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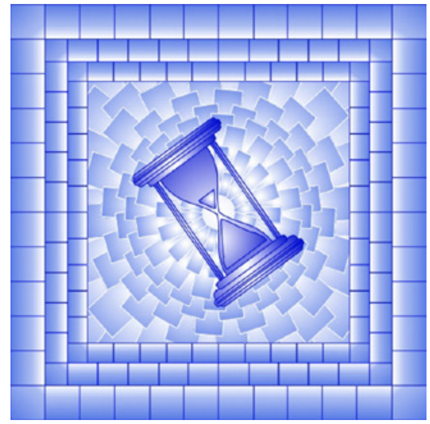
City comparisons of shelter costs in Canada: A hedonic approach



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A hedonic approach

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Preface

Prices Division first started publishing the Analytical Series in December 1996 as a means to convey conceptual and applied research undertaken by its staff, and at times, by other persons from within or outside Statistics Canada on the subject of price indexes.

All papers are reviewed by a panel of experts from within Statistics Canada or outside the agency. Views expressed in the papers are those of the authors and do not necessarily reflect those of Prices Division or Statistics Canada.

The purpose of the series is to disseminate knowledge and stimulate discussion. Questions and comments on any aspect of the papers are welcome and can be forwarded to the Director, Prices Division or to the Chief, Quality Assurance and Client Services Section, 13th Floor, Jean Talon Building, Statistics Canada, Ottawa, Ontario, K1A 0T6, Facsimile: 1 613 951–1539.

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Abstract

Until recently, the Inter-city Indexes of the Retail Price Differentials program of Prices Division excluded any reference to shelter because of conceptual issues. However, it is well documented that much of the geographical differences in price levels are explained by variations in shelter costs. The search for ways to remedy the omission of shelter has long been a topic of ongoing investigation. Recently, the use of hedonic modeling applied to a comprehensive set of rent data has generated promising results, which now permit the inclusion of shelter in the spatial program. It is now possible to produce an All-items spatial price index that provides a much more accurate measure of geographical differences in price levels among major Canadian cities. Expansion of the spatial All-items index will no doubt satisfy a growing demand for this type of information. A more comprehensive measure of city price differentials could, for example, be used as a deflator for comparing regional income differentials or for wage and salary adjustment exercises. This paper documents the approach used to construct the shelter element of the current spatial index program. A rental equivalence approach was used for measuring spatial variations in the costs of shelter services among cities. To control for quality variations across areas, a semi-log separate hedonic regression methodology was used to construct the Laspeyres, Paasche, and Fisher-Törnqvist inter-area indices.

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1. Introduction

Prices Division has produced the Inter-city Indexes of Retail Price Differentials (or spatial price indices) since 1955. Although these price indicators share certain commonalities with the better-known Consumer Price Index (CPI), they remain quite distinct in terms of their use and construction. Further, the level of detail of the spatial index program was incomplete, relative to the CPI. For instance, in a move to improve the coverage of the spatial indices, commodity categories such as restaurant meals, clothing and furniture were added in 1995. Even then, shelter-related costs remained excluded. The importance of this missing component is not to be underestimated. Economists have long known that shelter costs are the prime factor behind price level differences among areas.

Measures that compare geographical differences in price levels satisfy a growing demand for this type of information. Differences in regional prices have implications for regional cost-of-living comparisons. Information on regional price differences is important not only to government and academia, but also to businesses and individuals contemplating relocation. By quantifying these differentials, this new source of information has potential applications in decision-making—for use in wage adjustments and as a deflator for regional income levels. This is a critical issue in the present socio-economic context.

The expansion of the current spatial price index program to include shelter has been a topic of ongoing investigation by Prices Division. The inclusion of shelter in the spatial index is vital because most of the variation in living costs in Canada is explained by differences in shelter costs[1]. However, shelter has presented measurement challenges for the spatial index program. Specifically, the heterogeneity of shelter has prevented a meaningful comparison of prices across regions.[2] This paper continues the inquiry by further developing the techniques employed previously and by focusing attention on one particular model used to calculate the experimental shelter spatial price indices.[3]

This paper uses a rental equivalence approach to measure the cost of shelter service for homeowners. To control for the heterogeneous nature of shelter a hedonic approach is used to produce Laspeyres, Paasche, and Fisher-Törnqvist indices for the spatial comparison of shelter costs. A semi-log model specification is used to perform the hedonic quality-adjusted regression, which provides the information required for the calculation of the inter-area rental accommodation indices. Sixteen spatial indices are calculated for 16 urban centres and this allows the quality-adjusted rent prices for Census Metropolitan Areas (CMAs) to be compared across Canada.

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[1] Furthermore, it is interesting to note that shelter is the principal component of family expenditure accounting for 27.9% of average household expenditures in 1992. Due to the substantial differences in shelter cost price levels, variation in shelter costs can have a substantial effect on a consumer's budget allocation.

[2] The heterogeneity of shelter refers to the variety and diversity of the commodity "shelter". Shelter is made up of a variety of quality characteristics; this is discussed in greater detail in the body of the paper. Not all shelter units contain the same characteristics and, as such, not all dwellings are equal or homogeneous.

[3] Previous techniques are discussed in Prud'homme and Thivierge [1999].

In this paper, Section 2 outlines the methodology and assumptions used in the analysis. Section 3 briefly describes the data sources employed. Section 4 presents the model and estimation techniques that were used and the logic considered in their choice. Section 5 presents the data analysis and the results of both the regression output and the indices. Finally, Section 6 presents some concluding remarks.

2. Methodology

Rental equivalence

The cost of shelter service includes both tenant and owned accommodation. A rent-based measure is the generally agreed upon method for measuring tenant accommodation; however, the approach to measure owned accommodation is more controversial. There are several approaches to measuring housing costs: money outlays, net purchase, rental equivalence and user cost.

The money outlay approach calculates the cost as the sum of actual cash disbursements, inclusive or exclusive of equity payments that the homeowner must pay for the use of her home. The net purchase approach calculates the cost to the homeowner of purchasing her home outright, taking into consideration the costs associated with home maintenance.

This study focuses on the rental equivalence and user cost methods as the two most relevant approaches. The rental equivalence approach asks how much the homeowner would be willing to accept in rent for the dwelling, and the user cost approach focuses on the opportunity cost of owning and using the dwelling.[4] These approaches are operationally different, but are conceptually equivalent.

The rental equivalence approach is the preferred approach for several reasons. First, user cost estimates and market rent do not move together. Generally, rental prices are relatively stable through time, whereas cost estimates have a tendency to be volatile. Second, the definition and measurement of relevant variables required for the user cost estimation are problematic.[5] Finally, it has been argued that the collection of housing prices by region is expensive, which makes the user cost approach more burdensome on given resources relative to the simpler task of collecting observed market rents. Although, the rental equivalence approach may not be the best approach, it is certainly the most feasible for deriving spatial estimates [Darrough, 1983].

Rental equivalence uses observed market rents as approximations for cost of homeownership and, more generally, housing. This approach asks, “how much the homeowner would charge someone such as himself to rent his house” [Darrough, 1983; 603]. By observing actual market rental prices potential rent can be estimated. This approach assumes that the cost of the shelter or housing service for homeowners may be represented by observed market rents. The

4 Both approaches represent a measure of the cost of the flow of services resulting from owning and living in a dwelling.

5 Darrough [1983] argues that user cost methods should not be considered unreliable when variables are defined and measured appropriately. User cost estimates are typically sensitive to alternative assumptions surrounding variable calculation. Thus, appropriate estimation of relevant variables that address how to deal with capital gains and differential tax treatments of assets and individuals are essential.

rental equivalence approach is therefore the preferred approach for this study and is employed in the following analysis.

Hedonic approach

The hedonic regression approach has a long and established history in empirical economics for measuring price-quality relationships. It is essentially based on a utilitarian philosophy that compares the price of commodities to measure the welfare and satisfaction consumers derive from the consumption of goods and services. With the hedonic approach, most goods and services are considered a composite commodity formed from a series of other goods and services, and these are usually referred to as attributes or quality characteristics. The contribution of each attribute to the value of the composite commodity can be derived through hedonic methods. Thus, a hedonic regression for shelter can be used to measure the effects of specific dwelling quality characteristics on the rental price. Consequently, two rental accommodations exchanged in the same market, the first having more desirable features than the second, will result in the first having a higher renter valuation, and thus, a higher rental price.[6]

The hedonic method recognizes the rental price of housing as being the price of a stream of goods and services that are bundled together to produce a composite commodity labelled "housing". The stream of goods and services are quality characteristics that make up the pure space. Although, the quality characteristics of housing are not sold separately, using the hedonic technique, an implicit price can be derived for each attribute that makes up the composite product. This follows from the assumption that implicit markets exist for these quality characteristics. Implicit prices are assumed to be supply determined or market generated and external to the household's consumption decision (price taking behaviour). The assumption of supply-determined prices is a valid assumption when the good in question is a durable good (such as housing) with a relatively stable supply [Muellbauer, 1974]. However, the approach used in this study is demand oriented because it is the welfare of consumers that is being considered, and so the hedonic method used does not attempt to fully explain market phenomena.

It follows from the above assumptions that the rental price can be decomposed into the attributes' marginal prices. However, to achieve this result, it is also necessary to assume that the quality characteristics are homogeneous, and that the goods comprising the composite quality characteristics are also homogeneous. This assumption implies that the current state is the short run, and that any changes in characteristics and quality can only exist in the long run. Homogeneity is also important because it allows the good to take on an objective nature. Thus, the consumer's rental decision is between the collection of characteristics only and not between the qualities of specific attributes. This creates an opportunity to isolate the effect of quality change on prices [Lancaster, 1966].

For example, the assumption of homogeneous characteristics in the case of bedrooms implies that all bedrooms are equal. There are no distinctions made by square footage, number of windows per room, closet size, or whether there is an en suite bath. Thus, the assumption being made is that consumers make their rental decision based strictly on the "collection" of quality

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[6] "More desirable" can be understood to be not the quality of the attribute but the quantity of the quality characteristic.

characteristics and not on the “quality” of the quality characteristics. Continuing the bedroom example, consumers make their decision based strictly on the number of bedrooms in the dwelling and not on the quality characteristics of each bedroom (i.e. the size of the bedroom, number of windows in the room, size of the room’s closet, or access to a bathroom). In summary, all bedrooms are assumed to be equal within a dwelling, and across all dwellings and locations. In other words, a bedroom in Montréal is the same as a bedroom in Regina, and this holds for all attributes that comprise the good “shelter”.

3. Data sources

Two main sources of data are used in the analysis: the Labour Force Survey (LFS) [August 1998 to December 1999] and the 1996 Census of Canada. The sample size is 14,434 households. The LFS rent questionnaire provides the physical quality characteristics of the dwellings and the Census provides socio-economic characteristics of the neighbourhoods in which the dwellings are located. Consequently, the primary unit of analysis for this investigation is the dwelling and the secondary unit is the neighbourhood or Enumeration Area (EA). A more detailed description of the target population, survey design, and how the data sources are integrated can be found in Appendix 1. See Appendix 2 for sample size by urban area.

4. Statistical model

Economic theory does not suggest a functional form for hedonic models. Typically, researchers turn to the literature and goodness-of-fit criteria when choosing an appropriate functional form. Prud’homme and Thivierge [1999] reviewed several different models that could be used for the construction of hedonic indices. Specifically, separate regressions, dummy variables, and random coefficient models were all applied under various specifications such as linear, semi-log and log-linear.

In support of the choice of separate regressions, Muellbauer [1974] argues that, “as far as possible, markets should be divided into segments based on commodity groupings which make it likely that their consumers have similar MRS (marginal rates of substitution) and these segments should be studied separately”. He adds that this segmentation will result in less cross-sectional variation, but at the expense of more problems of multicollinearity. In the spatial shelter context, the separate regression approach implies that a regression is run for each segment, census metropolitan area, or location—as opposed to pooling all of the segments or locations together, controlling for area or segment, and running one regression. This paper assumes that consumers within a given location or segment have similar MRS and, as such, these areas are studied separately.

Based on Prud’homme and Thivierge [1999] and other related research, this study limited the hedonic models on rent to separate regressions, and then employed two specification tests to help determine the appropriate specification that would generate the best fit given the available data (Appendix 3).

Hedonic studies by MacDonald [1986] and Salois [1987] also employed linear and semi-log specifications in the examination of housing prices. The Cropper, Deck, and McConnell

[1988] simulation study compared the consistent performance of a wide spectrum of models that faced measurement and omitted variable scenarios, and found that simpler functional forms such as linear, semi-log, double-log, and the Box-Cox linear considerably outperformed quadratic and Box-Cox quadratic specifications.

A specification should be chosen because of its inherent qualities. Most importantly, it should have *a priori* analytical usefulness and it should be an accurate descriptor of the underlying character of the data. A model specification should be rejected if the relationship between the dependent and independent variables suggests that a more appropriate specification is required.

A semi-log model specification is used to describe the relationship between rental prices and dwelling attributes. It is clear from the tests that the semi-log specification is the best descriptor of the data. The model's *a priori* analytical usefulness comes from three main points: it has performed well in goodness-of-fit tests in the literature [Moulton, 1995]; it has demonstrated an ease of use in routine production of indices [Prud'homme and Yu, 1999]; and its regression coefficients have an interpretable meaning. The explanatory coefficients (β) measure the constant proportional or relative change in the dependent variable (Y) for a given absolute change in the independent variable (X).

$$\beta = \frac{relative\,\Delta\, in\, Y}{absolute\,\Delta\, in\, X} \cong \frac{\frac{Y_k - Y_{k-1}}{Y_{k-1}}}{X_k - X_{k-1}} \qquad (1)$$

Thus, the exogenous coefficients will vary proportionately with changes in the endogenous variable.

The natural logarithm of rental price is regressed on the physical and socio-economic attributes by location. The separate regression semi-log model can be described as:

$$Y_{vk} = \alpha_v + \sum_{j=1}^{J} \beta_{vj} X_{vjk} + \varepsilon_{vk} \qquad (2)$$

where Y_{vk} is the natural logarithm of monthly rent paid for the k^{th} dwelling in location v; α_v is the intercept of location v; β_{vj} is the coefficient vector for the j quality characteristics of dwellings, and X_{vjk} is the matrix of all attributes (physical and socio-economic). The error term is represented by ε_{vk} for the k^{th} dwelling in location v.

Variables

Essentially, there are three divisions in the data: physical, socio-economic and spatial. Spatial divisions were handled through separate regressions by location. The dwelling attributes or exogenous variables are made up of physical quality characteristics and socio-economic attributes.

The physical quality characteristics are attributes that are unique to the individual dwelling. A dwelling is "a set of living quarters that is structurally separate from the living quarters of other dwellings and has a private entrance outside the building or from a common hall or stairway inside the building" [Guide to Labour Force Survey, 2000]. Physical characteristics define the nature of the dwelling and thus the stream of services the dwelling provides. The socio-economic attributes are unique to the enumeration area (EA) or Census Tract (CT). Therefore, dwellings within the same enumeration area have identical socio-economic attributes. Socio-economic characteristics are calculated as the percentage of dwellings within the EA with the given attribute.

The physical characteristic independent variables included in the regression are type of dwelling, age of structure, number of bedrooms in the dwelling (ranging from bachelor apartments with no bedrooms to dwellings with 4 or more bedrooms), and a series of commodity dummy variables. The commodity dummy variables capture goods and services included with the rental price. They are heat, hot water, electricity, refrigerator, stove, washer, dryer, cable television, furniture, other major appliances, and parking. Composite commodity variables are created to limit the influence of multicollinearity. The calculation of composite commodity variables are discussed further in Appendix 3, and Appendix 1 describes all the variables used in the separate regressions.

The socio-economic variables are included in the model to avoid the variable proxy problem. Including neighbourhood information attempts to construct a model with a more complete specification. The independent neighbourhood variables used in the model are percentage of private dwellings rented in an enumeration area, percentage of private dwellings in need of major repairs, percentage of persons with post-secondary education, average commuting distance to work (km), and percentage of persons living under the low income cut-off. Low income cut-offs are set at income levels that are differentiated by size of area of residence (or degree of urbanization) and by family size. The 1992 national Family Expenditure Survey data are used to calculate the low income cut-off and the Consumer Price Index is used to update these levels yearly. If 70% or more of a family's income is spent on basic necessities such as food, shelter and clothing, then their circumstances are considered "straitened" and they were categorized as low income. The cut-off was an arbitrary number used to delineate family units into "low income" and "other" groups. Any family with income equal to or above the cut-off is considered in the "other" category [1996 Census Dictionary, 1997]. By including the socio-economic characteristics, it was assumed that implicit markets exist for these regional and neighbourhood ambient quality characteristics.

Estimation and indices

The calculation of hedonic indices is a two-step procedure. First, quality characteristic coefficients must be obtained from a regression of rental price on quality characteristics. In the second step, the coefficient estimates are used to construct a Fisher-Törnqvist spatial price index. Before proceeding with the regressions, problems with model specification, multicollinearity, omitted variable basis, and non-spherical errors are addressed. These issues are described in detail in Appendix 3.

The first step in the estimation of quality-adjusted price indices is to generate quality characteristic coefficients; this is done using separate regressions for each index area (i.e. each urban centre). Further, a Feasible Generalized Least Squares (FGLS) two-stage estimator was used to correct for the variation in disturbances within the classes of attributes.[7]

The second step in the production of inter-area indices is to apply the coefficients from the estimation to the construction of a Fisher-Törnqvist (*FT*) spatial price index, which is a geometric mean of the Laspeyres (*L*) and Paasche (*P*) price indices. Gillingham [1975] furthered the practice of constructing a geometric mean with semi-log hedonic quality-adjusted equations and Moulton [1995] extended the use of hedonic equations to inter-area indices. The Laspeyres index uses the reference area's mean value for characteristic *j* as the base ($\bar{X}_{jv_o}$) to weight the difference of the coefficients across areas:

$$P^{L}_{v_i v_o} = e^{\sum_j \left(\hat{\beta}_{jv_i} - \hat{\beta}_{jv_o}\right)\left(\bar{X}_{jv_o}\right)} \tag{3}$$

Note the reference area is represented by *o* and the comparison area by *i*. The Paasche index uses the area of comparison's mean value for characteristic *j* as the base ($\bar{X}_{jv_i}$):

$$P^{P}_{v_i v_o} = e^{\sum_j \left(\hat{\beta}_{jv_i} - \hat{\beta}_{jv_o}\right)\left(\bar{X}_{jv_i}\right)} \tag{4}$$

By geometrically averaging the two indices, a Fisher-Törnqvist index is produced:

$$P^{FT}_{v_i v_o} = \sqrt{P^{L}_{v_i v_o} P^{P}_{v_i v_o}} = \sqrt{e^{\sum_j \left(\hat{\beta}_{jv_i} - \hat{\beta}_{jv_o}\right)\left(\bar{X}_{jv_o}\right)} e^{\sum_j \left(\hat{\beta}_{jv_i} - \hat{\beta}_{jv_o}\right)\left(\bar{X}_{jv_i}\right)}} \tag{5}$$

$$P^{FT}_{v_i v_o} = \left(P^{L}_{v_i v_o} P^{P}_{v_i v_o}\right)^{\frac{1}{2}} = e^{\frac{1}{2}\left[\sum_j \left(\hat{\beta}_{jv_i} - \hat{\beta}_{jv_o}\right)\left(\bar{X}_{jv_o} + \bar{X}_{jv_i}\right)\right]} \tag{6}$$

[7] Appendix 3 discusses the estimator used in this analysis.

By using a geometric mean of the Laspeyres and Paasche indices, these indices' averages of characteristic *j* are used for the reference and comparison areas, respectively. The issue of non-transitivity of the Fisher-Törnqvist index still remains.[8]

5. Data analysis and results

The overall fit of the model is generally good and consistent with previous cross-sectional studies. If the majority of variable coefficients have *a priori* correct signs and are of reasonable magnitude, then any deviation from the priors are assumed to be caused by omitted variables. Included variables could be acting as proxies if the model is misspecified or does not include enough of the good's attributes to void the proxy relationships.

The discrete age variables were expected to have negative coefficients. Generally, as the age of a structure increases, the willingness to pay for the space decreases. It was expected that the dwelling type variable (DYTP1234) would have a positive sign as renters were expected to prefer a single detached housing style of living to apartment style living. The supporting argument is that if renters perceive neighbourhoods with single detached housing to have lower mortality rates, crime rates, mental illness, less juvenile delinquency, and less household overcrowding, then they may put a premium on detached housing, and the coefficient DYTP1234 should have a positive sign[9]. The bedrooms and all commodity variables were expected to be positive because they add to the convenience of the dwelling. The majority of coefficients fell in line with the expectations of the authors. Those that did not were usually not significant (refer to Table 1). Thus, the omitted variable issue is not considered to be a serious problem with the model specification.

There is an issue of the unlikely direction of estimates (unlikely positive or negative sign) and large standard errors for some of the coefficients. This may be due to the frequency or lack of frequency of a given variable in the city of interest. When a variable appeared either highly infrequently as in the case of washers and dryers in Montréal, or highly frequently as in the case of stoves and refrigerators in Charlottetown, it became impossible to estimate accurately the implicit price of the commodities. As Moulton [1995] suggested, some markets do not adjust through the implicit price of a quality characteristic but through the quantities consumed. This result lends support to the use of regional averages for the quality characteristics in the calculation of the indices. If national averages were used, boundary conditions such as the examples mentioned above may be inappropriately characterized.

The percentage of private dwellings rented within an enumeration area and the percentage of persons with post-secondary education were expected to have positive signs. It was

8 Appendix 3 describes in fuller detail the properties of these three indices.

9 However, there are competing theories. The coefficient sign of the dwelling type variable may be expected to be negative if it is believed that high urban density has an effect on the renter's choice decision. For example, if renters are more concerned with reducing their role in the maintenance of the dwelling (gardening, snow removal, etc.), then they may put an implicit value on these forgone activities, which would be incorporated as a premium for an apartment dwelling. There are also possible social advantages that would lead to a premium for an apartment dwelling, which are linked to high density living such as: "unparalleled opportunity for gratification, overload of opportunity and stimulation and involuntary exposure to education, cosmopolitanism and innovative ideas" [Choldin, 1978].

assumed that renters selectively choose to associate with persons who share similar values and motives. Thus, renters will pay a premium to be near other renters with similar education and income levels. The percentage of private dwellings in need of major repairs, average commuting distance and low income cut-off were all expected to have negative signs. Renters were expected not to prefer to live in dwellings that are in a state of disrepair, thus neighbourhoods with a high percentage of dwellings needing major repairs were expected to rent at a discount. It was also expected that as average commuting distances increased, the rent paid for the dwelling would decrease; thus, the savings from shorter commuting distances were expected to be incorporated as a premium in the total rental price. The variable, low income cut-off, was expected to have a negative coefficient because income levels were expected to be positively correlated with the magnitude of rent paid. The variables for neighbourhood characteristics are usually significant; however, they are not always consistent with this study's *a priori* expectations regarding their sign (see Table 1).

Table 1
Estimation of Model

Dependent Variable: Log (Rent Paid)

	St. John's		**Charlottetown**		**Halifax**		**Saint John**	
Variable	Coefficients	Std. Err.	Coefficients	Std. Err.	Coefficients	Std. Err.	Coefficients	Std. Err.
Intercept	5.609	0.146***	5.577	0.079***	5.640	0.071***	5.432	0.142***
10 < age < 20 years	0.001	0.053	-0.094	0.017***	0.087	0.023***	-0.223	0.066***
20 < age < 40 years	-0.024	0.051	-0.121	0.016***	0.039	0.015***	-0.211	0.061***
> 40 years	0.113	0.066*	-0.112	0.018***	0.028	0.025	-0.159	0.065***
Detached housing	-0.088	0.046*	0.022	0.017	-0.063	0.027***	0.002	0.055
Bedroom	0.100	0.021***	0.194	0.008***	0.194	0.008***	0.151	0.014***
Luxuries	0.135	0.132	0.026	0.015*	0.187	0.016***	-0.035	0.121
Utilities	0.053	0.112	0.063	0.030**	0.054	0.017***	0.027	0.029
Electricity	0.010	0.114	0.064	0.017***	0.003	0.027	0.049	0.030
Fridge/Stove	0.022	0.065	0.049	0.057	0.088	0.049*	0.134	0.086
Washer/Dryer	0.042	0.072	0.096	0.033***	0.064	0.040	0.065	0.074
Parking	0.055	0.055	0.040	0.027	-0.096	0.016***	0.171	0.032***
% of rented dwellings	0.002	0.001***	0.001	0.000***	0.001	0.000***	0.005	0.000***
% with major repairs	0.001	0.004	-0.002	0.001	0.003	0.002**	-0.008	0.003***
% post-secondary	0.004	0.001***	0.003	0.001***	0.005	0.001***	0.001	0.001
Commuting distance	0.007	0.007	-0.009	0.003***	-0.007	0.001***	0.003	0.004
% under low Y cut-off	-0.003	0.001*	0.001	0.001	-0.004	0.001***	-0.002	0.001***
Adj-R-sq	**0.255**		**0.643**		**0.892**		**0.714**	

	Fredericton		**Québec City**		**Montréal**		**Hull**	
Variable	Coefficients	Std. Err.	Coefficients	Std. Err.	Coefficients	Std. Err.	Coefficients	Std. Err.
Intercept	5.679	0.147***	5.928	0.059***	5.732	0.040***	5.761	0.052***
10 < age < 20 years	-0.028	0.064	-0.076	0.041*	-0.122	0.033***	-0.128	0.022***
20 < age < 40 years	-0.084	0.060	-0.223	0.030***	-0.147	0.028***	-0.177	0.023***
> 40 years	-0.177	0.067***	-0.314	0.036***	-0.228	0.028***	-0.137	0.026***
Detached housing	-0.066	0.046	-0.038	0.020*	0.023	0.018	0.029	0.019
Bedroom	0.174	0.018***	0.180	0.011***	0.135	0.005***	0.182	0.007***
Luxuries	0.168	0.046***	0.064	0.057	0.085	0.037**	0.028	0.023
Utilities	0.105	0.054*	0.115	0.021***	0.160	0.009***	0.025	0.026
Electricity	0.087	0.067	-0.018	0.021	-0.011	0.019	0.089	0.027***
Fridge/Stove	-0.233	0.071***	-0.112	0.024***	-0.088	0.011***	0.065	0.014***
Washer/Dryer	0.151	0.055***	0.031	0.049	0.106	0.089	0.065	0.048
Parking	0.096	0.063	-0.055	0.030*	-0.001	0.009	0.030	0.027
% of rented dwellings	0.006	0.001***	0.003	0.000***	0.003	0.000***	0.001	0.000***
% with major repairs	0.010	0.003***	-0.009	0.002***	-0.008	0.001***	-0.002	0.002
% post-secondary	0.006	0.001***	0.002	0.001***	0.005	0.000***	0.003	0.001***
Commuting distance	-0.025	0.007***	-0.004	0.003	0.000	0.002	-0.010	0.004**
% under low Y cut-off	-0.010	0.002***	-0.004	0.001***	-0.003	0.000***	-0.002	0.001***
Adj-R-sq	**0.598**		**0.470**		**0.372**		**0.730**	

*** Statistically significant at the 1% level.

** Statistically significant at the 5% level.

* Statistically significant at the 10% level.

Table 1 (continued)
Estimation of Model

Dependent Variable: Log (Rent Paid)

Variable	Ottawa Coefficients	Ottawa Std. Err.	Toronto Coefficients	Toronto Std. Err.	Winnipeg Coefficients	Winnipeg Std. Err.	Regina Coefficients	Regina Std. Err.
Intercept	6.031	0.060***	6.110	0.049***	6.211	0.077***	6.160	0.145***
10 < age < 20 years	-0.200	0.039***	-0.015	0.027	0.037	0.066	-0.518	0.130***
20 < age < 40 years	-0.224	0.033***	-0.086	0.027***	-0.086	0.066	-0.598	0.129***
> 40 years	-0.260	0.034***	-0.143	0.028***	-0.142	0.067**	-0.672	0.129***
Detached housing	0.026	0.021	-0.020	0.018	-0.074	0.022***	-0.080	0.024***
Bedroom	0.183	0.008***	0.173	0.005***	0.112	0.007***	0.151	0.011***
Luxuries	0.107	0.023***	0.008	0.016	0.094	0.011***	0.008	0.016
Utilities	0.043	0.016***	-0.003	0.016	0.032	0.012***	0.034	0.021
Electricity	0.042	0.017**	0.041	0.012***	-0.021	0.013*	-0.017	0.038
Fridge/Stove	0.049	0.032	-0.037	0.031	-0.091	0.035***	0.056	0.056
Washer/Dryer	0.009	0.033	0.136	0.018***	0.090	0.017***	0.059	0.020***
Parking	0.060	0.014***	0.074	0.010***	0.061	0.013***	0.070	0.033***
% of rented dwellings	0.001	0.000***	0.001	0.000***	0.000	0.000**	0.000	0.000
% with major repairs	-0.001	0.001	-0.005	0.001***	-0.007	0.001***	-0.006	0.002***
% post-secondary	0.005	0.000***	0.005	0.000***	0.001	0.000***	0.004	0.001***
Commuting distance	-0.007	0.002***	-0.004	0.002**	-0.018	0.002***	-0.001	0.003
% under low Y cut-off	-0.003	0.000***	0.001	0.000***	-0.003	0.000***	0.001	0.001*
Adj-R-sq	**0.631**		**0.477**		**0.513**		**0.650**	

Variable	Calgary Coefficients	Calgary Std. Err.	Edmonton Coefficients	Edmonton Std. Err.	Vancouver Coefficients	Vancouver Std. Err.	Victoria Coefficients	Victoria Std. Err.
Intercept	5.788	0.195***	6.199	0.145***	5.644	0.055***	5.694	0.129***
10 < age < 20 years	0.029	0.168	-0.296	0.128**	-0.174	0.030***	-0.073	0.103
20 < age < 40 years	-0.133	0.168	-0.373	0.127***	-0.103	0.027***	-0.237	0.087***
> 40 years	-0.137	0.170	-0.483	0.130***	-0.207	0.028***	-0.090	0.088
Detached housing	0.079	0.028***	0.103	0.023***	-0.009	0.022	0.063	0.033*
Bedroom	0.186	0.010***	0.142	0.009***	0.221	0.008***	0.208	0.014***
Luxuries	0.102	0.019***	0.062	0.019***	-0.073	0.010***	0.271	0.023***
Utilities	0.059	0.027**	0.059	0.021***	0.013	0.016	0.116	0.022***
Electricity	0.002	0.030	0.065	0.024***	-0.132	0.023***	-0.169	0.066***
Fridge/Stove	0.033	0.074	-0.036	0.060	0.151	0.017***	0.070	0.063
Washer/Dryer	0.078	0.022***	0.028	0.016	0.115	0.021***	-0.018	0.026
Parking	0.057	0.027**	-0.028	0.026	0.064	0.013***	-0.041	0.021**
% of rented dwellings	0.003	0.000***	0.001	0.000***	0.000	0.000	0.003	0.001***
% with major repairs	-0.002	0.002	0.002	0.001	0.000	0.001	-0.005	0.002***
% post-secondary	0.003	0.001***	0.001	0.000	0.012	0.001***	0.007	0.001***
Commuting distance	-0.017	0.003***	0.005	0.002***	-0.021	0.002***	0.001	0.003
% under low Y cut-off	-0.002	0.001***	-0.003	0.000***	-0.002	0.001***	-0.005	0.001***
Adj-R-sq	**0.681**		**0.550**		**0.837**		**0.716**	

*** Statistically significant at the 1% level.

** Statistically significant at the 5% level.

* Statistically significant at the 10% level.

The use of the semi-log functional form gives the regression coefficients an interpretable meaning. The regression coefficients measure the relative change in rent paid for a given absolute change in an explanatory variable. For example, one can easily measure the impact on rental price of an increase in the number of bedrooms in a dwelling, say, between Winnipeg and Vancouver. With every additional bedroom in Vancouver, the rental price increases by 22.1%; whereas in Winnipeg, the rental price increases by only 11.2%. These results highlight the differences in the willingness to pay for an additional bedroom in Vancouver relative to Winnipeg, and the premium placed on additional rooms across these urban centres. The coefficients of the remaining explanatory variables have a similar interpretation.

The Laspeyres, Paasche, and Fisher indices are reported for the CMA of Winnipeg as the base city. Appendix 3 presents the indices expressed in terms of 14 inter-city pairings. The Fisher index is the geometric mean of the Laspeyres and Paasche indices, and its value should always lie between the two. The magnitude of the Laspeyres and Paasche indices depends on the reference and comparison areas that are being compared and on the relativity of the average base characteristic. The indices compare favourably with the authors' expectations (refer to Table 2). Ottawa, Toronto and Vancouver were expected to be relatively higher than the remaining urban centres.[10] Using the Fisher index, the four highest cost quality-adjusted urban areas for shelter are Toronto, Ottawa, Vancouver and Victoria. The lowest cost quality-adjusted cities are, in ascending order, Québec City, Saint John, Regina and Charlottetown.

Table 2

Spatial Shelter Price Indices by Census Metropolitan Area
(Index Base Winnipeg=100)

	LASPEYRES	PAASCHE	FISHER
St. John's	106.7	97.8	102.2
Charlottetown	96.4	95.6	96.0
Halifax	111.9	109.5	110.7
Saint John	84.6	92.9	88.6
Fredericton	105.9	115.9	110.8
Québec City	85.9	89.9	87.9
Montréal	101.3	100.2	100.8
Hull	103.0	98.2	100.6
Ottawa	131.6	142.8	137.1
Toronto	162.6	174.2	168.3
Winnipeg	**100.0**	**100.0**	**100.0**
Regina	92.2	93.6	92.9
Calgary	118.5	125.1	121.7
Edmonton	99.6	103.9	101.7
Vancouver	124.5	150.2	136.8
Victoria	121.3	135.8	128.4

[10] The study's expectations were based on Prud'homme and Thivierge [1999].

6. Concluding remarks

For a number of years, Prices Division has produced a family of price indices used for making city comparisons of price "levels". However, their use was limited because the spatial indices, unlike their CPI cousin, did not include shelter costs—the most important component of family expenditure and often the most variable. Generally, geographic comparisons of living costs have always been problematic methodologically, but even more so in the particular case of shelter because of its heterogeneous nature.

To overcome the difficulties associated with making spatial comparisons of shelter, a new database was created, matching the rent questionnaire from the Labour Force Survey and the 1996 Census. The database contained detailed information on rental accommodations. The rental equivalence approach is combined with a semi-log separate hedonic quality-adjusted regression methodology to construct Laspeyres, Paasche and Fisher-Törnqvist indices. By focusing attention on one particular model used to calculate the experimental spatial price indices, a practical framework is investigated in detail. This methodology is technically and analytically straightforward to apply, and the results obtained are comparable to those of previous literature in the field.

The price indices that are generated are of such a reliable quality that city comparisons of shelter costs can now be made, and the construction of an "All-items" spatial price index is now possible. The expanded geographical price index series, inclusive of shelter, results in an "All-items" spatial index akin to its CPI counterpart. The index will satisfy the growing demand for this type of information. The data would be useful, for example, in wage adjustments for relocating employees, and for deflating nominal incomes in studies of regional income disparities.

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Appendix 1

Data sources

Two main sources of data are used in the analysis, the Labour Force Survey (LFS) [August 1998 to December 1999] and the 1996 Census of Canada.[11] After edit and imputation of the data, 14,434 households remain in the combined sample (Appendix 2). The LFS rent questionnaire provides the physical quality characteristics of the dwelling and the Census provides socio-economic characteristics of the neighbourhood in which the dwelling is located.

Labour Force Survey data

The LFS targets 98% of the Canadian population. Residents of the Northwest Territories, Indian Reserves and Crown lands are excluded from the survey. Inmates of institutions and full-time members of the Canadian Armed Forces are also excluded because they are considered to be outside of the labour market [Guide to Labour Force Survey, 2000]. The survey focuses on persons 15 years of age and older. Information that is collected with the LFS, but that has been omitted from the analysis includes dwellings that are used for the dual purpose of home and business operations, and dwellings subsidized by government, employer, or relative. The LFS has a rotating panel sample design. Households remain in the sample for six months, with one-sixth of the sample being replaced every month. As a result, there are six representative sub-samples and five-sixths of the sample overlap monthly. The rotational design limits response burden and is efficient for estimating month-to-month changes.

The LFS uses two types of strata. First, standard geographical areas, which include economic regions and employment insurance economic regions, are taken into account in the stratification. Second, strata are formed by combining smaller Enumeration Areas (EAs) into Census Metropolitan Areas (CMAs) [Gambino et al., 1998]. A CMA is a combination of a large urban area (known as the urban core) of at least 100,000 population and adjacent urban and rural areas (known as urban and rural fringes). The urban and rural fringes are areas that have a high degree of social and economic integration with the urban core [1996 Census Dictionary, 1997]. The level of integration is determined by commuter flows from the fringes to the urban core or vice versa.

The rent information is collected when the respondent first enters the Labour Force Survey. It is updated if and when the respondent reports any changes to the rent information previously supplied. For changes in the rental price, a simple average of the rents over the respondent's six-month period in the sample is used. The total sample used in this analysis ranges from August 1998 to December 1999. Respondents who enter the LFS sample in August leave after six months in January and a similar pattern is followed for the subsequent six-month rotations. If there are no changes in the respondent's rent information during the entire six-month period, then only the data from the first month are needed to include the respondent in the

[11] A third source of data was also used when aggregating the various shelter components. To reflect the relative importance of the shelter elements in the weighted average, expenditure data were taken from the 1996 Family Expenditure Survey. The use of these expenditure weights is consistent with those already in place in the spatial program.

sample. After accounting for the rotational design of the sample, the data set is complete for the year 1999.

A subset of the LFS comprising 16 urban centres makes up the sample used for this paper. From east to west, the CMAs used are St. John's, Charlottetown (including Summerside), Halifax, Saint John, Fredericton, Québec City, Montréal, Ottawa-Hull (Quebec portion hereafter referred to as Hull), Ottawa-Hull (Ontario portion hereafter referred to as Ottawa), Toronto, Winnipeg, Regina, Calgary, Edmonton, Vancouver and Victoria. All of these urban centres represent CMAs except for Charlottetown and Summerside, both of which are Census Agglomerations (CAs).

The LFS also provides several weights that can be employed during estimation. Of the available weights (cluster weight, stabilization weight, theoretical weight, balance factor, sub-weight, rural/urban factor, and special weight), the final weight is chosen. There are several advantages to using the final weight for each household. The main benefit is that the final weight is calculated in such a way that it represents the respondent's contribution to the total population. The estimates generated with these weights will be consistent with demographic estimates of the population. The weight is calculated as a product of three factors: a design weight, which incorporates design information (cluster and stabilization weights are used to calculate the design weight); a non-response adjustment, which compensates for non-responding households; and a balance factor which calibrates the sample to known population counts. The final weight also acts as an adjustment for coverage error. It reduces the sampling error of the estimates and it is a common weight for all members of the same household [Methodology of the Canadian Labour Force Survey, 1998].

Census data

The census data used in this analysis come from the 1996 Canada Census. The census variables obtained are for enumeration areas from the 20% sample database. The 20% sample is weighted to provide estimates for the entire population [1996 Census Dictionary, 1997]. Enumeration areas are the smallest standard geographic areas for which census data are reported. EAs are as compact as possible and their limits follow visible features such as rivers and streets. The number of dwellings in an EA will vary between a minimum of 125 in rural areas to a maximum of 440 in large urban areas [1996 Census Dictionary, 1997]. Some of the EAs are censored in the data for reasons of confidentiality and statistical reliability. To avoid this loss of information, censored EAs are aggregated one level. The aggregation follows three main criteria. Only adjacent EAs, EAs of the same Census Tract (CT), and EAs able to pass the confidentiality and statistical reliability conditions are grouped together. In some cases, it is necessary to aggregate to the CT level to ensure confidentiality and statistical reliability.[12] The 1996 census neighbourhood characteristics compiled by enumeration area and census tract are assumed to be constant up to and including the timeframe of the 1999 LFS.

[12] The census tract is the level of aggregation above the EA level and below the CA or CMA levels. Census tracts are formed based on both social and economic integration.

Data model

The linkages in Figure A1.1 show the integration of the data sets discussed in the previous sections. The Postal Code Conversion File (PCCF) is matched to the LFS by postal code. Thus, individual households are merged with their respective enumeration area. This combined data set is then matched by EA to the 1996 Census data. The final data set, which combines both the LFS and Census data, is the data set used in the estimation of inter-city price indices. Table A1.1 lists both the endogenous and exogenous variables used in the analysis and their definitions.

Figure A1.1: Data Model

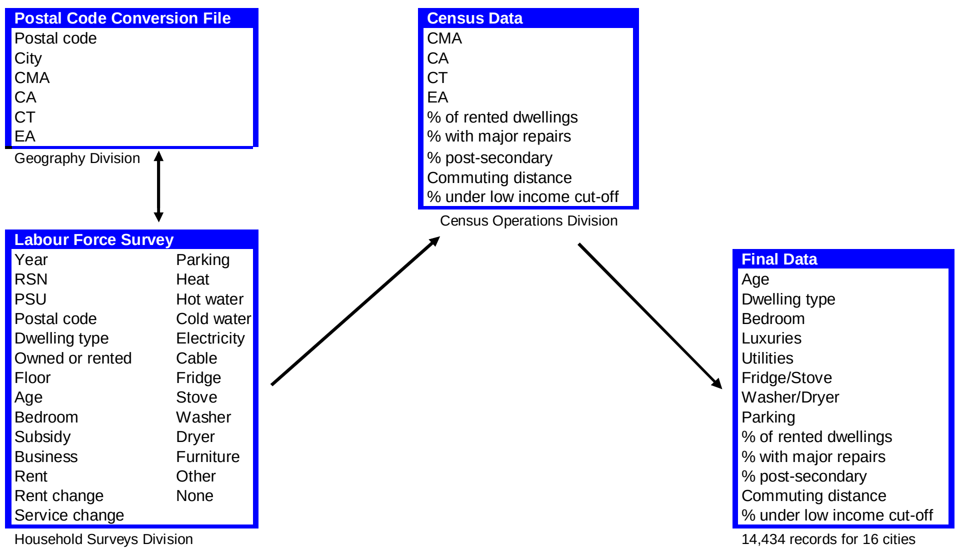

Table A1.1

Variables in Regression

Dependent Variable:	
Rent	total monthly log rent for the dwelling.
Independent Variables:	
Physical Dwelling Characteristics:	
Age12	the building is no more than 5 years old (Age1), and more than 5 but no more than 10 years old (Age2). Age of structure is a discrete variable.
Age3	more than 10 years old, but no more than 20.
Age4	more than 20 years old, but no more than 40.
Age5	more than 40 years old.
DYTP1234	this dummy variable is a composite of four dwelling types:
	DYTP1 single detached
	DYTP2 semi-detached (double)
	DYTP3 row or terrace
	DYTP4 detached duplex
DYTP56	this variable is a combination of two dwelling types:
	DYTP5 low-rise apartment with less than five stories or flats
	DYTP6 high-rise apartment with five stories or more
Floor	the floor number on which the respondent lives (continuous variable).
Bedroom	number of reported bedrooms in dwelling (continuous variable).
Electricity	a dummy variable that is equal to 1 if the service is included with rent, and 0 otherwise.
Luxuries	this dummy variable is a composite variable of commodities included as part of the monthly rent: cable television, furniture, or other major appliances.
Utilities	this dummy variable is a combination of utility commodities that are included as part of the monthly rent: heat and hot water.
Fridge/Stove	combination of the refrigerator and stove commodities.
Washdry	combination of the washer and dryer commodities.
Parking	dummy variable equal to 1 if parking facilities are included with the monthly rent.
Characteristics of the neighbourhood (enumeration area):	
Var4	percentage of private dwellings rented in an enumeration area.
Var7	percentage of private dwellings in need of major repairs. Major repairs refer to defective plumbing or electrical wiring, structural repairs to walls, floors or ceilings, etc.
Var11	percentage of persons with post-secondary education. Post-secondary education is defined as completed community college or university certificate, diploma or degree.
Var41	average commuting distance to work (km). The average commuting distance variable is a discrete variable, measured in 5 km increments up to 30 km or more.
Var43	percentage of persons living under the low income cut-off.

Appendix 2

Sample description

Table A2.1

Location	N
St. John's	235
Charlottetown	611
Halifax	819
Saint John	337
Fredericton	225
Québec City	793
Montréal	2,496
Hull	536
Ottawa	770
Toronto	2,319
Winnipeg	1,424
Regina	511
Calgary	656
Edmonton	762
Vancouver	1,400
Victoria	540
All	**14,434**

Table A2.2

Percentage of Dwelling Types by Census Metropolitan Area*

	Single Detached	Double	Row or Terrace	Duplex	Low-rise Apartment	High-rise Apartment
St. John's	10.6	12.3	9.8	37.9	27.2	2.1
Charlottetown	11.6	8.3	3.8	4.3	70.7	0.0
Halifax	7.6	3.8	2.0	7.0	54.0	23.4
Saint John	6.5	7.4	1.2	6.5	66.2	10.7
Fredericton	8.9	8.0	2.7	5.3	67.1	6.2
Québec City	3.7	3.8	3.2	5.8	76.8	6.2
Montréal	3.3	1.0	5.3	7.1	68.1	15.0
Hull	11.0	8.8	3.7	8.2	60.6	6.5
Ottawa	7.1	4.5	13.1	4.5	31.0	39.5
Toronto	7.8	4.7	5.5	1.6	21.2	58.4
Winnipeg	9.8	3.3	6.0	2.5	45.0	32.4
Regina	24.1	4.9	13.3	1.0	47.9	8.4
Calgary	20.7	6.3	13.0	8.5	33.4	18.0
Edmonton	17.8	2.1	13.1	2.5	42.9	18.8
Vancouver	17.9	3.6	4.4	7.6	42.6	21.2
Victoria	20.4	5.2	5.0	7.0	55.4	6.3

* Due to rounding, each CMA may not add up to 100%.

Table A2.3

Percentage of Structures within Age Range (Years) by Census Metropolitan Area*

	(< 5 years)	(5 < age < 10)	(10 < age < 20)	(20 < age < 40)	(> 40 years)
St. John's	4.3	12.3	26.0	34.0	23.4
Charlottetown	3.8	11.0	23.6	23.4	38.3
Halifax	5.4	13.8	17.9	42.1	20.8
Saint John	0.0	3.0	7.1	29.7	60.2
Fredericton	12.0	6.7	16.4	33.3	31.6
Québec City	1.6	11.6	16.1	40.6	30.0
Montréal	1.0	4.7	12.3	45.8	36.3
Hull	4.5	12.7	14.4	40.9	27.6
Ottawa	2.1	5.7	12.3	53.5	26.4
Toronto	1.7	4.0	17.0	52.6	24.7
Winnipeg	0.5	2.3	16.6	53.4	27.2
Regina	1.6	2.2	16.4	47.6	32.3
Calgary	1.4	1.8	17.4	60.7	18.8
Edmonton	2.4	1.8	16.3	62.5	17.1
Vancouver	5.6	6.9	17.1	48.3	22.1
Victoria	2.8	5.0	10.7	52.2	29.3

* Due to rounding, each CMA may not add up to 100%.

Table A2.4

Percentage of Dwellings by Number of Bedrooms and by Census Metropolitan Area*

	Bachelor	Single	Double	Triple	Quad
St. John's	1.3	23.4	47.2	24.3	3.8
Charlottetown	2.3	29.0	48.4	16.4	3.9
Halifax	5.3	36.6	40.4	15.4	2.3
Saint John	4.7	23.4	43.0	26.4	2.4
Fredericton	8.4	20.9	51.6	15.6	3.6
Québec City	4.5	31.1	50.7	11.9	1.8
Montréal	6.5	32.1	41.2	18.8	1.4
Hull	4.7	26.5	44.4	21.8	2.6
Ottawa	5.6	36.1	33.1	21.4	3.8
Toronto	5.5	38.8	37.0	16.1	2.6
Winnipeg	6.0	44.2	37.9	10.3	1.8
Regina	4.3	31.1	42.5	19.6	2.5
Calgary	1.8	31.7	38.9	19.5	8.1
Edmonton	7.9	34.5	30.3	22.3	5.0
Vancouver	8.1	41.7	30.4	14.2	5.6
Victoria	7.0	40.0	37.6	11.1	4.3

* Due to rounding, each CMA may not add up to 100%.

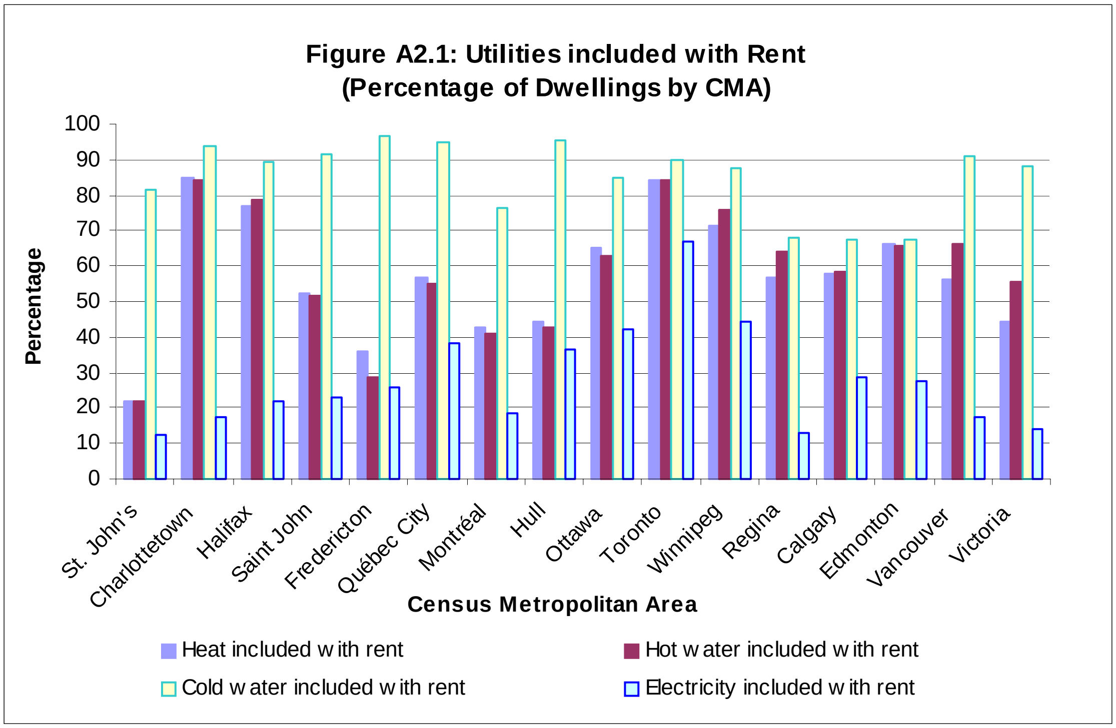
Figure A2.1: Utilities included with Rent
(Percentage of Dwellings by CMA)
Percentage
100
90
80
70
60
50
40
30
20
10
0
St. John's
Charlottetown
Halifax
Saint John
Fredericton
Québec City
Montréal
Hull
Ottawa
Toronto
Winnipeg
Regina
Calgary
Edmonton
Vancouver
Victoria
Census Metropolitan Area
Heat included with rent
Hot water included with rent
Cold water included with rent
Electricity included with rent

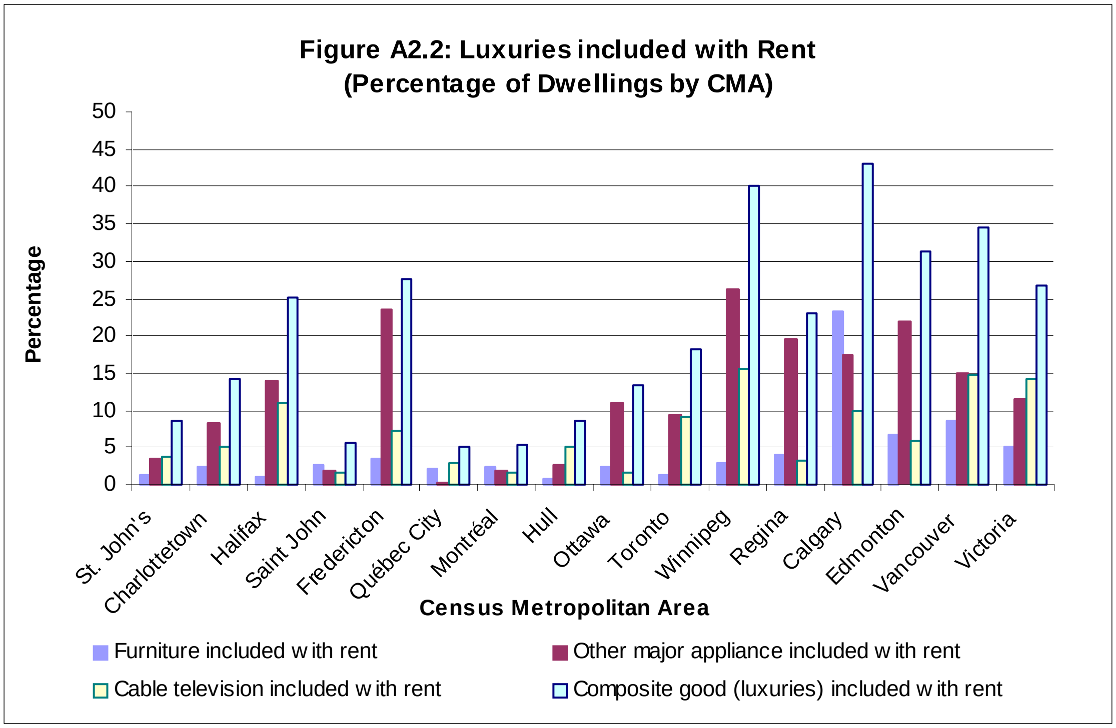
Figure A2.2: Luxuries included with Rent
(Percentage of Dwellings by CMA)
Percentage
50
45
40
35
30
25
20
15
10
5
0
St. John's
Charlottetown
Halifax
Saint John
Fredericton
Québec City
Montréal
Hull
Ottawa
Toronto
Winnipeg
Regina
Calgary
Edmonton
Vancouver
Victoria
Census Metropolitan Area
Furniture included with rent
Other major appliance included with rent
Cable television included with rent
Composite good (luxuries) included with rent

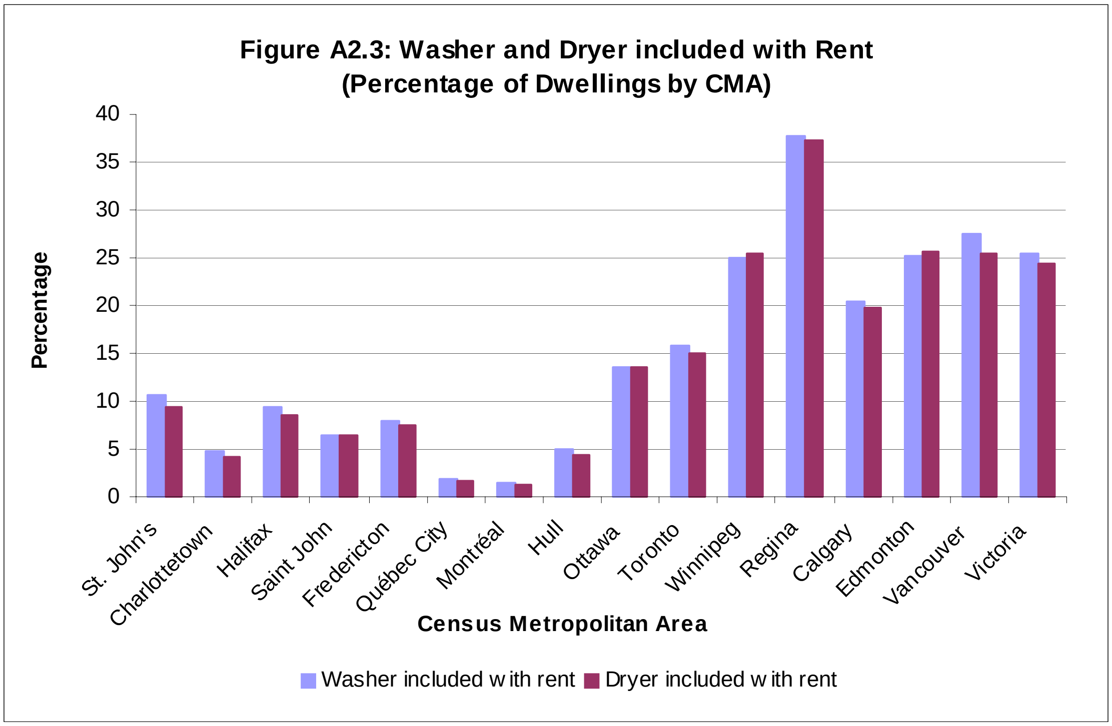
Figure A2.3: Washer and Dryer included with Rent
(Percentage of Dwellings by CMA)
40
35
30
25
20
15
10
5
0
Percentage
St. John's
Charlottetown
Halifax
Saint John
Fredericton
Québec City
Montréal
Hull
Ottawa
Toronto
Winnipeg
Regina
Calgary
Edmonton
Vancouver
Victoria
Census Metropolitan Area
Washer included with rent
Dryer included with rent

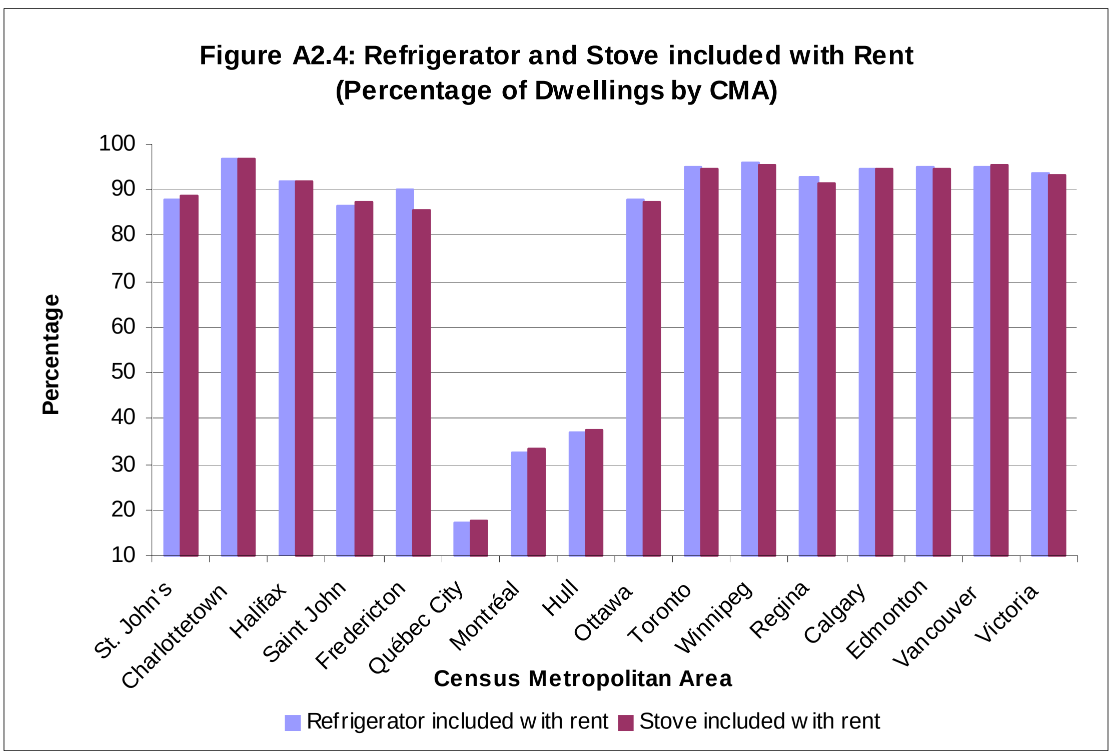
Figure A2.4: Refrigerator and Stove included with Rent
(Percentage of Dwellings by CMA)
100
90
80
70
60
50
40
30
20
10
Percentage
St. John's
Charlottetown
Halifax
Saint John
Fredericton
Québec City
Montréal
Hull
Ottawa
Toronto
Winnipeg
Regina
Calgary
Edmonton
Vancouver
Victoria
Census Metropolitan Area
Refrigerator included with rent
Stove included with rent

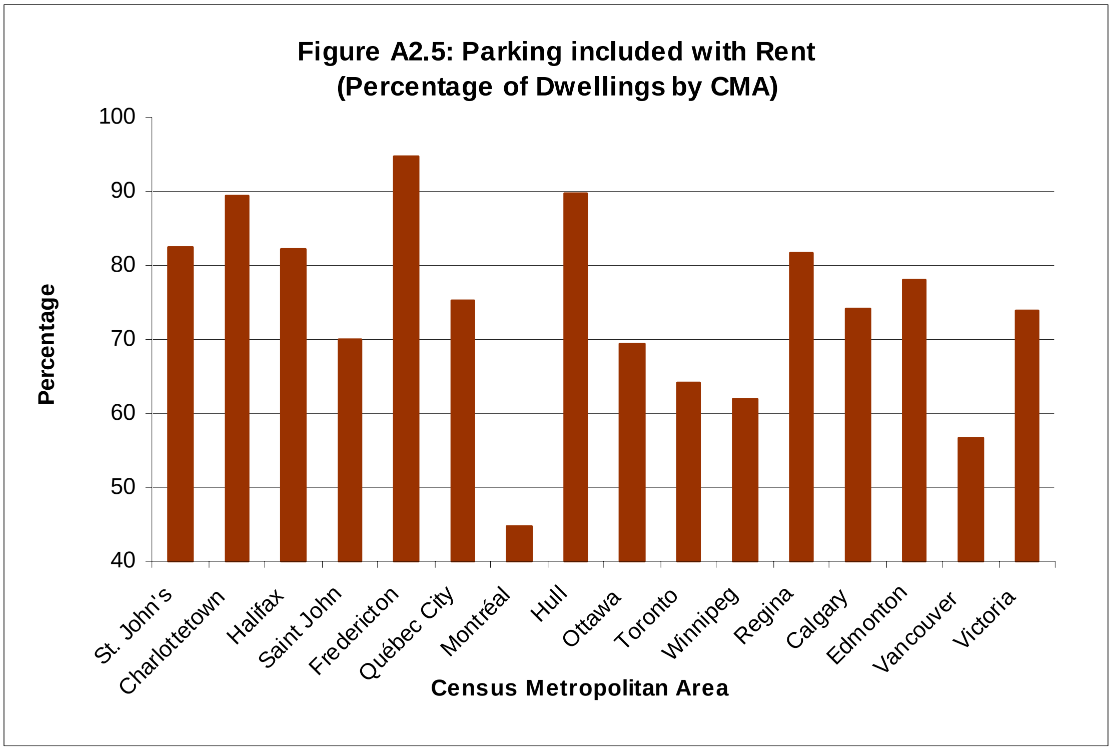

Table A2.5

Socio-economic Characteristic Means by Census Metropolitan Area

	Percentage of Rented Dwellings	Percentage with Major Repairs	Percentage with Post-secondary Education	Commuting Distance (km)	Percentage of Dwellings Under Low Income Cut-off
St. John's	43.1	6.1	54.9	6.1	17.8
Charlottetown	53.9	7.3	50.5	5.2	19.6
Halifax	67.2	6.3	60.3	5.7	23.7
Saint John	62.8	9.9	43.1	5.6	27.3
Fredericton	62.2	10.0	60.1	5.8	20.8
Québec City	64.9	5.8	46.3	5.4	28.5
Montréal	69.8	7.9	46.8	5.0	31.3
Hull	54.6	8.4	44.3	5.0	26.5
Ottawa	64.9	8.6	60.1	5.8	24.3
Toronto	68.8	9.3	52.3	5.9	27.8
Winnipeg	66.0	8.3	47.1	4.5	29.3
Regina	54.1	8.2	49.4	5.0	22.8
Calgary	59.5	8.2	59.0	6.1	22.8
Edmonton	61.5	6.4	53.6	6.9	25.4
Vancouver	58.7	7.8	60.6	5.8	22.4
Victoria	55.1	6.3	60.4	5.8	16.4

Table A2.6

Socio-economic Characteristic Medians by Census Metropolitan Area

	Percentage of Rented Dwellings	Percentage with Major Repairs	Percentage with Post-secondary Education	Commuting Distance (km)	Percentage of Dwellings Under Low Income Cut-off
St. John's	40.8	4.5	56.2	5.7	15.4
Charlottetown	51.2	6.0	50.4	4.5	17.6
Halifax	74.7	5.5	58.7	4.9	19.0
Saint John	70.8	8.3	42.2	5.6	22.2
Fredericton	68.7	8.4	62.6	6.1	21.4
Québec City	72.9	5.4	43.2	5.0	25.7
Montréal	72.6	7.2	44.3	4.6	30.8
Hull	54.0	7.0	42.9	4.7	24.5
Ottawa	66.7	8.8	59.3	5.1	21.6
Toronto	73.4	8.3	50.3	5.5	25.0
Winnipeg	69.6	6.3	47.1	4.3	26.1
Regina	50.7	7.9	49.5	4.5	22.2
Calgary	62.1	7.8	59.4	5.3	20.8
Edmonton	61.5	5.6	51.4	6.4	22.0
Vancouver	59.4	7.1	59.3	5.4	22.2
Victoria	58.7	5.3	61.7	5.5	10.8

Appendix 3

Model specification and estimation

Statistical model

Two tests are used to explore model specification, a Box-Cox transformation and the MacKinnon, White and Davidson [1983] PE test. The Box-Cox transformation is used first in an iterative fashion to test a variety of specifications that maintain their analytical practicality [Godfrey, McAleer and McKenzie, 1988]. Thus, a Box-Cox transformation was conducted on the dependent variable rent for each location.

$y_k(\lambda) = \alpha + \beta_j x_{jk} + \varepsilon_k$, where $y_k(\lambda)$ denotes the transformation. (A3.1)

$$\begin{aligned} y_k(\lambda) &= \left(y_k^{\lambda} - 1\right)/\lambda, \quad \lambda \neq 0, \quad y_k \geq 0 \\ &= \log y_k \quad , \quad \lambda = 0, \quad y_k > 0 \end{aligned} \qquad \text{(A3.2)}$$

The iteration of λ ranged from −1 to 3 with increments of 0.1. The adjusted R^2 and Akaike's information criterion (AIC) were used as measures of goodness of fit to compare the various specifications. The adjusted R^2 is the highest at 0.4842 when λ=0.1, while the AIC corresponding value is 3687. The specification λ=−0.2 has a lower adjusted R^2, but the AIC at 236 approaches zero (Table A3.1). To further support the choice of the semi-log specification, the PE test developed by MacKinnon, White and Davidson is employed. The test is non-nested and normality is not a necessary assumption (as it is under the Box-Cox transformation). The PE test is not expected to have optimality properties, and it can be expected to have less power than Wald, Lagrange Multiplier (LM), and likelihood ratio (LR) tests. However, it is suggested that despite its theoretical deficiencies, the PE test remains a powerful tool that is simple to use [MacKinnon, White and Davidson, 1983]. The term $\hat{\log} y_k$ is the predicted value of $\log y_k$ for the semi-log specification, and $\log \tilde{y}_k$ denotes the logarithm of the predicted value of y_k in the following equations:

$$\log y_k = \alpha + \beta_j x_{jk} + \gamma_o \left[\tilde{y}_k - e^{\left(\hat{\log} y_k\right)} \right] + \varepsilon_k \qquad \text{(A3.3)}$$

and

$$y_k = \alpha + \beta_j x_{jk} + \gamma_1 \left[\hat{\log} y_k - \log \tilde{y}_k \right] + \varepsilon_k \qquad \text{(A3.4)}$$

The hypothesis that the semi-log specification is not rejected is equivalent with γ_o=0; and γ_1=0 is equivalent to not rejecting the linear model specification. The test indicates that the semi-log specification is the most appropriate for the given data (Table A3.2).

Table A3.1

Box-Cox Specification Test

Lambda	R-squared	Adj-R-sq	AIC
-0.5	0.4811	0.4662	-3146
-0.4	0.4868	0.4721	-2026
-0.3	0.4915	0.4769	-898
-0.2	0.4950	0.4805	236
-0.1	0.4974	0.4830	1379
0	0.4984	0.4841	2530
0.1	0.4985	0.4842	3687
0.2	0.4971	0.4828	4853
0.3	0.4944	0.4801	6028

These are the average goodness-of-fit statistics for all locations.

Table A3.2

MacKinnon, White and Davidson PE Test

CPI	Location	T-statistic
1	St. John's	-2.34
2	Charlottetown	0.04
3	Halifax	-3.34
4	Saint John	0.26
5	Fredericton	-5.39
6	Québec City	0.74
7	Montréal	-8.17
8	Hull	-0.83
9	Ottawa	0.45
10	Toronto	-1.90
11	Winnipeg	4.19
12	Regina	-3.01
13	Calgary	-0.43
14	Edmonton	4.18
15	Vancouver	-1.44
16	Victoria	1.35

For the null hypothesis of the semi-log specification to not be rejected, the parameter should equal zero or $-1.95 < t < 1.95$ at the 5% significance level.

The natural logarithm of rental price was regressed on the physical and socio-economic attributes by location. The separate regression semi-log model can be described as:

$$Y_{vk} = \alpha_v + \sum_{j=1}^{J} \beta_{vj} X_{vjk} + \varepsilon_{vk} \qquad \text{(A3.5)}$$

$$E(\varepsilon_{vk}) = 0, \qquad \text{(A3.6)}$$

$$E(X_{vjk}\ \varepsilon_{vk}) = 0, \tag{A3.7}$$

$$E(\varepsilon^2_{vk}) = \sigma^2_{vk} \tag{A3.8}$$

where Y_{vk} is the natural logarithm of monthly rent paid for the k^{th} dwelling in location v. α_v is the intercept of location v. β_{vj} is the coefficient vector for the j quality characteristics of the dwelling, and X_{vjk} is the matrix of all attributes (physical and socio-economic). ε_{vk} represents the error term for the k^{th} dwelling in location v.

Statistical methods

This section discusses the difficulties with estimation and then briefly examines the techniques used in addressing those difficulties. The calculation of hedonic indices is a two-step process. First, quality characteristic coefficients must be obtained from a regression of rental price on quality characteristics. In the second step, the estimates are used to construct a Fisher spatial price index, which is a geometric mean of the Laspeyres and Paasche price indices.

Before the regressions could be conducted, problems with multicollinearity and omitted variables had to be reconciled. Multicollinearity was encountered with some of the variables. As a result, correlation tests were run for all variables used in the regressions. The heat and hot water; refrigerator and stove; and washer and dryer variables are correlated. To counter the multicollinearity problem, composite commodities are created (Appendix 2). This is justified because of the near perfect correlation among these variables. The complementary nature of the goods implies a natural course of action, which is to bundle the flow of services from these goods. Composite commodities are created for washer and dryer, by letting "washdry" equal one if there was a washer and dryer, and zero otherwise. A similar calculation is done for refrigerator and stove. The dummy variable for utilities equals one if there is heat and hot water, and equals zero otherwise. The variable electricity is included in the regression separately. The calculation for the luxury commodities (such as cable television, furniture and other major appliances) is different. The dummy variable for luxuries equals one if cable television, furniture or other major appliances are present in the dwelling, otherwise it equals zero. The age of structure, dwelling type, and percentage of private dwellings rented are examples of variables that had correlations with other variables, which were problematic. Nothing is done to resolve the problem of multicollinearity for these variables since coefficients in the regression did not consistently display implausible signs or magnitudes, and the standard errors were not inflated beyond expectations. Omitted variables are a result of two problems: limitations of the data and collinearity problems. A partial list of omitted variables may include: swimming pool, central air conditioning, square footage of the dwelling, number of rooms in the dwelling, land value, and potentially some type of environmental variables such as an air pollution or a vista index. It must also be noted that there will always be variables that are valued by consumers but which are unobservable, and therefore cannot enter the hedonic model.

Separate regressions are run for each index area (i.e. each urban centre). Ordinary least squares (OLS) is not an appropriate regression technique due to the non-spherical nature of the errors. The nature of this cross-sectional study led the authors to believe that heteroscedasticity might be present. Preliminary White specification tests were run to analyse specification and heteroscedasticity. The results are mixed as to whether the null of homoscedasticity is rejected for all locations but further testing is required due to the general nature of the White tests.

The asymptotic properties of the large sample prompted the authors in choosing a Breusch-Pagan-Godfrey multiplier test (BPG) to look for any significant presence of heteroscedasticity. The BPG test is a Lagrange Multiplier (LM) test of the null hypothesis of homoscedasticity. The LM statistic is calculated by dividing the explained sum of squares from the OLS regression of e^2_{vk} on z_{vk} and an intercept term by $2s^4$, where $s^2 = \frac{1}{K}\sum_k e^2_{vk}$. This test is quite sensitive to the assumption of normality.

A large sample Shapiro-Wilk (SW) test is performed to assess normality by location. The test revealed that the assumption of normality is not justified. Royston [1982] introduced this large sample SW extension:

$$W_{vk} = 1 - \left[(z_{vk})\sigma_y + \mu_y\right]^{1/\tau}, \qquad 0 < W_{vk} \leq 1 \qquad \text{(A3.9)}$$

where z_{vk} is a standard normal deviate, and μ_y and σ_y are the mean and standard deviation of y. The parameters τ, μ_y, and σ_y are functions of vk and are obtained from simulation results (refer to Royston [1982] for details). A departure from normality is indicated by small values of W. The Shapiro-Wilk test rejected the hypothesis that the aggregate data set had a normal distribution at the 0.01% significance level. When the data are divided into sub-samples by location, the test indicates that the assumption of normality is also not justified at the 0.01% significance level, and this is true for all locations (Table A3.3).

Table A3.3

Shapiro-Wilk Test for Normality

CPI	Location	p-stat
1	St. John's	0.0001
2	Charlottetown	0.0001
3	Halifax	0.0001
4	Saint John	0.0001
5	Fredericton	0.0015
6	Québec City	0.0001
7	Montréal	0.01
8	Hull	0.0001
9	Ottawa	0.0001
10	Toronto	0.01
11	Winnipeg	0.0001
12	Regina	0.0001
13	Calgary	0.0001
14	Edmonton	0.0001
15	Vancouver	0.0001
16	Victoria	0.0001

If a p-stat is less than or equal to 0.01, then the null hypothesis of a normal distribution is rejected (1% significance level).

Koenker and Bassett [1982] suggested a modification in the computation of the LM statistic for the BPG test, when normality is not an appropriate assumption. The suggested LM statistic is:

$$LM = \left(\frac{1}{H}\right)\left(u - \bar{u}\,i\right)' Z\left(Z'Z\right)^{-1} Z'\left(u - \bar{u}\,i\right) \qquad \text{(A3.10)}$$

where u is $(e^2_1, e^2_2, \ldots, e^2_K)$, $\bar{u} = \frac{e'e}{K}$, and i is a K by one column of 1's. The computation is based on a more robust estimator of the variance of $\varepsilon_{vk}{}^2$. The variance of $\varepsilon_{vk}{}^2$, if it is normally distributed, is not necessarily equal to $2\sigma^4$. Thus, the modification is $H = \frac{1}{K}\sum_k \left(e^2_{vk} - \frac{e'e}{K}\right)^2$.

Koenker and Bassett's calculation in the absence of normality will provide a more powerful test. However, under normality the modified statistic will have the same distribution asymptotically as the Breusch-Pagan LM statistic. The Lagrange multiplier statistic is asymptotically distributed as chi-squared with degrees of freedom equal to the number of variables in the regression. The Koenker and Bassett tests are all statistically significant at the 0.05% level (except for Québec City, Table A3.4); thus the null hypothesis of homoscedasticity is rejected in favour of the alternative hypothesis of heteroscedasticity.

Table A3.4

BPG Tests for Heteroscedasticity

CPI	Location	LM statistic
1	St. John's	48.9
2	Charlottetown	37.1
3	Halifax	82.2
4	Saint John	34.0
5	Fredericton	47.3
6	Québec City	13.7
7	Montréal	83.9
8	Hull	44.2
9	Ottawa	32.5
10	Toronto	48.7
11	Winnipeg	88.6
12	Regina	130.0
13	Calgary	85.4
14	Edmonton	115.7
15	Vancouver	39.6
16	Victoria	56.4

With DF=15, the chi-sq stat=26.3 at the 5% significance level. If the LM statistic is greater than the chi-sq statistic, then the null hypothesis of homoscedasticity is rejected.

A two-step estimator Feasible Generalized Least Squares (FGLS) process is employed to correct for heteroscedasticity—the variation in disturbances within the classes of attributes. The class of attributes refers to the discrete or binary measurement of the age of structure, dwelling type, or commodity variables. The OLS disturbances are used to get a consistent estimate of Ω by replacing the true, yet unknown, error covariance parameters. This is asymptotically equivalent to Generalized Least Squares (GLS), which converge in distribution to the maximum likelihood estimator, and thus estimates are unbiased, consistent, and efficient relative to ordinary least squares [Jobson and Fuller, 1980]. A general procedure suggested by Amemiya [1985] is to use the residuals from the ordinary least squares regression as the endogenous variable to estimate the parameters θ:

$$Var\left(\varepsilon_{vk}^{2}\right) = \sigma_{vk}^{2}\left(\theta' Z_{vk}\right) \qquad \text{(A3.11)}$$

The Z is a set of independent variables that, in this case, coincide with X. The θ's are consistent estimates of the unknown parameters of Ω, with this information from the regression:

$$\sigma_{vk}^{2} = \theta' Z \text{ or equivalently,} \qquad \text{(A3.12)}$$

$$e_{vk}^{2} = \theta' Z_{vk} + \upsilon_{vk} \qquad \text{(A3.13)}$$

The predicted values of e_{vk}^{2} can be used as an estimate of σ_{vk}^{2}, since they are asymptotically equivalent. Thus, the estimator employed provides a two-stage estimation of β.

$$\hat{\beta}^{*}_{vj} = \left[\sum_{k=0}^{K} \frac{1}{\sigma^2_{vk}} X'_{vjk} X_{vjk}\right]^{-1} \left[\sum_{k=0}^{K} \frac{1}{\sigma^2_{vk}} X'_{vjk} Y_{vk}\right] \quad \text{(A3.14)}$$

This estimator is equivalent to the weighted least squares estimator when $w_{vk} = 1/\sigma^2_{vk}$.

$$\hat{\beta}^{w}_{vj} = \left[\sum_{k=0}^{K} w_{vk} X'_{vjk} X_{vjk}\right]^{-1} \left[\sum_{k=0}^{K} w_{vk} X'_{vjk} Y_{vk}\right] \quad \text{(A3.15)}$$

The implicit assumption of normality of the error distribution may be problematic if the error distribution is non-normal. Carroll and Ruppert [1982a] suggested a method that is robust against outliers and non-normal distributions. They demonstrated that the generalized weighted least squares estimates are just as good asymptotically as if the weights are actually known.

The second step in producing inter-area indices is to apply the coefficients from the estimation to the construction of a Fisher-Törnqvist (FT) spatial price index, which is a geometric mean of the Laspeyres (L) and Paasche (P) price indices. By using a geometric mean of the Laspeyres and Paasche indices, both averages of *j* characteristics for the reference and comparison areas are being used. The problem of non-transitivity of the Fisher-Törnqvist index still remains though.

There are minimum desirable properties that any reasonably constructed temporal index should pass: the identity, proportionality, and change-of-unit tests. These properties also hold for spatial comparisons; however, price estimates have to be substituted for implicit quality characteristic prices. The identity test is satisfied when one area is compared with itself and the index does not change. Proportionality is satisfied when, if all prices move in proportion, then so does the index. Finally, the change-of-unit test is satisfied when price estimates are "invariant under any change in the money or physical units in which individual prices are measured" [Allen, 1975]. The Laspeyres, Paasche and Fisher indices all pass these tests; however, the Laspeyres and Paasche fail to pass two transitivity properties, time reversal and circularity. The Fisher index passes the time reversal test ($P_{st} = 1/P_{ts}$, where s is not equal to t, and s and t = 0, 1, 2…). However, the Fisher index does not pass the circular test ($P_{os}*P_{st} = P_{ot}$, where s is not equal to t, and s and t = 0, 1, 2…). If the circular test is passed, it implies that the course of prices does not matter over time and, from an economic perspective, this is a severe assumption.

Table A3.5

Spatial Shelter Price Indices Inter-city Pairings

Pair Number	Inter-city Pairing	LASPEYRES	PAASCHE	FISHER
1	St. John's with Halifax (100)	98.5	92.0	95.2
2	Charlottetown with Halifax (100)	87.4	88.7	88.0
3	Saint John with Halifax (100)	82.1	82.6	82.4
4	Ottawa with Halifax (100)	127.7	123.3	125.5
5	Toronto with Montréal (100)	163.1	160.0	161.6
6	Ottawa with Toronto (100)	81.0	80.5	80.7
7	Toronto with Winnipeg (100)	162.6	174.2	168.3
8	Regina with Winnipeg (100)	92.2	93.6	92.9
9	Edmonton with Winnipeg (100)	99.6	103.9	101.7
10	Edmonton with Vancouver (100)	69.1	74.3	71.6
11	Fredericton with Halifax (100)	101.4	103.8	102.6
12	Québec City with Montréal (100)	90.6	90.6	90.6
13	Calgary with Edmonton (100)	115.5	118.4	116.9
14	Victoria with Vancouver (100)	93.4	90.2	91.8

Appendix 4

Statistics Canada Statistique Canada

RENT QUESTIONNAIRE

1 FORM **04**

CONFIDENTIAL when completed

Authority-Statistics Act, Revised Statutes of Canada, 1985, Chapter S19.

FRANÇAIS AU VERSO

2 Docket no 3 Survey date 4 Assignment no. 5 P.S.U.

10 *INTERVIEWER CHECK ITEM:*

- *If first rent interview at this dwelling* 1 ○ *go to 11*
- *Otherwise* 2 ○ *go to 15*

11 *INTERVIEWER CHECK ITEM:*

- *If dwelling Code 5 in item 8 on F03* 1 ○ *go to 12*
- *Otherwise* 2 ○ *go to 13*

12 ON WHICH FLOOR DO YOU LIVE?

Enter 00 for dwellings located in the basement.

13 TO THE BEST OF YOUR KNOWLEDGE, HOW OLD IS YOUR BUILDING?

- No more than 5 years old 1 ○
- More than 5 but no more than 10 years old 2 ○
- More than 10 but no more than 20 years old 3 ○
- More than 20 but no more than 40 years old 4 ○
- More than 40 years old 5 ○

14 HOW MANY BEDROOMS ARE THERE IN YOUR DWELLING?

- *Enter 0 for bachelor*
- *If 9 bedrooms or greater, enter 9*

15 THIS MONTH, IS THE RENT FOR YOUR DWELLING:

- SUBSIDIZED BY GOVERNMENT OR AN EMPLOYER OR RELATIVE?

Yes 1 ○ *Specify in NOTES* No 2 ○

- USED FOR BOTH LIVING AND BUSINESS ACCOMMODATION?

Yes 3 ○ *Specify in NOTES* No 4 ○

16 HOW MUCH IS THE TOTAL MONTHLY RENT FOR YOUR DWELLING?

$ ☐☐☐☐ 00 *If 0000, specify in NOTES*

IF SUBSEQUENT INTERVIEW, SAME HOUSEHOLD ONLY *Otherwise, go to 18*

17 SINCE LAST MONTH, HAVE THERE BEEN ANY CHANGES IN THE AMOUNT OF RENT PAID?

Yes 1 ○ No 2 ○

18 DOES THIS MONTHLY RENT INCLUDE PARKING FACILITIES?

Yes 3 ○ No 4 ○ *go to 20*

19 WHAT TYPES OF PARKING FACILITIES ARE INCLUDED IN YOUR RENT?

		No. of Spaces
Closed garage or indoor parking	5 ○	☐
Outside parking with plug-in	6 ○	☐
Outside parking without plug-in	7 ○	☐

For codes 3, 4 or 5 in Item 8 on the F03 enter the number of spaces (exclude driveways)

IF SUBSEQUENT INTERVIEW, SAME HOUSEHOLD ONLY *Otherwise, go to 21*

20 SINCE LAST MONTH HAVE THERE BEEN ANY CHANGES IN THE SERVICES, EQUIPMENT, FURNISHINGS OR OTHER FACILITIES INCLUDED IN THE RENT?

Yes 1 ○→ No 2 ○ *go to 22*

21 WHICH OF THE FOLLOWING COMMODITIES ARE INCLUDED AS PART OF THE MONTHLY RENT?
Check all that apply

Heat	01 ○	Range	07 ○
Heating of water	02 ○	Washer	08 ○
Cold water	03 ○	Dryer	09 ○
Electricity	04 ○	Other major appliances	10 ○ *Specify in NOTES*
Cablevision	05 ○	Furniture	11 ○ *Specify in NOTES*
Refrigerator	06 ○	None of the above	12 ○

22 COMPLETION STATUS

Completed 1 ○ Partially completed 2 ○ Refused 3 ○ *Specify in NOTES*

NOTES

Item no 99 Item no. 99

99 99

7-5030-474 06-06-89 STC-PRI 415-60059 STC-P-PU-015

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