	2148.6
% of urban fringe incorporated 1980	7.27	0.61	33.51	6.51
Intergov. transfers as % of local revenues 1967	33.7	13.4	70.4	9.6
Bars and restaurants per thousand people	1.45	0.85	2.51	0.3
Major road density in urban fringe (m/ha)	0.85	0.51	1.54	0.37
% population growth 1970-1990	34.9	-15.6	179.8	34.0
Herfindahl index of incorporated place sizes	0.32	0.015	1.0	0.25
Latitude	38.11	25.8	47.6	5.0
Longitude	-93.1	-122.8	-70.2	14.6

It is helpful to familiarize the reader with the Burchfield et al. variables but, given the thorough treatment in Burchfield et al., there is no need to discuss them in detail. The variables are selected to reflect the implications of the monocentric city model, geographic features and political factors.

The implications of the monocentric city model are characterized primarily by two variables. Differences among cities in business/industry structure and resulting locations of employment is captured by the share of the employment in the central sector of the metro area in 1977. The underlying belief is that cities with more centralized employment will be more compact. The measure of streetcar passengers in 1902 is intended to capture lower transportation costs, clearly with historical implications.[16] Demographic features are included in this group of variables. Metro areas having faster decennial population growth (from 1920–1970) are expected to develop land more quickly, in part to keep commuting costs low, and leave less open space. That is, faster growth is expected to be associated with less sprawl. The percentage population growth 1970–90 serves as a supplementary indicator. A more uncertain rate of growth, as measured by the standard deviation of decennial population growth, is expected to be linked to greater sprawl, particularly due to more leapfrogging development.

Geographic and environmental features are reflected in a second group of variables. The presence of aquifers at the urban fringe affords the opportunity to drill wells rather than connect to water systems and is projected to be associated with more scattered development. Steep elevation range at the urban fringe (as mountains) is expected to discourage sprawl as “sprawl hits the wall.” Small-scale irregularities, measured by the ruggedness index, are expected to have the opposite effect. Open space is expected to be more desirable in temperate climates so extremes of temperature (more heating and cooling days) are projected to reduce sprawl. Latitude and longitude provide less precise proxies of geographical features.

Political features are also expected to influence the scatteredness of development. Regulation of development stands out. Fewer restrictions are felt to exist outside incorporated areas; that is, in the counties beyond cities and towns. Hence, the variable accounting for the percentage of the urban fringe incorporated in 1980. Jurisdictional fragmentation of metropolitan areas, as measured by the Herfindahl index, is considered to have an uncertain effect. Finally, it is projected that as transfers as a percentage of local revenues increases the cost of local services to local residents is lowered and sprawl promoted.

From their analysis, Burchfield et al. conclude:

[16] Bars and restaurants per capita is included as an amenity variable and road density to indicate car-friendliness.

"We find that sprawl is positively associated with the degree to which employment is dispersed; the reliance of a city on the automobile over public transport; fast population growth; the value of holding on to undeveloped plots of land; the ease of drilling a well; rugged terrains and no high mountains; temperate climate; the percentage of land in the urban fringe not subject to municipal planning regulations; and low impact of public service financing on local taxpayers." (p. 625.)[17]

Specifics of the Burchfield et al. Sprawl Indexes

Burchfield et al. (2006) calculate two measures of sprawl: a stock index and a flow index. Both measure sprawl in the neighbourhood of an average residential property. Essentially, sprawl is measured as the amount of undeveloped land surrounding an average urban dwelling.

The stock index is the simpler of the two measures. For each 30 x 30 metre cell of residential development, the percentage of open space in the immediately surrounding square kilometre is calculated. The average of those across all residential development in the metropolitan area yields the sprawl index. Thus, the index is "the percentage of undeveloped land in the square kilometre surrounding an average residential development."[18] This index is calculated for each metro area for 1976 and for 1992. A metro area's values for the two years are highly consistent.[19] This consistency is suggested by the values in Table 3 for the two years. There is substantial variation in the values across the metro areas — from about 20 (Miami-Ft. Lauderdale, Florida) to about 67 (Dover, Delaware) in 1976 and 75 (Burlington, Vermont) in 1992.

Table 3. Summary Statistics of Burchfield et al. Sprawl Indices for 109 Observations

	Mean	Minimum	Maximum	Standard Deviation
Sprawl_1976	41.5	20.0	67.5	9.8
Sprawl_1992	41.9	20.7	75.1	10.1
Sprawl_1976-92	60.1	33.3	88.5	10.4

[17] This summary differs somewhat from the statement in their Abstract (p. 587). That reads, "Ground water availability, temperate climate, rugged terrain, decentralized employment, early public transit infrastructure, uncertainty about metropolitan growth, and unincorporated land in the urban fringe all increase sprawl." Part of the difference may be emphasis and strength of the empirical results, but noting that sprawl is associated with past population growth (p. 625) appears contrary to the empirical results.

[18] Burchfield et al. (2006) p.600.

[19] The correlation coefficient for the 275 Burchfield et al. data is 0.96 and it is 0.95 for the 109 observations in this study.

Burchfield et al. also calculate a flow-sprawl index. This index indicates how sprawl relates to new development between 1976 and 1992. In this case the calculation proceeds as follows: "we identify 30-metre cells that were not developed in 1976 but were subject to development between 1976 and 1992, calculate the percentage of land not developed by 1992 in the square kilometer containing each of these 30-metre cells, and average across all such newly developed cells in the metropolitan area."[20] This index measures the average sprawl in the neighbourhood of residential property developed between 1976 and 1992. The average value for this measure is 60.1; that is, there is more open space nearby new residential development than nearby the average residential property within a metro area (for which the value was 41.9 in 1992). Again, the range of values is wide; from 33.4 in Phoenix to 88.5 in Burlington.[21]

Burchfield et al. are most interested in explaining the flow-sprawl index but find the same variables also explain the stock indexes. The primary interest in this paper is to explain the cross-sectional variation in the stock but the flow index is also examined though to a lesser extent. Similar results are obtained using each.

An Initial Series of Regressions and Their Results

A useful starting point is a comparison of regression results of the Burchfield et al. (2006) specification of their Sprawl_1992 model with those when the three public finance variables are added. Those results appear in Table 4. Because this (further) extension of the "causes of sprawl" is motivated by distinct differences between the results reported in McMillan (2016) based on the 83 metro area observations available at that time and those obtained when the data set was expanded to 109 observations, Table 4 shows initial results when using the original 83 observations as well as those from using 109 observations.[22]

The first column shows the level of significance of the Burchfield et al. model when estimated on their 275 observations.[23] Only one variable, centralized sector employment, did not have a significant coefficient. All the others were significant, two at the five-per-cent level and eight at the one-per-cent level.

The regression results with the same specification but with 83 observations did not identify individual causes nearly so well although the R^2 increased from 0.404 to 0.547. With the smaller number of observations, only the presence of aquifers had a coefficient significant at the one-per-cent level and heating days at the five-per-cent level. Decennial population growth and transfers as a percentage of revenue were significant at the 10-per-cent level. The

[20] Burchfield et al. (2006) p.599.
[21] The correlation of Sprawl_1976_92 with Sprawl_1976 is 0.68 and with Sprawl_1992 is 0.82.
[22] The results for the 83 observations are those reported in Table 4 of McMillan (2016).
[23] This column is based on regression results (4) of Table IV on page 616 of Burchfield et al. (2006).

Table 4. Initial Regression Results on Sprawl_1992				
	Burchfield et al. Specification		Public Finance Variables Added	
	Significance when 275 observations	Coefficient (Standard Error) 83 observations	Coefficient (Standard Error) 83 observations	Coefficient (Standard Error) 109 observations
Centralized-sector employment 1977	–	-0.95109 (0.80792)	-0.88657 (0.90550)	0.15983 (0.77948)
Streetcar passengers per capita 1902	***	-0.01678 (0.01156)	-0.02699 (0.01233)**	-0.02811 (0.01002)***
Mean decennial % population growth 1920-1970	***	-0.19395 (0.11020)*	-0.19828 (0.11946)^	-0.37588 (0.10465)***
Std. dev. decennial % population growth 1920-1970	**	0.03167 (0.13349)	0.02945 (0.15733)	0.22214 (0.12920)*
% of urban fringe overlying aquifers	***	0.09432 (0.02297)***	0.09645 (0.02441)***	0.06563 0.02158***
Elevation range in urban fringe (m)	**	-0.00217 (0.00210)	-0.00171 (0.00209)	-0.00085 (0.00115)
Terrain ruggedness index in urban fringe (m)	***	0.29562 (0.28834)	0.28289 (0.28847)	0.22216 (0.10175)**
Mean cooling degree-days	***	-0.00532 (0.00351)	-0.00559 (0.00339)^	-0.00443 (0.00258)*
Mean heating degree-days	***	-0.00286 (0.00142)**	-0.00287 (0.00144)**	-0.00253 (0.0009)***
% of urban fringe incorporated 1980	***	-0.18395 (0.11163)^	-0.19331 (0.12182)^	-0.24048 (0.11125)**
Intergov. transfers as % of local revenues 1967	***	0.18125 (0.10456)*		
Property tax as percentage of total taxes			-0.08592 (0.05344)^	-0.04515 (0.04852)
Charges as percentage of total taxes			-0.07949 (0.09493)	0.00159 (0.07063)
Transfers as percentage of total taxes			0.01570 (0.02085)	0.00798 (0.01884)
Constant		79.979 (22.893)***	91.989 (23.378)***	65.007 (18.697)***
Observations	275	83	83	109
R^2	0.404	0.5467	0.5539	0.3914
Adjusted R^2		0.4764	0.4699	0.3081

Note: Coefficients are reported with standard errors below. Standard errors are heteroskedastic-consistent. ***, ** and * indicate significance at the one-, five- and 10-per-cent levels. ^ indicates significance between the 10- and 12-per-cent levels.

significance of the percentage of the urban fringe incorporated fell just under the 10-per-cent level.

The results when our public finance variables are added to the Burchfield et al. specification (less their transfers percentage) are presented in the adjacent column.[24] Aquifers and mean heating days again have significant coefficients at the same levels. The coefficient of streetcar passengers now becomes significant at the five-per-cent level. Decennial population growth slips to just below the 10-per-cent level and the incorporated percentage of the urban fringe is, as with the Burchfield et al. specification, not significant but marginally under the 10-per-cent level. Mean cooling days now also has a coefficient barely missing the 10-per-cent standard. The addition of the public finance variables only slightly improves the fit (to an R^2 of 0.554). None of those variables (including transfers) have coefficients significant at the conventional levels but the signs are as expected and the property tax variable, with a $t = -1.61$, is only marginally below the 10-per-cent criterion. [25]

Overall, the results are not improved when the regression is run on 109 observations. While several more coefficients become significant at the conventional levels, eight rather than three, the coefficients of the public finance variables are not significant. Furthermore, the fit of the regression deteriorates notably with R^2 declining from 0.554 to 0.391 (a level comparable with that of Burchfield et al.).

These results are hardly encouraging but we know from McMillan (2016) that, with some re-specification of the model, the added public finance variables help explain sprawl. To illustrate, the results of a regression on Sprawl_1992 from McMillan (2016)[26] are reported in the first column of Table 5. There, property taxes as a percentage of total taxes variable has a negative coefficient significant at the one-per-cent level.[27] A modest variation of the 2016 model is estimated using the expanded set of 109 observations (the second column of regression results) and, for comparison (see the third column), also on the original 83 observations. Despite the same specification, there are notable differences between the estimates using the 83 and the 109 observations (i.e., the second and third columns of results). First, there is some variation between the two in the variables that are significant and the levels of significance. In particular, the public finance variables perform less well with 109 observations. While property taxes had a significant coefficient (at the five-per-cent level) with 83 observations, its coefficient is not significant (though just somewhat short of the 10-per-cent mark) when estimated with 109 observations.

[24] Property taxes, charges and transfers here are their 1977 values as a percentage of 1977 total taxes. In subsequent regressions, the percentages for charges and transfers are modified.
[25] The contributions of the different categories of variables are interesting. The monocentric city group have an R^2 of 0.222, adding the geographic variables raises that to 0.509, including the incorporated fringe brings the R^2 to 0.528, and the public finance variables increase it to 0.554. Obviously, geographic variables have the largest influence.
[26] See Table 5, specification 4 in McMillan (2016).
[27] Also, explanatory power increases relative to that of the 83 observation model with public finance variables in Table 4. That is, the R^2 increases from 0.554 to 0.622.

Table 5. Regression Results for Sprawl_1992 with Extended Specifications on 83 and 109 Observations			
	83 observations and 2016 specification	109 observations and current specification	83 observations and current specification
Centralized-sector employment 1977	-0.91324 (0.88143)	0.90993 (0.92128)	-0.74701 (0.92936)
Streetcar passengers per capita 1902	-0.01947 (0.01369)	-0.03852 (0.01420)***	-0.02633 (0.01544)*
Mean decennial % population growth 1920-1970	-0.09848 (0.16093)	-0.35486 (0.14896)**	-0.07357 (0.15460)
Std. dev. decennial % population growth 1920-1970	-0.04605 (0.19124)	0.22635 (0.15933)	-0.04268 (0.19197)
% of urban fringe overlying aquifers	0.09469 (0.02485)***	0.03382 (0.02505)	0.06970 (0.02766)**
Elevation range in urban fringe (m)	-0.00206 (0.00203)	-0.00041 (0.00197)	-0.00114 (0.00229)
Terrain ruggedness index in urban fringe (m)	0.36720 (0.28209)	0.16842 (0.15563)	0.44642 (0.35893)
Mean cooling degree-days	-0.00526 (0.00336)	0.00654 (0.00286)**	-0.00543 (0.00298)*
Latitude	-1.09369 (0.51363)**	-1.38854 (0.45112)***	-1.14193 (0.45149)**
% of urban fringe incorporated 1980	-0.21289 (0.11514)*	-0.23082 (0.13414)*	-0.21945 (0.12252)*
Road density in urban fringe		0.17753 (2.99656)	5.56712 (3.1355)*
Population 1992 to 1976 (x100)	0.11122 (0.03501)***	0.05331 (0.04161)	0.11691 (0.03641)***
Population 1976 to 1960 (x100)	-0.14062 (0.05715)**	-0.06093 (0.06422)	-0.13656 (0.05659)**
Population 1976 ('000)	-0.00051 (0.00084)	-0.00045 (0.00082)	-0.00065 (0.00086)
Standardized city population 1977 to metro population 1976		-17.76751 (6.13696)***	-5.27970 (5.99913)
Property tax as percentage of total taxes	-0.12489 (0.04623)***	-0.07454 (0.46373)^	-0.13630 (0.04824)**
Charges as percentage of total taxes, 1992	-0.12205 (0.09073)	-0.06515 (0.04839)	-0.13975 (0.08459)^
Transfers as percentage of total revenue	0.00658 (0.02782)	-0.15476 (0.11549)	0.01223 (0.10283)
Constant	126.567 (28.513)***	113.0869 (29.01021)***	123.14160 (29.16815)***
Observations	83	109	83
R^2	0.6223	0.5119	0.6515
Adjusted R^2	0.5307	0.4143	0.5535

Notes: a) Coefficients are reported with standard errors below. Standard errors are heteroskedastic-consistent. ***, ** and * indicate significance at the one-, five- and 10-per-cent levels. ^ indicates significance between 10- and 12- per-cent levels.

b) Coefficients in the shaded area are for 1976 charges as a percentage of total taxes (rather than 1992 charges) and for transfers as a percentage of total taxes (rather than total revenue); that is, as in McMillan (2016).

Also, the coefficient of the charges variable, which narrowly missed the10-per-cent level of significance with 83 observations, is well beyond significance in the 109 observation case. Second, and striking, is the considerable deterioration in the explanatory power of the regression when estimated on the 109 observations; the R^2 declines from 0.651 to 0.512. These features suggest that there is something different about the 26 additional observations. The outstanding difference, as shall be seen, is in population size. Before proceeding with that aspect of the analysis, however, the expanded set of variables included in the regression require explanation.

Specification of the Current Model

The standard specification of the regressions used in this paper are a refinement of that in McMillan (2016) which, in turn, built upon the Burchfield et al. (2006) model. The major groups of the Burchfield et al. data are included: that is, the variables representing the monocentric city, geographic features and the incorporated fringe. Given the focus of this study, the public finance variables are added. Property taxes are taken as a percentage of total local taxes in 1976. Charges are measured as charges in 1992 as a percentage of total taxes for regressions on Sprawl_1996 and Sprawl_1976_92 but as charges in 1976 as a percentage of total taxes in 1976 for estimates on Sprawl_1976. The reason for the change when measuring charges for regressions involving 1992 is that the role of charges increased substantially between 1976 and 1992 – from 25.4 per cent of total taxes to 35.5 per cent for the 109 observations. Revenues from intergovernmental transfers are included as a percentage of total revenue. Total revenue, rather than total taxes,[28] was selected as the base because that form contributed slightly to the results although the transfer variable never appears with a significant coefficient. Burchfield et al. also used total revenue as the base for their transfer variable.

The remaining variables are refinements of or additions to those available in the Burchfield et al. data.[29] Latitude replaces heating degree-days. Population change between 1960 and 1976 and between 1976 and 1992 are added in place of Burchfield et al's population growth from 1970 to 1990. Population in 1976 is also added. The standard specification here adds two variables to those appearing in McMillan (2016). Road density in the urban fringe (included in the Burchfield et al. data) is included as a further characterization of the urban fringe. The other addition is the population of the fiscally standardized city in 1977 relative to the metropolitan population in 1976. It reflects the portion of the metropolitan area's population within the fiscally standardized city. This variable has a significant and negative coefficient in regressions using the 109 observations (e.g., Table 5). This result indicates that when a city encompasses a larger portion of the metropolitan population, sprawl is reduced. That outcome may arise because

[28] The comparison was made to total taxes (not total revenues) in McMillan (2016).
[29] Trial regressions resulted in some of the Burchfield et al. variables being omitted.

the city has control over land use in a larger share of the metro area (or, alternatively, that fringe municipalities have less influence on metro-wide land use and development).

As indicated by the results in Tables 4 and 5, the additional variables increase the explanatory power of the regressions. The concern that remains, however, is the deterioration of the performance with the expanded number of observations.

Examination of the Data

The expansion of the Lincoln Land Institute's fiscally standardized city data base enabled the expansion of the public finance enhanced data set from 83 to 109 observations. As the previous analysis suggests, the additional 26 observations do not correspond well with the original 83. (See Appendix Table 1.) The outstanding difference is the population sizes of the additional metropolitan areas. The 1976 population of the 26 metropolitan areas averages 236,570 persons while that of the 83 metropolitan areas is 1,490,000. Half of the 26 additional cases had populations smaller than the minimum (164,000) in the 83 observation data set and only two had a population exceeding one million. Obviously, the additional 26 observations are a group of relatively small(er) metro areas.

Among the other characteristics, some further differences are notable. The sprawl is somewhat greater in the 26 newly added metro areas. None had streetcars in 1902 and the added cities tended to be located in cooler areas of the country. Of particular interest are two features of their public finances. First, there is considerably greater reliance on property taxes than among the original sample – property taxes average 87 per cent of total taxes compared to 72 per cent and the minimum level is 59 per cent versus 28 per cent. Second, charges are greater among the new observations. In 1992, charges average 50 per cent of total taxes for the 26 in contrast to 31 per cent for the 83 observations.

Further examination of the data and trial regressions led to dividing the 109 observations into three groups (based on population size) for further analysis. Thus, there are small, medium and large metro area sub-sets. The three sub-sets, were defined so that they had an equal number of observations. The small population group is made up of 36 metro areas with 1976 populations less than 340,000 persons. The mid-sized group includes 37 metro areas with a population between 340,000 and 880,000. The large metro area group includes those 36 with populations exceeding 880,000 persons.

The characteristics of the three metro-area groups (and those for the total sample) are presented in Table 6. Certain differences are evident. As expected, the group with the metro areas having populations under 340,000 features many of the characteristics of the additional 26 observations. The mean population is 190,140 persons, none had streetcars in 1902, they are in cooler regions, and rely more heavily on property taxes and on charges for funding than do metro

Table 6. Variable Means and Standard Deviations for Population Sub-Groups

	Population in 1976 (000)			
	Less than 340 36 observations	340-880 37 observations	Greater than 880 36 observations	All 109 observations
Sprawl_92	43.17 (11.94)	43.68 (9.42)	38.72 (8.19)	41.87 (10.12)
Sprawl_76	42.93 (10.96)	43.48 (9.31)	38.02 (8.32)	41.49 (9.82)
Sprawl1976_92	61.96 (11.50)	61.25 (9.55)	57.21 (9.82)	60.15 (10.44)
Centralized-sector employment 1977	23.09 (1.00)	22.63 (0.97)	22.68 (0.86)	22.80 (0.96)
Streetcar passengers per capita 1902	0.00 (0.00)	21.02 (54.83)	128.52 (110.31)	49.58 (90.12)
Mean decennial % population growth 1920-1970	24.82 (16.62)	25.55 (16.16)	27.60 (21.68)	25.99 (18.17)
Std. dev. decennial % population growth 1920-1970	14.71 (14.88)	12.73 (8.92)	12.26 (11.63)	13.23 (11.97)
% of urban fringe overlying aquifers	24.12 (33.34)	28.59 (37.00)	27.89 (32.38)	26.88 (34.06)
Elevation range in urban fringe (m)	750.36 (755.78)	653.86 (927.98)	776.36 (939.95)	726.19 (872.53)
Terrain ruggedness index in urban fringe (m)	11.81 (13.06)	7.75 (7.96)	8.81 (8.01)	9.44 (10.01)
Mean cooling degree-days	1007.95 (730.63)	1556.71 (728.09)	1219.74 (1004.44)	1264.18 (853.53)
Latitude	39.97 (5.15)	36.04 (3.88)	38.39 (5.23)	38.11 (5.01)
% of urban fringe incorporated 1980	4.68 (4.37)	8.35 (8.22)	8.75 (5.63)	7.27 (6.51)
Road density in urban fringe 1980	0.73 (0.40)	0.86 (0.34)	0.96 (0.34)	0.85 (0.37)
Population 1992 to 1976 (x100)	126.47 (23.89)	144.09 (38.88)	131.55 (24.23)	134.13 (30.58)
Population 1976 to 1960 (x100)	130.41 (22.22)	132.56 (29.18)	129.45 (22.39)	130.82 (24.66)
Population 1976 ('000)	190.14 (86.92)	551.86 (167.19)	2848.83 (3151.42)	1191.03 (2149.48)
Standardized city population 1977 to metro population 1976	0.55 (0.18)	0.47 (0.19)	0.36 (0.16)	0.46 (0.19)
Property tax as percentage of total taxes 1977	81.16 (16.26)	72.76 (16.21)	73.86 (18.15)	75.90 (17.14)
Charges as percentage of total taxes 1977	30.05 (17.22)	26.91 (13.28)	19.30 (10.38)	25.43 (14.50)
Charges as percentage of total taxes 1992	44.34 (27.85)	35.28 (14.47)	27.02 (12.70)	35.55 (20.58)
Transfers as percentage of total revenue 1977	35.38 (10.21)	37.39 (9.65)	40.29 (10.40)	37.68 (10.19)

Note: Mean values are reported with standard deviations below the mean.

areas in the other two groups.[30] However, the mean sprawl indices are similar to (rather than larger than) the overall averages although they are larger than those of the large population group. The large population group also has some unusual characteristics. Naturally, mean population is the largest at about 2.85 million. The average sprawl indices are lower than in the other two groups. Streetcar use in 1902 is by far the greatest in these large metro areas. The public finances of this group utilize user charges the least. The mid-sized group, with an average population of approximately 552,000 persons, tends to have characteristics that are about average for the 109 observations or parallel those of one or the other groups. Also to be noted is that certain features trend consistently across the three groups. Streetcar use is an obvious example but charges and city population in 1977 to metro population in 1976 both are highest in small population group and smallest in the large while road density in the fringe is the opposite.

Further Regressions and Results

The results of regressions for each of the three population size subgroups are presented for each measure of sprawl (i.e., Sprawl_1992, Sprawl_1976 and Sprawl_1976_92). Regression results are presented initially with all variables included. As to be expected, few variables show statistically significant coefficients. Selective exclusion of variables typically causes only minor reductions in fit while providing a better sense of the important determinants of sprawl. Hence, the regression results for truncated specifications are also reported for each case. An overview of the regression results that highlights the main conclusions completes this section of the paper. Public finance variables are relevant but not uniformly so for all sizes of metropolitan areas.

Regressions on Sprawl_1992

Using the specification in Table 5, regressions are run on each of the three metro-area population classes. The results for Sprawl_1992 are reported in Table 7 (along, for convenience reference, with the results for all 109 observations from Table 5). With R^2 ranging from 0.736 to 0.781, the regressions fit the Sprawl_1992 data quite well and notably better than the regression on all 109 observations which had a R^2 of 0.512. Not surprisingly, however, given the number of variables, very few of the coefficients are statistically significant. In part, because a number of the variables have considerable correlation with each other, it is possible to eliminate some variables without an undue sacrifice of explanatory power. Hence, a set of regressions with truncated specifications are reported in Table 8. Variables were included or excluded depending

[30] Certain other features differ somewhat. For example, the percentage of the urban fringe that is incorporated, road density in the urban fringe and the percentage of the fringe overlying aquifers are lower in these metro areas while terrain ruggedness is greater.

upon their contribution to fit and the impacts upon the relevance of other variables in the equation (while always maintaining the public finance variables).

Table 7. Regression Results with Extended Specification by Population Classes on Sprawl_1992

	109 observations	Less than 340 36 observations	340-880 37 observations	Greater than 880 36 observations	Less than 880 73 observations	Greater than 340 73 observations
Centralized-sector employment 1977	0.90993	3.80631	2.10435	-4.40383	1.96675	-0.65426
	(0.92128)	(5.03943)	(1.79602)	(2.53161)*	(1.34123)	(1.17796)
Streetcar passengers per capita 1902	-0.03852	no obs.	-0.04741	-0.01067	-0.03175	-0.02432
	(0.01420)***		(0.41917)	(0.03369)	(0.02347)	(0.01554)
Mean decennial % population growth 1920-1970	-0.35486	-0.65875	0.28905	0.70855	-0.33287	-0.06705
	(0.14896)**	(0.54531)	(0.46480)	(0.70472)	(0.18685)*	(0.22132)
Std. dev. decennial % population growth 1920-1970	0.22635	0.67886	-0.73878	-1.07188	0.20919	-0.17376
	(0.15933)	(0.59475)	(0.67086)	(0.87398)	(0.19685)	(0.33240)
% of urban fringe overlying aquifers	0.03382	0.10094	0.12782	0.06086	0.05273	0.06422
	(0.02505)	(0.10027)	(0.09780)	(0.06475)	(0.38831)	(0.03159)**
Elevation range in urban fringe (m)	-0.00041	0.00674	0.00382	-0.00072	0.00083	-0.00093
	(0.00197)	(0.01040)	(0.00571)	(0.00695)	(0.00297)	(0.00255)
Terrain ruggedness index in urban fringe (m)	0.16842	-0.12145	-0.50007	0.21281	-0.06271	0.35606
	(0.15563)	(0.41329)	(0.92274)	(0.68686)	(0.31300)	(0.33821)
Mean cooling degree-days	0.00654	-0.00270	-0.00201	-0.00397	-0.00832	-0.00340
	(0.00286)**	(0.01393)	(0.01972)	(0.00816)	(0.00501)	(0.00441)
Latitude	-1.38854	-1.19051	-0.01934	-0.83575	-1.76195	-1.07416
	(0.45112)***	(2.16179)	(3.18135)	(1.33597)	(0.73703)**	(0.63686)*
% of urban fringe incorporated 1980	-0.23082	-0.04089	0.07110	-0.44865	-0.09479	-0.24926
	(0.13414)*	(0.56158)	(0.51161)	(0.37844)	(0.19633)	(0.15245)
Road density in urban fringe	0.17753	3.83098	1.76276	10.7693	-1.49527	5.69735
	(2.99656)	(11.58054)	(8.32265)	(10.44371)	(3.81677)	(4.35591)
Population 1992 to 1976 (x100)	0.05331	0.14698	0.05429	0.25844	0.04663	0.12557
	(0.04161)	(0.17054)	(0.07423)	(0.19597)	(0.05944)	(0.04646)***
Population 1976 to 1960 (x100)	-0.06093	-0.16740	-0.14548	-0.45961	-0.06677	-0.15430
	(0.06422)	(0.20393)	(0.12814)	(0.44961)	(0.08637)	(0.11573)
Population 1976 ('000)	-0.00045	-0.06697	-0.03043	-0.00024	-0.01752	-0.00047
	(0.00082)	(0.044413)	(0.01632)*	(0.00095)	(0.00818)**	(0.00089)
Standard city population 1977 to metro population 1976	-17.76751	-48.39606	-18.71181	-15.80327	-31.8788	-7.02097
	(6.13696)***	(15.05097)***	(18.69753)	(13.77926)	(7.52290)***	(8.00466)
Property tax as percentage of total taxes	-0.07454	-0.14066	-0.29478	-0.08525	-0.14983	-0.11517
	(0.46373)	(0.16647)	(0.15083)*	(0.11586)	(0.07049)**	(0.06175)*
Charges as percentage of total taxes, 1992	-0.06515	-0.18941	-0.01183	-0.03267	-0.13778	0.01403
	(0.04839)	(0.11992)	(0.20362)	(0.19791)	(0.05552)**	(0.09273)
Transfers as percentage of total revenue	-0.15476	-0.25597	-0.30851	-0.03513	-0.24233	-0.02519
	(0.11549)	(0.33161)	(0.33308)	(0.23507)	(0.15914)	(0.11855)
Constant	113.0869	74.5278	68.91275	201.6081	133.3351	115.7631
	(29.01021)***	(190.418)	(144.6686)	(92.94364)**	(47.48832)***	(41.89836)***
Observations	109	36	37	36	73	73
R^2	0.5119	0.7429	0.7809	0.7357	5864	0.6390
Adjusted R^2	0.4143	0.5001	0.5618	0.4558	0.4486	0.5286

Note: Coefficients are reported with standard errors below. Standard errors are heteroskedastic-consistent. ***, ** and * indicate significance at the one-, five- and 10-per-cent levels.

Table 8. Regression Results with Truncated Specifications by Population Classes on Sprawl_1992						
	109 observations	Less than 340 36 observations	340-880 37 observations	Greater than 880 36 observations	Less than 880 73 observations	Greater than 340 73 observations
Centralized-sector employment 1977	0.76880 (0.86096)	3.06956 (2.93237)	1.85463 (1.17695)	-5.10691 (1.77645)***	1.63394 (1.02189)	
Streetcar passengers per capita 1902	-0.05092 (0.01009)***	no obs.	-0.03609 (0.02486)			-0.03417 (0.01164)***
Mean decennial % population growth 1920-1970	-0.34331 (0.09579)***	-0.36847 (0.21192)*	0.23123 (0.25474)	0.87964 (0.48862)*	-0.17607 (0.06077)***	
Std. dev. decennial % population growth 1920-1970	0.20023 (0.12087)	0.40177 (0.21691)*	-0.65509 (0.41975)	-1.32250 (0.59132)**		-0.31666 (0.16297)*
% of urban fringe overlying aquifers		0.06487 (0.05928)	0.11216 (0.04367)**	0.06724 (0.04962)	0.06125 (0.02634)**	0.06269 (0.03019)**
Elevation range in urban fringe (m)						
Terrain ruggedness index in urban fringe (m)						
Mean cooling degree-days	-0.00852 (0.00270)***			-0.00415 (0.00631)	-0.00766 (0.00382)**	-0.00601 (0.00403)
Latitude	-1.60879 (0.44605)***	-0.61493 (0.47004)		-0.85630 (1.04482)	-1.72192 (0.61670)***	-1.25969 (0.60392)**
% of urban fringe incorporated 1980	-0.24251 (0.12496)*			-0.51076 (0.28998)*		-0.18345 (0.12839)
Road density in urban fringe				9.85993 (6.17229)		
Population 1992 to 1976 (x100)			0.07805 (0.04321)*	0.28589 (0.13576)**		0.10891 (0.03562)***
Population 1976 to 1960 (x100)			-0.17531 (0.07919)**	-0.51207 (0.27678)*		-0.15287 (0.08712)*
Population 1976 ('000)		-0.05797 (0.03320)*	-0.02645 (0.00959)**		-0.02115 (0.00529)***	
Standard city population 1977 to metro population 1976	-20.57266 (5.09806)***	-49.92385 (12.17827)***	-16.34415 (10.84103)	-18.69468 (9.04536)*	-31.50238 (5.98308)***	-11.87588 (7.89138)
Property tax as percentage of total taxes	-0.09451 (0.04303)**	-0.21908 (0.11136)*	-0.24749 (0.07711)***	-0.04517 (0.07558)	-0.14004 (0.05557)**	-0.11114 (0.05758)*
Charges as percentage of total taxes, 1992	-0.07958 (0.04537)*	-0.14676 (0.06541)**	-0.00282 (0.14269)	0.00858 (0.15027)	-0.11262 (0.04146)***	0.00183 (0.09122)
Transfers as percentage of total revenue	-0.17733 (0.10423)*	-0.17274 (0.23325)	-0.16517 (0.14765)	-0.00656 (0.15978)	-0.17374 (0.13255)	-0.08349 (0.10322)
Constant	133.09500 (26.83426)***	67.19170 (64.38429)	60.19383 (26.08374)**	216.40100 (60.94447)***	129.53760 (34.90323)***	124.00120 (26.78656)***
Observations	109	36	37	36	73	73
R^2	0.4765	0.6653	0.7567	0.7128	0.5500	0.5995
Adjusted R^2	0.4171	0.5314	0.6350	0.5214	0.4774	0.5194
R^2 extended specification	0.5119	0.7429	0.7809	0.7357	0.5864	0.6390

Note: Coefficients are reported with standard errors below. Standard errors are heteroskedastic-consistent. ***, ** and * indicate significance at the one-, five- and 10-per-cent levels.

Before considering the results in Table 8 for the three population groups, consider the regression on the 109 observations for reference. The truncated specification there eliminated seven variables while reducing R^2 by only 0.035. The variables with significant coefficients remain and those coefficients change only marginally. The difference here is that the coefficients of the public finance variables become significant with that of the property tax variable become significant at the 5-per-cent level. [31]

The regression results for the three population classes generate numerous statistically significant coefficients with the truncated specifications. In the case of the under 340,000 person group, five additional variables have significant coefficient (although four are at the 10-per-cent level). Two of those variables are property taxes (at the 10-per-cent level) and charges (at the 5-per-cent level).[32] The results for the mid-sized class reveal similar improvement and show a small reduction in fit. Four additional variables now have significant coefficients (with three of those at the 5-per-cent level). In addition, the coefficient of property tax, which was significant at the 10-per-cent level in Table 7, is now significant at the 1-per-cent level. The regression on the large population group has only four variables omitted but six additional variables have significant coefficients and the one that was significant previously is now significant at the 1-per-cent rather than the 10-per-cent level. In this case, however, none of the public finance variables have significant coefficients. The contribution of the public finance variables to explaining sprawl appears to differ depending upon the population of the metro area.

To garner further insight into the possible contributors to the explanation of sprawl, two additional regressions are reported in Tables 7 and 8. The first regression reports on estimates from metro areas with populations less than 880,000 people; that is, it combines the data of the two smaller population classes for 73 observations. The second regression is estimated on data for metro areas with populations exceeding 340,000 persons; that is, the 73 observations from the two larger population classes. Thus, the data in each group overlaps the mid-sized population class. This selection was made so as to a) increase the number of observations, b) combine the data for the two (smaller) population classes that showed some evidence of public finance variables being important, and c) to combine the two larger population classes so as to have a group more closely approximating the 83 observations used in the previous paper.

With 73 observations in each of two population classes, there are some noticeable changes in the regression results. First, in the full specifications (Table 7), the fit of the regressions diminishes considerably from those of the regressions on the three population

[31] The significance of the coefficients of the public finance variables are sensitive to the exclusion of the aquifers variable which did not have a significant coefficient in the truncated specifications.
[32] If the aquifer variable is omitted, the coefficient of the property tax variable is significant at the 5-per-cent level but R^2 drops 0.025.

classes. Second, more variables show significant coefficients than in the three class case. Third, the property tax and the charge variables have significant coefficients at the 5-per-cent level for the under 880,000 group but only that for property tax is significant (and then at the 10-per-cent level) for the over 340,000 group. Truncating the specifications (Table 8) has modest effects. The reduction in R^2 is minor, selected (but sometimes different) variables in the two groups appear relevant for explaining sprawl and the roles of the public finance variables are similar to the full specification cases. That is, property taxes and charges are both important (but with greater t-values) for the under 880,000 class while, for the over 340,000 class, only the property variable has a significant coefficient and still at the 10-per-cent level. The weakness of property taxes and charges for the over 340,000 class is somewhat unexpected given the relevance of those variables for the half of the observations with populations between 340,000 and 880,000 persons. Regardless, these results are a further indication that the determinants of sprawl differ somewhat between the smaller and larger population metro area and that the public finance features are more important in explaining sprawl in the smaller areas.[33]

Regressions on Sprawl_1976

Burchfield et al. (2006) also have a measure of sprawl in 1976. Their Sprawl_1976 data are analyzed in this section in a similar fashion to that above. In general, while the fits of the regressions are not quite as good as for Sprawl_1992, the results are quite similar.

The regression results for the specification including all variables are shown in Table 9 for the 109 observations and for the various sub-classes previously analyzed.[34] The results for the 109 observations in Table 9 parallel closely those in Table 7. Streetcar passengers, mean population growth from 1920 to 1970, cooling days, latitude , metro to city populations and property taxes as a percentage of total taxes again each have coefficients that are statistically significant at conventional levels. Only the percentage of the urban fringe incorporated did not appear with a significant coefficient with Sprawl_1976 when it did for Sprawl_1992. The Sprawl_1976 results for the three population sub-classes are also similar to those in Table 7. The same three variables appear with significant coefficients but now, the fourth, central employment for the over 880,000 population group, no longer has a significant coefficient. For the two overlapping samples of 73 observations, the results differ somewhat from those for Sprawl_1992 but are still quite similar. Overall, to focus on the prime interest here, property taxes are observed to have a significant negative influence on sprawl in four of the six regressions.

[33] Similar results are obtained when the 109 sample is divided into two groups, those under and those over 500,000 people.
[34] There are two changes in the variables required. Population growth from 1976 to 1992 is omitted and charge revenue is taken as a percentage of total taxes in 1977.

Table 9. Regression Results with Extended Specification by Population Classes on Sprawl_1976						
	109 observations	Less than 340 36 observations	340-880 37 observations	Greater than 880 36 observations	Less than 880 73 observations	Greater than 340 73 observations
Centralized-sector employment 1977	1.05697	2.89213	3.28241	-3.15646	2.27278	0.20253
	(1.01343)	(4.16042)	(1.90183)	(2.41899)	(1.28997)*	(1.26464)
Streetcar passengers per capita 1902	-0.03658	no obs.	-0.05790	-0.01951	-0.03349	-0.03189
	(0.01375)***		(0.04487)	(0.04191)	(0.02322)	(0.0166)*
Mean decennial % population growth 1920-1970	-0.30960	-0.27825	0.33993	0.25533	-0.17403	-0.20348
	(0.17278)*	(0.33505)	(0.45418)	(0.84202)	(0.18872)	(0.28107)
Std. dev. decennial % population growth 1920-1970	0.16353	0.27605	-0.80076	-0.69705	0.06352	-0.07879
	(0.17639)	(0.34639)	(0.58129)	(1.00842)	(0.19148)	(0.39328)
% of urban fringe overlying aquifers	0.03227	0.07535	0.09948	0.04833	0.05375	0.05305
	(0.02872)	(0.08821)	(0.09439)	(0.07363)	(0.03678)	(0.03906)
Elevation range in urban fringe (m)	-0.00165	0.00061	0.00222	-0.00128	-0.00197	-0.00125
	(0.00199)	(0.00861)	(0.00591)	(0.00713)	(0.00249)	(0.00318)
Terrain ruggedness index in urban fringe (m)	0.19631	-0.02551	-0.59032	0.56336	0.01366	0.38118
	(0.14799)	(0.37939)	(0.88989)	(0.76237)	(0.27619)	(0.40471)
Mean cooling degree-days	-0.00655	-0.00149	-0.00699	-0.00163	-0.00760	-0.00530
	(0.00348)*	(0.00981)	(0.02436)	(0.01028)	(0.00434)*	(0.00513)
Latitude	-1.36571	-1.00342	-0.61708	-0.40956	-1.68342	-1.23764
	(0.53901)**	(1.49024)	(3.74448)	(1.68580)	(0.66658)**	(0.73603)*
% of urban fringe incorporated 1980	-0.19428	-0.00441	0.19399	-0.30347	-0.02572	-0.19590
	(0.14849)	(0.63183)	(0.53905)	(0.37052)	(0.25053)	(0.19846)
Road density in urban fringe	-0.58739	1.04147	-1.56328	10.15691	-2.98762	4.29379
	(3.20028)	(10.81076)	(8.51378)	(9.36521)	(3.99857)	(4.49911)
Population 1976 to 1960 (x100)	0.04819	0.02829	-0.01053	0.01478	0.03029	0.08688
	(0.07866)	(0.21458)	(0.11354)	(0.43010)	(0.06931)	(0.16133)
Population 1976 ('000)	-0.00049	-0.06002	-0.03366	-0.00034	-0.01549	-0.00052
	(0.00070)	(0.04684)	(0.01579)**	(0.00094)	(0.00780)*	(0.00084)
Standard city population 1977 to metro population 1976	-16.96807	-46.27874	-28.38650	-12.35350	-33.28622	-9.61974
	(6.92266)**	(14.66568)***	(18.12955)	(14.63535)	(7.75283)***	(8.26405)
Property tax as percentage of total taxes	-0.10782	-0.17901	-0.32082	-0.15415	-0.15940	-0.14123
	(0.04879)**	(0.15280)	(0.13839)**	(0.12707)	(0.06484)**	(0.07371)*
Charges as percentage of total taxes	-0.05759	-0.18917	-0.11947	-0.14431	-0.13967	-0.05631
	(0.07472)	(0.23291)	(0.17353)	(0.18582)	(0.07742)*	(0.12023)
Transfers as percentage of total revenue	-0.09929	-0.16164	-0.37425	-0.02670	-0.17987	-0.00365
	(0.10535)	(0.28901)	(0.33995)	(0.21820)	(0.13390)	(0.12558)
Constant	101.24840	76.78698	78.80512	137.73980	112.60590	97.66856
	(35.12148)***	(147.26860)	(172.24320)	(89.17709)	(44.92284)**	(47.27753)**
Observations	109	36	37	36	73	73
R^2	0.4629	0.6330	0.7243	0.6369	0.5409	0.5379
Adjusted R^2	0.3626	0.3240	0.4775	0.2940	0.3990	0.3951

Note: Coefficients are reported with standard errors below. Standard errors are heteroskedastic-consistent. ***, ** and * indicate significance at the one-, five- and 10-per-cent levels.

Table 10. Regression Results with Truncated Specifications by Population Classes on Sprawl_1976						
	109 observations	Less than 340 36 observations	340-880 37 observations	Greater than 880 36 observations	Less than 880 73 observations	Greater than 340 73 observations
Centralized-sector employment 1977		2.87216 (2.07431)	3.19781 (1.12814)***	-3.75900 (1.48632)**	2.13704 (1.12745)*	
Streetcar passengers per capita 1902	-0.40509 (0.01214)***	no obs.	-0.03838 (0.03071)			-0.03993 (0.01221)***
Mean decennial % population growth 1920-1970	-0.17089 (0.07759)**			0.51801 (0.23150)**	-0.11099 (0.06273)*	-0.06010 (0.15145)
Std. dev. decennial % population growth 1920-1970			-0.33939 (0.16400)**	-0.98479 (0.36407)**		-0.29375 (0.25767)
% of urban fringe overlying aquifers	0.03701 (0.02747)	0.08276 (0.04207)*	0.10479 (0.03445)***		0.06640 (0.02528)**	0.05779 (0.03388)*
Elevation range in urban fringe (m)						
Terrain ruggedness index in urban fringe (m)				0.48305 (0.30721)		0.17095 (0.21400)
Mean cooling degree-days	-0.00714 (0.00309)**				-0.00625 (0.00359)*	-0.00531 (0.00422)
Latitude	-1.33337 (0.50102)***	-0.79650 (0.38537)**			-1.54005 (0.55635)***	-1.24767 (0.62638)*
% of urban fringe incorporated 1980	-0.17968 (0.13927)			-0.33319 (0.22731)		
Road density in urban fringe				15.01582 (7.30558)*		
Population 1976 to 1960 (x100)						
Population 1976 ('000)	-0.00045 (0.00048)	-0.06285 (0.03030)**	-0.02634 (0.00982)**	-0.00049 (0.00041)	-0.01927 (0.00529)***	
Standard city population 1977 to metro population 1976	-16.72416 (5.58145)***	-48.93323 (9.23781)***	-20.38118 (7.04603)***	-17.56077 (9.08079)*	-31.78342 (6.02257)***	-13.39709 (6.88206)*
Property tax as percentage of total taxes	-0.11624 (0.04463)**	-0.18489 (0.09806)*	-0.26123 (0.06975)***	-0.14757 (0.07931)*	-0.16157 (0.05142)***	-0.13624 (0.06191)**
Charges as percentage of total taxes	-0.04056 (0.06794)	-0.17877 (0.11249)	-0.06665 (0.10397)	-0.11992 (0.16023)	-0.09941 (0.06640)	-0.03528 (0.10284)
Transfers as percentage of total revenue	-0.15425 (0.09731)	-0.17247 (0.17715)	-0.12133 (0.12197)	-0.02303 (0.13443)	-0.16476 (0.10713)	-0.05011 (0.10709)
Constant	131.9676 (22.97918)***	71.56833 (44.82414)	22.63053 (23.61202)	127.24310 (34.30623)***	106.44920 (35.15297)***	118.06490 (27.84709)***
Observations	109	36	37	36	73	73
R^2	0.4267	0.6024	0.6655	0.5702	0.5222	0.4784
Adjusted R^2	0.3617	0.4845	0.5540	0.3731	0.4451	0.3844
R^2 extended specification	0.4629	0.6330	0.7243	0.6369	0.5409	0.5379

Note: Coefficients are reported with standard errors below. Standard errors are heteroskedastic-consistent. ***, ** and * indicate significance at the one-, five- and 10-per-cent levels.

The results from the truncated versions of the regressions are found in Table 10. A number of variables can be omitted from each specification without a serious reduction in explanatory power. When the regression is conducted on all 109 observations, the R^2 dropped only from 0.463 to 0.423despite the omission of six variables and the remaining variables appearing with significant coefficients here are those having significant coefficients in Table 9 although here significant to a somewhat greater degree. Compared to the results in Table 9, numerous additional variables appeared with significant coefficients in the regressions on the three population-size groups. The variables that appear relevant, however, differ somewhat across the set of regressions. The results for the two overlapping groups show similar variation among the relevant variables. Only the population change between 1960 and 1976 variable is omitted from all six regressions. Elevation, terrain ruggedness, per cent of the fringe incorporated and road density each appear only in one regression. On the other hand, the per cent of the fringe overlying aquifers and population in 1976 appear in five. The ratio of the city population in 1977 to the metro population in 1976 is in every equation and has a significant coefficient in each. Also, of major interest for the public finance investigation, the property tax variable has a significant coefficient in all six regressions. Charges does not, however, although its coefficient was significant at the 10-per-cent level in one instance in Table 9.

Regressions on Sprawl_1976_92: Sprawl of New Development

The main interest and the focus of the previous analyses has been on obtaining a better understanding of the reasons for differences in the degree of urban sprawl observed across a selection of U.S. metropolitan areas at a point in time; that is, differences in the patterns of the stock of development. It is also interesting to examine sprawl surrounding new development; that is, the scatteredness of residential development neighbouring properties developed between 1976 and 1992. This is the sprawl index that Burchfield et al. (2006) focus on in their paper. They found that both the flow index and the stock index(es) of sprawl were subject to the same determinants.

The approach to analyzing the flow-sprawl index data, Sprawl_1976_92, is as before. The regression results from the full or extended specification are reported initially (Table 11) and then the results from the truncated specifications (Table 12) are examined. The pattern of the results from the full specification is similar to the earlier results from the stock indices. The regression on all 109 observations reports several (six) variables with significant coefficients and the fit is slightly better than for Sprawl_1992. Regressions on the three population classes have in total only three variables with significant coefficients, and none for the class with the largest population, but the explanatory power of the regressions are considerable superior to the fit with 109 observations. The regressions on the two overlapping groups show several variables with significant coefficients but the R^2 are lower than for the three group regressions.

Table 11. Regression Results with Extended Specification by Population Classes on Sprawl_1976_92

	109 observations	Less than 340 36 observations	340-880 37 observations	Greater than 880 36 observations	Less than 880 73 observations	Greater than 340 73 observations
Centralized-sector employment 1977	0.06130 (0.71859)	3.68583 (4.34726)	0.98056 (2.60917)	-3.51518 (2.74242)	1.00209 (1.09678)	-0.66642 (1.14956)
Streetcar passengers per capita 1902	-0.03046 (0.01394)**	no obs.	-0.02076 (0.04151)	-0.01036 (0.03061)	-0.01651 (0.02482)	-0.01846 (0.01539)
Mean decennial % population growth 1920-1970	-0.54628 (0.13256)***	-1.13384 (0.60977)*	0.01792 (0.42019)	0.41711 (0.66612)	-0.61546 (0.19772)***	-0.26033 (0.18357)
Std. dev. decennial % population growth 1920-1970	0.57751 (0.17853)***	1.33988 (0.66444)*	-0.16984 (0.65527)	-0.50904 (0.90022)	0.63714 (0.26149)**	0.25227 (0.30328)
% of urban fringe overlying aquifers	0.02892 (0.02478)	0.10609 (0.10332)	0.16805 (0.06425)**	0.04702 (0.07218)	0.07005 (0.04069)*	0.05686 (0.02988)**
Elevation range in urban fringe (m)	0.00099 (0.00201)	0.00960 (0.00923)	0.00500 (0.00503)	-0.00187 (0.00551)	0.00357 (0.00322)	-0.00079 (0.00297)
Terrain ruggedness index in urban fringe (m)	0.16674 (0.15789)	-0.00200 (0.32405)	-0.29905 (0.75323)	0.21710 (0.57113)	-0.04069 (0.28638)	0.38731 (0.36112)
Mean cooling degree-days	-0.00599 (0.00299)**	0.00487 (0.01295)	0.00185 (0.01006)	-0.00468 (0.00587)	-0.00455 (0.00640)	-0.00435 (0.00458)
Latitude	-1.12359 (0.49322)**	0.21771 (2.05030)	0.48305 (1.64009)	-0.66477 (0.90772)	-1.15498 (0.96062)	-0.75858 (0.71745)
% of urban fringe incorporated 1980	-0.28285 (0.12704)**	0.25189 (0.52544)	-0.09364 (0.35575)	-0.57108 (0.40514)	-0.21612 (0.18143)	-0.38044 (0.16855)**
Road density in urban fringe	2.69255 (3.15254)	11.31357 (11.41966)	5.10565 (9.43862)	5.98071 (10.72802)	3.57755 (4.46413)	3.99189 (4.56695)
Population 1992 to 1976 (x100)	0.00839 (0.04513)	0.15965 (0.16860)	-0.03375 (0.07276)	0.22949 (0.19004)	-0.02307 (0.05757)	0.05936 (0.05808)
Population 1976 to 1960 (x100)	-0.08682 (0.06002)	-0.11037 (0.21503)	-0.14582 (0.22649)	-0.61451 (0.38820)	-0.03697 (0.09168)	-0.21042 (0.09155)**
Population 1976 ('000)	-0.00027 (0.00078)	-0.04997 (0.04691)	-0.02517 (0.01800)	-0.00009 (0.00095)	-0.01209 (0.00766)	-0.00031 (0.00081)
Standard city population 1977 to metro population 1976	-7.27515 (5.58937)	-25.79242 (17.14271)	-1.58776 (19.07760)	-4.36577 (17.40970)	-14.79706 (8.35447)*	3.80521 (7.59222)
Property tax as percentage of total taxes	-0.04169 (0.04941)	-0.10517 (0.15906)	-0.19373 (0.17170)	-0.01111 (0.12269)	-0.08530 (0.07702)	-0.05964 (0.06468)
Charges as percentage of total taxes, 1992	-0.07687 (0.05553)	-0.14918 (0.11768)	0.08378 (0.19358)	0.08424 (0.20775)	-0.12435 (0.06468)*	0.06655 (0.10137)
Transfers as percentage of total revenue	-0.08569 (0.10274)	-0.03762 (0.32681)	-0.04687 (0.35697)	-0.12568 (0.27147)	-0.04467 (0.15262)	-0.01872 (0.13201)
Constant	136.92870 (28.06958)***	-13.23048 (152.28720)	63.29503 (105.32060)	216.53420 (82.20102)**	123.09550 (51.58619)**	130.49580 (43.33195)***
Observations	109	36	37	36	73	73
R^2	0.5564	0.7217	0.7842	0.8123	0.5716	0.6603
Adjusted R^2	0.4677	0.4589	0.5685	0.6136	0.4288	0.5471

Note: Coefficients are reported with standard errors below. Standard errors are heteroskedastic-consistent. ***, ** and * indicate significance at the one-, five- and 10-per-cent levels.

Table 12. Regression Results with Truncated Specifications by Population Classes on Sprawl _1976_92						
	109 observations	Less than 340 36 observations	340-880 37 observations	Greater than 880 36 observations	Less than 880 73 observations	Greater than 340 73 observations
Centralized-sector employment 1977		2.19315 (2.64428)		-2.63104 (1.47062)*		
Streetcar passengers per capita 1902	-0.03573 (0.00974)***	no obs.				-0.02664 (0.01060)**
Mean decennial % population growth 1920-1970	-0.54433 (0.11013)***	-0.85079 (0.23074)***			-0.68954 (0.15627)***	-0.17164 (0.07733)**
Std. dev. decennial % population growth 1920-1970	0.55793 (0.15094)***	1.04487 (0.21551)***			0.68776 (0.26107)**	
% of urban fringe overlying aquifers		0.04987 (0.05296)	0.17421 (0.03323)***	0.06376 (0.04277)	0.08495 (0.02861)***	0.05876 (0.02417)**
Elevation range in urban fringe (m)		0.00532 (0.00366)	0.00308 (0.00172)*	-0.00371 (0.00231)	0.00389 (0.00177)**	
Terrain ruggedness index in urban fringe (m)	0.15985 (0.08403)*		-0.21646 (0.26673)	0.37988 (0.36776)		0.23910 (0.15170)
Mean cooling degree-days	-0.00710 (0.00262)***					-0.00456 (0.00363)
Latitude	-1.27858 (0.44034)***				-0.47933 (0.24599)*	-0.77813 (0.54069)
% of urban fringe incorporated 1980	-0.28631 (0.11560)**			-0.59892 (0.28036)**		-0.32084 (0.10328)***
Road density in urban fringe		10.91603 (5.81914)*			5.36508 (3.96112)	
Population 1992 to 1976 (x100)				0.17738 (0.10016)*		
Population 1976 to 1960 (x100)	-0.07670 (0.04208)*		-0.19990 (0.06637)***	-0.49523 (0.10534)***		-0.16825 (0.05746)***
Population 1976 ('000)		-0.04576 (0.02683)	-0.02452 (0.00928)**		-0.01615 (0.00515)***	
Standard city population 1977 to metro population 1976	-9.46630 (4.89385)*	-21.81335 (16.41636)			-12.67006 (6.47994)*	
Property tax as percentage of total taxes	-0.04379 (0.04523)	-0.18762 (0.09761)*	-0.14475 (0.08601)	0.05309 (0.07602)	-0.07382 (0.06253)	-0.04954 (0.05722)
Charges as percentage of total taxes, 1992	-0.09555 (0.05137)*	-0.13915 (0.04711)***	0.08447 (0.08043)	0.18646 (0.14087)	-0.09520 (0.04903)*	0.06701 (0.08183)
Transfers as percentage of total revenue	-0.09598 (0.09923)	0.03149 (0.23229)	-0.04356 (0.13011)	-0.06463 (0.21691)	0.01531 (0.13193)	-0.03831 (0.10615)
Constant	151.66830 (20.10834)***	44.80377 (57.76020)	105.14600 (15.87640)***	154.29880 (34.51710)***	99.86762 (15.62153)***	125.25240 (27.89073)***
Observations	109	36	37	36	73	73
R^2	0.5452	0.6731	0.7450	0.7562	0.5396	0.6333
Adjusted R^2	0.4884	0.5232	0.6721	0.6587	0.4566	0.5671
R^2 extended/full specification	0.5564	0.7217	0.7842	0.8123	0.5716	0.6603

Note: Coefficients are reported with standard errors below. Standard errors are heteroskedastic-consistent. ***, ** and * indicate significance at the one-, five- and 10-per-cent levels.

The regression results for the truncated versions appear in Table 12. As before, a number of variables can be omitted at a minor cost to the explanatory power of the regressions but revealing a number of relevant explanatory variables. Note the regression on the 109 observations in which omitting six variables resulted in four additional variable appearing with significant coefficients (though all at the 10-per-cent level) while the R^2 fell only 0.011. Across the other five regressions, numerous variables appear important but there is little uniformity among them. All the variables appear in at least one of the six regressions but only one, the percent of the fringe overlying aquifers, is deemed relevant in at least five; that is, beyond the public finance variables which are imposed in every equation. Interestingly, among the public finance variables, it is charges as a percentage of total taxes in 1992 which has a significant coefficient most often (although only three times) while property taxes as a percentage of total taxes has a significant coefficient only once.

The weak performance of the property tax variable should not be unexpected. The data are being used in an effort to explain the scatteredness surrounding newly developed property. While greater property taxes should be expected to have an restraining effect on sprawl (note the consistently negative coefficients for the property tax variable), the impact of property taxes on new development is expected to be smaller than its role in explaining the variations in sprawl across metro areas among which property taxes as a percentage of total taxes differs considerably. In contrast, the role of charges increased substantially between 1976 and 1992 (from 25.4 to 35.5 per cent of total taxes from 1977 to 1992) so new developers can be expected to be more cognizant of them in situating new developments.

The limited role of property taxes in explaining the scatteredness of new development may be impacted by other factors as well. The regressions indicate that sprawl neighbouring new development is very much influenced by the pace of growth, geographic/environmental features and the degree of incorporation at the fringe and is relatively insensitive to the means of public finance (especially property taxation). This outcome may be expected if development is largely opportunistic; that is, it occurs on those properties that are available when developers are prepared to invest. Not all property holders in an area may be willing to sell or develop property at the same time. Filling in to the city norm may take some time. Some support for this argument seems to come from the fact that the correlations of the Sprawl_1976 and Sprawl_1992 indexes with Sprawl_1976_92 are well below the correlation of the two stock indexes (0.68 and 0.82 as opposed to 0.95). That is, the measure of sprawl for metro areas as a whole in 1976 and in 1992 are highly correlated but the sprawl index for new development (largely on the fringe) is not as well correlated with the city-wide measure. Presumably, sprawl in the developing areas will evolve toward that of the larger community. That is, the land-use pattern in developing areas does not initially replicate that in already built-up areas.

Overview of the Regression Results

It is useful to pause and take stock of the substantial array of regression results.[35] To begin, the number of regressions arises largely because the causes of sprawl vary somewhat by the population size of the metropolitan area. That is observed across all three measures of sprawl. The explanatory power of each of the three population sub-classes dominates by a considerable margin that of the 109 observation data set. In addition, those fits are also superior to those of the two overlapping classes so, for these data, the three class grouping seems best.

Burchfield et al. (2006) advanced numerous variables as potential explanations for the causes of sprawl. Those were categorized as relating to the monocentric city model (including demographic variables), geographic and environmental features, and political characteristics. For this study, those variables were augmented with three supplementary demographic variables (i.e., population size in 1976, and population growth between 1960 and 1976 and between 1976 and 1992) and a variable to reflect the city's inclusiveness of the metro area (i.e., the ratio of city population to metro area population). How have these variables contributed to explaining sprawl?

Consider the monocentric city/demographic variables first. Central-sector employment plays a more important role in explaining sprawl in the sub-groups than across the full 109 observations. Notable is that when included, the signs depends upon the population size – negative when the population is large but positive when it is medium sized or small. Streetcar usage has a significant coefficient for all three sprawl measures when estimated on all 109 observations but it has a very modest role in the size class regressions and is significant only for the large 73 observation group. Mean decennial population growth also has significant coefficients for all three of the regressions on the full data set. Its role over the various sub-classes is less consistent. The standard deviation of decennial population growth is not deemed a relevant variable for the stock sprawl measures (Sprawl_1992 and Sprawl_1976) when estimated using 109 observations but it is important for the flow measure Sprawl_1976_92. Neither the signs nor the significance levels are consistent across size classes (e.g., Sprawl_1992) or for a given class. The supplementary demographic variables play only a minor role in the regressions on the 109 observations but they are more important in the regressions on the size classes. Population in 1976 appears most relevant (with a negative impact) in the cases of the small to medium size metro areas. Note too that 1976 to 1992 population growth coefficients have a positive sign while 1960 to 1976 population growth coefficients are negative in regressions of Sprawl_1992 and Sprawl_1976_92 for the medium and large population groups. Also, the coefficients for the greater than 880 class are considerably greater than for the 340-880 class.

---

[35] Besides the results above, there was an effort to incorporate housing supply elasticities generated by Saiz (2010) as an explanatory variable. Those relatively unsuccessful exercises are discussed in an appendix.

The geographic and environmental variables also display an uneven pattern among the regressions. The percentage of the fringe overlying aquifers is only included once in the regressions on 109 observations and the coefficient is not significant. However, it appears in almost all of the regressions on the various size classes and more often than not with a significant coefficient. Elevation and terrain ruggedness in the fringe rarely appear relevant and never with a significant coefficient in the regressions on the stock indices. Those variables do, however, contribute to the size class regressions on Sprawl_1976_92. That is, they help explain the sprawl nearby new development but not the existing (stock) levels of sprawl. Cooling days and latitude have significant coefficients in the regressions on the full data set but only once across the three size class regressions. Both, and especially latitude, contribute significantly to the fit of the under 880 group with 73 observations for the stock measures of sprawl but contribute less to the over 340 group.

Of the original political variables, the percentage of the fringe incorporated is relevant in the three regressions on the full set of data. That variable contributes little to the regressions by size class and when relevant it is for the larger sized metro areas. Road density in the fringe is relevant infrequently and usually without a significant coefficient. The supplementary political variable city to metro population is important in explaining Sprawl _1992 and Sprawl_1976 in all regressions. The negative values indicate that the larger the dominant city's population share is of the metro region, the lower is sprawl (presumably because the city has greater control of land use in the region). That the small population metro regions display considerably larger coefficients than in the other cases suggests that the role of this characteristic is greater in the smaller metro areas.

The contributions of the non-public finance variables are not as substantial as in Burchfield et al. but a relatively consistent set of variables from each category are important despite this much smaller dataset. Focusing on the results from the truncated specifications, across the 109 observations, streetcar use, decennial population growth, cooling, latitude, fringe incorporation and city to metro population regularly have significant coefficients. However, when analyzing by population size classes, the contributing variables are not uniform. Variables that are important across the 109 observations are often found not to be important for explaining sprawl in the subsets (e.g., streetcar use and cooling days). On the other hand, variables not important in the analysis of the 109 observations often make significant contributions to explaining sprawl in one or more of the subsets (e.g., centralized employment, population, population change and aquifers). In addition, the signs of the coefficients of some variables differ across the size classes (e.g., centralized employment and the standard deviation of decennial population growth). The city to metro population ratio is notable in that (for the stock sprawl regressions) it is an important explanatory variable in most regressions; that is, for the full dataset and across most subsets. Also noteworthy are the differences in the sizes of the coefficients of city to metro populations among population classes. Overall, the results demonstrate a need to recognize that the causes of sprawl may differ among metro regions of different sizes.

Now turn to the public finance variables. The parsimonious specifications of the regressions on the stock sprawl measures reveal that property taxes as a percentage of total taxes almost consistently has a significant negative coefficient; that is, that property taxes are associated with less sprawl. In only one of the 12 regression results in Tables 8 and 10, is its coefficient not statistically significant at conventional levels. Furthermore, generally the value of the coefficient is smaller in regressions on the larger sized metro areas. Property taxes did not appear important in explaining sprawl about new development (i.e., Sprawl_1976_92). As explained, this result should not be surprising.

There are some indications in the results that as charges as a percentage of taxes increases sprawl is reduced. The charges in 1992 variable has a significantly negative coefficient in three of the six regressions on Sprawl_1992. However, the coefficients on the charges in 1977 variable are never significant in regressions on Sprawl_1976. It is believed that the growing importance of charges during the intervening years and their greater importance in the smaller metro areas resulted in greater consideration being paid to charges in making development choices in the later years. This is also suspected to be a reason for charges to appear with significant negative coefficients in three of the regressions on Sprawl_1976_92.

Transfers as a percentage of total revenues is the third public finance variable. Over the 18 regressions in Tables 8, 10 and 12, the transfer variable has a significant coefficient in only one case (and then at the 10-per-cent level). The weak performance is not surprising as the impacts of transfers would need to work through their impacts on taxes and charges which are expected to directly impact land-use decisions. The puzzling feature of the coefficients reported is that all but two are negative when a positive value (as found in Burchfield et al.) was expected.[36]

The results indicate that public finance methods may impact sprawl. In particular, a greater reliance on property taxes (rather than local sales or income taxes) is associated with less sprawl. Similarly, greater utilization of user charges for basic public utilities may contribute to reduced sprawl. How large those impacts might be is the remaining question.

Impacts on Sprawl

The regression results indicate that public finance variables can impact sprawl but of at least equal interest are the magnitudes of those impacts. Indications of the magnitudes are

[36] If transfers were calculated as a percentage of total taxes rather than of total revenues, the coefficients were positive as often as negative but were not statistically significant.

reported in this part of the paper. To obtain a measure of the effects, the sprawl index is estimated using the mean value of the relevant observations and that is compared with the estimated values when high and low levels of property taxes and charges are substituted for their means. In addition, because the ratio of the central city population to the metropolitan population proved an important new determinant, the impacts of varying that variable are also explored. Calculations are made for both Sprawl_1992 and Sprawl_1976.

Consider the impacts upon Sprawl_1992. Those are reported in Table 13 for estimates on four population groups -- the full set of 109 observations and the three sub-groups. The calculations use the estimated coefficients from the truncated specifications in Table 8. The estimated Sprawl_1992 value when all variables take on their mean value for the respective group appears in the first column. These values approximate closely the group means. For example, the estimated value for the 109 observations is 41.84 and the group mean is 41.87.

Values of the sprawl index are also calculated when high and low values of the public finance variables are imposed. For property taxes as a percentage of total taxes, the high value is set at 93 and the low value at 60. Those contrast with the mean of 75.90 for the 109 observations. Those values are selected as representative of the upper and lower portions of the range. There are 21 observations with property taxes exceeding 93 and 17 with values lower than 60. For charges in 1992 as a percentage of total taxes, the high and low values are set at 50 and 20 respectively (which compare to the mean of 35.55). There are 20 observations with values larger than 50 and 19 with values below 20.[37] To aid comparisons among the results for population groups, these same high and low values are imposed on the estimates for each group.

The estimated impacts on sprawl from changing only the property taxes are reported in the third column. For the 109 observations, the estimated sprawl index is 40.22 when property taxes are 93 and 43.43 when 60. The difference is 3.12 and amounts to 7.46 per cent of the estimated value of Sprawl_1992 at the means. That is, across all observations, a metro area with property taxes amounting to 93 per cent of total local taxes is estimated to have 7.46 per cent less sprawl than one having property taxes at 60 per cent (all else the same). For metro areas having populations less than 340,000 and for those with populations in the 340,000 to 880,000 range, the estimated impacts of property taxes are considerably larger. The estimated reductions in sprawl associated with property taxes at 93 per cent rather than 60 per cent are 16.75 and 18.93 per cent (relative to their mean values). The consequence for the large population metro areas, those with populations exceeding 880,000, is projected to be minor with only a 3.84 per cent difference. Note too that the coefficient used for this estimate is not statistically significant. Thus, greater reliance on property taxes is predicted to reduce sprawl in metro areas but the

[37] The 93 and 60 values approximate the mean plus and minus one standard deviation for the property tax variable but the 50 and 20 range for the charges is somewhat narrower than that if using standard deviations.

impacts are estimated to be distinctly greater in (or even limited to) the small and medium sized metros.

Table 13. Impacts of Selected Variables on Estimated Sprawl_1992 Values[a]				
Estimated Sprawl_1992 value at means	Levels of impacting variables[b]	Modified Variables		
		Property tax	Property tax & 1992 charges	City to metro population ratio
All 109 Observations				
41.84	High	40.22	39.07	37.58
	Low	43.34	44.58	46.16
	Difference	3.12	5.51	8.58
	Percentage	7.46	13.17	20.51
Population < 340				
43.17	High	40.34	39.51	37.10
	Low	47.57	51.15	57.91
	Difference	7.23	11.64	20.81
	Percentage	16.75	26.96	48.20
Population 340-880				
43.64	High	38.62	38.58	40.41
	Low	46.79	46.83	47.22
	Difference	8.17	8.25	6.89
	Percentage	18.93	19.11	15.77
Population > 880				
38.80	High	37.94	38.13	33.06
	Low	39.43	39.37	40.86
	Difference	1.49	1.24	7.40
	Percentage	3.84	3.19	20.10

Notes: a) All calculations use the regression coefficients reported in Table 8. b) The high values versus the low values are: property taxes to total taxes, 93 vs 60; 1992 charges, 50 vs 20; and city to metro population ratio, 0.667 vs 0.250.

The impacts of different levels of charges is reflected in the adjacent column which reports the estimated sprawl index when both property taxes and charges are set at the higher and lower levels. Across the 109 observations, the combined effect is a 13.17 per cent difference in sprawl when property taxes are 93 and charges are 50 compared to when those values are 60 and 20. A higher level of charges is estimated to reduce the sprawl index an addition 5.71 percent (the change from 7.46 to 13.17 percent). The impact is also relatively large for the small metro areas where a higher level of charges is predicted to reduce the sprawl index 26.96 per cent as opposed to the 16.75 per cent reduction when only the higher level of property taxes is present. A higher level of charges is predicted to have little impact on sprawl in the medium and larger metro areas (i.e., those two groups with populations over 340,000 persons). The regression coefficients are not statistically significant in those two cases and, in fact, that for the over 880,000 population group is positive. So, charges also appear to matter but only in the small metro areas.

The ratio of city population to metro population appears as a relevant, and a newly recognized, determinant of sprawl. Hence, the impacts of high and low values for that variable (when the values of all other variables including property taxes and charges are held at their mean levels) are also reported in Table 13. The high value is 0.667 and the low value at 0.250. The mean value for the 109 observations is 0.46 and 20 observations have values exceeding 0.667 and 17 have a value lower than 0.25. Across the 109 observations, the 0.667 value implies a sprawl index that is 20.51 per cent smaller than if 0.25 is the value of the ratio. Essentially the same outcome is predicted for the over 880,000 population group. The impact upon the medium population group is estimated (at 15.77) to be somewhat smaller but the regression coefficient is not statistically significant although it is similar to that for the large group. The predicted consequence, 48.20 per cent, is largest for the small population group of observations.

A parallel analysis is done for Sprawl_1976 and the outcomes are reported in Table 14. Overall, the results are quite similar to those reported for Sprawl_1992. For changes in the property tax, the effect of a change from 60 to 93 is estimated to be a decline in sprawl of 9.23 per cent across the 109 observations but the predicted changes over the three population groups are larger with a range from 12.77 to 19.86 per cent. Notable here is that the impact for the over 880,000 population group is larger than for the Sprawl_1992 measure and the coefficient is statistically significant. Adding charges also generates similar predicted changes (but for the large population group for which the estimated impact is larger) although, here, none of the regression coefficients are statistically significant. Varying the city to metro population ratio also yields results comparable to those for Sprawl_1992 but here all the regression coefficients upon which the estimates are based are statistically significant.

The analysis of Sprawl_1992 and Sprawl_1976 indicate that public finance is a determinant of sprawl and that the impacts are meaningful. The results are strongest for property taxes as a percentage of total taxes. The impacts of having property taxes being 93 per cent of total taxes rather than 60 per cent are largest for the small and medium sized metro areas where the estimates range from about a 14 to a 20 per cent reduction in the sprawl index. The estimated impacts on large metro areas are smaller and less consistent but still negative. The estimated consequences of higher charges as a percentage of total taxes are smaller than for property taxes (at least in part because charges are less than property taxes) and also considerably less reliable but they still suggest some negative effect and especially so in the small population metro areas.

While not a public finance variable, the ratio of city to metro populations showed a strong effect -- the greater the ratio, the lower the sprawl. A metro area with a ratio of 0.667 compared with one at 0.25 can be expected to have an approximately 20 per cent lower measure of sprawl. For small metro areas, the sprawl index is predicted to be almost 50 per cent smaller. It is reasonable to suspect that the impact of this factor results from greater regulatory control of metro land use by the dominant city. [38]

Table 14. Impacts of Selected Variables on Estimated Sprawl_1976 Values[a]

Estimated Sprawl_1976 value at means	Levels of impacting variables[b]	Modified Variables: Property tax	Property tax & 1977 charges	City to metro population ratio
All 109 Observations				
41.47	High	39.48	39.01	38.00
	Low	43.31	43.78	44.98
	Difference	3.83	4.77	6.98
	Percentage	9.23	11.50	16.83
Population < 340				
42.70	High	40.51	39.27	36.98
	Low	46.61	49.48	57.38
	Difference	6.10	10.21	20.40
	Percentage	14.29	23.91	47.75
Population 340-880				
43.41	High	38.13	37.45	39.40
	Low	46.75	47.61	47.90
	Difference	8.62	10.16	8.50
	Percentage	19.86	20.40	19.58
Population > 880				
38.12	High	35.29	33.17	32.73
	Low	40.16	40.80	40.05
	Difference	4.87	7.63	7.32
	Percentage	12.77	20.01	19.20

Notes: a) All calculations use the regression coefficients reported in Table 10. b) The high values versus the low values are: property taxes to total taxes, 93 vs 60; 1976 charges, 37 vs 14; and city to metro population ratio, 0.667 vs 0.250.

[38] The results for Sprawl_1976_92 are not reported because a) interest here is focused on the stock sprawl measures, b) the regression coefficients for these variables are generally not significant and c) there are reasons to believe that they may have less impact on the dynamic measure of sprawl. However, property taxes and charges (in 1992) have significant coefficients for the less than 340 population group and for it, the predicted differences for the high and low levels of property taxes is 10.00 per cent and for property taxes and charges together is 16.76 per cent.

Comparison to Related Literature

As noted earlier, Wassmer (2016a) provides an extensive survey of the theoretical and empirical literature on the determinants of sprawl. There he notes seven empirical studies that seek to explain a measure of sprawl (e.g., area, density) by including a property tax measure (e.g., effective property tax rate, share of municipal revenue). The implications for the effects on sprawl are inconsistent, with some implying that greater property taxes reduce sprawl, others implying that they increase sprawl, and others (i.e., lacking significant results) suggesting no or an ambiguous impact. Recent OECD studies including some additional references, come to a similar conclusion; that is, "different studies…come to different conclusions" (OECD 2017, page 102; Blochliger, et al., 2017). Wassmer's empirical analysis in that paper found differing consequences among single-family residential, multi-residential, commercial and industrial properties. In a variation on that paper (Wassmer 2016b), Wassmer examines the impact of residential property taxes on sprawl. There, in contrast to his previous result, he concludes that higher effective residential property tax rates promote sprawl.[39]

The empirical results are not consistent and the results presented here do not resolve the issue. However, there are some important differences between this study and previous analyses. The most notable is the measure of sprawl. A common measure is area per person; that is, area with population as a control variable (e.g., Wassmer, 2016a,b). The measure here is the percentage of undeveloped land in the square kilometre surrounding an average residential development within a jurisdiction. Both measures are legitimate but rather different indicators of sprawl and they may not be highly correlated. That correlation is unavailable but, to illustrate, Burchfield et al. (2006, p 607) report the correlation between their sprawl index and median lot size to be 0.521. In addition, Wassmer's observations are on urbanized areas which are smaller units than the metropolitan areas Burchfield et al. study. Thus, the sprawl measures differ.

A second notable difference is the property tax measure. Much of the previous work (see Wassmer, 2016a) has focused largely on property tax rates. Tax rates or effective tax rates are not easily acquired. Hence, for example, Wassmer (2016a,b) uses statewide average effective tax rates to approximate the urbanized area rates for his analysis. Also, tax rates are affected by many factors; for example, expenditure responsibilities and levels, property values, transfers, charging policies, alternative taxes, etc. The analysis here is focused on the impact on sprawl of relying upon property taxes as the source of local tax revenue (or, alternatively, the impact of relying on non-property tax revenues) based on property taxes making undeveloped land more costly to hold than alternative local taxes. Earlier work is typically concerned about the relative

[39] Wassmer (2016b) also finds that a greater reliance on charges (state average per cent of own-source local revenue) promoted sprawl.

impacts of property taxes on the intensity of land use (i.e., the capital to land ratio) and the impact on dwelling size (i.e., smaller homes).[40] The question here is whether higher property taxes would result in less undeveloped property; that is, less sprawl as measured by the Burchfield et al. indexes. Other work concentrates upon the impact on land use of the effects of property taxes upon improvements while this study looks at the impact on the amount of undeveloped property.

A study utilizing the Burchfield et al. sprawl index and approach was undertaken on Spanish urban areas (Gomez-Antonio et al., 2016). Sprawl was measured as of 2000 for 3890 municipalities in 63 of Spain's 67 urbanized areas. Data limitations restricted the analysis to 3131 observations. The main and new finding was that there exists significant spatial correlation among neighbouring municipalities. The determinants of sprawl were found to be "…consistent in the main with those for the US case…" (page 239). Contrary to the US results, however, was that sprawl diminished as distance from the city center increased – a result attributed to the European preference to proximity to the urban core. Because the public finance variables (property taxes and intergovernmental transfers as percentages of total revenues) were available for only 1914 observations, those results were not reported in the paper but are available from the authors. Those results indicated that as intergovernmental transfers as a percentage of revenues increased sprawl increased but that, as in the results presented here, greater property taxes as a percentage of revenues were associated with less sprawl.[41]

There continues to be no consistency in the empirical studies seeking insight into the impacts of property taxes on sprawl. The studies differ considerably, however, in their measures of sprawl and of property taxes. A suggestion for future research is to measure the burden of property taxes relative to income.

Conclusion

The objective of this paper has been to explore the possible impacts of local public finance policies upon urban sprawl (i.e., scatteredness of development). Burchfield et al. (2006) presented path-breaking research into the causes of sprawl across U.S. metropolitan areas. Utilizing a (newly expanded) subset of their data for which it was possible to match

[40] In a comparatively novel study, Banzhaf and Lavery (2010) examine the impact of local governments in Pennsylvania using split mill rates (with a low rate on improvements/structures and a high rate on land). They find that split rates increase density making the urban area more compact; that is, greater reliance on land taxation reduces sprawl.

[41] The public finance variables were measured as of 1995. In 1995, intergovernmental grants amounted to 35.7 per cent of the total revenue of local governments, property taxes represented 14.5 per cent of total revenue and 29.6 per cent of total local tax revenue (IMF 2001). Property taxes have been increasing in importance as a source of local government tax revenues reaching 42.9 per cent in 2014.

comprehensive information on local public finances, their analysis was extended (though on a smaller scale) to assess the potential influence of local public finance on urban land use.

A previous analysis based on 83 observations found that property taxes as a percentage of total local taxes implied less sprawl and suggested that user charges (largely for water, sewer and solid waste services) had a similar effect (McMillan 2016). The opportunity to expand the number of observations to 109 allowed further investigation as reported here. Examination of the extended dataset (expanded with the addition of predominately small metropolitan areas) revealed that, although it constrained the econometric analysis, three subsets of the data should be examined separately – three approximately equal sized groups distinguished by population size (under 340,000 persons, 340,000 to 880,000 and over 880,000).

Given the degrees of freedom constraints, the most interesting results came from the truncated or parsimonious specifications of a more comprehensive model. In those, the property taxes as a percentage of total taxes variable was found to have an almost uniformly negative and significant impact on the levels of sprawl (i.e., the stock sprawl measures in 1992 and 1976). That is, the greater the reliance on property taxes as a source of local taxes the lower the level of sprawl.[42] The impacts, however, appear smaller for the large population group. For example, if property taxes were 93 per cent of tax revenue rather than 60 per cent, the sprawl indexes are predicted to be about 17.5 per cent lower in the small and mid-sized metropolitan areas but (perhaps) half of that for the largest population group.

The charges as a percentage of taxes variables provided only indications of a negative influence on sprawl. Although they typically appeared with negative coefficients, user charges were not statistically important in explaining sprawl in 1976 but were important in explaining Sprawl_1992 and Sprawl_1976_92 for the small population group. Charges as a percentage of taxes increased substantially between 1977 and 1992 (from about 25 per cent to 35 per cent) and were particularly large in the smaller metro areas (44 per cent in 1992) and these features are believed to explain the outcomes. To illustrate the impact, in small metropolitan areas, the effect of having charges at 37 per cent of taxes rather than 14 per cent (in addition to a higher reliance on property taxes) was to reduce the predicted level of Sprawl_1992 by 27 per cent in contrast to 17 per cent; that is, the higher level of charges decreased sprawl by an additional ten percentage points or by more than half again. Hence, when sufficiently large, charges appear to matter.

The roles of other variables are noteworthy. First, a reasonable but much reduced number of the Burchfield et al. explanatory variables contribute to explaining sprawl across the 109 observations. There is, however, limited consistency among those variables in their contributions to explaining sprawl across the three sub-groups. That is hardly surprising given the potential

[42] As seem reasonable, property taxes appeared unimportant in explaining sprawl surrounding new development; that is, in explaining the dynamic index Sprawl_1976_92.

differences in characteristics across metro areas of different sizes and the limited number of observations available. Second, a new variable, the ratio of city population to metropolitan population, was added. It is believed to reflect the degree of the major city's influence over land use in the metropolitan region. This variable was found to be an important contributor to the explanations of the sprawl levels in 1976 and 1992. Where that ratio is 0.667 rather than 0.25, the predicted level of sprawl is almost 20 per cent less across the 109 metropolitan areas. The predicted impact is greatest for the small metro areas where it is about twice that of the two larger population sub-groups.

The results of this data and analysis suggest that local public finance is a determinant of sprawl. In particular, the greater the reliance on property taxation and possibly the greater utilization of user charges for utilities will diminish sprawl. The impacts, however, appear sensitive to the population size and appear to be greater in smaller metropolitan areas. These results add to the diversity of empirical outcomes from investigations of the effect of property taxes on sprawl. Obviously, more study is required. Benefits may be realized from measuring the burden of property taxes (e.g., residential property taxes as a percentage of household income) and from comparing the outcomes when using alternative measures of sprawl.

Appendix Table 1. Variable Means and Standard Deviations of Added, Original and Combined Observations						
	26 observations (added)		83 observations (original)		109 observations (combined)	
	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
Sprawl_1992	45.814	12.680	40.640	8.917	41.874	10.124
Sprawl_1976	45.395	11.370	40.272	9.010	41.494	9.817
Sprawl1976_92	63.085	12.004	59.232	9.797	60.151	10.438
Centralized-sector employment 1977	23.096	1.079	22.706	0.908	22.799	0.961
Streetcar passengers per capita 1902	0.000	0.000	65.114	98.349	49.582	90.117
Mean decennial % population growth 1920-1970	20.351	9.817	27.752	19.810	25.987	18.175
Std. dev. decennial % population growth 1920-1970	11.857	7.167	13.659	13.123	13.229	11.968
% of urban fringe overlying aquifers	24.593	32.494	27.598	34.695	26.881	34.059
Elevation range in urban fringe (m)	708.885	695.693	731.615	924.668	726.193	872.527
Terrain ruggedness index in urban fringe (m)	13.222	14.578	8.256	7.817	9.440	10.006
Mean cooling degree-days	867.537	620.116	1388.425	881.343	1264.177	853.533
Latitude	40.929	4.682	37.232	4.808	38.114	5.013
% of urban fringe incorporated 1980	4.286	3.999	8.205	6.870	7.271	6.508
Road density in urban fringe 1980	0.756	0.434	0.875	0.343	0.846	0.368
Population 1992 to 1976 (x100)	121.751	23.011	138.004	31.718	134.127	30.575
Population 1976 to 1960 (x100)	129.063	19.927	131.371	26.045	130.821	24.657
Population 1976 (000)	236.572	272.686	1490.012	2383.954	1191.026	2149.482
Standardized city population 1977 to metro population 1976	0.444	0.193	0.462	0.193	0.458	0.192
Property tax as percentage of total taxes	86.974	12.053	72.429	17.081	75.898	17.144
Charges as percentage of total taxes, 1976	34.992	21.826	22.438	9.675	25.433	14.500
Charges as percentage of total taxes, 1992	49.673	32.729	31.120	12.163	35.545	20.576
	36.559	12.956	38.034	9.230	37.682	10.195

Transfers as percentage of total revenue			

Appendix: Exploring a Further Refinement

Albert Saiz has made estimates of the housing-supply elasticities for major U.S. metropolitan areas (Saiz, 2010). Drawing upon detailed geographic data, he calculates the area of undevelopable land within a 50 kilometre radius of each metropolitan central city. Surfaces considered undevelopable for residential purposes include land with slopes in excess of 15 per cent (severely constrained); wetlands, lakes, rivers and other internal water bodies; and oceans and the Great Lakes. Saiz finds that limiting geography was a strong predictor of house prices and growth in the 1970–2000 period. Land-use restrictions also influence prices and growth. Saiz finds that land-use regulations are endogenous to geographic constraints on land availability and growth. He estimates housing-supply elasticities for metro areas using a model integrating the endogeneity of land-use regulation. The question is, do those residential supply elasticities help explain the measures of sprawl?

Burchfield et al. (2006) included variables related to geographic features and institutional characteristics that could affect the availability of land for development in their metropolitan areas. Variables reflecting geographic features are, most notably, elevation range and ruggedness in the fringe area and the broader metro area but also, from the perspective of facilitating development, the percentage overlying aquifers. The percentage of area incorporated in 1980 (fringe and metro area) was included to capture the more lenient regulatory regimes of unincorporated areas. The Herfindahl index of incorporated place sizes might also be related to regulatory aspects of inter-municipal competition. Burchfield et al. found elevation range, ruggedness and incorporation in the fringe areas to be determinants of sprawl. They also explored wetlands, public lands and oceans, but did not find those features empirically relevant.

The housing-supply elasticities estimated by Saiz are added to the data. Saiz reports elasticities for 95 metro areas. Matching those estimates with the 109 observations left 71 observations. The housing-supply elasticity variable generated significant positive coefficients (at the 10-per-cent level) in regressions for Sprawl_1976_92 but the coefficients were insignificant for both Sprawl_1992 and Sprawl_1976 (in a variety of specifications). Interestingly, The Saiz supply elasticity coefficients were significant only if ruggedness remained in the equation. Thus, the Saiz elasticity appears to supplement, not replace, the Burchfield et al. geographic features.[43]

Saiz also reported a measure of the stringency of land-use regulation for the metro areas he analyzed. That measure is the Wharton Residential Urban Land Regulation Index (WRI) as

---

[43] Elevation and ruggedness are correlated with the Saiz elasticities in the 0.3 to 0.4 range. In regressing those variables against the Saiz elasticities, only ruggedness was a significant determinant and the R^2 low (e.g., 0.173).

measured in the 2005 Wharton Regulation Survey. Although the impacts of land-use regulation are already incorporated into the housing-supply elasticity estimates, the WRI is introduced into the regressions — initially independent of the supply elasticities and then together. The WRI variable did not contribute empirically to any of the regression estimates (although the regulation proxy of the percentage incorporated was often important).

The underwhelming performance of these two variables is both somewhat disappointing and the reason that those results are not reported. Larger data sets may overcome the limitations with these as well as some of the variables used in the previous equations.

References

Angel, Shlomo, *Planet of Cities* (Cambridge, Mass.: Lincoln Institute of Land Policy, 2012).

Angel, Shlomo et al., Atlas of Urban Expansion, Volumes 1 and 2, (Cambridge, Mass.: Lincoln Institute of Land Policy, 2016).

Angel, Shlomo et al., "The Persistent Decline in Urban Densities: Global and Historic Evidence of 'Sprawl,'" Working Paper (Cambridge, Mass.: Lincoln Institute of Land Policy, 2010).

Angel, Jason Parent and Daniel L. Civco, "The Fragmentation of Urban Footprints: Global Evidence of Sprawl, 1990-2000," Working Paper (Cambridge, Mass.: Lincoln Institute of Land Policy, 2010).

Arnott, Richard, "Effects of Property Taxation on Development Timing and Density: Policy Perspectives," *Brookings-Wharton Papers on Urban Affairs* (2006): 189-230.

Banzhalf, H. Spencer and Nathan Lavery, "Can the Land Tax Help Curb Urban Sprawl? Evidence from Growth Patterns in Pennsylvania," *Journal of Urban Economics* (March 2010):169-179.

Bazel, Philip and Jack Mintz, "The Free Ride is Over: Why Cities, and Citizens, Must Start Paying for Much Needed Infrastructure," University of Calgary School of Public Policy Research Paper (May 2014).

Benton, J. Edwin, "Trends in Local Government Revenues: The Old, the New and the Future," in *Municipal Revenues and Land Policies*, ed. Gregory K. Ingram and Yu-Hung Hong (Lincoln Institute of Land Policy, 2010), 81-112.

Blochliger, Hansjorg, Chrisian Hilber, Olivier Schoni, Maximilian von Ehrlich, "Local Taxation, Land Use Regulation and Land Use," OECD Economics Department Working Papers, No. 1375, (2017).

Brueckner, Jan K. "Strategic Interaction Among Governments: An Overview of Empirical Studies," *International Regional Science Review* (April 2003): 175-188.

Brueckner, Jan K. "Property Taxation and Urban Sprawl," in *Property Taxation and Local Government Finance*, ed. Wallace E. Oates (Lincoln Institute of Land Policy, 2001), 153-172.

Burchfield, Marcy et al., "Causes of Sprawl: A Portrait from Space," *Quarterly Journal of Economics* (May 2006): 587-633.

Dahlby, Bev and Melville McMillan, "Do Local Governments Need Alternative Sources of Tax Revenue? An Assessment of the Options for Alberta Cities," University of Calgary School of Public Policy Research Paper (September 2014).

Duranton, Gilles and Diego Puga, "Urban Land Use," in *Handbook of Regional and Urban Economics*, ed. Gilles Duranton, J. Vernon Henderson and William C. Strange (Elsevier, 2015), 537-544.

Gomez-Antonio, Miguel, Miriam Hortas-Rico and Linna Li, "The Causes of Urban Sprawl in Spanish Urban Areas: A Spatial Approach," *Spatial Economic Analysis* (June 2016): 219-247.

Hauptmeiera, Sebastian, Ferdinand Mittermaierb and Johannes Rinckec, "Fiscal Competition over Taxes and Public Inputs," *Regional Science and Urban Economics* (May 2012): 407-419.

Ingram, Gregory K. and Yu-Hung Hong, *Municipal Revenues and Land Policies*, (Lincoln Institute of Land Policy, 2010).

IMF, *Government Finance Statistics Yearbook 2001*, (International Monetary Fund, 2001)

Kitchen, Harry and Almos T. Tassonyi, "Municipal Taxes and User Fees," in *Tax Policy in Canada*, ed. Heather Kerr, Ken McKenzie and Jack Mintz (Canadian Tax Foundation, 2012), 9.1-9.34.

Ladd, Helen F. "Introduction," in *Local Government and Land Use Policies in the United States: Understanding the Links*, ed. Helen Ladd and Wallace E. Oates (Lincoln Institute of Land Policy, Edward Elgar, 1998), 1-22.

Ladd, Helen F. "Theoretical Controversies: Land and Property Taxation," in *Local Government and Land Use Policies in the United States: Understanding the Links*, ed. Helen Ladd and Wallace E. Oates (Lincoln Institute of Land Policy, Edward Elgar, 1998), 25-40.

Lincoln Institute of Land Policy, Fiscally Standardized Cities Database, http://datatoolkits.lincolninst.edu/subcenters/fiscally-standardized-cities .

McGuire, Therese J. and David L. Sjoquist, "Urban Sprawl and the Finances of State and Local Governments," Chapter 10 in *State and Local Finances under Pressure*, David L. Sjoquist (editor), (Edward Elgar, 2003), 299-326.

McMillan, Melville L., "Municipal Revenue Generation and Sprawl: Implications for the Calgary and Edmonton Metropolitan Regions Derived from an Extension of 'Causes of Sprawl'" (Technical Paper), School of Public Policy, University of Calgary, Vol. 9, Issue 40, December 2016.

OECD, *The Governance of Land Use in OECD Countries: Policy Analysis and Recommendations*, (Organization for Economic Development and Cooperation Publishing, 2017).

Oueslati, Walid, Seraphim Alvanides and Guy Garrod, "Determinants of Urban Sprawl in European Cities," *Urban Studies* (July 2015): 1594-1614.

Pagano, Michael A. "Creative Designs of the Patchwork Quilt of Municipal Finance," in *Municipal Revenues and Land Policies*, ed. Gregory K. Ingram and Yu-Hung Hong (Lincoln Institute of Land Policy, 2010), 116-140.

Saiz, Albert, "The Geographical Determinants of Housing Supply," *Quarterly Journal of Economics* (August 2010): 1253-1296.

Slack, Enid, "Municipal Finance and the Pattern of Urban Growth," C.D. Howe Institute Commentary (February 2002).

Sjoquist, David L., Sally Wallace and Barbara Edwards, "What a Tangled Web: Local Property, Income and Sales Taxes," in *City Taxes, City Spending*, ed. Amy Ellen Schwartz (Edward Elgar, 2004), 42-70.

Wassmer, Robert W., "Further Empirical Evidence on Property Taxation and the Occurrence of Urban Sprawl," Working Paper WP16RW1 (Lincoln Institute of Land Policy, March 2016a).

Wassmer, Robert W., "Further Empirical Evidence on Residential Property Taxation and the Occurrence of Urban Sprawl," *Regional Science and Urban Economics* (November 2016b), 73-85.

Yinger, John, "Who Pays Development Fees?" in *Local Government and Land Use Policies in the United States: Understanding the Links*, ed. Helen Ladd and Wallace E. Oates (Lincoln Institute of Land Policy, Edward Elgar, 1998), 218-233.

Department of Economics, University of Alberta
Working Paper Series

2018-03: Financially-Constrained Lawyers: An Economic Theory of Legal Disputes – **Landeo, C.,** Nikitin, M.
2018-02: Information and Transparency in Wholesale Electricity Markets: Evidence from Alberta – **Brown, D., Eckert, A.,** Lin, J.
2018-01: Does a Discount Rate Rule Ensure a Pension Plan Can Pay Promised Benefits without Excessive Asset Accumulation? – **Landon, S., Smith, C.**
2017-13: Income Inequality and Violence Against Women: Evidence from India – Rashad, A., **Sharaf, M.**
2017-12: The Local Effects of the Texas Shale Boom on Schools, Students, and Teachers – **Marchand, J.,** Weber, J.
2017-11: Self-Sabotage in the Procurement of Distributed Energy Resources – **Brown, D.,** Sappington, D.
2017-10: Public Private Competition – **Klumpp, T., Su, X.**
2017-09: Testing for State-Dependent Predictive Ability – **Fossati, S.**
2017-08: Default Risk, Productivity, and the Environment: Theory and Evidence from U.S. Manufacturing – **Andersen, D.**
2017-07: Does Maternal Employment Affect Child Nutrition Status? New Evidence from Egypt – Rashad, A., **Sharaf, M.**
2017-06: The Effect of Default Rates on Retail Competition and Pricing Decisions of Competitive Retailers: The Case of Alberta – **Brown, D., Eckert, A.**
2017-05: Optimal Procurement of Distributed Energy Resources – **Brown, D.,** Sappington, D.
2017-04: The Impact of Schooling Intensity on Student Learning: Evidence from a Quasi-Experiment – Andrietti, V., **Su, X.**
2017-03: The Voting Rights of Ex-Felons and Election Outcomes in the United States – **Klumpp, T.,** Mialon, H., Williams, M.
2017-02: Does the Design of a Fiscal Rule Matter for Welfare? – **Landon, S., Smith, C.**
2017-01: Carbon Pricing with an Output Subsidy under Imperfect Competition: The Case of Alberta's Restructured Electricity Market – **Brown, D., Eckert, A., Eckert, H.**
2016-18: Monetary Policy Tradeoffs Between Financial Stability and Price Stability – **Shukayev, M.,** Ueberfeldt, A.
2016-17: Managing Risk Taking with Interest Rate Policy and Macroprudential Regulations – Cociuba, S., **Shukayev, M.,** Ueberfeldt, A.
2016-16: On the Role of Maximum Demand Charges in the Presence of Distributed Generation Resources – **Brown, D.,** Sappington, D.
2016-15: Implementing Cross-Border Interbank Lending in BoC-GEM-FIN – **Shukayev, M.,** Toktamyssov, A.
2016-14: The Effects of Early Pregnancy on Education, Physical Health and Mental Distress: Evidence from Mexico – **Gunes, P.,** Tsaneva, M.
2016-13: An Equilibrium Selection Theory of Monopolization – **Eckert, A., Klumpp, T., Su, X.**
2016-12: Education Curriculum and Student Achievement: Theory and Evidence – Andrietti, V., **Su, X.**
2016-11: Poverty and Aging – **Marchand, J.,** Smeeding, T.
2016-10: Local Labor Markets and Natural Resources: A Synthesis of the Literature – **Marchand, J.,** Weber, J.