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Economies of Scale in Fire and Police Services in Ontario

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UNIVERSITY OF TORONTO

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Economies of Scale in Fire and Police Services in Ontario

Adam Found

Abstract
This paper analyzes economies of scale for two municipal services by considering how per-household municipal costs are affected by a municipality's size. An econometric model is used to estimate costs associated with fire and police services using data for 445 municipalities in the Province of Ontario. The results show that the costs per household of fire services are minimized for municipalities with a population of about 20,000 residents. For police services, costs are minimized with a population of about 50,000 residents. Based on these results, implications are drawn for municipal amalgamation policy.

Keywords: municipal finance, police services, fire services, economies of scale
JEL codes: H11, H72

Economies of Scale in Fire and Police Services in Ontario

1. Introduction

Municipal amalgamation has touched almost every municipality in Ontario. Between 1991 and 2001, hundreds of municipalities were amalgamated, reducing the number from 839 to 448. At the time, the provincial government openly sought the reduction in the number of municipalities as a policy objective in itself (Bish 2001; Sharma 2003). Some amalgamations were forced directly, whereby the province imposed amalgamation either by special legislation or by delegating sweeping powers to single-person restructuring commissions (Sancton 2000). In other cases, amalgamation was initiated locally to avoid the more contentious and extensive amalgamation forced by the province (Downey and Williams 1998).

A consistent justification cited by provincial politicians, bureaucrats, and restructuring commissioners and advisors for forcing municipal amalgamations in Ontario was the promise of cost savings resulting from economies of scale.[1] Such predictions, however, were largely based on anecdotes, unsubstantiated assertions, and vague accounting analyses rather than econometric or research-based evidence (Armstrong and Kitchen 1997; Farrow 1999; Kitchen 2000; Meyboom 1997; O'Brien 1999; Shortliffe 1999; Thomas 1999). Since Ontario's municipalities spend about 5.5 percent of the provincial GDP, there is a public policy interest in examining municipal economies of scale to gain a sense of the extent to which cost savings from amalgamation have materialized in Ontario.

This study examines the extent to which economies of scale are present for two critical municipal services that together constitute more than one-fifth of municipal operating budgets in Ontario: fire and police. I have used the current variation in the size of Ontario's municipalities to estimate the relationship between per-household costs and the number of households served. The cost curves for both fire and police costs are U-shaped—that is, there is a particular population size at which these services can be provided at lowest cost per household, referred to as the minimum efficient scale. For fire services, costs per household are minimized at 9,000 households (or about 20,000 residents), while for police services they are minimized at 21,000 households (about 50,000 residents).[2]

1. Economies of scale in the classical sense relate to *technical economies*, and are concerned with the relationship between average costs and output. In contrast, economies of scale in the population sense are referred to as *population economies*, and are concerned with the relationship between per-capita costs and population. Although apparently not explicitly established in the literature, it turns out that, in the context of congestible local public goods (e.g., municipal services) where population and output are directly linked, these two notions of economies of scale are equivalent. A proof of this results is beyond the scope of this paper, but it means that the present study can accord with the literature by taking the population economies route to economies of scale.
2. According to Statistics Canada's 2011 Census, the average household in Ontario contains 2.4 residents. This figure is used to convert the household numbers into populations rounded to the nearest 5,000 mark.

2. Literature Review

The literature on estimating municipal economies of scale can be broken into two somewhat overlapping groups: studies that omit output measures and those that employ fully parametric models.

Three studies that focus on Ontario—Bodkin and Conklin (1971), Kushner et al. (1996), and Jerrett et al. (2002)—rely on fully parametric modelling of the cost for various Ontario municipal services. These studies found that municipal services are subject to either constant returns to scale (scale efficiencies are neither lost nor gained as population increases) or diseconomies of scale. In addition, these studies do not include output measures in their analyses, which can bias the main estimates.

Several recent U.S. and other studies have estimated the extent of economies of scale in local government, but only with fully parametric models that do not include measures of output. Benton and Gamble (2003) focused on the merger of the City of Jacksonville and the County of Duval in Florida and used time-series data to conclude that the merger led to higher expenditures and taxes, assuming that service levels remained unchanged after the merger. Couch et al. (2004) found that duplication has not been wasteful for Alabama municipalities, and that economies of scale were essentially non-existent.

While considering two-tier local government structures in England, Andrews and Boyne (2009) found that municipal administration is subject to extensive economies of scale and recommend municipal amalgamation into unitary (single-tier) governments. Holcome and Williams (2008) analyzed 487 American municipalities with populations over 50,000 and found that, while density has a significant effect on costs, municipalities essentially operate under constant returns to scale. Hendrick, Benedict, and Lal (2011) found that local government expenditures tend to rise with both vertical fragmentation (an increase in the number of government tiers) and centralization (a decrease in the number of local governments for a given geographic population). However, a comprehensive literature review by Byrnes and Dollery (2002) found that results are very mixed.

A few studies have analyzed economies of scale for fire and police services. These studies employ parametric models, but incorporate variables for levels of output (that is, service levels). Duncombe and Yinger (1993) studied the fire departments of municipalities in the State of New York and used output measures such as dollar loss due to fires and the number of emergency calls. They concluded that fire services are subject to constant returns to scale.

Gyimah-Brempong (1987), Finney (1997), and Southwick (2005) studied municipal police departments in the State of Florida, Los Angeles County, and the State of New York, respectively. All three studies used methods similar to Duncome and Yinger (1993) and included police output measures such as number of arrests, crime rates, and motor vehicle accidents. The first two studies concluded that policing is subject to diseconomies of scale, while the third study found that policing is most efficiently provided to populations in the range of 22,000 to 36,000 residents.

Although he did not study municipal services per se, Yatchew (2000) found that local electricity distribution in Ontario exhibits a cost-per-customer curve that is "bathtub"-shaped. That is, there is a considerable range in the number of customers who can be served cost-effectively. This range begins at about 20,000 customers, so once at this size an electricity distributor has exhausted all available economies of scale. In particular, the largest utility in the sample—Toronto Hydro, with approximately 688,000 customers—was found to be the most inefficient in the province. Even though electricity distribution is not a municipal service in Ontario, Yatchew (2000) is relevant in that his econometric approach is adopted by this paper for municipal services.[3]

In summary, a review of the literature raises two main issues:[4]

1. Omission of Service Levels: Measures of municipal service levels have been omitted from all Ontario-based studies and most other studies estimating municipal economies of scale, which may lead to estimation bias in the results. Including such measures, however, means dealing with difficulties in defining municipal output, identifying measures of municipal output, and acquiring data on such measures.
2. Imposition of Parametric Specifications: In principle, the per-capita or per-household cost curve may exhibit any profile, not necessarily a curve that implies a single, unique cost-minimizing population. By comparison, past studies on municipal economies of scale using fully parametric models have assumed particular cost curve profiles, thereby limiting the range of results obtained.

The present study explicitly includes some measures of service levels to strengthen the analysis. If service levels (such as response times or crime rates) and population are correlated, then an econometric analysis that omits service levels is unlikely to reveal the pure impact of population size on per-capita costs. There are various possible explanations for this correlation. For instance, if residents with strong preferences for low emergency response times tend to live in large cities, higher fire service costs would be observed for larger municipalities. By omitting response-time data on fire services,

3. In Ontario, local electricity distributors are independent corporations typically owned at least in part by local municipalities. In this sense, local electricity distribution (a private good) is interpreted as a non-municipal service, meaning that Yatchew (2000) is not viewed here as a study of municipal economies of scale.

4. There are two additional but relatively peripheral issues with regard to the literature. First, municipalities may not operate in the same way as profit-maximizing firms. Estimating the cost of service provision for an economic entity is meaningful only if we are satisfied that the entity faces a problem to which the solution is cost-minimizing behaviour (that is, technical efficiency). Otherwise, we remain uncertain as to what exactly is being estimated. Second, municipal economies of scale are conceived in terms of per-capita cost rather than the average cost of output, without any comprehensive rationale for why the two conceptions may be equivalent. Although addressing these issues directly is beyond the scope of this paper, it is worth noting that they can be addressed by applying yardstick competition theory and club theory (in the context of a congestible club good subject to economies of scale), respectively.

previous analyses would have attributed these higher costs to diseconomies of scale, whereas they may reflect superior fire services.[5]

With respect to the second issue, it cannot necessarily be assumed that costs per capita have a single optimal point (that is, a precise population at which costs per capita are minimized). For instance, the curve representing costs per capita may be "bathtub"-shaped, exhibiting constant returns to scale over a large range of population. This paper follows Yatchew (2000) in that the analysis may, in principle, capture a wide range of cost-per-capita curves. This approach should confirm whether a fully parametric model sufficiently captures the relationship between per-capita costs and municipal size.

Finally, virtually all studies analyze economies of scale with respect to *operating* costs only, and omit *capital* costs such as those for building, vehicle, and infrastructure investments. Although the quantity of capital is not needed to estimate costs, data on the price of capital and its condition are needed.[6] The exclusion of capital costs in other studies is due to a widespread lack of data on the condition and amount of capital accumulated by municipalities. Indeed, this study faces the same problem, and thus adopts the prevailing practice of focusing on operating costs.

3. The Structure of Ontario's Municipalities

In Ontario, municipalities are classified as lower-tier, upper-tier, or single-tier. It is important to understand the nature of and major differences among these types of municipal structure. The *Municipal Act* provides for a general demarcation of municipal services between upper- and lower-tier municipalities, in which each upper tier federates a unique set of constituent (geographically contained) lower-tier municipalities.[7]

Out of the 444 municipalities in Ontario, 241 are lower tiers, 30 are upper tiers, and 173 are single tiers.[8] In northern Ontario, all municipalities are single-

5. The question of what constitutes service quantity and quality remains open and commonly unaddressed in the literature. With output often characterized as complex and multi-dimensional, consensus on its definition is unlikely to be reached, since any particular definition of municipal output is usually incomplete.

6. The condition of a municipality's capital stock will likely impact operating costs to the extent capital and operating inputs are substitutable and linked.

7. The *Municipal Act* rules out the possibility of an upper-tier municipality with only one constituent lower tier; a lower-tier municipality that belongs to more than one upper-tier municipality; and an upper-tier municipality within which there is an area that is not within the jurisdiction of a lower tier.

8. Since 2001, when the number of municipalities stood at 448, (i) the Township of Dack and the Town of Charlton amalgamated on January 1, 2003, to form the Municipality of Charlton and Dack, (ii) the Town of New Liskeard, the Town of Haileybury, and the Township of Dymond amalgamated on January 1, 2004, to form the City of Temiskaming Shores, and (iii) the Township of Gordon and the Township of Barrie Island amalgamated on January 1, 2009, to form the Township of Gordon–Barrie Island. These voluntary amalgamations have brought the total number of municipalities down to the current 444. However, since the last-mentioned amalgamation occurred after 2008, the 2005–2008 dataset used for the present study has a total of 445 municipalities.

Table 1: Distribution of Municipal Structure

Group	Sub-Group	Count
All Municipal Structures	Lower Tier	241
	Upper Tier	30
	Single Tier	173
Lower-Tiers	Within a Region	43
	Within a County	198
Upper-Tiers	Region	8
	County	22
Single Tiers	In Northern Ontario	144
	In Southern Ontario	29

tier municipalities. Table 1 outlines how municipal structure is distributed across Ontario's municipalities.

The *Municipal Act* generally delegates services of a regional nature such as public health and arterial roads to upper-tier municipalities, and services of a local nature such as fire protection and zoning to lower-tier municipalities. It turns out this demarcation is such that an upper tier spends an amount roughly equal to the aggregate expenditure of its constituent lower-tier municipalities. An upper tier together with its constituent lower-tier municipalities constitutes a two-tier municipal system.

Lower-tier municipalities are usually called Village, Township, Town, City, or Municipality, and each one is federated with neighbouring lower-tier municipalities under a unique upper-tier municipality. Examples include the Village of Oil Springs, the Township of East Hawkesbury, the Town of Oakville, the City of Owen Sound, and the Municipality of Leamington.[9]

Upper-tier municipalities are either a county, such as the County of Lennox and Addington, or a regional municipality, such as the Regional Municipality of Halton. Counties and regional municipalities (or simply "regions") have different legal powers and responsibilities.[10] Legislatively, regions have a greater scope of

9. Historically, a city by definition was automatically a single-tier municipality. However, the creation of regional municipalities as upper tiers in the late 1960s and early 1970s meant that cities within their boundaries became lower-tier municipalities, causing them to give up about half of their responsibilities to regional government. Such cities remained the only cities with a lower-tier structure until three exceptions developed in the 1990s: The City of Sarnia became part of the County of Lambton (1991); the City of Clarence-Rockland was formed by the amalgamation of lower tiers in the County of Prescott and Russell and inherited the lower-tier status of the amalgamating municipalities (1998); and the City of Owen Sound became part of the County of Grey (2001).

10. There are two exceptions. The District of Muskoka and the County of Oxford are the legal equivalents of a regional municipality.

power and responsibility than do counties. A defining feature of regional municipalities is that they always contain cities as constituent municipalities, whereas counties do not, except in rare cases.

Overlap occurs within a two-tier system if the upper tier provides a municipal service that is also provided by at least one of its constituent lower tiers; that is, upper and lower tiers are given joint responsibility for a service under the *Municipal Act*, or there is delegation of responsibility for a service between the upper tier and a subset of its lower tiers. This sort of overlap is not uncommon for general government services, libraries, planning, and waste management.

Lower tiers may choose to delegate authority to the upper tier, in which case upper-tier provision of a delegated service is exclusive to households within the delegating lower tier. Given this type of overlap, standard financial reports may not accurately reflect the number of households actually served. This problem is most apparent if an upper tier is delegated authority to provide a service by only a few of its constituent lower tiers, so that the upper tier's financial reports overstate the number of households served. Fortunately, there is no service overlap for fire or police services within any two-tier system in Ontario—one good reason to focus on these two services.

Single-tier municipalities are responsible for providing the entire spectrum of municipal services to residents, and thus their expenditures are generally twice those of comparable upper or lower tiers. Single-tier municipalities are not federated under an upper-tier municipality, although they may be geographically surrounded by an upper-tier municipality or by one or more other single-tier municipalities.[11]

Single-tier municipalities may be called Village, Town, Township, City, County, or Municipality. Examples are the County of Prince Edward, the City of Pembroke, and the Municipality of Whitestone. Northern Ontario has only single-tier municipalities, loosely federated in very large geographic areas known as districts. A district is not a municipality, and serves only as a resource-pooling agent for soft regional services such as public health and social assistance. There are no corresponding districts in southern Ontario.

4. Municipal Amalgamation Policy in Ontario

Within Ontario's history, two distinct waves of municipal amalgamation can be identified. These waves are summarized in Table 2.

During the latter half of the second amalgamation wave, various provincial responsibilities (and their costs)—such as court security, social services, social housing, provincial offences administration, rural policing, certain provincial highways, and property tax rebates for the farmland property class—were reassigned to municipalities. This move was officially dubbed "Local Services

11. A single-tier municipality may be surrounded by a county or by a number of counties and/or other single tiers.

Table 2: Ontario Municipal Amalgamation Waves

Wave	Description
First Wave (1953–1974)	Metropolitan Toronto was created in 1953. Twelve additional regional municipalities were created between 1968 and 1974. Except for Metropolitan Toronto, all regional municipalities were created using the boundaries of former counties.[12] The creation of regional governments resulted in mergers at the lower-tier level and the incorporation of previously separated cities into the new regional two-tier systems as lower tiers. There was also a transfer of greater municipal responsibility to the new upper tiers.
Second Wave (1991–2001)	Hundreds of Ontario's municipalities were amalgamated, reducing the number of municipalities in the province from 839 to 448. Many of these mergers were imposed by the Province itself. Others were forced indirectly, whereby amalgamation was initiated locally to avoid an amalgamation directly forced by the province. In this wave, a number of upper tiers were completely amalgamated with their constituent municipalities to form mega city-regions or city-county single tiers.[13]

Realignment" and was a commonly cited justification for forcing municipal amalgamations. The Province claimed that small municipalities would lack the necessary fiscal capacity to take on these new responsibilities effectively and efficiently, even though for two-tier systems they were largely reassigned to upper tiers rather than the much smaller lower tiers.[14]

As Local Services Realignment coincided with many of the amalgamations, it would be extremely difficult to determine the fiscal impact of amalgamation with before-and-after analysis. This difficulty is exacerbated because of the lack of data on service levels before amalgamation and because several amalgamations occurred in mid-year. Hence, an empirical strategy to identify the effects of amalgamation by directly comparing merged municipalities before and after amalgamation is not readily apparent. Such a strategy would allow researchers to

12. The exception is the District of Muskoka, which was not previously a county.

13. In the case of the Municipality of Chatham-Kent (1998), the separated (single-tier) City of Chatham was merged with the County of Kent and its constituent lower-tier municipalities. Also, when the Regional Municipality of Haldimand-Norfolk was restructured, all lower-tier municipalities were dissolved and the former Counties of Haldimand and Norfolk were recreated, but as single-tier counties.

14. Amalgamating an upper tier with its constituent lower tiers clearly does not change the scale nor tax base on which an upper-tier service is provided. With respect to the provincial services downloaded onto upper tiers, total amalgamation of two-tier systems would not affect scale efficiency nor the extent of the tax base, so it interesting to note that the most radical amalgamations forced by the province occurred in two-tier systems, many of which were heavily urbanized by population.

estimate the effect of amalgamation on costs directly, rather than having to infer this effect by estimating per-household cost curves using the current variation in the size of municipalities left by the 1991–2001 amalgamations.

Between 1995 and 2001, laws were passed by the provincial government that led to the amalgamation of hundreds of municipalities. The first was the *Savings and Restructuring Act*, which contained a so-called "single municipality trigger" for municipal restructuring. The effect of this legislative feature was that the municipal amalgamation process for an entire two-tier system could be irreversibly set in motion by the request of just one member municipality of that system. Once such a request was made, a restructuring commissioner was appointed by the provincial government without local input or consent, and was delegated sweeping powers to override the will of locally elected municipal councils.[15]

The second major piece of restructuring legislation was the *City of Toronto Act*, which was specifically drafted to amalgamate the Municipality of Metropolitan Toronto with its six constituent municipalities to form the single-tier (new) City of Toronto, referred to at the time as the "megacity." This imposed amalgamation remains the largest municipal amalgamation in Canadian history; it faced extensive and bitter public opposition and filibustering in the Ontario Legislature throughout 1997, during the lead-up to amalgamation.

The Ontario Legislature also passed the *Fewer Municipal Politicians Act*, which led to the provincial appointment of special advisors to study and report on restructuring alternatives for four regional municipalities: Sudbury, Ottawa-Carleton, Hamilton-Wentworth, and Haldimand-Norfolk. By early 2000, each of the four special advisors filed reports recommending complete amalgamation of these regions into large single-tier municipalities. These recommendations were accepted and implemented by the province without local consent, creating the single-tier municipalities of the City of Greater Sudbury, the (new) City of Ottawa, the (new) City of Hamilton, the County of Haldimand, and the County of Norfolk.

Underlying these restructurings were the policy objectives held by the provincial government at the time. These objectives were advanced as justifications for implementing municipal amalgamations without local consent, and were reflected in the terms of reference of restructuring commissioners and special advisors on restructuring. The policy objectives were based on assuming or asserting that fewer and larger municipalities would:

- Reduce municipal bureaucracy and inefficiency, and make municipal governance more streamlined and effective;
- Realize cost savings from economies of scale (e.g., by reducing duplication and overlap in service provision);

15. For example, the *Savings and Restructuring Act* was used in 1997 to amalgamate the County of Kent with its 21 constituent municipalities, along with the separated City of Chatham, to form Ontario's first city-county single-tier municipality: the Municipality of Chatham-Kent.

- Provide clear lines of accountability by capturing costs and benefits within the same jurisdiction;
- Accommodate provincial downloading by pooling assessment, increasing fiscal capacity, and creating "strong" or "viable" municipalities.

Provincial officials, bureaucrats, consultants, restructuring commissioners, and special advisors typically stated that cost savings arising from economies of scale were a justification for implementing and forcing municipal amalgamations. All of the reports of restructuring commissioners and special advisors contained sections dedicated to quantifying cost savings predictions; however, these sections were often vague about how the cost savings would actually be achieved by the amalgamated municipality.

By 2002, all municipal restructuring law was eventually consolidated into the *Municipal Act*. Potent features such as the single municipality trigger were removed, and shortly thereafter the provincial government announced it would no longer impose amalgamations. Under the current legislation, a necessary condition for obtaining provincial approval of locally initiated municipal restructuring is the express consent of all the affected municipalities through their elected councils.[16] Under the *Municipal Act*, Ontario Regulation 216/96 outlines the types of municipal restructuring the province is willing, as well as unwilling, to consider. One ominous clause in the regulation states that the province will not consider "a restructuring that results in an increase in the number of local municipalities." Although the term "municipal restructuring" in principle encompasses several possible types of reform, it is clear that municipal restructuring in Ontario has been, and continues to be, a one-way street in the direction of fewer and larger municipalities.

In Ontario and other jurisdictions, municipal restructuring has become synonymous with amalgamation in much the same way that "fiscally strong" municipal government has become synonymous with "large" municipal government. Indeed, such equivalencies continue to be asserted by policymakers and restructuring officials. This study tests the validity of such assertions.

5. Econometric Model

I have adopted the methods used by Yatchew (2000), who estimated economies of scale in Ontario's local electricity distribution industry. The approach he used can

16. For example, a locally initiated referendum was held during the October 2010 Ontario municipal election on whether or not the neighbouring cities of Kitchener and Waterloo should formally undertake "amalgamation discussions." The referendum passed with a 2:1 margin in Kitchener, but lost by the same margin in Waterloo. The fact that Waterloo is assessment-rich compared to Kitchener, so that a merger would have shifted taxes off Kitchener residents and onto Waterloo residents to maintain service levels, may have played a role in the referendum results. Since Waterloo has rejected amalgamation with Kitchener, the current provincial government's policy is not to force an amalgamation.

capture a range of scale effects, such as one in which per-customer costs fall initially, but then rise after some threshold number of customers are served.[17] Since we do not know the shape of the curve for per-household costs in advance, it is ideal to allow for the possibility of various shapes, including flat, linear, and other profiles.

Implementation of the Yatchew (2000) model follows a two-step procedure tailored to the present study.[18] First, the collective effect of output and other non-scale variables that could affect costs (see Table 3) is removed from the cost-per-household variable, leaving a residual variance in the cost-per-household variable that cannot be explained by the non-scale variables.[19] Second, this residual variance is regressed non-parametrically on the scale variable (the number of households), permitting the scale effect to be determined without imposing any functional form or profile onto the resulting curve. For more detail on Yatchew's method, please see Appendix A.

Below is the econometric model tailored to each of the two municipal services considered, where the subscripts are defined as m = municipality, f = fire, and p = police. Definitions of each of the variables (without the subscripts) are shown in Table 3.

$$\begin{aligned}\ln C_{fm} &= f_f(\ln H_m) + \beta_{1f}\ln D_m + \beta_{2f}\ln W_{fm} + \gamma_{1f}ST_m + \gamma_{2f}North_m + \delta_{1f}\ln Calls_m \\ &\quad + \delta_{2f}\ln Response_m + \delta_{3f}FT_m + \delta_{4f}V_m + \delta_{5f}\ln Income_m + e_{fm}\end{aligned}$$

$$\begin{aligned}\ln C_{pm} &= f_p(\ln H_m) + \beta_{1p}\ln D_m + \beta_{2p}\ln W_{pm} + \gamma_{1p}ST_m + \gamma_{2p}North_m + \delta_{1p}\ln Crime_m \\ &\quad + \delta_{2p}\ln Accidents_m + \delta_{3p}\ln Income_m + e_{pm}\end{aligned}$$

As shown in Table 3, the model includes non-scale variables that have potential impacts on costs, capturing differences across municipalities that may or may not be related to municipal size. For example, the household density of a municipality can have an effect on service costs, because dense and congested cities may face longer emergency response times, more difficulty in locating and capturing criminals, or a higher risk of the spread of fire between neighbouring structures. Also, wages are included, because they directly affect the costs of service provision. I have included an indicator for single-tier status to capture the effect of providing both regional and local municipal services as opposed to providing just one set or the other. I have also included an indicator for being

17. Yatchew (2000) used a semi-parametric, partial-linear model.

18. In a partial-linear model, all variables affecting municipal costs per household (the dependent variable) are assumed to have a linear relationship with those costs, except for the number of households (the scale variable).

19. Population for this study is measured by number of households for statistical analysis. Thus, the terms "population" and "households" are largely interchangeable, as are the terms "per capita" and "per household."

Table 3: Variable Definitions

Variable	Definition
C	Operating costs per household
H	Number of households
f(H)	Non-parametric scale effect
D	Household density (households/km^2)
W	Hourly wage for civil servant
ST	Indicator for single-tier status
North	Indicator for being located in northern Ontario
Calls	Number of emergency calls for fire services per household
Response	Average response time for fire services
FT	Indicator for being a full-time fire department
V	Indicator for being a volunteer fire department
Crime	Number of criminal offences per household
Accidents	Number of vehicular accidents/collisions per household
Income	Average household income

located in northern Ontario because materials and other inputs tend to cost more in northern Ontario, given higher transportation costs.

For fire services, the specific output measures used are emergency calls per household and average response time. Emergency calls for fire services are made through Ontario's 911 system, and the Office of the Fire Marshal requires municipalities to record data for each call. Calls may pertain to fires, explosions, gas leaks, vehicle extrication, medical resuscitation, and those eventually deemed false alarms. Municipalities are also required to record the response time achieved by their fire department for each emergency call, measured as the number of minutes elapsed between when the fire department is notified of (that is, dispatched to) an emergency and when fire trucks or other responding resources first arrive on the scene. Accordingly, more emergency calls per household and lower response times will represent higher service levels delivered.

The composition of a fire department (e.g., full-time, volunteer, hybrid) is considered here as a proxy for unavailable output variables. For instance, full-time fire departments are better able to deliver dispatch, public education, and fire prevention services compared with volunteer fire departments. A fire department is classified as "full-time" if all of its firefighters are either full- or part-time employees, "volunteer" if all of its firefighters are employed as volunteer, and "hybrid" if a combination of full-time, part-time, and volunteer firefighters are employed.[20] Given the differences between full-time and volunteer fire

20. In Ontario, firefighters are volunteers if they are not compensated for 24/7 standby services; however, they are usually compensated on an hourly basis for training and for each emergency call to which they respond.

departments, indicator variables on fire department composition are included to capture service level differences.

There are two output variables for police services: crime rates and vehicle collisions on public roads. The level of crime in a municipality affects policing costs, and a stronger criminal presence will likely mean the need for a stronger police presence to provide community safety (although crime rates are at least partly affected by policing costs). The crime rate is, in a sense, a composite proxy for various types of policing output (e.g., beat patrols, traffic stops, crime prevention activities, etc.), data for which are not readily available—the higher the incidence of crime, presumably the greater the level of policing output required. Similar to the effect of calls for fire service, the number of police-reported vehicle collisions on municipal roads is expected to affect policing costs.

Municipal output is difficult to define completely, so these primary output measures may be seen as deficient. I have therefore included a general proxy for municipal output to mitigate any deficiencies in the primary output measures. Since municipal output is at least partly driven by local demand, which in turn depends on local wealth, average household income is included as an explanatory variable to help capture features that may be underrepresented or missed by the primary output measures.

6. Municipal Data

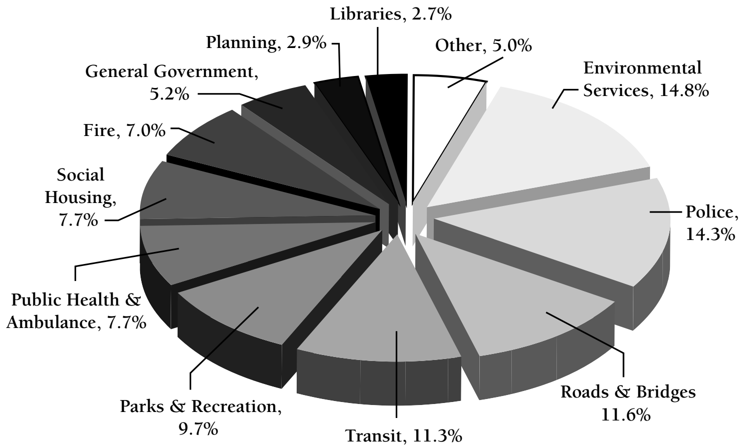
I chose to study fire and police services in particular because these services are uniformly defined across service-providing municipalities, there is a direct connection between costs and population served (especially as congestion sets in), responsibilities are clearly assigned within two-tier systems, and service level data are readily available. Moreover, these services together account for more than 20 percent of municipal operating costs in Ontario, as indicated in Figure 1.[21]

Data have been assembled for the 445 municipalities in Ontario that existed between 2005 and 2008 and averaged over the four years by municipality.[22] The data are from the Ministry of Municipal Affairs and Housing, the Office of the Fire Marshal (Ontario), the Ministry of Finance, the Ministry of Transportation, and Statistics Canada. Table 4 summarizes the constituent data used to form the variables appearing in the model, as well as the corresponding sources.

21. Social assistance is excluded from the total operating expenditure base, as the costs are currently being phased in as an upload to the provincial government. The phase-in is scheduled to be completed in 2018. Environmental services are composed of water, wastewater, and waste management. The Ministry of Municipal Affairs and Housing defines general government services as governance services (councillors, council support, elections, etc.) and corporate management services (city manager, budgeting, taxation, etc.).

22. Like many other public-sector organizations and institutions dominated by the budgetary process and relatively insulated from economic shocks, municipalities do not dramatically change financial course over time. Data averaged over four years paints a reasonably accurate picture of the state of a municipality's finances.

Figure 1: Municipal Operating Costs in Ontario



The Ministry of Municipal Affairs and Housing requires municipalities to submit standardized financial information returns and performance measurements annually. These reports contain information on total service costs, labour costs, households, municipal structure, geographic location, and criminal offences.

The Office of the Fire Marshal requires fire departments to file annual reports on departmental characteristics (e.g., firefighter staffing) and quarterly reports on

Table 4: Constituent Data Summary

Description	Source
Operating Costs	Ministry of Municipal Affairs and Housing
Number of Households	
Labour Costs	
Municipal Structure	
Geographic Location in Ontario	
Criminal Offences	
Firefighter Staffing	Office of the Fire Marshal
Emergency Fire Calls	
Average Fire Response Time	
Fire Department Type	
Household Income	Ministry of Finance
Vehicular Accidents	Ministry of Transportation
Land Area in km^2	Statistics Canada
Police Officer Staffing	

incidents requiring emergency response (including data used to calculate response times). Staffing levels are divided into total labour costs to obtain average wage rates for firefighters using weights of 0.24 and 0.18 for part-time and volunteer positions, respectively.[23] The Office of the Fire Marshal's dataset contains data on the number of annual emergencies responded to and the corresponding annual average response time.

As with fire services, police officer staffing levels are divided into total labour costs (reported in the financial information returns) to generate average wages. Households are divided into the number of criminal offences to obtain crime rates per 1,000 households.

Rather than using conventional population statistics (that is, the total number of residents), I have chosen to use the number of households to measure municipal size. Municipalities tend to report their population according to the most recent census (2005 for these data). Many municipalities used their 2005 population for reports from 2005 through 2008, so the population information is often out of date. By comparison, the Municipal Property Assessment Corporation tracks annual changes in the number of households in each municipality as it must continuously update the assessment roll for every municipality, a service critical to maintaining the provincial property tax system. Therefore its numbers are more accurate and up to date. According to Statistics Canada's 2011 Census, the average household in Ontario contains 2.4 residents.

The Ministry of Municipal Affairs and Housing disaggregates the expenditures detailed in the financial information returns into the following standardized categories:

1. Salaries, wages, and employment benefits
2. Long-term debt charges in terms of interest
3. Materials
4. Contracted services
5. Rents and financial expenses
6. Long-term debt charges in terms of principal
7. Transfers to own funds (transfers from the revenue fund to other funds)
8. Inter-functional adjustments (internal transfers that sum to zero in the aggregate)
9. Allocation of program support (allocation of overhead costs to each function)
10. Amounts for unfunded liabilities

According to the Ministry of Municipal Affairs and Housing, the definition charges (interest and principal) and transfers to own funds. This is therefore the definition adopted here.

23. These are the standard full-time equivalent (FTE) weights applicable to these positions (Brad Patton, Fire Chief of the Township of Centre Wellington, 2011).

Table 5: Number of Households					
Municipalities	Count	Mean	Std. Dev.	Min.	Max.
Lower Tiers	241	9,334	20,380	192	222,800
Upper Tiers	30	75,691	90,156	13,610	380,000
Single Tiers	174	15,612	85,504	48	1,052,945
All Municipalities	445	16,262	62,737	48	1,052,945

Table 6: Land Area (km²)					
Municipalities	Count	Mean	Std. Dev.	Min.	Max.
Lower Tiers	241	363	259	2	1,474
Upper Tiers	30	2,916	1,375	967	7,382
Single Tiers	174	387	587	2	3,201
All Municipalities	445	544	837	2	7,382

Table 7: Fire Costs Per Household					
Municipalities	Count	Mean	Std. Dev.	Min.	Max.
Lower Tiers	227	$144	$90	$36	$502
Single Tiers	151	$167	$97	$26	$438
All Municipalities	378	$153	$93	$26	$502

Table 8: Police Costs Per Household					
Municipalities	Count	Mean	Std. Dev.	Min.	Max.
Upper/Lower Tiers	30	$562	$82	$389	$722
Single Tiers	29	$620	$133	$363	$933
All Municipalities	59	$591	$113	$363	$933

Tables 5 to 8 show the averaged data for 2005 to 2008. Within any given two-tier system, fire services are provided only by lower-tier municipalities, while police services may be provided either by the upper or the lower tiers.[24] For fire and police operating costs (Tables 7 and 8), only the municipalities for which the requisite data for analysis is complete are summarized.

24. Except for the County of Oxford (which is legally equivalent to a regional municipality), all regional municipalities provide policing. Out of Ontario's 22 counties, only the County of Wellington and the County of Stormont, Dundas, and Glengarry have been delegated policing responsibility by their lower-tier municipalities.

Only those municipalities served by a local police force are included in the police analysis. Municipalities served by the Ontario Provincial Police (OPP) are excluded because the OPP is engaged in policing at the provincial level rather than the municipal level. In addition to its hundreds of municipal policing contracts, the OPP polices provincial highways, waterways, government buildings, native reserves, and casinos, and deals with large-scale issues such as organized crime and terrorism. The OPP also provides specialized services and assistance (e.g., forensic analysis, air support, emergency management, cold case review, etc.) to municipal police forces when the need arises. Moreover, the *Police Services Act* requires the OPP to heavily discount payable rates for municipalities meeting certain criteria and even requires the OPP to provide policing free of charge to certain municipalities. Since the OPP operates in a way that is completely different from that of local police forces, municipalities procuring its services have been excluded from the police analysis.

7. Results

The results for each service are shown in Figures 2 and 3, where the graphs show cost per household on the vertical axis and a logarithmic scale for the number of households on the horizontal axis (the logarithmic scale is used to narrow the wide range of municipal size). These graphs plot (i) the residualized cost for each municipality once the non-scale effects are removed, (ii) the per-household cost curve non-parametrically fitted to these residualized costs, and (iii) an alternative quadratic curve representing a parametric quadratic model (the conventional type of model typically used in the literature).

The estimates of the coefficients for both the partial-linear model and the quadratic model as well as confidence bands for the partial-linear model's cost curves are provided in Appendix B. The presence of economies of scale has been checked using the V-statistic and the competing quadratic model has been tested against the partial-linear model using a V-test. The V-test determines whether the quadratic model can fit the data as well as the partial-linear model. The V-statistic and the V-test are defined in Appendix B.

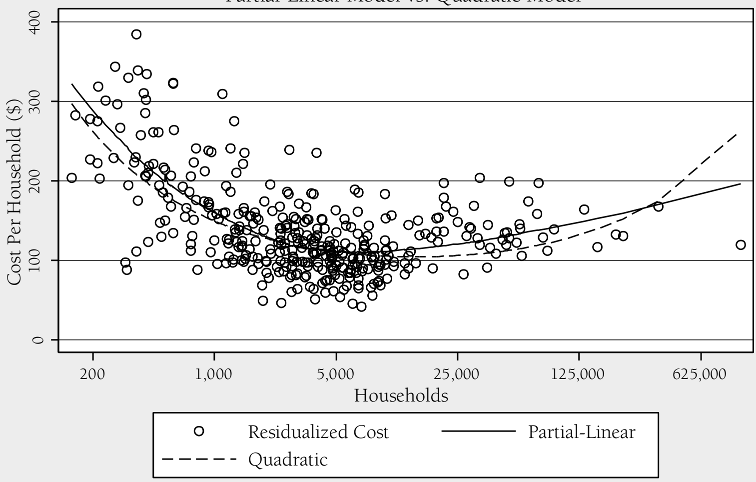
7.1 Fire Services

It is clear that calls per household and response times have a statistically significant effect on costs. A 10 percent increase in the number of calls per household raises costs per household by about 2.7 percent, whereas achieving 10 percent decrease in average response time raises costs per household by about 2.6 percent. Also, the average wage in a fire department affects costs as expected, in that a 10 percent increase in the wage increases costs per household by about 2.2 percent. Full-time fire departments appear to have a cost premium of about 35 percent compared with mixed full-time/volunteer fire departments, whereas volunteer fire departments' costs are about 74 percent as high. These results imply that volunteer fire departments are about 55 percent as costly as full-time fire departments. Whether amunicipality is located in the north or is of a single-tier structure does not appear to affect fire costs.

The graph in Figure 2 suggests a strong and significant scale effect as represented by the U-shaped cost curve. This relationship is supported by the large

Figure 2: Fire Costs

Partial-Linear Model vs. Quadratic Model



V-statistic of 8.3, which indicates that these services do not operate under constant returns to scale. Moreover, the V-test, with a test statistic of 1.9, shows that the fit of the partial-linear model is more congruent with the data than that of the quadratic model. The partial-linear model results suggest that the cost of fire services falls from about $300 per household for a small village to about $110 per household for a medium-sized town with a minimum efficient scale (MES) of approximately 9,000 households.[25] These results suggest that the lowest fire costs are achieved by medium-sized towns and large townships, such as the Town of Grimsby or the Township of Scugog, where the population is about 20,000 residents.

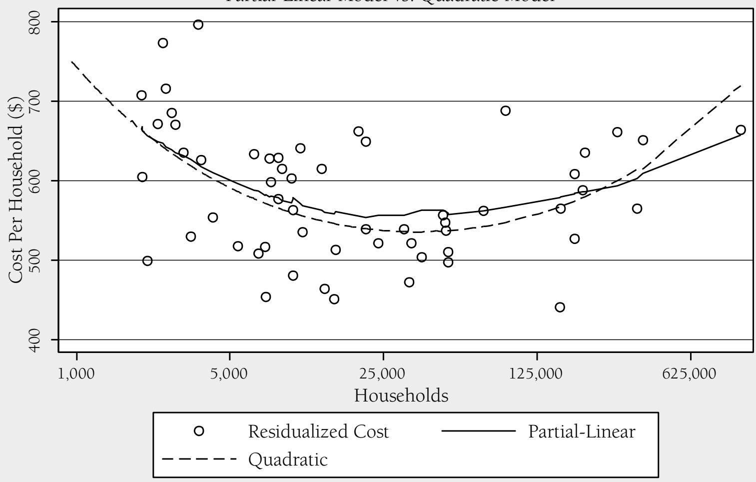
7.2 Police Services

Some of the non-scale variables affect the cost of police services. Density appears to have a statistically significant effect on costs, in that a 10 percent increase in density increases costs by 0.66 percent. Also, a 10 percent increase in the crime rate is associated with a 1.8 percent increase in costs per household. The number of vehicle accidents, the average police department wage, and average household income appear to have no impact on costs. The fact that wages do not seem to affect costs suggests data or reporting inconsistencies for the constituents of this variable are present. Although a single-tier municipal structure does not seem to affect police costs, northern municipalities do seem to experience a cost premium

25. This figure compares to an MES of about 14,000 households for the quadratic model.

Figure 3: Police Costs

Partial-Linear Model vs. Quadratic Model



in the order of 10 percent. Overall, the police analysis is not as strong as that for fire services, especially considering that only 59 observations were left once the OPP-contracting municipalities (including those using a hybrid of local and OPP policing) were omitted.

The partial-linear model generates a U-shaped per-household cost curve in which predicted per-household costs fall from $650 to $530 at a MES of about 21,000 households, and eventually rise again to $650.[26] Although the V-statistic of 2.9 indicates that police services do not exhibit constant returns to scale, the V-test indicates that the partial-linear model is not necessarily superior to the quadratic model, probably because there are only 59 observations available for the police analysis. Indeed, the partial-linear model regression line for police is less smooth than that of fire services, since the former service has far fewer observations than the latter. The partial-linear model results suggest that the lowest police costs are achieved by small cities, such as the City of North Bay or the City of Belleville, which have populations of about 50,000 residents.

7.3 Limitations

Given this study's reliance on municipally reported data and the need to combine information from separate databases held by different organizations, it was inevitable that some limitations would be encountered. These limitations are summarized in Table 9.

26. This figure compares to an MES of about 35,000 households for the quadratic model.

Table 9: Summary of Limitations	
Limitation	**Description**
Financial Information Return (FIR) Reporting Inconsistencies	Municipal FIR reporting may not be standardized in practice, even though in theory the rules and guidelines for FIR reporting are standardized.
Data Reporting Errors	Municipalities and other organizations may report incorrect or internally/mutually inconsistent data. For instance, there is evidence of such inconsistency with wage and staffing data, which may explain why dividing total staffing into total wages sometimes yields questionable average wages, especially for police services
Absence of Capital Costs	Capital costs could not be included; only operating costs were analyzed. Since the quality of capital equipment and structures can affect operating costs, economies of scale inferred from only operating costs may not reflect those for total costs.
Low Number of Local Police Services	Only 59 observations were available for police services, whereas fire services had 378 observations, which is why the partial-linear model curve for police is less smooth than that of fire and is also likely why the quadratic model could not be rejected for police services.
Relationship between Crime Rates and Police Expenditures	Since a component of the level of crime in a municipality is likely affected negatively by policing expenditures (via deterrence, diminished opportunity to commit crime, etc.), there may be a downward bias on the crime effect, thereby potentially affecting the results for economies of scale.

8. Concluding Remarks

The debate as to whether municipalities in Ontario enjoy economies of scale has been at the heart of this paper and its analyses of fire and police services, which together account for more than one-fifth of total municipal operating costs. A featured approach of the paper was to estimate the scale effect for these services in a manner that would remove the need to make any prior assumptions about the functional profile and shape of the cost per household curve. Another feature was the inclusion of municipal output measures for fire and police services (such as response times and crime rates), which had not been undertaken in any prior Ontario-based study on municipal economies of scale.

Overall, the evidence indicates that economies of scale certainly do exist for fire and police services, but it also indicates that these economies are limited. These services exhibited scale effects inconsistent with constant returns to scale, unlimited increasing returns, and global decreasing returns.

Specifically, fire services exhibited U-shaped per household costs, which were minimized at about 20,000 residents. The cost of a fire department was clearly affected by the number of calls received and average response time. Police services also exhibited U-shaped per-household costs, which were lowest for a municipality of about 50,000 residents. Population density and crime rates were found to significantly affect policing costs.

This general cost structure is inconsistent with the unqualified promise of cost savings typically advanced by municipal amalgamation proponents, at least for these two services. Indeed, the data do not support a premise of unlimited capacity to realize municipal economies of scale.

Appendix A: Estimation Method

Following Yatchew (2000) and suppressing subscripts, the general model employed is of a partial-linear structure:[27]

$$y = f(x) + z\beta + e$$

Here, the non-parametric variable *x* is the log of households and the vector *z* comprises the various covariates entering the model parametrically. Given this specification's additive separability, it is amenable to differencing techniques, where differencing may be of any order $m \geq 1$. Thus, a two-step estimation process can be used, where the parametric effect β is estimated first using differencing and parametric techniques, followed by the estimation of the non-parametric effect $f(x)$ using non-parametric (e.g. local averaging) techniques.

The essential requirement for the validity of the differencing estimators is that the average distance between the ordered *x's* asymptotically approaches zero sufficiently fast either with the order of differencing or the sample size, both of which decrease the variance of $\hat{\beta}$ (which may be obtained by ordinary least squares) as they grow. With this requirement satisfied, it can be shown that the parametric estimator generated by differencing is asymptotically Normal, where

$$\hat{\beta} \sim N\left(\beta, \left(1 + \frac{1}{2m}\right)\frac{\sigma_e^2}{n}\Sigma_{z|x}^{-1}\right)$$

where *m* is the order of differencing, *n* is the sample size, σ_e^2 is the variance of *e*, and $\Sigma_{z|x}$ is the expected value of $Cov(z|x)$, where σ_e^2 and $\Sigma_{z|x}$ can be estimated consistently. Notice that the variance of $\hat{\beta}$ decreases in both the order of differencing and number of observations. Second-order differencing (i.e., $m = 2$) is used for both fire and police analyses, but it should be noted that each order of differencing necessarily results in the loss of an observation. See Yatchew (1998, 2000) for details on differencing procedures and the asymptotic properties of the parametric estimator.

This estimation process requires the data to be ordered according to the non-parametric variable *x*, thus ensuring that the *x's* are "close" to one another, so that differencing the data removes the non-parametric effect. With the non-parametric effect removed, the parametric effect can be isolated and estimated using conventional techniques (e.g., ordinary least squares) on the differenced data to obtain the estimator $\hat{\beta}$. Subsequently, the predicted parametric effect $z\hat{\beta}$ can be removed from *y* to allow for pure non-parametric estimation of $f(x)$ by using a smoothing or local averaging procedure on the approximation

$$y - z\hat{\beta} = z(\beta - \hat{\beta}) + f(x) + e \cong f(x) + e$$

27. The discussion that follows is consistent with consideration of a cross-section of data, and so references to variables should be interpreted accordingly.

For this analysis, the local averaging procedure "Running" is used once the parametric effect is removed, which is a running line smoothing technique and a type of Symmetric Nearest Neighbour Smoother (SNNS).[28] Essentially, Running estimates each point in the dataset by running a locally weighted least squares regression on the ordered data points that lie within a symmetric local neighbourhood of the point of estimation. Each data point captured in this local neighbourhood is assigned a weight proportional to its distance from the point of estimation so that points farther away receive lower weights, while points outside of the local neighbourhood receive zero weight.

For the SNNS Running, a local neighbourhood is defined as a proportion μ of the number of observations n, so that each local regression uses the closest μn points (rounded up to the nearest integer) to the point of estimation. In this sense, $\mu \in (0,1]$ represents a bandwidth, so that larger values of μ lead to greater degrees of smoothing as larger bandwidths of the data are used for local estimation. A bandwidth of 75 percent is applied to both fire and police services to implement the local smoother Running.

As discussed in Yatchew (2000), various parametric hypotheses can be tested against the partial-linear specification using the V-statistic (under the null hypothesis)

$$V = \sqrt{mn}\left(\frac{S_R^2 - S_{PL}^2}{S_{PL}^2}\right) \rightarrow N(0,1)$$

where S_R^2 is the estimate of the residual variance of the parametric model (an alternative hypothesis), S_{PL}^2 is the estimate of the residual variance of the partial-linear model (the null hypothesis), m is the order of differencing, and n is the number of observations used for the partial-linear model.

An alternative hypothesis will comprise a parametric specification of $f(x)$, such as a constant, linear, or quadratic functional form with respect to x, as well as a parametric estimation method (e.g., ordinary least squares).[29] Testing against such an alternative is one-sided since the partial-linear model should always be able to explain more than an analogous parametric model ($S_R^2 > S_{PL}^2$), meaning that a V-statistic above 1.65 will be considered significant at the conventional 5 percent level.[30] The default alternative hypothesis tested is $f(x)$ specified as a constant function (i.e., the default alternative hypothesis is constant returns to scale), thus

28. One advantage of using Running is that it is capable of producing 95 percent confidence bands around the smoothed function. See Lokshin (2003) for a treatment of partial-linear regression and Cleveland and Devlin (1988) for a more general treatment of local averaging techniques.

29. Differencing is generally not used for such an alternative hypothesis.

30. For analyses with a relatively low number of observations, differencing may actually cause the partial-linear model to have less explanatory power than a fully parametric alternative model, since each order of differencing necessitates the loss of an observation.

the V-statistic can be viewed as test for the presence of economies of scale. However, it will prove worthwhile also to test against an analogous fully parametric quadratic model, as this functional form is ubiquitous throughout the literature. The test comparing the partial-linear model against the quadratic model is called the V-test.[31]

Appendix B: Estimation Output and Confidence Bands

B1. Fire Services

Table B1: Fire Partial-Linear Model Output

plreg logfire logdensity st north logfirecalls logresponse ft v logfirewage logincome, nlf(loghouse) order(2) gen(Func_Fire)

Partial Linear regression model with Yatchew's weighting matrix

Source	SS	df	MS			
				Number of obs	=	376
				F(9, 367)	=	46.324
Model	40.65905841	9	4.51767316	Prob > f	=	0.0000
Residual	35.79119679	367	.097523697	R-squared	=	0.6978
Total	76.450	376	.203325147	Root MSE	=	0.3123

logfire	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval
logdensity	-.0628581	.0177167	-3.55	0.000	-.097697	-.0280191
st	.0733865	.0781503	0.94	0.348	-.080292	.2270651
north	-.0119259	.089107	-0.13	0.894	-.1871503	.1632985
logfirecalls	2688715	.0284471	9.45	0.000	.2129317	.3248113
logresponse	-.2632686	.0699239	-3.77	0.000	-.4007704	-.1257667
ft	.3459411	.0920612	3.76	0.000	.1649075	.5269747
v	-.2592917	.0552934	-4.69	0.000	-.3680234	-.1505599
logfirewage	.2200775	.0296871	7.41	0.000	.1616994	.2784556
logincome	.0306574	.0289153	1.06	0.290	-.026203	.0875179

Significance test on loghouse: V = 8.281 P>|V| = 0.000

31. By default, the partial-linear output tables are generated indicating explanatory power in relation to variation in the differenced data as opposed to the original data. Therefore, R-squared numbers in the partial-linear output tables have been adjusted after estimation so that they indicate explanatory power in relation to the original data.

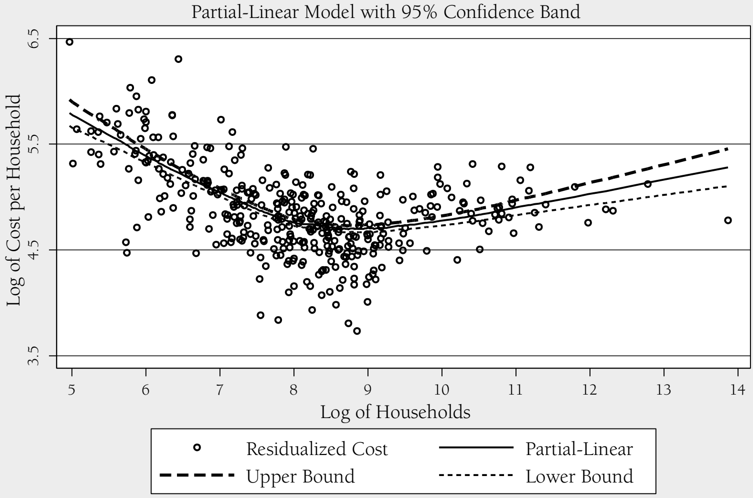
Table B2: Fire Quadratic Model Output

```
reg logfire loghouse loghousesq logdensity st north logfirecalls logresponse ft v logfirewage
logincome

      Source |       SS         df        MS          Number of obs  =     378
-------------+-----------------------------------     F( 11, 366)    =   69.62
       Model |  80.1277941     11    7.28434491       Prob > F       =  0.0000
    Residual |  38.2938378    366   .104627972       R-squared      =  0.6766
-------------+-----------------------------------     Adj R-squared  =  0.6669
       Total |  118.421632    377   .314115734       Root MSE       =  .32346
---------------------------------------------------------------------------------------
     logfire |      Coef.    Std. Err.       t     P>|t|    [95% Conf.       Interval
-------------+-------------------------------------------------------------------------
    loghouse |  -.9642936    .1093619     -8.82    0.000     -1.17935      -.749237
  loghousesq |   .0503322    .0061404      8.20    0.000     .0382572      .0624071
  logdensity |  -.0603023    .0162382     -3.71    0.000    -.0922341     -.0283705
          st |   .1111031     .071628      1.55    0.122     -.029751      .2519572
       north |   .0110219    .0832479      0.13    0.895    -.1526823       .174726
logfirecalls |   .2618448    .0272675      9.60    0.000     .2082241      .3154655
 logresponse |  -.2947016    .0664848     -4.43    0.000    -.4254417     -.1639615
          ft |   .5008758    .0796265      6.29    0.000     .3442929      .6574586
           v |  -.2150697    .0482405     -4.46    0.000    -.3099331     -.1202064
 logfirewage |   .2139126     .028063      7.62    0.000     .1587276      .2690977
   logincome |   .0486264    .0260867      1.86    0.063    -.0026723      .0999251
       _cons |   8.120401     .622935     13.04    0.000      6.89542      9.345382
---------------------------------------------------------------------------------------
```

Figure B1: Fire Costs

Partial-Linear Model with 95% Confidence Band



B2. Police Services

Table B3: Police Partial-Linear Model Output

plreg logpolice logdensity st north logcrime logaccidents logpolicewage logincome if opp==0, nlf(loghouse) order(2) gen(Func_Police)

Partial Linear regression model with Yatchew's weighting matrix

Source	SS	df	MS			
				Number of obs	=	57
				F(7, 50)	=	10.408
Model	1.202071624	7	.171724518	Prob > f	=	0.0000
Residual	.8249722241	50	.016499444	R-squared	=	0.6009
Total	2.027	57	.035562173	Root MSE	=	0.1285

logpolice	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval
logdensity	.065503	.0178209	3.68	0.001	.0297086	.1012974
st	-.0089492	.0513483	-0.17	0.862	-.1120854	.094187
north	.1190644	.0612461	1.94	0.058	-.003952	.2420808
logcrime	.1842267	.0702462	2.62	0.012	.0431331	.3253203
logaccidents	.0109172	.0503341	0.22	0.829	-.0901818	.1120161
logpolicewage	-.0451094	.1335952	-0.34	0.737	-.3134434	.2232245
logincome	-.0090741	.122453	-0.07	0.941	-.2550283	.2368801

Significance test on loghouse: V = 2.900 P>|V| = 0.002

Table B4: Police Quadratic Model Output

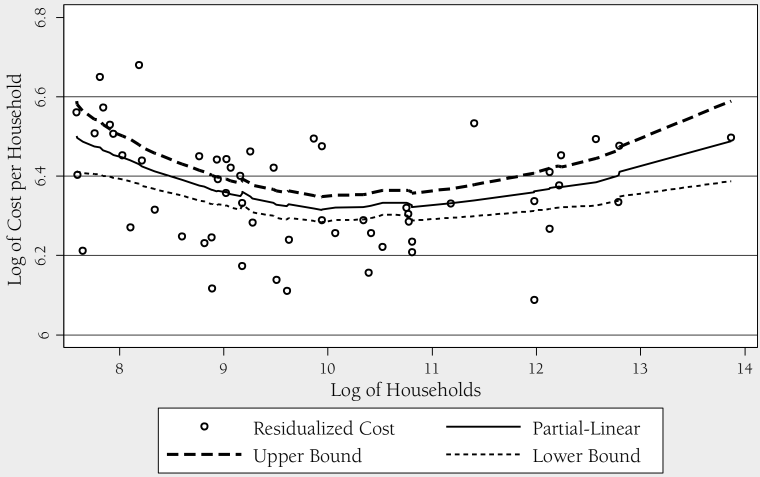
reg logpolice loghouse loghousesq logdensity st north logcrime logaccidents logpolicewage logincome if opp==0

Source	SS	df	MS			
				Number of obs	=	59
				F(9, 49)	=	8.30
Model	1.24821966	9	.138691074	Prob > F	=	0.0000
Residual	.818939908	49	.016713059	R-squared	=	0.6038
				Adj R-squared	=	0.5311
Total	2.06715957	58	.035640682	Root MSE	=	.12928

logpolice	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval
loghouse	-.5385034	.136062	-3.96	0.000	-.8119303	-.2650765
loghousesq	.0257039	.0065893	3.90	0.000	.0124622	.0389456
logdensity	.0498185	.0164132	3.04	0.004	.016835	.082802
st	-.0068305	.0478953	-0.14	0.887	-.1030797	.0894188
north	.095564	.0624555	1.53	0.132	-.0299451	.221073
logcrime	.2479792	.0644371	3.85	0.000	.118488	.3774704
logaccidents	-.0222573	.0328578	-0.68	0.501	-.0882875	.0437728
logpolicewage	-.0017426	.1351331	-0.01	0.990	-.2733027	.2698176
logincome	.0612438	.119216	0.51	0.610	-.1783298	.3008174
_cons	6.860406	1.756178	3.91	0.000	3.331235	10.38958

Figure B2: Police Costs

Partial-Linear Model with 95% Confidence Band



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