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MUNICIPAL REVENUE GENERATION AND SPRAWL: IMPLICATIONS FOR THE CALGARY AND EDMONTON METROPOLITAN REGIONS DERIVED FROM AN EXTENSION OF "CAUSES OF SPRAWL" (TECHNICAL PAPER)[†]

Melville L. McMillan

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 published in 2006[1] 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 gives insight into the impacts of local public finance on sprawl. There is evidence that greater reliance on local property taxes reduces sprawl. The evidence that user charges (primarily for water, sewerage and solid waste services) could have a similar effect is weak but suggestive. The combined effects of a high reliance on property taxes and user charges (compared to typical levels) might reduce sprawl by as much as one-third. For Calgary and Edmonton, this means that the current heavy reliance on property taxes in both cities reduces sprawl and that the adoption of alternative local taxes—that reduce reliance on property taxes—is expected to increase sprawl. Further analysis of the impacts of local public finance on urban sprawl is warranted.

† Thank you to the Alberta Land Institute for financial support of this research project and the accompanying paper "Municipal Revenue Generation and Development in the Calgary and Edmonton Metropolitan Regions" by Brian W. Conger, Bev G. Dahlby and Melville L. McMillan.

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

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. Although the municipal finance aspect is but a small part of the broader dialogue, the examination of its role is a major task in our Alberta Land Institute research project and it is the topic of this paper.[2] This paper extends existing work on the causes of sprawl to explore relationships between municipal finance and metropolitan land-use patterns.

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 120 global cities and, in particular, reports on the development between 1990 and 2000 and provides measures of land-use fragmentation (i.e., sprawl).[3] Also, the associated work illustrates the emerging analyses.[4] 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 10 are in the United States — too small a number of relatively comparable cities.[5] Instead, data generously provided by Marcy Burchfield on U.S. metropolitan areas that were examined in Burchfield et al. are utilized.[6]

In leading work, Burchfield et al. 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

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[2] This study was part of the Municipal Revenue Generation and Implications for Land Use and Environmental Quality research project undertaken for the Alberta Land Institute by Bev Dahlby, Melville McMillan and Brian Conger. ALI is thanked for its support.

[3] See Shlomo Angel et al., *Atlas of Urban Expansion* (Cambridge, Mass.: Lincoln Institute of Land Policy, 2012).

[4] See Shlomo Angel, *Planet of Cities* (Cambridge, Mass.: Lincoln Institute of Land Policy, 2012); Shlomo Angel et al., “The Persistent Decline in Urban Densities: Global and Historic Evidence of ‘Sprawl,’” Working Paper (Cambridge, Mass.: Lincoln Institute of Land Policy, 2010); and Shlomo 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).

[5] A new and expanded edition of the atlas is planned. That may allow a more adequate data set to be established.

[6] Burchfield et al., “Causes of.” 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: Gilles Duranton 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. A recent study of the determinants of sprawl using European data is Walid Oueslati, Seraphim Alvanides and Guy Garrod, “Determinants of Urban Sprawl in European Cities,” *Urban Studies* (July 2015): 1594-1614.

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

This study is directed towards better understanding 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 the Fiscally Standardized Cities database, which 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 exists for 112 cities.[7] Cities in that database are matched with the metropolitan areas in the Burchfield et al. data set resulting in 83 observations for which detailed public finance information is available. Those 83 observations are then analyzed following, or largely following, the approach and methods of Burchfield et al. Local public finance matters, in particular, greater reliance on property taxation reduces sprawl. In part to illustrate the implications of the findings and in part to assess potential implications for Canadian metro areas, the impacts of introducing the characteristics of two Alberta cities, Calgary and Edmonton, are subsequently estimated and discussed.

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

[7] That database has been expanded to 150 cities since the analysis for this paper was completed.

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.[8]

The possible impacts of local property taxes on urban sprawl have not gone unnoticed (although they have received less attention than user charges). Brueckner[9] 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.[10] Arnott[11] 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[12] proposes potentially feasible changes to the property tax system that 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.[13]

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8 For discussions of the role for user fees and their implications, see (for example), Philip Bazel 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); Harry Kitchen 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; and Enid Slack, "Municipal Finance and the Pattern of Urban Growth," C.D. Howe Institute Commentary (February 2002). Yinger argues that development charges may not be paid entirely by users but shared with the owners of undeveloped land: John Yinger, "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.

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

10 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. See Brueckner, "Urban Sprawl" for a discussion. There he 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.

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

12 ibid.

13 Also see Helen F. Ladd, "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.

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).[14, 15] 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 we suspect that a greater reliance on property taxation should discourage sprawl. In this paper, the issue is explored as a purely empirical question.

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.[16] This work is intended as a step towards correcting that deficiency. 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.,[17] 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 112 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.[18] The public

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14 These numbers come from the U.S. *Statistical Abstract*, 2012. For an overview of local government taxes in the United States see David L. Sjoquist, 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.

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

16 Overviews discussing, among other factors, the possible roles of local public finance upon land use are Ladd, "Introduction," and McGuire and Sjoquist, "Urban Sprawl." Wassmer provides a comprehensive review of theoretical and empirical works on the determinants of sprawl with a focus on the role of property taxes: Robert W. Wassmer, "Further Empirical Evidence on Property Taxation and the Occurrence of Urban Sprawl," Working Paper WP16RW1 (Lincoln Institute of Land Policy, March 2016). Wassmer also presents new empirical results.

17 Burchfield et al., "Causes of."

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

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.

The available public finance data cover only a subset of the 275 metropolitan areas studied by Burchfield et al.[19] While there are 112 cities in the Fiscally Standardized data, 83 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 46.2 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 19.3. 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 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,[20] 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 83 observations, property taxes averaged 72.4 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 111 standardized cities (excluding Washington D.C. as a special case), sales taxes contributed 15.9 per cent of taxes and income taxes 4.9 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

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[19] Burchfield et al., "Causes of."

[20] See, for example, Jan K. Brueckner, "Strategic Interaction Among Governments: An Overview of Empirical Studies," *International Regional Science Review* (April 2003): 175-188; and Sebastian Hauptmeiera, Ferdinand Mittermaierb and Johannes Rinckec, "Fiscal Competition over Taxes and Public Inputs," *Regional Science and Urban Economics* (May 2012): 407-419.

sources. Clearly, many cities rely upon private firms to provide and charge for electricity and gas. Almost all cities report each of the charges we 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 3.4 to 50.7 per cent.

TABLE 1 SUMMARY STATISTICS OF THE PUBLIC FINANCE VARIABLES, 1977

	Mean	Minimum	Maximum	Standard Deviation
	Measured as a Percentage of Total Taxes			
Property taxes	72.4	28.1	99.5	17.1
Charges (selected)	22.4	3.4	50.7	9.7
Transfers	112.1	46.3	252.4	38.7
	Measured as a Percentage of Total Revenue			
Property taxes	25.8	7.9	48	8.5
Charges (selected)	7.6	1.3	14.5	2.8
Transfers	38.0	18.2	66.7	9.2

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 112.1 per cent of total taxes. Again, the variation across the cities/metro areas is large; from 46.3 to 254.4 per cent with a standard deviation of 38.7. 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 about one-half their funding from transfers (and over 40 per cent from property taxes). Of the 111 standardized cities, city governments averaged about 31 per cent of their revenues from transfers, only slightly less than the revenues from taxes.[21] Per capita, transfers in 1977 amounted to $390.

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 38 per cent, are the single largest source of revenues for the local governments. That implies that own-source revenues amount to 62 per cent. Total taxes are about 35 per cent. The specific sources of own-source revenues we analyze are property taxes at 25.8 per cent and the selected charges (as noted above) at 7.6 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.[22]

[21] City governments and school districts represent over 80 per cent of the standardized cities, with counties and special districts accounting for the remainder.

[22] For overviews of local public finance in the United States, refer to J. Edwin Benton, "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; and Michael A. Pagano, "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.

The Burchfield et al. Independent Variables

Burchfield et al. 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 83 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 the elevation range on the urban fringe had larger means and standard deviations in our data set.[23] 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 are employed, in addition to the public finance variables, in this analysis.

It is helpful to familiarize the reader with the Burchfield et al. variables but, given the thorough treatment in Burchfield et al.,[24] 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 in 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.[25] Demographic features are included in this group of variables.

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23 For streetcar passengers, the mean here of 65.1 contrasts with the Burchfield et al. mean of 21.5, while the elevation range mean here is 731.6 metres as compared to 542.4 metres.

24 Burchfield et al., "Causes of."

25 Bars and restaurants per capita were tried as an amenity variable and road density to indicate car-friendliness, but neither was found important.

TABLE 2 SUMMARY STATISTICS OF BURCHFIELD ET AL. VARIABLES FOR 83 OBSERVATIONS

	Mean	Minimum	Maximum	Standard Deviation
Centralized-sector employment 1977	22.7	20.8	25.2	0.91
Streetcar passengers per capita 1902	65.1	0	312.6	98.3
Mean decennial % population growth 1920-1970	27.7	5.9	117.1	19.8
Std. dev. decennial % population growth 1920-1970	13.7	2.3	85.6	13.1
% of urban fringe overlying aquifers	27.6	0	100.0	34.7
Elevation range in urban fringe (m)	731.6	4	4048	924.7
Terrain ruggedness index in urban fringe (m)	8.25	0.06	34.29	7.82
Mean cooling degree-days	1388.4	108.3	3972.5	881.3
Mean heating degree-days	4350.6	242.6	8138.3	2021.6
% of urban fringe incorporated 1980	8.01	0.89	33.51	6.87
Intergov. transfers as % of local revenues 1967	34.2	17.9	54	7.9
Bars and restaurants per thousand people	1.45	0.85	2.48	0.28
Major road density in urban fringe (m/ha)	0.87	0.05	1.54	0.34
% population growth 1970-1990	35.46	-15.6	179.8	36.4
Herfindahl index of incorporated place sizes	0.28	0.015	0.93	0.24
Latitude	37.2	25.8	47.6	4.8
Longitude	-93.2	-122.7	-71.4	14.6

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. While the jurisdictional fragmentation of metropolitan areas is considered to have an uncertain effect, the Herfindahl index of place sizes was examined and did not contribute to the explanation of sprawl. Finally, it is projected that the higher the percentage that transfers are of local revenues imply a lower cost of local government services to local residents and, so, promote sprawl.

From their analysis, Burchfield et al. conclude:

> "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.)[26]

Specifics of the Burchfield et al. Sprawl Indexes

Burchfield et al. 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 and the average across all residential development in the metropolitan area is calculated to arrive at the sprawl index. Thus, the index is "the percentage of undeveloped land in the square kilometre surrounding an average residential development."[27] 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.[28] This consistency is suggested by the values in Table 3 for the two years.

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[26] This summary differs somewhat from the statement in the 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.

[27] Burchfield et al., "Causes of." p.600

[28] The correlation coefficient for the 275 Burchfield et al. data is 0.96 and it is 0.95 for the 83 observations in this study.

There is substantial variation in the values across the metro areas — from about 20 (Miami-Ft. Lauderdale, Fla.) to about 63 (Knoxville, Tenn.).

TABLE 3 SUMMARY STATISTICS OF BURCHFIELD ET AL. SPRAWL INDEXES FOR 83 OBSERVATIONS

	Mean	Minimum	Maximum	Standard Deviation
Sprawl 1976	40.3	20.0	63.9	9.0
Sprawl 1992	40.6	20.7	62.5	8.9
Sprawl 1976-92	59.2	33.4	79.2	9.8

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."[29] This index measures the average sprawl in the neighbourhood of residential property developed between 1976 and 1992. The average value for this measure is 59.2; 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 40.6 in 1992). Again, the range of values is wide; from 33.4 in Phoenix to 79.2 in Pittsburgh.[30]

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.

A SERIES OF REGRESSIONS AND THEIR RESULTS

A useful starting point is a comparison of regression results of the Burchfield et al. specification of their Sprawl 1992 model with those when the three public finance variables are added. Those results appear in Table 4. The first column shows the level of significance of the Burchfield et al. model when estimated on their 275 observations. 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 were not nearly so strong (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 significance of the percentage of the urban fringe incorporated fell just under the 10-per-cent level.

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29 Burchfield et al., "Causes of." p.599

30 The correlation of Sprawl 1976-92 with Sprawl 1976 is 0.60 and with Sprawl 1992 is 0.77.

TABLE 4 INITIAL REGRESSION RESULTS ON SPRAWL 1992

	Burchfield et al. Specification		Public Finance Variables Added
	Significance when 275 Observations	Coefficient (Standard Error)	Coefficient (Standard Error)
Centralized-sector employment 1977	_	-0.95109	-0.88657
		0.80792	0.90550
Streetcar passengers per capita 1902	***	-0.01678	-0.02699
		0.01156	(0.01233)**
Mean decennial % population growth 1920-1970	***	-0.19395	-0.19828
		(0.11020)*	(0.11946)^
Std. dev. decennial % population growth 1920-1970	**	0.03167	0.02945
		0.13349	0.15733
% of urban fringe overlying aquifers	***	0.09432	0.09645
		(0.02297)***	(0.02441)***
Elevation range in urban fringe (m)	**	-0.00217	-0.00171
		0.00210	0.00209
Terrain ruggedness index in urban fringe (m)	***	0.29562	0.28289
		0.28834	0.28847
Mean cooling degree-days	***	-0.00532	-0.00559
		0.00351	(0.00339)^
Mean heating degree-days	***	-0.00286	-0.00287
		(0.00142)**	(0.00144)**
% of urban fringe incorporated 1980	***	-0.18395	-0.19331
		(0.11163)^	(0.12182)^
Intergov. transfers as % of local revenues 1967	***	0.18125	
		(0.10456)*	
Property tax as percentage of total taxes			-0.08592
			(0.05344)^
Charges as percentage of total taxes			-0.07949
			0.09493
Transfers as percentage of total taxes			0.01570
			0.02085
Constant		79.979	91.989
		(22.893)***	(23.378)***
Observations	275	83	83
Adjusted R2	0.404	0.5467	0.5539

Note: 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.

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. 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.

These results suggest that there is little to choose between the two specifications. However, including the public finance variables appears to tease out some evidence of some additional variables contributing to the explanation of sprawl. Also, the fuller characterization of local public finance and indications of some sensitivity to specification suggests potential for further exploration.[31]

Extensions of the Sprawl 1992 Model Specification

The results reported in Table 4 were not satisfying but did encourage further analysis. Numerous alternative specifications were explored, initially using only variables available from Burchfield et al., first without and then with our public finance variables, and then introducing some modifications. It quickly became apparent that, of the Burchfield et al. variables, only the percentage of the fringe area overlying aquifers consistently appeared as an explanatory variable having a high degree of confidence. Streetcar passengers in 1902 sporadically had coefficients with conventional levels of confidence. Cooling and/or heating degree-days behaved similarly. Transfers as a percentage of revenues occasionally had a 10-per-cent level of confidence (but only if our public finance variables were excluded). A number of variables never showed statistically significant coefficients in any (of the many) specifications examined. Those variables were centralized-sector employment, decennial population growth and its standard deviation, and also the elevation range and the terrain ruggedness index.

The experiments led to introducing some modifications. When latitude was substituted for heating degree-days, latitude consistently appeared as an explanatory variable at conventional levels of confidence and its inclusion added consistency to the role of the cooling degree-days variable. Also, with latitude included, the percentage of the fringe incorporated in 1980 typically appeared with a significant coefficient. The failure of decennial population growth to contribute to the explanation of sprawl in our data led to substituting the 1976 population as a percentage of the 1960 population in its place. Metropolitan area population growth between 1960 and 1976 consistently proved to be a relevant explanatory variable. Following Burchfield et al., population growth from 1970 to 1990 was also introduced. Unlike their results, where both that variable and decennial population growth together had significant coefficients, neither it (nor the two together) made a significant contribution. Instead, the variable population in 1992 as a percentage of the 1976 population was introduced and it (like the 1960 to 1976 population growth but with different signs) appeared as an important explanatory variable. Among our public finance variables, property tax revenue as a percentage of total tax revenue was the only one to have a significant coefficient.

A set of regression results summarizing our analyses is reported in Table 5. All four regressions include a broad selection of the geographic variables, percentage of urban fringe incorporated, and the new population growth and public finance variables. The first regression also includes streetcar passengers. The variables with significant coefficients are streetcar ridership in 1902, the percentage of the urban fringe overlying aquifers, cooling degree-days, latitude, percentage of the fringe incorporated in 1980, population growth from 1960 to 1976 and from 1976 to 1992, and property taxes as a percentage of total taxes.

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31 The contributions of the different categories or 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 are the dominant group.

TABLE 5 EXTENDED REGRESSION RESULTS FOR SPRAWL 1992

	Regressions			
	1	2	3	4
Centralized-sector employment 1977			-1.1261	-0.91324
			0.96061	0.88143
Streetcar passengers per capita 1902	-0.02615		-0.02560	-0.01947
	(0.01036)**		(0.01029)**	0.01369
Mean decennial % population growth 1920-1970			-0.11618	-0.09848
			0.15358	0.16093
Std. dev. decennial % population growth 1920-1970			-0.04025	-0.04605
			0.19105	0.19124
% of urban fringe overlying aquifers	0.09403	0.10184	0.09160	0.09469
	(0.02716)***	(0.02739)***	(0.02431)***	(0.02485)***
Elevation range in urban fringe (m)	-0.00256	-0.00241	-0.00217	-0.00206
	0.00185	0.00223	0.00191	0.00203
Terrain ruggedness index in urban fringe (m)	0.32962	0.38684	0.35219	0.36720
	0.25769	0.29056	0.27117	0.28209
Mean cooling degree-days	-0.00649	-0.00526	-0.00560	-0.00526
	(0.00324)**	0.00341	(0.00328)*	0.00336
Latitude	-1.06110	-0.94774	-1.15519	-1.09369
	(0.53198)**	(0.55931)*	(0.50593)**	(0.51363)**
% of urban fringe incorporated 1980	-0.24786	-0.21998	-0.22209	-0.21289
	(0.10284)**	(0.10665)**	(0.10940)**	(0.11514)*
Population 1992 to 1976 (x100)	0.12249	0.12779	0.11170	0.11122
	(0.03848)***	(0.03791)***	(0.03403)***	(0.03501)***
Population 1976 to 1960 (x100)	-0.19961	-0.20006	-0.13226	-0.14062
	(0.05317)***	(0.05283)***	(0.05839)**	(0.05715)**
Population 1976		-0.00105		-0.00051
		(0.00045)**		0.00084
Property tax as percentage of total taxes	-0.13729	-0.12407	-0.12259	-0.12489
	(0.04623)***	(0.04488)***	(0.04504)***	(0.04623)***
Charges as percentage of total taxes	-0.07993	-0.08656	-0.09689	-0.12205
	0.09586	0.09580	0.09221	0.09073
Transfers as percentage of total taxes	-0.00510	0.00400	0.00368	0.00658
	0.02987	0.02997	0.02726	0.02782
Constant	111.075	101.489	133.013	126.567
	(21.499)***	(23.401)***	(30.264)***	(28.513)***
Observations	83	83	83	83
R2	0.5613	0.5654	0.6118	0.6223

Note: Heteroskedastic-consistent standard errors appear in brackets. ***, ** and * indicate significance at the one-, five- and 10-per-cent levels.

The second regression omits streetcar passengers and adds population in 1976. This change demonstrates the relatively high correlation between the two variables (0.57). Streetcar usage in 1902 was to indicate urban centres historically less friendly to automobile use. But streetcar ridership is highly correlated with population and cities with larger populations normally have higher land values, which should discourage undeveloped open space and sprawl. When the 1976 population replaces streetcar passengers, population size has a significant coefficient and it has a negative effect on sprawl. Otherwise the regression results are essentially unchanged.

The third equation includes the Burchfield et al. variables associated with the monocentric city model. Those include streetcar passengers and it is the only variable of the group with a statistically significant coefficient. As to be expected, the fit improves with the R^2 increasing to 0.61 from 0.56. Otherwise, except for a reduction in the size of the 1960 to 1976 population growth coefficient, the results are similar to those of the previous two equations.

Equation 4 is like Equation 3 but with population in 1976 added. Because of the correlation already noted, neither the population in 1976 nor streetcar usage have significant coefficients.

These results demonstrate the consistency in the variables found to be important in explaining sprawl. Population appears to be a reasonable alternative for historic streetcar passenger ridership and to have its own merits. The new population growth variables are highly correlated with decennial population growth and with its standard deviation and are consistently important while those two Burchfield et al. variables are never statistically important to these regressions. The percentage of the urban fringe overlying aquifers contributes to sprawl. The percentage of the fringe incorporated is also a determinant. The combination of cooling degree-days and latitude work quite well, although the cooling degree-days variable fluctuates between having and not having a statistically significant coefficient. Finally, the variable of property taxes as a percentage of total taxes consistently has highly significant coefficients indicating that property taxes are associated with less sprawl. Neither the charges nor the transfers as a percentage of taxes ever appear important. However, coefficients of the charge variable are, as expected, consistently negative.[32, 33, 34]

Results from Regressions for Sprawl 1976

Given the consistency in the sprawl indexes over time and, especially, the importance and stability of the geographic (and environmental) characteristics, the same variables that explained sprawl in 1992 are expected to do well in explaining the cross-sectional variation in sprawl in 1976. While we find that the main factors continue to be important, the models do not perform quite as well for 1976. Regression results in Table 6 illustrate the outcomes.

The variables that appeared in Table 5 are included in Table 6.[35] As indicated by the somewhat smaller R^2, the models do not fit the data quite as well for 1976. In particular, cooling days, latitude and percentage of the fringe incorporated do not contribute as effectively as before. However, unlike the 1992 regressions, terrain ruggedness does appear with a significant coefficient in one equation (Equation 4). Streetcar passenger ridership in 1902 has considerable explanatory power but population in 1976, as before, is an effective substitute. However, 1960–1976 population growth does not appear with a significant coefficient in these equations but neither does decennial population growth from 1920–1970. Road density on the fringe is included in two equations. It has a positive sign and coefficients significant at the 10-per-cent

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32 More will be said about charges after examining the results for Sprawl 1976.

33 When the public finance variables are expressed as percentages of total local revenues, the performance of the property tax variable deteriorates and, in these specifications, if it is significant it is only so at the 10-per-cent level. We expect that taxes as a percentage of tax revenue is a better indicator to taxpayers and landowners of the cost of property ownership and the costs of forgoing development.

34 Road density on the rural fringe was not found to be important by Burchfield et al. However, when added here, it has a positive coefficient significant at the 10-per-cent level. Burchfield et al. see road density as possibly having opposing effects: "…while more roads may facilitate scattered development, scattered development leads to a less dense road network" (p. 618).

35 Naturally, population 1992 to 1976 (x100) is excluded. To be entirely consistent in structure, Population 1960 could be substituted for Population 1976. To maintain uniformity, that was not done. Doing so had no effect on the results but for a marginal effect in one instance that is noted below.

level. The strongest and most consistent variables for explaining sprawl in 1976 are percentage of the fringe overlying aquifers, property taxes as a percentage of total taxes and streetcar passengers (or population).

The public finance variables are more interesting in this case. First, the property tax percentage is, again, negative with coefficients significant at the one-per-cent level. As before, transfers lack explanatory power.[36] The interesting addition here is that the coefficient of charges as a percentage of total taxes, as well as being negative, is significant at the 10-per-cent level. Indeed, in Equation 2, the t-value is -1.99, so the significance level barely misses the five-per-cent level.[37] It appears that charges measured relative to taxes in 1977 are better at explaining sprawl in 1976 than at explaining sprawl in 1992. This outcome causes reconsideration of the Sprawl 1996 analysis. When charges as a percentage of total taxes in 1992 is substituted for the charges variable in 1976, it improves somewhat the R^2 values in all the equations in Table 5 and the coefficients are significant at the 10-per-cent level in two equations (equations 1 and 4). That charges in 1992 may contribute explanatory power is not surprising. With the resistance to property tax increases and growth in restrictions on property tax increases that blossomed in the 1970s and 1980s, local governments turned increasingly to charges to generate local revenue.[38] For the cities within the data set, the charges included here grew from 22.4 to 31.1 per cent of tax revenue. The growing importance of charges during the 1970s and 1980s could be expected to strengthen their impact on land-use decisions and the levels observed in 1992 better reflect the charges and the expectations for future charges during the period.[39] Hence, although not having as distinct an impact as property taxes on urban sprawl, there is evidence that charges associated with land use and development also tend to reduce sprawl.

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36 Also, the public finance variables are of little importance when measured as a percentage of total revenue.

37 If the population in 1960 is substituted for the population in 1976, the coefficient of the charges variable is significant at the five-per-cent level with a t-value of 2.01.

38 See Benton, "Trends in"; Daniel R. Mullins, "Popular Processes and the Transformation of State and Local Government Finance," in *State and Local Finances under Pressure*, ed. David L. Sjoquist (Edward Elgar, 2003), 95-162; Arthur O'Sullivan, "Limits on Local Property Taxation," in *Property Taxation and Local Government Finance,* ed. Wallace E. Oates (Lincoln Institute of Land Policy, 2001), 177-207; and Pagano, "Creative Designs."

39 Consistent with the expanded role of charges, the coefficients of the 1992 charges variable are larger than those for the 1976 charges.

TABLE 6 REGRESSION RESULTS FOR SPRAWL 1976

	Regressions			
	(1)	(2)	(3)	(4)
Centralized-sector employment 1977	-0.25836	-0.24504	-0.30203	-0.24067
	(1.11063)	(0.93647)	(0.82786)	(0.91843)
Streetcar passengers per capita 1902	-0.03389	-0.02445		-0.02513
	(0.01113)***	(0.01432)*		(0.01400)*
Mean decennial % population growth 1920-1970	-0.07650	-0.15232		-0.14013
	(0.15566)	(0.21728)		(0.20501)
Std. dev. decennial % population growth 1920-1970	-0.10597	-0.02990	-0.13947	-0.01859
	(0.18382)	(0.23042)	(0.13151)	(0.22672)
% of urban fringe overlying aquifers	0.07387	0.07600	0.07772	0.07106
	(0.03152)**	(0.03242)**	(0.03284)**	(0.03109)**
Elevation range in urban fringe (m)	-0.00277	-0.00305	-0.00204	-0.00193
	(0.00200)	(0.00237)	(0.00275)	(0.00239)
Terrain ruggedness index in urban fringe (m)	0.44915	0.49413	0.57831	0.56968
	(0.29335)	(0.32416)	(0.35619)	(0.34016)*
Mean cooling degree-days	-0.00566	-0.00517	-0.00437	-0.00468
	(0.00382)	(0.00396)	(0.00389)	(0.00379)
Latitude	-1.16211	-1.10165	-1.0026	-1.09739
	(0.63381)*	(0.64935)*	(0.64578)	(0.60887)*
% of urban fringe incorporated 1980	-0.21004	-0.19099	-0.18226	-0.20601
	(0.14233)	(0.15135)	(0.15249)	(0.15129)
Road Density			6.8008	6.92515
			(3.90321)*	(3.86000)*
Population 1976 to 1960 (x100)		0.05217	0.03329	0.05791
		(0.09550)	(0.07424)	(0.09554)
Population 1976		-0.00064	-0.00132	-0.00791
		(0.00078)	(0.00040)***	(0.00076)
Property tax as percentage of total taxes	-0.14403	-0.14584	-0.14635	-0.15955
	(0.05127)***	(0.05383)***	(0.05365)***	(0.05518)***
Charges as percentage of total taxes	-0.17278	-0.22958	-0.15214	-0.21219
	(0.10152)*	(0.11529)*	(0.11929)	(0.11764)*
Transfers as percentage of total taxes	0.01494	0.02921	0.02782	0.02922
	(0.02812)	(0.03090)	(0.03057)	(0.02988)
Constant	113.677	104.427	91.040	95.865
	(37.937)***	(37.510)***	37.642	(36.806)**
Observations	83	83	83	83
R^2	0.5058	0.5335	0.5088	0.5563

Note: Heteroskedastic-consistent standard errors appear in brackets. ***, ** and * indicate significance at the one-, five- and 10-per-cent levels.

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 in new development; that is, the scatteredness of residential development for properties developed between 1976 and 1992. This is the sprawl index that Burchfield et al. 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 results of the regressions on the flow-sprawl index, Sprawl 1976-92, are reported in Table 7. The set of possible determinants is relatively successful in explaining sprawl in the areas surrounding new residential development. The three specifications each have R^2 in excess of 0.65, greater than for the stock-sprawl indexes. A larger number of the variables have significant coefficients and often at a higher level. As in the regressions explaining Sprawl 1992, the percentage of the fringe overlying aquifers, the percentage incorporated and population growth from 1960 to 1976 are major explanatory variables. Decennial population growth and its standard deviation also contribute. Surprisingly, population growth from 1976 to 1992 does not have a significant coefficient. The variable of streetcar passengers in 1902 contributes to explaining sprawl but, in this case, population in 1976 is a somewhat inferior substitute. Cooling days and latitude make regular contributions, while elevation range and ruggedness consistently continue to appear without significant coefficients.

Unlike the results from the stock-sprawl regressions, the public finance variables do not appear to be determinants of the degree of sprawl surrounding new development. None of the public finance variables, including, notably, the variable for property taxes as a percentage of total taxes, has a significant coefficient in the regressions reported in Table 7.[40] However, these results may understate the role of property taxes. If the included variables are pared down to those making the most contribution and having the most significant coefficients, the coefficient for the property tax percentage emerges with significance in the nine- to 11-per-cent range.

The weak performance of the property tax variable may not be entirely unexpected. 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 insensitive to the means of public finance. 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 (0.60 and 0.77 as opposed to 0.96). 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.

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[40] The property-tax-share and charges variables consistently appear with the expected sign but not the transfer variable.

TABLE 7 REGRESSIONS RESULTS FOR NEW DEVELOPMENT: SPRAWL 1976-92

	Regressions		
	1	2	3
Centralized-sector employment 1977	-0.46217	-0.57943	-0.48932
	(0.89917)	(0.90922)	(0.91203)
Streetcar passengers per capita 1902	-0.02233	-0.02571	-0.02657
	(0.01375)	(0.00994)**	(0.01006)***
Mean decennial % population growth 1920-1970	-0.38049	-0.39003	-0.39865
	(0.15485)**	(0.14764)***	(0.14880)***
Std. dev. decennial % population growth 1920-1970	0.43500	0.43797	0.43943
	(0.19522)**	(0.19203)**	(0.19002)**
% of urban fringe overlying aquifers	0.06554	0.06377	0.06323
	(0.02449)***	(0.02364)***	(0.02406)**
Elevation range in urban fringe (m)	-0.00152	-0.00159	-0.00146
	(0.00237)	(0.00226)	(0.00227)
Terrain ruggedness index in urban fringe (m)	0.39909	0.39077	0.39345
	(0.29198)	(0.28404)	(0.28419)
Mean cooling degree-days	-0.00503	-0.00521	-0.00512
	(0.00261)	(0.00256)**	(0.00256)**
Latitude	-0.79197	-0.82596	-0.82904
	(0.41230)*	(0.40729)**	(0.41358)**
% of urban fringe incorporated 1980	-0.33893	-0.34397	-0.34894
	(0.12992)***	(0.12497)***	(0.10886)***
Population 1992 to 1976 (x100)	0.02356	0.02381	
	(0.04100)	(0.04057)	
Population 1976 to 1960 (x100)	-0.15439	-0.14987	-0.12779
	(0.05814)***	(0.05750)***	(0.04187)***
Population 1976	-0.00028		
	(0.00079)		
Property tax as percentage of total taxes	-0.04965	-0.04836	-0.04440
	(0.05077)	(0.04971)	(0.04771)
Charges as percentage of total taxes	-0.02903	-0.01512	-0.01860
	(0.09933)	(0.09976)	(0.09948)
Transfers as percentage of total taxes	-0.00264	-0.00426	-0.001998
	(0.02549)	(0.02480)	(0.02478)
Constant	133.049	136.618	134.698
	(27.779)***	(28.413)***	(28.288)***
Observations	83	83	83
R2	0.6580	0.6554	0.6533

Note: Heteroskedastic-consistent standard errors appear in brackets. ***, ** and * indicate significance at the one-, five- and 10-per-cent levels.

Exploring a Further Refinement

Albert Saiz has made estimates of the housing-supply elasticities for major U.S. metropolitan areas.[41] 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 explain the measures of sprawl?

Burchfield et al. 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[42] reports elasticities for 95 metro areas. Matching those estimates with the 83 observations left 67 observations. Coefficients of the housing-supply elasticities failed to generate significant coefficients in regressions for any of the three sprawl indexes (in any of a variety of specifications). Recall that elevation range and ruggedness also failed to appear as causes of sprawl in the regressions reported on above.

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). Although the impacts of land-use regulation are already incorporated into the housing-supply elasticity estimates, the WRI is introduced into the existing 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 regularly important). In a final effort, both the WRI and the supply-elasticity variables were added to the sets of independent variables. This improved the performance of both these variables for the stock-sprawl indexes (Sprawl 1976 in particular), although neither realized coefficients with a level of significance as high as 10 per cent. Both appeared with negative coefficients. A negative coefficient is expected for the WRI but the sign of supply elasticity may be more an empirical matter. 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.

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

42 ibid.

Impacts of Changes on Sprawl

What impacts changes in (or differences in) the variables have on sprawl is naturally of interest. The impacts of a 10-per-cent increase in the variables upon the Sprawl 1992 measure are reported in Table 8. The increases are from the mean values of the variables and the impact is from the predicted Sprawl 1992 measure at the means.

The impacts implied differ substantially. A 10-per-cent increase in latitude has the greatest effect. It reduces the sprawl index by 4.07 or 10 per cent of its predicted (and mean) value. A change in the employment in the central sector in 1977 appears to have a notable impact at 5.1 per cent of the sprawl index, but the coefficient of that variable is not statistically significant in these regressions so that effect must be discounted.[43] Population changes from 1960 to 1976 and from 1976 to 1992 have large but opposing impacts (in the order of four per cent of the index value for a 10-per-cent change) and the variables coefficients are statistically significant.[44]

The public finance variables are the next most important. A 10-per-cent increase in property taxes as a percentage of total taxes reduces the sprawl index by 2.2 per cent. Because the variable lacks strong statistical significance, the role of charges is more tenuous. The results suggest a 10-per-cent increase in the role of charges from their 1977 level is associated with a 0.7-per-cent decrease in Sprawl 1992. Recall, however, that the level of charges in 1992 had a stronger influence in explaining Sprawl 1992 and that charges had increased by about 40 per cent in importance relative to total taxes between 1977 and 1992. The effect implied when using the charges as a percentage of total taxes in the 1992 variable and the higher level of charges at that time is that a 10-per-cent increase in charges would reduce the sprawl index about one per cent. In sum, a 10-per-cent greater reliance on property taxes and on user charges implies sprawl about three-per-cent less than otherwise.

In summary, latitude, population growth and public finance variables (property taxes and user charges) appear to have the largest impacts on sprawl. With the exception of the percentage of the fringe overlying aquifers (which has a relatively modest effect), the other variables do not have statistically significant coefficients and/or the impacts implied by a 10-per-cent change are relatively small. [45, 46]

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43 In addition, the percentage of employment data in the central district are tightly clustered, with a standard deviation of only 0.91, so a 10-per-cent change of 2.07 is large.

44 More rapid near-term population growth is associated with more sprawl, while growth further in the past (15 to 30 years before) is associated with less sprawl. That is, early sprawl is followed by infilling.

45 Broadly speaking, a parallel examination of the results for Sprawl 1976 reveals similar results.

46 This is an opportune point at which to comment on related work. Wassmer, "Further Empirical," Table 2 notes seven empirical studies that seek to explain a measure of sprawl (e.g., area, density) including a property tax measure (e.g., effective tax rate, share of municipal revenue). The implications for the effects on sprawl are inconsistent, with some implying that greater property taxes reduced sprawl, others implying they increased sprawl, and others lacking significant results. Wassmer's own empirical work in that paper found differing consequences across single-family residential, multi-residential, commercial and industrial properties. In a revised but yet unpublished paper that has a somewhat different specification, Wassmer concludes that higher effective residential property tax rates promote sprawl. Clearly the question needs further investigation.

TABLE 8 IMPACTS OF A 10-PER-CENT INCREASE IN VARIABLE MEAN VALUE UPON THE PREDICTED SPRAWL 1992 VALUE[A,B]

	Impact	Percentage of predicted Sprawl 1992 value at means
Centralized-sector employment 1977	-2.07	-5.1
Streetcar passengers per capita 1902	-0.13	-0.3
Mean decennial % population growth 1920-1970	-0.27	-0.7
Std. dev. decennial % population growth 1920-1970	-0.06	-0.2
% of urban fringe overlying aquifers***	0.26	0.6
Elevation range in urban fringe (m)	-0.15	-0.4
Terrain ruggedness index in urban fringe (m)	0.3	0.7
Mean cooling degree-days (*)	-0.73	-1.8
Latitude**	-4.07	-10
% of urban fringe incorporated 1980*	-0.17	-0.4
Population 1992 to 1976 (x100)***	1.53	3.8
Population 1976 to 1960 (x100)**	-1.84	-4.5
Population 1976	-0.08	-0.2
Property tax as percentage of total taxes***	-0.9	-2.2
Charges as percentage of total taxes (*)[c]	-0.27	-0.7
Transfers as percentage of total taxes	0.07	0.2

Notes: a) Using Equation 4, Table 5; b) stars (*, **, ***) indicate the significant levels of the coefficients of the variables in the regression; c) see text for explanation.

IMPLICATIONS FOR ALBERTA'S METROPOLITAN REGIONS

What implications might these regression results have for Alberta's metropolitan regions, Calgary and Edmonton? Given the broad similarity of local government, local public finance and of many geographic/environmental features in the U.S. and in Canada, it seems reasonable that the results above can offer insights into the nature of sprawl in Canadian metro areas, specifically the Calgary and Edmonton census metropolitan areas (CMAs). In addition, examining the influence of various factors on sprawl in Calgary and Edmonton provides further insight into their impacts elsewhere.

This exploration into the influences on sprawl considers the effects on each of the three measures of sprawl. It begins by noting the average values of those measures from the 83 observations analyzed in this study. Those are reported in the initial column of Table 9 for ease of comparison. The remaining columns report the estimated sprawl index values when the levels of selected variables characterizing Calgary and Edmonton are introduced. Shown are, first, the estimated sprawl indexes as impacted by geographical (or environmental) characteristics; then the indexes when local population characteristics are added to the local geographic features; and, finally, the estimated indexes when experiencing the combined impacts of the Calgary and Edmonton geographic, population and public finance characteristics. The stepwise sequence reveals the impacts on sprawl of these three sets of characterizing features. That is, one can see the impact of each as the estimated sprawl index deviates from the others and from the 83-observation mean.[47] The analyses also demonstrate the implications of some modest differences between Calgary and Edmonton.

Calgary and Edmonton have somewhat different characteristics than many of the U.S. metro regions. The geographical, population and public finances features are most readily quantifiable and so their impacts are estimated. Fortunately, these also are the features that are most important statistically and quantitatively in the regressions. While it could be interesting to examine the impacts of differences for the other characteristics, data for the other variables are not, or not readily, available. However, with the exception of the percentage of the urban fringe overlying aquifers, the other variables are not statistically significant determinants. Comparable information on the fringe overlying aquifers for Calgary and Edmonton are lacking, so the average for the U.S. cities is applied.[48] The estimated sprawl index values use the mean values of the 83 observations for the independent variables other than the selected Calgary and Edmonton characteristics being examined. The values of the characteristics for Calgary and Edmonton used for estimating the sprawl indexes, and their 83-observation counterparts, are reported in Table 10.

TABLE 9 ESTIMATED SPRAWL INDEX VALUES FOR ALBERTA METROPOLITAN REGIONS AS IMPACTED BY THEIR GEOGRAPHIC, POPULATION AND PUBLIC FINANCE CHARACTERISTICS

Alberta Metro Region	Mean Value of 83 Observations	Estimated Sprawl Indexes Allowing for Alberta Metro's Characteristics				
		Geography	Geography and Population	Geography, Population and Public Finance		
				Property Tax Only Included	Charges Only Included	Property Tax and Charges Combined
	Sprawl 1992					
Calgary	40.6	33.2	32.4	30.2	29.8	27.6
Edmonton	40.6	31.6	30.5	27.0	24.8	21.3
	Sprawl 1976					
Calgary	40.3	32.2	33.7	30.9	29.1	26.3
Edmonton	40.3	29.8	31.0	26.6	21.1	16.7
	Sprawl 1976-92					
Calgary	59.2	54.9	52.5	51.7	51.9	51.0
Edmonton	59.2	53.2	51.4	50.0	50.0	48.6

Notes: The estimates are based on equations 4, 4 and 1 from Tables 5, 6 and 7 respectively.

[47] The mean index values of the observations are equal to (or essentially equal to) the estimated values from the regressions when using the mean values of the independent variables. Only the estimated value for Sprawl 1976-92 differs slightly from the 83-observation mean (59.4 versus 59.2).

[48] This assumption may underestimate groundwater availability in the two metro regions. Despite there being extensive coverage of water services in those areas, the potential for residential wells appears high (based on familiarity with the areas and hydrological reports; e.g., Alberta Water Portal). If a larger value is more appropriate, the estimated sprawl indexes would be larger, but the effects of the geographic, population and public finance variables are not changed. Not considered is that the cost of residential wells varies widely and can be high.

TABLE 10 SELECTED VARIABLES AND THEIR MEANS AS USED IN ESTIMATING SPRAWL INDEXES FOR CALGARY AND EDMONTON (U.S. BASELINE DATA FOR SPRAWL 1992, CALGARY AND EDMONTON)

Variable in Sprawl 1992	Mean Value of 83 Observations	
Geographic		
Cooling degree-days	1388.4	
Latitude	37.2	
Terrain ruggedness	8.25	
Population		
Population 1992 to 1976 (x100)	138	
Population 1976 to 1960 (x100)	131	
Population 1976 ('000)	1490	
Public Finance		
Property tax as percentage of total taxes, 1977	72.43	
Charges as percentage of total taxes, 1977	22.44	
Variable Used in Calculating Alberta Metro Sprawl Indexes	Calgary	Edmonton
Geographic		
Cooling degree-days	590.2	590.2
Latitude	48.0	48.0
Terrain ruggedness	8.25	4.07
Population		
Population 2014 to 1999 (x100)	151.9	142.1
Population 1999 to 1984 (x100)	149.4	144.6
Population 1999 ('000)	925.5	934.4
Public Finance		
Property tax as percentage of total taxes, 2011	89.9	100.0
Charges as percentage of total taxes, 2011	62.9	77.5

Calgary and Edmonton are northern cities. This has implications for the values of cooling degree-days and latitude, which were variables included in the regressions and often (if not usually) having significant coefficients. Preferring to not push beyond the range of the U.S. data, the number of cooling degree-days in Minneapolis and a latitude of 48 were set as the values for both cities while, for determining the impact of these geographic characteristics, all other independent variables were set at their mean levels.[49] Both these variables have negative coefficients. As a result, these Alberta metro area geographic features reduce the expected levels of sprawl compared to that of the city in the sample studied with average features. To illustrate, for Sprawl 1992 and Calgary, the model predicts that the geographic features of Calgary imply a sprawl index of 33.2 compared to an index of 40.6 for the average U.S. city, an almost 20-per-cent reduction from the sample mean. A similar impact occurs in the case of Sprawl 1976. The small differences between the estimated indexes for Calgary and Edmonton are due to differences in the ruggedness measures.[50]

[49] Cooling degree-days are somewhat higher in Minneapolis than in Calgary and Edmonton but, although the Calgary and Edmonton degree-days are within the range of the U.S. cities data, the Minneapolis conditions seem to most parallel those for these Canadian cities. Also, although never statistically important, terrain ruggedness at the fringe was, to reflect differences between the two cities, also set at the Minneapolis level for Edmonton but left at the average level for Calgary.

[50] The impacts of the individual variables are reported and discussed in the appendix. That analysis illustrates the impacts on Sprawl 1992 for Calgary. It demonstrates the impacts on sprawl of the individual variables comprising the geographic, population and public finance features addressed here.

Differences in population growth and size also need to be taken into account. For this exercise, population growth for Calgary and Edmonton are taken as that from 1984 to 1999 and from 1999 to 2014 rather than that from 1960 to 1976 and from 1976 to 1992. Both census metropolitan areas have grown faster than the average city in the data. On the other hand, Calgary and Edmonton in 1999 had about two-thirds of the mean 1976 population of the metro areas studied (Table 10). Clearly, it is assumed here that the impacts of recent patterns of population growth and size on sprawl parallel those estimated for 1976 and 1992.[51] Those estimates show that greater recent population growth tends to be associated with more sprawl while greater population growth in an earlier (the preceding) period implies less sprawl. Population size tends to be negatively related to sprawl.[52] Introducing the levels of population and population growth for Calgary and Edmonton in addition to the cities' geographic characteristics results in a small additional reduction in the predicted Sprawl 1992 and Sprawl 1976-92 indexes but they caused a slight increase in the Sprawl 1976 index. The estimated increase in the Sprawl 1976 index is the result of relatively solid population growth from 1984 to 1999 (the recent period, without any possibly constraining influence of an even earlier period of growth being present). Overall, the population characteristics of Calgary and Edmonton had relatively little additional impact on the estimated sprawl indexes beyond the geographic determinants.

The potential impacts of public finances are of prime interest in this analysis. The regression results indicated that a greater reliance on property taxes reduced the stock-sprawl indexes (i.e., Sprawl 1976 and Sprawl 1992). The regressions suggested (particularly for Sprawl 1976) that greater utilization of user charges, notably for water and sewer and for solid waste services, also tended to moderate the stock-sprawl indexes.

Before examining the estimated impacts of Calgary's and Edmonton's public finances, those finances need to be surveyed. The features of finances in the two cities in 2011 are used. The current characteristics adequately represent the finances of the two metro regions and there has been little change over time. Information on the cities' public finances in 2011 and 1996 and a history of local government finance in Alberta are found in Dahlby and McMillan.[53, 54]

Both Calgary and Edmonton rely heavily on property taxation. In addition to the municipal property taxes, there are provincial (previously local school board) school property taxes and those are included in the tax measures. In 2011, property taxes represented 100 per cent of the total taxes collected by the City of Edmonton and 89.9 per cent of those collected in Calgary. The lower level in Calgary reflects business taxes levied by the city.[55] Edmonton recently abandoned its business taxes replacing them with an increase in the property tax rate applying to commercial and industrial property. The reliance on property taxes in the Alberta metro

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51 That is, we assume the effect of recent patterns are as if they had occurred in the years analyzed by Burchfield et al. or, alternatively, that the estimates on the Burchfield et al. data apply equally well to recent years.

52 The streetcar-passenger-use variable, with which population size is closely related, also had a negative impact. Calgary and Edmonton did not have streetcar service in 1902 (beginning in 1909 and 1908 respectively). We rely on population size to capture the relevant effects.

53 Bev Dahlby and Melville McMillan, "Do Local Governments Need Alternative Sources of Tax Revenue? A Background Paper on Municipal Finance in Alberta," University of Calgary School of Public Policy Research Paper (November 2014).

54 Further background is available in Edward LeSage and Melville McMillan, "Alberta: Municipal System Overview," University of Alberta, Western Centre for Economic Research, Information Bulletin 135 (January 2010), http://www.business.ualberta.ca/Centres/WCER/Publications/InformationBulletins/.

55 It might be argued that business taxes are sufficiently related to property to be considered property taxes, but we make the distinction here.

areas is high relative to that in most U.S. metro areas where property taxes in 1977 averaged 72.4 per cent of total local taxes for the 83 observations.[56]

The heavy reliance on property taxes in Calgary and Edmonton reduce sprawl. The levels of property tax in the two cities is estimated to reduce the sprawl indexes about 10 per cent — somewhat more in Edmonton and somewhat less in Calgary. For example, the geographic and population characteristics of Calgary yield an estimated Sprawl 1992 value of 32.4 but, when the Calgary level of property tax is introduced, the estimated index becomes 30.2 (a seven-per-cent decline). Sprawl 1976 estimates generate only slightly larger reductions in the index. These calculations assume no other changes in the public finance variables.

Accounting for differences in charges for local government services is somewhat more complicated. Charges for the U.S. cities consisted mostly of charges for water, sewer and solid waste services. The amounts are relatively modest, averaging 22.4 per cent of total taxes for the metro areas, although they are said to be gross revenues of those operations. Edmonton especially, but also Calgary, have a history of charging for services and especially for utilities. Estimates of comparable charges in Calgary and Edmonton (in 2011) are relatively large compared to the levels in the U.S. cities. Charges as a percentage of total taxes are calculated to be 44 and 69 per cent respectively. While the Calgary figure is comparatively large, the 69-per-cent level in Edmonton is beyond the 50.7-per-cent largest value for the U.S. cities.[57] Nevertheless, but with the observation that the values are at the upper level or somewhat beyond the U.S. city data, the Calgary and Edmonton values are introduced to estimate (or at least illustrate) the possible effects of charges.

The econometric results suggest that charging for municipal services also diminishes sprawl. At the levels observed in Calgary and Edmonton, the impacts of charges (alone) on sprawl are equivalent to or exceed the impacts of their higher levels of property taxes (Table 9). To illustrate using the Sprawl 1992 estimates for Calgary in Table 9, the impact of charges (alone, at 44 per cent of taxes) is estimated to lower the sprawl index to 29.8 from the 32.4 level predicted by the geographic and population characteristics. This reduction is comparable to that predicted for the effect of the higher level of property taxes in Calgary. With a higher level of charges (69 per cent of taxes), the impact in Edmonton is greater — the 24.8 level is 19-per-cent smaller than the 30.5 level of the sprawl index implied by the geographic and population characteristics. The impacts on the estimated Sprawl 1976 values are similar although somewhat larger.

Intergovernmental transfers are provided to assist municipal governments and to fund local schools in Alberta. Transfers tend to be about 20 per cent of municipal revenues and municipal transfers amount to about one-third of total transfers (i.e., municipal and school).[58] In 2011, transfers were the equivalent of 98.4 per cent of taxes in Calgary and 130.1 per cent in Edmonton, but the exact levels fluctuate somewhat over time depending upon special programs (e.g., assistance for light-rail-transit construction). The levels in Alberta are comparable to the 112-per-cent average of the 83 U.S. observations. This variability and comparability contribute

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[56] Only 13 of those 83 had property taxes exceeding 90 per cent of total taxes. If one excludes those 13, the average percentage is 67.9 per cent. So, where the reliance on property taxes is low(er), about one-third of tax revenues comes from other taxes (primarily local sales taxes). Local income taxes exist in some areas.

[57] The charge levels cited for the U.S. cities are for 1977. Charges as a percentage of total taxes had risen by 1992. (Recall that the 1992 charge data were used here in supplementary regressions.) The 1992 maximum was 64.9 per cent and 10 observations exceeded 50 per cent.

[58] Transfers went through a rather turbulent period during the 1990s with deep cuts, but with the funds restored later. See Lesage and McMillan, "Alberta" for a review.

to ignoring the impact of differences in transfers in the analysis of the impacts of public finance characteristics on sprawl. At least equally important was that those coefficients were small, were never significant in the regressions, and that the implications of the levels in Calgary and Edmonton are minor (in part because they did not diverge much from the 83-observation mean).

Local public finance appears to impact sprawl. When the property tax and the charge values observed in Calgary and Edmonton are used to calculated predicted sprawl indexes (i.e., included along with the two metro areas' geographic and demographic characteristics), the stock-sprawl indexes decline notably. The Sprawl 1992 index for Calgary falls from 32.4 to 27.6 (a reduction of about 15 per cent) from the combined effects of property taxes and charges. The estimated impact in Edmonton is greater — a decline from 30.5 to 21.4 (about 30 per cent). The estimates from the Sprawl 1976 regressions suggest even larger effects, reductions of 22 and 46 per cent for Calgary and Edmonton. Thus, the greater reliance on property taxes and on user charges in Calgary and Edmonton compared to the 83 U.S. cities is found to reduce sprawl in the Alberta metropolitan regions (on average by one-quarter and about one-third for Edmonton).

A simple assessment of the numbers suggests that about 40 per cent of the decline in the estimated sprawl indexes for Calgary and Edmonton is attributable to the importance of the property taxes and about 60 per cent is due to the high level of charges. That apportionment, however, needs to be viewed with caution. The econometric results imply that the impacts of property taxation on the stock-sprawl indexes are the more reliable of the two influences. There is considerably less statistical confidence in the role of charges. Nevertheless, and although the charge levels in Calgary and Edmonton strain the range of the data used in the regressions, the results do suggest that charges for major local services may have a noticeable negative impact on the scatteredness of residential development.

Even the modest differences between Calgary and Edmonton imply some interesting differences for sprawl. The difference in the property tax reliance in the two cities (89.9 per cent in Calgary and 100 per cent in Edmonton) indicates that the negative effect on the stock-sprawl indexes in Edmonton is over 50-per-cent larger than in Calgary. Similarly, comparatively higher charges in Edmonton (69 versus 44 per cent of total taxes), imply twice the impact on the stock-sprawl indexes in Edmonton compared to Calgary. That is, even at the Alberta levels, differences in public finance matter to the degree of sprawl in a metro area.

The implication of imposing the Alberta cities' public finance characteristics on the average metro area in this data provides another perspective on the influence of public finance on sprawl. To illustrate, consider Edmonton. With property tax reliance at 100 per cent rather than 72.4 per cent and charges at 69 rather than 22.4 per cent, the estimated stock-sprawl indexes decline from about 40 to 30. Overall, the results suggest that a different form of local public finance could see sprawl in U.S. cities reduced by about one-quarter. Again, 40 per cent of that reduction can be attributed to greater reliance on property taxation and 60 per cent to charges being more important.

Sprawl in newly developing areas did not appear to be impacted by local public finance. (See the Sprawl 1976-92 results.) Even the reliance-on-property-tax variable did not have significant coefficients in the regressions, although the signs for that (and the charges) variable were negative. Substituting Calgary and Edmonton characteristics in the calculation of the predicted flow-sprawl index, Sprawl 1976-92, have similar effects to those for the stock indexes except that the absolute and relative changes are small. This result is not unexpected because new developments in a city are undertaken in a specific, and a given, public finance environment.

Implications of Some Possible Alternatives for the Alberta Environment

It is also interesting to consider some "what ifs" — that is, what are the implications for sprawl if events had been different or if circumstances changed? While the potential options are numerous, the implications of three alternative scenarios are presented in Table 11.

Alberta has experienced rapid population growth. Suppose population growth had been slower. Specifically, assume that the populations of Calgary and Edmonton had increased in parallel with that of the average metropolitan area in Canada. If so, population would have grown by 25 per cent over the past 15 years and by 36 per cent during the preceding 15 years rather than by about 50 per cent in Calgary and by over 40 per cent in Edmonton in each 15-year period. Imposing the lower rates of growth (while maintaining the other Calgary and Edmonton characteristics) generates an estimated Sprawl 1992 index of 26.5 for Calgary and 20.6 for Edmonton. Both estimates are lower than the estimates for the current situation (27.6 and 21.3 respectively) but only somewhat so. Population growth rates have an effect on sprawl but it is relatively small.

TABLE 11 ESTIMATED SPRAWL 1992 INDEX VALUES UNDER ALTERNATIVE SCENARIOS

	Calgary	Edmonton
Estimates for the current situation (from Table 9)	27.6	21.3
If population growth had been at average of other Canadian metro areas[a]	26.5	20.6
If future population growth slows (over next 15 years)[b]	23.3	18.7
If reliance on property taxes declines to the average of 83 U.S. cities[c]	29.8	24.8

Notes: a) Values of 136 and 125 rather than 149.4 and 151.9 for Calgary and 144.6 and 142.1 for Edmonton; b) assumes population increases only 15 per cent over 15 years (i.e., use a value of 115); c) apply U.S. average of 72.4 per cent of total taxes rather than 89.9 for Calgary and 100 for Edmonton.

Suppose that the rate of population growth slows substantially from the recent high rates. The current difficulties in Alberta's energy sector might imply such a decrease. A mid-level projection of Canadian population growth over the next 15 years is for population to increase only 15 per cent. If the Calgary and Edmonton populations were to grow by only 15 per cent over the next 15 years, the estimated sprawl index values are 23.3 and 18.7. A rapid deterioration in the rate of population growth is estimated to have a noticeable effect on sprawl with the measures declining from 12 to 15 per cent.

Calgary and Edmonton are pursuing city charters and pressing for new tax powers.[59] Assuming that they were successful in realizing and, in turn, introducing alternatives to supplement the property tax, what might be the consequences for sprawl? If the two cities imposed alternative local taxes that reduced the reliance on property taxes to that of the average of the 83 U.S. cities (72.4 per cent of total taxes), sprawl is estimated to increase. The 29.8 value in Calgary represents an eight-per-cent increase in the sprawl index and the 24.8 value estimated for Edmonton implies a 16-per-cent increase.

Putting Local Public Finance in Perspective

Despite the indications from the above results that local public finance affects sprawl in metro areas, it is important to keep the finance role in perspective. When people think of land use and

59 The cities signed a memorandum of understanding on charters with the provincial government in 2014. See Government of Alberta Municipal Affairs website, "Framework Agreement for Charters" at http://www.municipalaffairs.alberta.ca/documents/1007-Framework-Agreement-for-Charters-Oct-2014.pdf. For some discussion of the various pressures for alternative taxes, see Dahlby and McMillan, "Do Local."

patterns of development, they will typically think of local governments' land-use regulation, infrastructure extension policies and, in general, growth policies. An insightful discussion of these considerations is provided in Taylor et al.,[60] who review and examine closely post-Second World War land use and development in Calgary and Edmonton (with special attention to the period since 1991) and compare it with that in Toronto and Vancouver.[61]

The comparatively rapid, though rather erratic population growth of Calgary and Edmonton since the Second World War has provided ample opportunity to consider the options of "grow up or grow out." At least for the first 50 years, the approach could be characterized as "… an efficiency-oriented expansion policy regime." Annexation, particularly of agricultural land, was the norm, although managed in part by regional planning commissions (until 1995) and, if necessary, provincial input. Changing attitudes led to some shift in policy first evidenced in Calgary in the 1990s with policies to promote more intensification of land use, in part associated with the expansion of public transit.[62] Although not without meeting some resistance, the shift in policies has demonstrated some success since the turn of the century. While there has been modest intensification in the core, the most substantial impacts are at the fringe, where suburban areas now use two hectares of land per 100 residents compared to 6.5 hectares in the years 1991–2001. With a multiplicity of municipalities and, since 2008, a Capital Region Board, the land-use situation in the Edmonton metropolitan region has been more complex. Regardless, Edmonton has also shown a shift toward denser development with three hectares per 100 residents in the suburban areas in the 2001 to 2011 period compared to seven hectares per 100 residents in the years 1991to 2001. A challenge Edmonton faces is a tightening of its supply of land available for industrial development.

The patterns of land use and development in Vancouver contrast with those in Calgary and Edmonton. There, constraints on land development have a long history and land use is more intense. Although different, pressures for and policies to promote more intensive urban land use are evolving in Alberta's metro areas. To some extent, land-use policies are endogenous to the physical and demographic character of the urban areas[63] but, as they evolve, the policies do influence the patterns of development. This analysis suggests that local public finance policies also have some influence.

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[60] Zack Taylor, Marcy Burchfield and Anna Kramer, "Alberta Cities at the Crossroads: Urban Development Challenges and Opportunities in Historical and Comparative Perspective," University of Calgary School of Public Policy Research Paper (May 2014).

[61] Readers will also find interesting the Arnott paper that assesses Calgary's Municipal Development Plan and its Transportation Plan: Richard Arnott, "Reflections on Calgary's Spatial Structure: An Urban Economist's Critique of Municipal Planning in Calgary," University of Calgary School of Public Policy Research Paper (October 2015). Arnott is critical of the extent of plans for spatial containment and of intensification centred on the central business district.

[62] More recently, restricting water supply has been adopted as a policy by the City of Calgary, aimed at controlling urban growth in the surrounding areas.

[63] See Saiz, "The Geographical."

CONCLUSION

The objective of this paper has been to explore the possible impacts of local public finance policies upon urban sprawl (land-use fragmentation, scatteredness of development). Burchfield et al.[64] presented path-breaking research into the causes of sprawl among U.S. metropolitan areas. Utilizing a subset of their data for which it was possible to match comprehensive information on local public finances, their analysis is extended (though on a smaller scale) to assess the potential influence of local public finance on urban land use.

Using the smaller data set (83 rather than 275 observations), many of the variables that Burchfield et al. found to contribute to explaining the variation in their sprawl indexes across metro areas were not statistically significant in the regressions. However, the percentage of the fringe area overlying aquifers, mean cooling degree-days and latitude appeared as important determinants of the metropolitan-wide sprawl measures (stock-sprawl indexes). Also, population (which is closely related to their streetcar-ridership variable) and the modified population growth measures we introduce add explanatory power. Of particular interest here, property taxes as a percentage of total local taxes was found to be an important variable. User charges (largely for water, sewer and solid waste services) typically lacked or had only low statistical significance but (partly through supplementary analysis) had consistent impacts and indicated influence. Unlike, the Burchfield et al. results, transfers (their sole public finance variable) were found to be unimportant. When seeking to explain sprawl in newly developing areas (the Burchfield et al. flow-sprawl index rather than their stock indexes), public finance variables did not contribute, and more of the Burchfield et al. variables stemming from the monocentric city model played a role.

Local public finance appears to be a determinant of the extent of sprawl in the full metropolitan area. To illustrate, it was assumed the results of the regressions based on data to 1992 applied to more recent features of Calgary and Edmonton. The heavy reliance on property taxation and on user changes in the two cities was estimated to reduce sprawl relative to what it would have been if their public finance mimicked that of the typical U.S. metro region in the data. Overall, the present public finance policies in Calgary and Edmonton were estimated to reduce the measure of sprawl by about one-quarter (more in the case of Edmonton, less in the case of Calgary). That is, the analysis suggests that the percentage of undeveloped land surrounding the average residential development could be one-quarter less due to expanded reliance on property taxes and user charges (i.e., parallel to those in Calgary and Edmonton). About 40 per cent of that change can be confidently attributed to the greater reliance on property taxation — a tax that, compared to local sales and income taxes, imposes a cost on holding (especially undeveloped) land. Sixty per cent of the decrease in sprawl attributable to public finance seems to be related to a greater dependence on user charges. Because of the weak statistical performance of that variable, there is less confidence in this possible effect but, for conceptual reasons and given the consistency of the results, the outcome seems hard to ignore. Although the predicted absolute change was somewhat greater, similar results were realized when Edmonton's public finance features were substituted for the average of those of the 83 U.S. metro areas. Again, sprawl was projected to be reduced by about one-quarter and the 40:60 attributions remained.

The results suggest that local public finance does impact sprawl. While the suggested consequences of user charges outlined here may justifiably be discounted, the sprawl-reducing effects of local property taxes is a strong result. The possible impacts of local public finances should be explored further in future research into the determinants of sprawl.[65]

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[64] Burchfield et al., "Causes of."

[65] This conclusion is reinforced by the diverse results surveyed in Wassmer, "Further Empirical."

APPENDIX

This appendix is to provide additional insight into the impacts of the individual variables and selected combinations of variables upon estimated sprawl values. The calculations are for Calgary and for the Sprawl 1992 index (Equation 4 of Table 5). The effects of nine variables and three groupings (those related to geography/environment, population and public finance) are reported in the table.

Mean cooling degree-days and latitude are the geography-/environment-related variables. The effect of introducing the mean cooling-degree-day value for Calgary upon the sprawl index (when all other variables take the mean value of the 83 U.S. city observations) is to increase the estimated value from 40.6 to 45.0. The effect of introducing latitude of 48 (with all other variables valued at the 83-city average) is to reduce the sprawl estimate to 29.0. Independently, cooling degree-days and latitude have considerable, but opposing, impacts on the estimated sprawl index. Introducing the two Calgary values simultaneously results in an estimated value of 33.2. The combined effect for the two geography/environmental variables implies a considerable reduction in the sprawl estimate from the U.S. average of 40.6.

APPENDIX TABLE IMPACTS ON ESTIMATED SPRAWL INDEX FOR CALGARY RESULTING FROM IMPOSING THE CALGARY VALUE FOR SELECTED VARIABLES

<table>
<tr><th rowspan="2">Influencing Variable</th><th colspan="4">Impacts of Changes on Sprawl Index</th></tr>
<tr><th>Change of Individual Variable</th><th colspan="2">Selected Combined Effects</th><th>Total Combined Impact</th></tr>
<tr><td>Geography/environment</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Mean cooling degree-days</td><td>45.0</td><td rowspan="2">33.2</td><td></td><td rowspan="10">27.6</td></tr>
<tr><td>Latitude</td><td>29.0</td><td></td></tr>
<tr><td>Population (and Calgary geography/environment)</td><td></td><td></td><td></td></tr>
<tr><td>Population growth: recent</td><td>34.7</td><td rowspan="2">32.1</td><td rowspan="3">32.4</td></tr>
<tr><td>Population growth: early</td><td>30.6</td></tr>
<tr><td>Population size</td><td>33.8</td><td></td></tr>
<tr><td>Public finance (and Calgary geography/environment)</td><td></td><td></td><td></td></tr>
<tr><td>Property tax as percentage of total taxes</td><td>31.0</td><td rowspan="2">26.0</td><td></td></tr>
<tr><td>Charges as percentage of total taxes</td><td>28.2</td><td></td></tr>
</table>

Note: See Table 10 for values used in the calculations.

The population-related variables appear next in the table. To indicate the impacts of these variables in the context of Calgary (and as reported in Table 9), the estimated values assume the Calgary geography/environment conditions apply. Thus, comparisons should be made to the 33.2 estimate derived above. Rapid recent (i.e., over the 15 years 1999 to 2014) population growth at the Calgary level has a quite modest positive impact on the sprawl estimate, increasing it to 34.7 from 33.2. Rapid earlier population growth (from 1984 to 1999), followed by an average level in the more recent period, reduces sprawl with the estimate falling to 30.6. The combined effects of the rapid population growth in both periods as occurred in Calgary results in an estimate of 32.1. The effect of Calgary's population being smaller than the average of the U.S. cities has a positive effect on the estimate, increasing it to 34.8 from 33.2. Taking the Calgary population growth and size characteristics together generates an estimate of 32.4, which is only slightly different than the 33.2 values estimated without introducing those changes. The population factors have some influences on the estimated sprawl but the effects are relatively minor.

The impacts of the public finance variables are reported at the bottom of the table. Again, Calgary geographic/environmental conditions are imposed but, other than the specific variables being investigated, the others are set at their 83-U.S.-city means. Imposing the level of Calgary property taxes generates an estimated Sprawl 1992 index value of 31.0, a drop of 4.2 from 33.2. Imposing the Calgary level of charges (but the U.S. level of property taxes) yields a larger decrease with an estimate of 28.2. If both the Calgary levels of property taxes and charges are introduced, the estimated combined effect is a Sprawl 1992 value of 26.0; a 22-per-cent reduction from 33.2.

Combining the Calgary characteristics for geography/environment, population, and public finance, the estimated value is 27.6 (as reported in Table 9). The bulk of the drop in the estimated sprawl-index value from 33.2 is due to Calgary's public finance. That is, the greater reliance on property taxes and on charges in Calgary than in the average of the 83 U.S. cities is predicted to reduce sprawl.

About the Author

Melville L. McMillan is a Professor Emeritus in the Department of Economics and a Fellow of the Institute of Public Economics at the University of Alberta. He served as Chair of the Economics Department from 1987 to 1997. His BA and MSc are from the University of Alberta and his PhD is from Cornell University. He was on the faculty of the University of Wisconsin (Madison) before joining the University of Alberta in 1975. McMillan's research and teaching interests are in public economics and, in particular, urban and local economics, fiscal federalism, and the demand for and supply of public goods and services. These interests were the focus of his research while on leaves at the Australian National University, Canberra and at the University of York, England. He has published extensively in these areas and has also advised governments and organizations nationally and internationally (e.g., the World Bank). From 1994 to 2011, he served as a faculty association representative on the Sponsors Working Group of the Universities' Academic Pension Plan. Although "retired", Melville McMillan remains actively involved in academic and policy matters and is usually found in his office in the Department of Economics. Further details are available at https://sites.google.com/a/ualberta.ca/mel-mcmillan/.

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The School of Public Policy
University of Calgary, Downtown Campus
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Calgary, Alberta T2P 1H9
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