COMPOSITIONAL SHIFTS AND HOUSE-PRICE INDEXES

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April 1997

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This project was carried out with the assistance of a grant from Canada Mortgage and Housing Corporation under the terms of the External Research Program (CMHC File 6585-R065). The views expressed are those of the authors and do not represent the official views of the Corporation.

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With the Assistance
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April, 1997

Abstract

This paper examines the effect of compositional shifts in the types of homes sold on standard house-price indices. Standard house-price indices, which are constructed as simple averages of the prices of houses sold during a particular month may be misleading indicators of the month-to-month changes in general house prices if the types of homes sold varies significantly from month to month. This paper examines three alternative methods of correcting for such compositional shifts. Two of the methods require no more information than the prices of those houses that have sold during a specific month. The third method is based on a hedonic model of house prices and requires information on the non-price characteristics of the houses.

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Executive Summary

Retail real-estate prices are reported year-round by the media. Consumers are interested in the price of the "average" house, as well as how this average price changes over time and varies by region. The reporting of average house prices, however, is problematic because changes in the composition of the houses sold each month leads to changes in reported average prices that do not reflect "pure" changes in overall house prices. This is referred to as the problem of *compositional shifts*.

The challenge in developing a good real-estate price index is to isolate the pure price change from the change in the mix of properties sold. It is generally accepted that most real-estate data have this problem of compositional shifts and, further, that there has been little effort in the real-estate industry to correct for it. Most of the work has been confined to academic research.

This paper examines the extent of bias in standard house-price indexes, and builds slightly more complicated price indexes to deal with the problem. We examine the standard mean index (which is the one typically used in media reports of house prices). We then provide two corrections to this standard mean index—the overall-weights index and the price-ratio-adjusted index. These corrections require information only on the price of the houses that actually sold during a given month. Finally, we build a price index based on a hedonic model of housing prices—one that uses information on the non-price characteristics of the houses that sold during the month.

Each index has its own advantages; but each also has its own problems. First, each index provided lower or about equal estimates of house-price changes compared to the standard mean index. Also, the hedonic index provides the lowest period-to-period fluctuations in estimated "pure" house-price changes.

Second, the results of the overall-weights and price-ratio-adjusted indexes indicate that compositional bias is significant. Correcting for this reduces the large period-to-period fluctuations in the index. Furthermore, the performance of the hedonic index indicates that housing characteristics other than just region should also be accounted

for when constructing house-price indexes, because compositional shifts in these other characteristics have a significant effect.

Third, the results suggest that the overall-weights index appears superior to the price-ratio-adjusted index in controlling for compositional shifts. This appears to be due to non-uniform house-price changes across the 10 geographic regions (of Montreal) used in the study.

Fourth, the hedonic index provides lower period-to-period fluctuations when compared to the standard mean index. In fact, it is the only index that demonstrates a clear price trend. Whereas all other indexes show prices rising on average over time, the hedonic index demonstrates a downward price trend after about 1990. The paper offers some explanations for this observation based on the significant recession that took place in 1990-91.

Overall, it is difficult to say which index method is best. It does, however, appear that the first correction of the standard mean index, the overall-weights index, is better at correcting for compositional shifts than the second correction, the price-ratio-adjusted index. The hedonic method is the most accurate, although it is the most difficult to use.

LES VARIATIONS DE LA COMPOSITION ET LES INDICES DES PRIX DES MAISONS

par

Christopher Ragan

Résumé

Toute l'année, les média publient de l'information sur le prix moyen des maisons. Les consommateurs s'intéressent au prix de la maison «moyenne» et aux variations de ce prix dans le temps et par région. La publication des prix moyens des maisons pose une difficulté. Des maisons différentes étant vendues tous les mois, le prix moyen publié est sujet à des modifications qui ne correspondent pas aux fluctuations tangibles du prix moyen des maisons dans l'ensemble. On emploie l'expression *variations des compositions* pour décrire cette difficulté.

La conception d'un indice valable des prix de vente moyens des maisons pose la difficulté d'isoler les variations de prix tangibles des variations de la composition des propriétés vendues. On reconnaît généralement que cette difficulté se manifeste dans la plupart des données portant sur l'activité immobilière et que le secteur immobilier n'a pas vraiment cherché à la résoudre. Seuls les universitaires ont étudié la question.

Dans ce rapport, nous étudions l'importance de la déviation dans les indices de prix de maisons standard, et nous en proposons deux un peu plus complexes pour résoudre la difficulté. D'abord, nous examinons l'indice des prix moyens, celui qui figure généralement dans les rapports que publient les médias sur le sujet. Ensuite, nous proposons deux manières de corriger l'indice des prix moyens standard : un indice fondé sur une pondération globale et un indice fondé sur des coefficients de prix ajustés. Pour effectuer ces corrections, il suffit de connaître le prix des maisons vendues durant un mois donné. En dernier lieu, nous élaborons un indice qui s'inspire d'un modèle hédonique du prix des maisons, c'est-à-dire fondé sur les caractéristiques des maisons vendues durant un mois donné autres que le prix.

Chaque indice comporte des avantages et des inconvénients. Premièrement, avec chacun nous avons pu obtenir des estimations du prix des maisons presque équivalentes ou inférieures à celles obtenues avec l'indice des prix moyens. En outre, avec l'indice hédonique nous avons obtenu les plus faibles fluctuations d'une période à l'autre dans les variations tangibles du prix estimé des maisons.

Deuxièmement, les résultats obtenus avec les indices utilisant une pondération globale et des coefficients de prix ajustés démontrent que la variation de la composition est considérable. Si on corrige la variation, on réussit à réduire les importantes fluctuations d'une période à l'autre inhérentes à l'indice des prix moyens. En outre, à l'utilisation, on a constaté qu'il faut tenir compte des caractéristiques des maisons autres que celles liées à la région lorsqu'on conçoit un indice hédonique, puisque la variation de la composition des ces caractéristiques a des répercussions considérables.

Troisièmement, la recherche semble indiquer que l'indice de pondération globale est plus efficace que l'indice des coefficients des prix ajustés pour diminuer les effets des variations de la

composition qui découlerait des modifications irrégulières du prix des maisons dans les 10 régions géographiques de Montréal faisant l'objet de l'étude.

Quatrièmement, l'indice hédonique permet d'obtenir de plus basses fluctuations d'une période à l'autre que l'indice des prix moyens standard. En réalité, c'est le seul indice qui indique une tendance claire des prix. Alors que tous les autres indices démontrent que la moyenne des prix croît au cours des années, l'indice hédonique démontre que les prix ont eu tendance à baisser après 1990. Dans le rapport on tente d'expliquer cette observation par la récession considérable de 1990-1991.

Dans l'ensemble, il est difficile de dire quel indice est le meilleur. Cependant, il semble que la première correction apportée à l'indice des prix moyens standard, l'indice de pondération globale, corrige les fluctuations de composition plus efficacement que la seconde correction, l'indice des coefficients des prix ajustés. L'indice hédonique est le plus précis, mais le plus difficile à employer.

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Introduction

Retail real-estate prices are reported year-round by the media. Consumers are interested in the price of the "average" house, as well as how this average price changes over time and varies by region. As Case and Quigley (1991) argue, however, the reporting of average retail prices is problematic because "reports of increases in the price of real-estate make front page news, but the techniques used for measuring these price changes are quite crude". Specifically, there is one major problem with the reporting of average real-estate prices, clearly explained by Bailey, Muth and Nourse (1963):

> Index numbers of the prices of real-estate properties are difficult to construct. The major problem is the great variation in quality among properties. Thus, indexes based upon the average sales prices of all properties of some particular kind in a given period....are likely to be deficient in two respects. First, variation in the quality of properties sold from period to period will cause the index to vary more widely than the value of any given property. Second, if there is a progressive change in the quality of properties sold at different times, the index will be biased over time.

This is a standard statistical problem. There is a heterogeneous population of homes in a region, and there is some average-price home for this population. However, we generally have only a sample of price data consisting of homes that actually sell each month. (Data on homes that are listed for sale but end up not selling is generally not available). The mean value is calculated for this sample, and it is used to represent the mean value of all housing. The key issue is how well the average selling price from the sample represents the value of the average home from the actual population.

This paper addresses the two problems mentioned above by Bailey, Muth and Nourse (hereafter BMN). The focus of this paper, however, is the first problem, which is referred to here as a problem of *compositional shifts*. The challenge in developing a good real-estate price index is to isolate the pure price change from the change in the mix of properties sold. For example, Diagram 1 represents a standard mean index for retail housing in Montreal over a period of 57 months—from February 1988 to July 1993. This is simply a price index based on the average selling price of all homes that sold in a given month. The dramatic fluctuations over the sample period (some of which is clearly a seasonal fluctuation) are obvious. With this type of index, however, it is unclear whether price increases in any given month are attributable to price increases which apply to houses of all types, or simply that a disproportionate share of the relatively more expensive homes happened to sell in that particular month. In the latter case, the data of homes sold in that month are unrepresentative of the total stock of housing in the market. This results in an obvious bias in the reported price index.

It is generally accepted that most real-estate data have this problem of compositional shifts and, further, that there has been little effort in the real-estate industry to correct for it. Most of the work has been confined to academic research. Various methods have been established to deal with this problem, most of which are outlined in Section 1.

The second problem referred to in BMN is that the quality and characteristics of the stock of housing change over longer periods of time. For example, in terms of style, technology, and neighbourhood characteristics, a house constructed in 1940 is very different from one constructed in 1980. Many researchers argue that comparisons of mean house prices over such long periods are inappropriate because they are essentially not measuring the same product. (This same problem, of course, lies at the heart of the upward bias in the constructed Consumer Price Index, as compiled by Statistics Canada.) Since the data used later in the empirical section of this paper spans only five years, the problem of a changing stock of housing will not be the focus here, as this is likely too short a period of time for the housing stock to change dramatically. However, this issue is a significant challenge for long-term real-estate indexes, and thus it is addressed in the theoretical section that follows.

This paper consists of four sections. Section 1 is a selective survey of the literature of real-estate index methodology. It describes and evaluates two alternatives to the standard mean index—the general hedonic index, and the repeat sales index. Section 2 presents specific information about the data used in Section 3, in which four different index methods are compared. Section 4 offers a brief conclusion.

1. Alternative Methods to the Standard Mean Index

The general change in house prices is the overall rate of price change, from period to period, of a population of houses. For example, given the entire population of houses in Montreal, there is some average price that changes over time. A standard mean index measures this rate of change by computing the average selling price of retail home sales for each period in question and then examining the change in the value of this index over time.

But this method has two problems. The first, as mentioned in the Introduction, is the presence of compositional shifts. In calculating the general change in house prices, one is forced by data limitations to use only a sample of houses, a strict subset of the actual population of houses. This sample comprises the set of all houses *that sold* over the period in question, which in our case is one month. (In fact, the sample is slightly more restrictive than this; data is only available for those houses that sold and were listed with a registered real-estate agent. Information on private sales is not available.) For houses that did not sell (or were not even listed for sale) in that month, there is no observable price. Indeed, since each month has a different set of houses that sell, it is best to think of having many monthly samples, each being a strict subset of the population.

In any city, each monthly sample contains house sales of many sizes, styles, and from many regions. If these monthly data represent a random sample of the overall population, then the average selling price based on the monthly sample is equal to the average selling price of the entire population. However, if the monthly data is not a random sample of the population, and instead differs from the population in some systematic way, then the estimated change in house prices will be a biased estimate of the true change in the population.

If the stock of housing is constant over time—a reasonable assumption only over short periods—then an unbiased monthly sample requires that the composition of each monthly sample be constant from month to month. In other words, unbiasedness requires that each monthly sample contains constant proportions of houses of various sizes, styles and regions. If this is not so—for example, if the sample proportion of 3-bedroom bungalows changes significantly from month to month—then the sample is biased, and is thus unrepresentative of the population. The result is that the estimated rate of change of house prices will be a biased measure of the rate of change in the population as a whole.

An example will help to make this point clear. Suppose there is a general increase in all house prices of 1 percent per month. This means that *every* house in the population is experiencing a price increase of 1 percent per month. Further suppose that 3-bedroom bungalows sell at a lower price than other homes. Now consider the estimated change in house prices from January to February. If the fraction of bungalows in the monthly sample rises for some reason in February, then the estimated rate of change of house prices from January to February will be lower than 1 percent; the increased importance of low-price homes in the monthly sample will pull down the average house price ***in the sample*** even though there is no change in the population.

The second problem with the standard mean index is that characteristics of the housing population change over longer periods of time. Even if there were no compositional shifts, mean comparisons over long periods may be uninformative because housing characteristics change significantly over time. The calculation of the Consumer Price Index faces the same problem. Based on the average person's consumption, a basket of goods is selected in some base year and the appropriate weights are assigned to each item. Then, based on this basket, price data is collected and a measure of the price level is computed. Over longer periods of time, however, the basket of goods consumed by the average person changes. To address this problem, a new base year, basket of goods, and weights must be selected that better represent the average consumer's consumption. In the case of real-estate, however, the problem is more difficult to overcome because there is no representative basket of housing to determine. There is only data on homes that actually sell. However, much like the representative basket of the Consumer Price Index, over longer periods the quality of homes changes significantly.

To accommodate for the problems of compositional shifts and changing house quality over time, two alternative index methods to the standard mean index have evolved: the general hedonic index and the repeat-sales index. This section explains these indexes and discusses the problems facing each. Note that each method's goal is the same: to adequately measure the prices of the general housing population and thus to accurately portray changes in house prices over time.

A. The General Hedonic Index

A natural method to remedy the two problems discussed above is the hedonic price index, where the product "housing" is decomposed into a number of sub-components for which both price changes and quality changes can be observed and measured. It involves estimating an hedonic price equation with the house's sale price as the dependent variable. The independent variables can be any quantifiable characteristics, such as size, number of bedrooms or bathrooms, age, distance from schools or shopping; as well as any qualitative characteristics such as whether the home has a garage, fireplace, hardwood floors, and the like. Dummy variables are also included denoting the period in which the dwelling sold. This method therefore suggests the estimation of a regression equation such as

$$P_{it} = \alpha + \sum_{t=1}^{N} \beta_t \cdot T_{it} + \sum_{k=1}^{K} \gamma_k \cdot X_{it} + \varepsilon_{it} \qquad (1)$$

where P_{it} is the selling price of house i in month t. Here, the month t does not refer to one of the 12 calendar months but rather to the N monthly data samples. T_{i1} through T_{iN} are a series of dummy variables indicating the month of sale; for each observed house sale, all the Ts are zero except the one corresponding to the month of the sale. X_{i1} through X_{iK} are a series of observable housing characteristics on house i, such as size or the number of bedrooms. Note that, this specification permits the same house to be sold several times in the entire sample. But in this case, the house is effectively treated as a different house each time since the price, month, and characteristics may all change (the month will definitely change).

Since the month dummy, T_{it}, denotes the month when the house sold, its coefficient measures the period-specific effect on the house's price. As a result, this term can be interpreted directly as the price index. Examples of this technique can be found in Ferri (1977), Palmquist (1980), Dale-Johnson (1982), and Clapp, Giaccotto and Tirtiroglu (1991).

- *Problems with the Hedonic Index*

The major advantage of the hedonic index is that it accounts for house characteristics, and thus avoids the problems of compositional shifts and changing house quality over time. However, it does face the other problems which can distort its index results. There are three general problems.

First, the hedonic index requires that each monthly sample be representative of the overall population of houses. In the case of retail housing sales, however, the data is not randomly selected. Researchers only have information on homes that have been sold on the market; there is no information on houses that were listed for sale but ended up not being sold. It is possible, therefore, that the houses which appear in the monthly sample of sales share some common characteristics that makes them more desirable to consumers, therefore predisposing them to sell. If this characteristic is observable, then this can be accounted for by including it in the list of X variables in Equation (1). But if this common characteristic is unobservable—"charm" and "well kept" come to mind—then there will be a problem of bias. Unfortunately there is little that can be done to correct for this problem of self-selection bias. (This is a more severe problem than what labour economists are now well-trained to deal with. In problems of sample-selection bias dealt with in labour economics, observations are typically available on two types of individuals—those that choose some action Z and those that do not choose Z. But here we have no information whatsoever on the houses that do not sell, and so the standard Heckman-style correction is not feasible.)

A second problem facing the hedonic index is one that challenges all regression work: the model must be correctly specified. This means that the correct functional form must be selected and the correct set of explanatory variables must be chosen. The correct functional form is difficult to discern because here is no obvious reason why any one form is more desirable than any other (Palmquist, 1980). Throughout the literature the standard model employs a log-linear form. This is likely based on the pragmatic reason that it makes the construction of an index straightforward; but it has little grounding in theoretical principle.

Selecting the appropriate set of right-hand-side variables is also difficult. Usually, important data such as neighbourhood and locational attributes are not easily available. As is discussed in the next section, one of the advantages of moving to a repeat-sales index is that it avoids this problem. Thus, even though the hedonic method is used to accommodate the problem of progressively changing housing characteristics, it cannot do so entirely because it is impossible to perfectly specify the model and its regressors. Incorrectly specified models can result in biased estimates, which will distort the housing-price index.

A final problem with the hedonic index is that it cannot account for compositional shifts of characteristics that are not explicitly included in the regression. This is also a standard problem in regression estimation—we do not observe all relevant information and thus it becomes important just which factors get left out (and thus get included in the error term, ε_{it}). Compositional shifts can occur in any housing characteristics, and since it is impossible to collect data on all of them, the hedonic index is still subject to the problem of compositional shifts distorting its index results. A natural solution to avoid this and the specification problems mentioned above is a regression method that does not use housing characteristics. It is primarily for this reason that the repeat-sales index evolved as a popular alternative to the hedonic index.

B. The Repeat-Sales Index

The repeat-sales index uses observations on houses that sell two or more times in any sample of real-estate data, and has at its core the maintained assumption that the characteristics of such houses do not change between each sale. This method therefore permits an estimation of housing price changes without requiring data on non-price house characteristics. This approach to constructing a price index evolved as a popular alternative to the hedonic index for two reasons. First, researchers argued that any index comparing properties over time must be a "constant quality index" (Case, Pollakowski, and Wachter, 1991). The hedonic price index may account for the individual characteristics of each home, but it does not take advantage of the controls inherent in houses that have transacted more than once. By constraining the sample to only these types of houses, specifically ones that have not been renovated between sales, one is isolating a pure price change. In this way, the index is comparing identical homes over two periods, rather than two completely different homes. This is unlike a standard mean or hedonic index that is an index of all housing types over time, and may not be capturing the pure price change of the representative home.

The second advantage with the repeat-sales index is that it avoids the model-specification problems associated with the hedonic index. The repeat-sales index need not consider the characteristics of each home, and thus it does not have to rely on a specific functional form; nor does it face the consequences of excluding any necessary regressors. The original version of this model can be found in BMN (1963); however, Case et al. (1991) use a less complicated one which appears to have become the standard. In it the difference between the transaction prices at two dates is solely a function of the intervening time. It takes the form

$$\ell n P_t = \ell n P_\tau + \sum_{n=\tau+1}^{t} \gamma_n + \xi_t \qquad (2)$$

where P_τ is the selling price of the house at the time of the initial transaction, P_t is the selling price of the same house at the time of a subsequent transaction, and thus $\tau < t$. ξ_t is an observation on a well-behaved disturbance term, and the set of γ parameters are to be estimated; each one represents the rate of change in house prices for the n^{th} period, where $n = (1, \ldots, t)$. Note that homes may transact more than twice, and thus t represents every subsequent transaction after τ. Also note how the model reduces the possibility of specification bias by not incorporating information about house characteristics. Furthermore, the houses sampled for this method have had no major renovations between sales, and thus the price change between these two periods is presumably a much purer change.

• *Problems with the Repeat-Sales Index*

The advantages of the repeat-sales index over the hedonic index are, first, that it reduces the problems of model specification, and second, by taking advantage of the controls inherent in repeat transactions, it presumably isolates a less distorted or purer price change over time. The repeat-sales index does, however, have several problems.

The first problem is bias in its sampling method. The repeat-sales index is estimated using a sub-sample of data from the overall sample—which is itself likely to be a biased sample—and thus there is little doubt that the repeat-sales sample is also biased (Clapp, Giaccotto, and Tirtiroglu, 1991). There are some solid reasons to believe this. First, the overall sample is likely to be over-weighted by so-called "starter homes" that individuals hold for just a few years before selling and moving up to more permanent homes. This over-weighting is likely to be especially severe in the repeat-sales sub-sample because the sub-sample is drawn based on the criterion that homes have transacted multiple times, and were thus held for shorter periods. Also, because the selection criteria excludes homes that have been renovated, this further biases the sample with less expensive properties relative to the actual population. This is based on the reasonable assumption that, *ceteris paribus*, renovated homes are generally more expensive. Clapp, Giaccotto and Tirtiroglu (1991) argue, however, that this bias will not affect the index because "it is reasonable to expect that arbitrage will force all properties in a given area to appreciate at approximately the same rate." Given the evidence of real-estate data used later in this paper, however, this argument seems incorrect because it can be seen that different types of houses demonstrate different rates of price increase.

A second problem with the repeat-sales index is that it does not account for time interactive effects. The index produces a measure of the general rate of change of house prices for each period. However, it cannot account for certain housing characteristics appreciating (or depreciating) more rapidly than others. In other words, it does not account for "fads". It implicitly assumes that the value of all houses move together.

A third problem is that even though the houses used in the sub-sample for the repeat-sales index have not had any major renovations, there is still one characteristic, age, that changes between transactions. Because the age of the house necessarily changes between two transaction dates, there is no single observation with absolutely unchanged characteristics. This may seem insignificant; however, most empirical studies suggest that the age of a structure significantly influences its transaction price (Case, Pollakowski and Wachter, 1991). Since the repeat-sales method estimates the price change of houses with no attributes except age changing between transaction dates, the influence of age becomes confounded with time. One cannot resolve whether the index shows pure price changes or simply age-induced price changes.

BMN (1963) recognized this problem, but econometric problems precluded them from estimating the effect of time within their model. Palmquist (1980) established that "the true price effects and [age-induced] depreciation effects cannot be distinguished without using additional data to provide an independent estimate of the rate of depreciation" (Palmquist, 1980). Palmquist's solution is problematic because the depreciation estimates must be independently derived form a hedonic model which, of course, must be specified. It is in avoiding problems of model specification that one moves to a repeat-sales index in the first place. At any rate, to include this variable in the repeat-sales model defeats its purpose because the model must also then be specified. This problem is critical for the repeat-sales index, and is partly why the hybrid index was developed.

The final problem with the repeat-sales index is efficiency. By using only repeat-sales, the number of observations falls substantially. In the existing literature, such sample-size reductions range from 65 to 96 percent (Clapp, Giaccotto and Tirtiroglu, 1991). It has been argued that this is not a relevant criticism of the repeat-sales index. One faces some particular problem and devises some necessary solution. In this case the problem is to develop a constant quality index; the solution involves analyzing some particular type of housing, and this requires dropping large portions of data. Overall it is a difficult issue to resolve. The relevant issue is whether the gain from removing bias by using a repeat-sales index outweighs the loss of efficiency by dropping a considerable amount of data.

C. Is One Index "Best"?

It is not clear that any one of these index methods is "best". Each one has its advantages and disadvantages. It appears that the most appropriate method depends on the type of data one has, and the question one is asking. Where data is plentiful, and one is concerned with specification error, the repeat-sales method appears to be better. Where data is scant, the general hedonic method enables one to control for age and renovation, but at the risk of model misspecification.

2. The Greater Montreal Housing Data

The data set used in this paper describes the characteristics of houses sold through the Multiple Listing Service (MLS) in the greater Montreal area between February 1988 and July 1993. The sample originally contained over 112,000 observations, where each observation corresponds to the sale of a single dwelling. The relevant variables for each observation are sale price, area of house and property, number of bedrooms, number of bathrooms, total taxes in sale year, style and age of house, address, and sale date.

It is inevitable that some of the observations contain errors, likely the result of mistyping during the original data-entering process. Some of these are undetectable even for the most meticulous searching methods. For example, a two-bedroom home could be entered as having three bedrooms, and there is no practical way to determine that this value is incorrect. Fortunately, however, many errors are obvious. An example is a negative value for total taxes or a negative sales price. But they may not be as conspicuous as this. For example, it is very unlikely that a four-bedroom house located in Westmount would sell for as little as $70,000, but it is logically possible. Criteria had to be established to search for such mistakes. Thus, initial procedures were followed to remove the most obvious errors from the data. These alone reduced the sample to about 83,000 observations. A method was then established to find errors that were not as apparent, but upon reflection could be seen as not practically possible.

To purge the data of errors, searching criteria were used that either listed or flagged the data. Observations that met conditions of being possibly flawed were listed and then considered individually for plausibility. Observations were flagged when they met the criterion of being obviously flawed.

Observations were listed if they met any of the following criteria:

- the number of bedrooms was greater than 9;
- the number of bathrooms was greater than 7;
- the sale price was greater than $1,000,000;
- the number of half-baths was greater than 6;
- total municipal taxes paid exceeded $30,000.

Data was flagged as obviously bad if:

- the property was smaller than 1,000 square feet;
- the dwelling had zero bedrooms;
- the dwelling had a zero bathrooms.

In the first two cases, an exception was made if the dwelling was either an apartment or a plexus. In these cases, a small property and no bedrooms (as in a studio apartment) is certainly possible.

The first procedure listed several hundred observations that were then individually considered. Observations with errors were then flagged as in the second procedure. Admittedly, this first method is subjective because it is only by intuition that many observations can be determined to be bad. Even the criteria for simply listing the observations is subjective, but they were chosen on the grounds of plausibility. For example, it is difficult to imagine a four-bedroom detached home with only an 800 square-foot property. Casual observation of the data suggested that many of these errors existed and thus some method was needed to find them. Of course, all observations with extreme values could simply have been removed, but this would have resulted in eliminating many legitimate ones. Furthermore, all listed observations were carefully examined before they were flagged—only those with the most blatant errors were marked. The resulting sample, after being purged of all anomalous observations, includes 66,519 observations.

• **Zone.** Many real-estate indexes subdivide data into smaller regions to accommodate for compositional shifts between regions (Haurin, Hendershott and Kim, 1991). Following this logic, ten zones were constructed based on the districts specified by the Greater Montreal Real Estate Board, and the data were divided along these lines. These zones are summarized in Table 1. Table 1 also presents averages for sale price, with standard deviations given in parentheses. As expected, wealthier zones such as Greater Montreal West have higher selling prices.

• **Style.** There are several different styles of house. However, not all of these are appropriate for the exercise here, and the inappropriate ones were thus dropped from the data. The remaining styles have been used as dummy variables and are summarized in Table 2. A break-down of style by zone is provided in Table 3.

• **Age.** The data consists of homes with construction dates that range from the previous century to July 1993. Six age dummy variables were constructed to describe this variable, and are displayed in Table 4. A break-down of construction year by zone is is provided in Table 5. One advantage of using dummy variables for each category of the age of the house, rather than simply having a single continuous variable, is that the relationship between age and price is not then restricted to being linear.

• **Bedrooms/Bathrooms/Taxes.** Dummy variables were also constructed for the number of bedrooms and the number of bathrooms. Cross-sectional data on these variables is provided in Tables 6 and 7. Finally, Table 8 provides cross-sectional data on Total Taxes paid by each dwelling.

Overall, the data is of only moderate quality for the purposes at hand. Many important variables are not available, such as the distance to the nearest park or school, or the presence of hardwood flooring, new windows, or renovated bathrooms or kitchens. Information is available on whether major renovations were made on the dwelling at some time, but this is deficient in two respects. First, there is no definition for

Table 1.—Summary Data on Housing Transactions
(Standard Deviations in Parentheses)

Zone	Name	Obs.	Sale Price $
1	Hudson	2,168	109,679 (68,664)
2	South Shore West	1,887	84,190 (22,041)
3	South Shore Centre	12,263	109,679 (41,870)
4	South Shore East	8,679	110,014 (41,633)
5	North Shore	11,814	98,864 (37,763)
6	Laval	9,006	104,160 (32,571)
7	Gtr. Montreal East	2,365	108,986 (34,831)
8	Montreal Proper	4,190	125,304 (56,464)
9	Gtr. Montreal West	2,121	175,199 (108,912)
10	West Island	12,026	140,749 (63,108)
	Total	66,519	

Table 2.—Description of Dwelling Styles

- Style 1 — Bungalow, Raised Bungalow, Split Entry Bungalow
- Style 2 — Split Level
- Style 3 — Cottage
- Style 4 — Apartment
- Style 5 — 1-6 Plexus

Table 3.—Distribution of House Styles by Zone

Zone	Name	*BU/BS/BE*	*SL*	*CT*	*AP*	*X*	Total
1	Hudson	1,320	339	482	27	0	2,168
2	South Shore West	1,451	144	289	3	0	1,887
3	South Shore Centre	6,181	995	4,110	962	15	12,263
4	South Shore East	5,124	1,324	2,114	114	3	8,679
5	North Shore	7,341	1,857	2,455	146	15	11,814
6	Laval	4,940	1,090	2,470	502	4	9,006
7	Gtr. Montreal East	946	160	868	386	5	2,365
8	Montreal Proper	863	143	1,528	118	18	4,190
9	Gtr. Montreal West	288	121	887	824	1	2,121
10	West Island	3,536	2,171	5,888	427	4	12,026

Table 4.—Description of Age Dummy

- Age1 — From 1980 to 1993
- Age2 — From 1960 to 1979
- Age3 — From 1940 to 1959
- Age4 — From 1920 to 1939
- Age5 — From 1900 to 1919
- Age6 — Before 1899

Table 5.—Percentile Rank and Mean of Construction Year

Zone	Name	*1%*	*5%*	*10%*	*25%*	*50%*	*75%*	*90%*	*95%*	*99%*	*Mean*
1	Hudson	1922	1952	1958	1967	1976	1985	1988	1989	1993	1974
2	South Shore W	1935	1955	1958	1962	1972	1983	1987	1988	1991	1971
3	South Shore C	1930	1952	1958	1970	1976	1985	1987	1989	1990	1975
4	South Shore E	1940	1957	1961	1971	1976	1985	1988	1989	1991	1975
5	North Shore	1947	1959	1965	1974	1980	1987	1989	1990	1991	1978
6	Laval	1947	1956	1958	1964	1977	1984	1987	1988	1990	1974
7	Gtr Montreal E	1936	1952	1956	1961	1970	1983	1986	1987	1989	1970
8	Montreal Proper	1907	1926	1940	1951	1960	1984	1987	1988	1991	1963
9	Gtr Montreal W	1905	1927	1940	1952	1966	1983	1988	1989	1990	1965
10	West Island	1933	1950	1954	1961	1971	1982	1987	1988	1991	1970

Table 6.—Distribution of Bedrooms by Zone

Zone	Name	≤1	2	3	4	5	6	7	≥8	Total
1	Hudson	13	178	1,082	739	133	19	1	3	2,168
2	South Shore West	2	168	1,044	551	105	13	1	3	1,887
3	South Shore Centre	132	1,484	5,939	3,750	801	117	20	20	12,263
4	South Shore East	24	751	4,307	2,950	558	70	8	11	8,679
5	North Shore	60	1,841	6,206	3,060	554	67	13	10	11,814
6	Laval	41	1,337	4,724	2,444	414	37	5	4	9,006
7	Gtr. Montreal East	52	442	1,260	495	103	10	3	0	2,365
8	Montreal Proper	226	1,214	1,724	745	145	23	9	4	4,190
9	Gtr. Montreal West	109	506	854	432	165	43	8	4	2,121
10	West Island	79	720	4,611	5,301	1,120	170	20	5	12,026

Table 7.—Distribution of Bathrooms by Zone

Zone	Name	1	2	3	4	≥5	Totals
1	Hudson	1,458	641	62	7	0	2,168
2	South Shore West	1,534	341	10	0	2	1,887
3	South Shore Center	8,944	3,094	201	10	14	12,263
4	South Shore East	6,124	2,440	101	10	4	8,679
5	North Shore	9,007	2,672	113	9	13	11,814
6	Laval	6,822	2,079	94	4	4	9,006
7	Gtr. Montreal East	1,953	388	17	1	6	2,365
8	Montreal Proper	3,326	775	73	2	14	4,190
9	Gtr. Montreal West	1,306	687	113	14	1	2,121
10	West Island	7,202	4,347	460	10	7	12,026

Table 8.—Percentile Rank and Mean of Total Taxes (dollars)

Zone	Name	*5%*	*25%*	*50%*	*75%*	*90%*	*95%*	*Mean*
1	Hudson	1,016	1,432	1,735	2,106	2,514	2,807	1,806
2	South Shore W	976	1,445	1,709	2,041	2,410	2,672	1,780
3	South Shore C	1,010	1,411	1,776	2,199	2,687	3,111	1,875
4	South Shore E	941	1,372	1,692	2,042	2,435	2,734	1,750
5	North Shore	953	1,378	1,733	2,147	2,563	2,896	1,811
6	Laval	1,308	1,738	2,067	2,553	3,128	3,516	2,217
7	Gtr Montreal E	1,021	1,370	1,729	2,166	2,614	2,942	1,828
8	Montreal Proper	1,188	1,621	2,108	2,743	3,550	4,193	2,372
9	Gtr Montreal W	1,275	1,841	2,427	3,332	4,515	5,484	2,780
10	West Island	1,342	1,793	2,244	2,797	3,435	3,977	2,396

what constituted a major renovation; and second, these homes were designated as such by replacing their construction year variable with the abbreviation "Renn", thus failing to provide information on the date of renovation, and removing the information on construction year in the process. These observations were eliminated. Because renovated homes are more expensive than nonrenovated ones, the exclusion of these likely biases this price data downward. But it is difficult to even guess at how this affects the changes in the constructed price indexes.

3. Correcting for Compositional Shifts

This section presents and compares four house-price indexes. First, however, it is worth discussing some conditions that might be satisfied by a "good" index. We also address the extent of compositional shifts in the data.

A. Some Preliminary Issues

To a certain extent, the criteria of what defines a good price index are subjective. Different statisticians may want to do different things, and no particular index is likely to be appropriate for all of these. It is important, however, to have some objective criteria by which to judge the quality of an index. Furthermore, because four different indexes are presented in this paper, it would be useful to have some constant standard by which all may be compared. Mark and Goldberg (1991) have set out three criteria that are reasonable standards for any index. An index should be:

C1) conceptually sound and rooted in straightforward theory;

C2) simple to construct and not rely on awkward sampling procedures;

C3) reasonably stable in response to changes in the sample universe.

How one weights each of these criteria depends on the type of work one is doing and what one is attempting to achieve. For example, if one is interested in an extremely precise, stable index, C3 could be given much more weight than C1. Under these circumstances a hybrid index would be more desirable than any other, even though it is the most theoretically challenging. For the most part, these criteria are weighted equally here because the goal of this paper is to arrive at a reasonably accurate, but also straightforward, index.

The data used in this paper spans only five years, and thus the main concern of the indexes presented here is with short-term compositional shifts that may distort the index, as opposed to the problem of long-term quality changes mentioned in Section 1. This is not to say, however, that the issue of quality changes does not deserve attention. Indeed, comparisons of house-price indexes over long periods of time are potentially much more fraught with problems than are comparisons over just a few years. This is because indexes that compare price averages that are, say, 60 years apart, are essentially not comparing the same product. The entire *population* of housing styles and characteristics is systematically and significantly changing over many years. This can lead to a spurious index where essentially different products are being compared between periods. For the data presented here, however, five years is an insufficient amount of time for the population of houses to change in any significant way.

The greater concern for the shorter-term indexes presented in this section are compositional shifts from month-to-month. In Section 1 these were described as locational shifts—homes from specific areas predominating the sample in any one month. But they can apply to any housing characteristic. For example, in any of the ten regional data sets described above, two-bedroom bungalows may predominate sales in one period. If one wants to be meticulous about correcting for this type of problem, all sources of compositional bias should be considered. Unfortunately, there are as many potential sources of compositional shift as there are individual house characteristics, so correcting for all of them is not practical.

In keeping with the goal of having relatively simple indexes, we choose a single attribute to correct for in terms of compositional shifts. It would be desirable if this single attribute were the greatest source of compositional shifts. The conventional wisdom within the real-estate industry appears to be that the greatest single factor contributing to a house's price is its location (Goodman, 1978). All other things being equal, a home in a wealthy neighbourhood like Westmount sells for much more than a similar home in a poorer neighbourhood. Thus the data was divided into regions based predominantly on the criteria of status and wealth. As seen in Table 1, there are marked differences in average selling prices between the regions, and thus the divisions seem a good proxy for measuring this variable.

The final concern, then, is if there are indeed significant regional compositional shifts within the data. Table 9 provides data on how many homes sold in each month for each region. It is clear that compositional shifts do indeed exist.

The next section presents two indexes that correct for compositional shifts. We begin with Model 1 which is simply the standard mean index. It is presented because it is so widely used. It is therefore desirable to develop a simple method to correct for the compositional bias. Two corrections are therefore presented which correct for compositional shifts in regions. Following this, Model 2, a general hedonic model, is presented.

B. The Standard Mean Index

This is presented as a benchmark for comparison with the two corrections that follow. It is simply a standard mean index and, as such, makes no attempt to correct for compositional shifts. Thus variations in the value of this index reflect both general changes in prices and changes in the average quality of houses sold (i.e., compositional shifts). Corrections 1 and 2 that follow each use some method to purge the effect of changes in house quality in order to isolate the pure price changes.

It is useful to present the method of calculating the standard mean index because this will aid in the presentation and understanding of Corrections 1 and 2. For each of the 10 regions there are 57 months in total; this generates a (10 x 57) matrix of average prices. The standard mean index simply weights each region's monthly average price by the proportion of total transactions in the region for the given month. This is quite clearly a simple arithmetic average of the prices of all houses sold during the month (across all regions). The equation defining the standard mean index is

$$I_0^t = \sum_{n=1}^{10} \pi_n^t \cdot P_n^t \qquad (3)$$

where π_n^t is the proportion of total sales for month t that occurred in region n, n = (1,...,10), t = (1,...57); P_n^t is the average selling price for region n in month t.

Table 9. Monthly Sales Totals

Mth	Reg. 1	Reg. 2	Reg. 3	Reg. 4	Reg. 5	Reg. 6	Reg.	Reg. 8	Reg. 9	Reg. 10	Total
1	12	7	58	32	61	29	9	21	4	30	263
2	58	49	347	241	334	246	110	168	56	258	1867
3	33	22	258	188	304	255	68	154	53	217	1552
4	30	30	225	173	215	158	55	161	33	214	1294
5	31	25	150	106	114	126	31	73	22	149	827
6	29	15	115	86	97	91	26	63	20	142	684
7	37	26	169	83	152	122	18	72	16	156	851
8	33	34	174	120	151	134	40	83	16	141	926
9	44	38	181	108	195	154	49	110	31	153	1063
10	65	62	420	255	441	291	103	201	63	294	2195
11	88	62	395	266	414	328	112	231	53	305	2254
12	36	46	285	183	273	204	84	158	43	228	1540
13	34	35	229	119	245	145	63	140	41	202	1253
14	20	16	141	145	134	104	41	71	28	104	804
15	24	18	147	126	161	151	38	74	38	142	919
16	24	22	105	105	97	91	37	59	27	171	738
17	28	19	147	114	147	118	43	75	29	161	881
18	37	33	195	124	144	170	46	93	51	170	1063
19	34	42	231	157	230	173	76	147	47	193	1330
20	76	63	509	284	439	396	139	305	94	416	2721
21	86	76	509	324	472	399	159	288	101	381	2795
22	43	47	376	198	350	314	93	196	71	251	1939
23	33	50	255	164	237	204	69	160	70	190	1432
24	24	29	190	132	156	144	39	124	46	159	1043
25	24	19	128	83	104	117	20	79	34	128	736
26	18	15	106	53	90	63	15	54	19	119	552
27	21	7	112	100	126	72	26	68	33	140	705
28	26	14	106	88	118	94	47	69	35	134	731
29	27	18	152	102	172	146	57	123	32	126	955
30	48	55	345	195	290	257	73	207	86	326	1882
31	71	67	404	242	340	312	107	226	117	337	2223
32	61	52	382	209	326	225	101	206	82	288	1932
33	43	45	302	185	308	202	86	187	80	272	1710
34	27	39	245	174	197	165	46	140	55	236	1324
35	22	16	152	94	101	102	30	94	44	168	823
36	30	11	131	100	90	83	16	52	41	167	721
37	27	16	128	94	107	80	16	76	57	156	757
38	29	24	139	99	138	91	29	66	44	154	813
39	25	21	157	102	159	109	38	127	48	131	917
40	73	54	402	214	391	243	90	222	88	313	2090
41	56	85	507	336	468	326	163	278	106	411	2736
42	76	64	409	289	370	320	109	272	104	344	2357
43	46	30	286	201	277	177	79	175	72	338	1681
44	26	27	201	143	189	142	37	141	75	241	1222
45	27	21	169	120	146	132	34	103	44	222	1018
46	32	18	122	84	96	66	21	53	38	180	710
47	29	21	154	90	106	80	26	73	52	176	807
48	33	35	173	116	155	110	27	121	62	195	1027
49	41	25	188	113	174	137	43	134	67	165	1087
50	62	49	396	252	362	246	116	244	121	346	2194
51	82	66	409	271	394	292	111	262	112	393	2392
52	54	56	368	245	336	251	107	213	114	352	2096
53	73	51	338	273	292	189	75	209	99	271	1870
54	53	26	230	215	197	151	67	143	84	256	1422
55	26	17	139	117	123	100	28	116	51	180	897
56	26	14	113	65	81	45	20	54	44	127	589
57	12	17	64	58	64	52	15	37	29	108	456
	2285	1961	13468	8955	12450	9724	3423	7851	3222	12327	75666

• *Correction 1: The Overall-Weights Index*

This method corrects for compositional shifts by weighting each region by its total proportion of the total *stock* of houses in the sample. In this way, the model corrects for compositional shifts from month-to-month because each region's total proportion of homes in the sample is a proxy measure for its total proportion of homes in the actual population. Thus, monthly averages are calculated, and a matrix is created as above. Then, the index is computed as follows:

$$I_1^t = \sum_{n=1}^{10} \Pi_n \cdot P_n^t \qquad (4)$$

where Π_n is the proportion of houses in the entire 57-month sample that are sold in region n.

For the overall-weights index, small sample sizes in each month can be troublesome. The collection of houses sold in any given month and region represents a random sample from the actual population. Thus, the average price calculated from this sample is a random variable, and as such, its distribution may have a high variance if its sample size is small. The problem with the overall-weights index is that months with smaller sample sizes are given much more weight than the standard mean index would give them (that is, they would be weighted by the actual number of sales in that month, which is quite small). This transfers the higher variance into the index, exacerbating its effect. It can result in overestimation or underestimation of the index in any given period.

• *Correction 2: The Price-Ratio-Adjusted Index*

The previous index accounts for compositional shifts by weighting each month's average price by the overall proportion of sales its respective region represents in the entire sample. Correction 2 attempts to account for compositional shifts as well, but with a different approach. Rather than taking average prices as given and adjusting each region's proportion of sales, this correction takes the proportion of sales as given and adjusts prices. Each region's average price is calculated over the entire 57-month sample, and the ratios of each of these average prices to the average price in Region 1 are computed. Finally, each region's monthly prices are adjusted by these respective price ratios. The index is then constructed as follows:

$$I_2^t = \sum_{n=1}^{10} \Pi_n \cdot \theta_n \cdot P_n^t \qquad (5)$$

where θ_n is simply equal to $(\bar{P}_1/\bar{P}_n)$ where $\bar{P}_n$ is the average price in region n across all 57 months in the sample.

In this way, each region's prices are converted to their "Region 1 equivalent", so overall average prices from region-to-region are equal, but each region's prices still vary from month-to-month. After the price-ratio adjustment has been made, a compositional shift no longer distorts the estimate of overall price changes. Each region is assumed to have the same underlying rate of price change and, as such, after the price-ratio adjustment no one region's average price can distort the index in any particular month. Furthermore, note that each month's average price is weighted by its proportion of total sales for that month. A compositional shift to one region does indeed pull up the index in favour of this region; however, there is an equal reduction in weight to all other regions, which pulls down the index. Because the price-ratio adjustment has equalized prices across all regions, the net effect of the compositional shift is zero. There is no effect of higher or lower average prices distorting the index. Therefore, varying monthly sales is not an issue of concern because, presumably, each region's prices are changing the same way, and since no one region is any more or less expensive than any other, the weights do not matter.

Like the overall-weights index, this model does attempt to control for compositional shifts. However, it makes no attempt to control for the number of sales each month. Rather, it adjusts prices such that all regional prices are based in Region 1. The question is whether this adjustment is correct. It is assumed that the overall change in house prices is the same for all regions. If this assumption is false, a compositional shift in one month will transfer an over- or under estimation of price change to the index. To see this, think of Region 1's and Region 2's price trends as plotted lines with positive constant slope (reflecting general increases in house prices). Also, assume Region 1's prices are rising more slowly than Region 2's. The index adjustment first shifts Region 2's line such that it intersects Region 1's mid point. If a compositional shift toward Region 1 occurs before the midpoint, this will result in an underestimation of overall house price increases, and an overestimation if the compositional shift accrues after its midpoint. To attempt to correct for this with a θ that varies monthly, rather than being an average of all 57 months, would essentially impose too much structure on the data of Regions 2 and 9. This amounts to converting all price trends of these regions into Region 1's trend, which would render analysis of all other regions pointless.

- *Results: Comparing Three Indexes*

The index values can be found in Table 10. Diagrams 1 to 3 display index values and Diagrams 4 to 6 show monthly rates of house-price changes—what is called "inflation" in the diagrams. Diagram 6, which shows monthly rates of change of the overall-weights index versus the price-ratio-adjusted index, demonstrates the importance of correcting for compositional shifts in regions. The price-ratio-adjusted index displays larger monthly fluctuations compared to the overall-weights index. Recall that the price-ratio-adjusted index does not control for the number of houses selling in each region. Rather, it attempts to reduce the distortions created by compositional shifts by adjusting all prices to one base region. It was assumed that all regions' house prices moved together and that after the adjustment compositional shifts should make little difference. However, any region in any one month can still have a disproportionate number of sales due to a compositional shift. And if there is a marked difference in price movements between regions, there will be an incorrect estimate of overall price changes. Given the evidence, it appears the assumption that house prices move together across regions may be inappropriate. From Diagrams 2 and 5 it can be seen that the price-ratio-adjusted index fluctuates just as much as the standard mean index. This seems to suggest that the price-ratio-adjusted index does not do as good a job at correcting for compositional shifts as does the overall-weights index.

Table 10. Index Values For Standard Mean Index and Corrections 1 and 2

	Adjusted Average Prices			One Month Inflation			Twelve Month Inflation		
Mth	Mean	Ov.-Wgt	Pr.-Rat.	Mean	Ov.-Wgt	Pr.-Rat.	Mean	Ov.-Wgt	Pr.-Rat.
1	100.000	100.000	100.000	–	–	–	–	–	–
2	100.070	102.497	99.587	0.070	2.497	-0.413	–	–	–
3	107.339	107.048	103.788	7.264	4.440	4.219	–	–	–
4	109.834	106.362	106.914	2.324	-0.641	3.011	–	–	–
5	113.157	107.278	108.672	3.026	0.861	1.645	–	–	–
6	110.880	107.823	106.681	-2.012	0.508	-1.832	–	–	–
7	110.983	105.586	106.287	0.093	-2.074	-0.369	–	–	–
8	106.267	104.355	103.692	-4.249	-1.166	-2.442	–	–	–
9	108.612	106.545	106.350	2.207	2.098	2.563	–	–	–
10	104.796	104.090	101.706	-3.514	-2.304	-4.366	–	–	–
11	110.781	108.144	108.212	5.710	3.894	6.396	–	–	–
12	108.039	107.108	105.681	-2.475	-0.958	-2.338	–	–	–
13	112.980	109.737	109.529	4.573	2.455	3.641	12.980	9.737	9.529
14	114.245	111.234	109.655	1.120	1.364	0.115	14.166	8.525	10.110
15	112.368	110.234	109.368	-1.644	-0.899	-0.262	4.685	2.976	5.376
16	115.446	110.966	111.635	2.740	0.664	2.073	5.110	4.329	4.416
17	117.023	110.792	110.180	1.365	-0.157	-1.304	3.416	3.276	1.387
18	116.266	110.811	112.038	-0.647	0.017	1.687	4.857	2.772	5.022
19	111.819	108.618	107.123	-3.825	-1.979	-4.387	0.753	2.871	0.786
20	110.093	106.935	105.953	-1.543	-1.550	-1.092	3.601	2.472	2.181
21	110.424	105.920	106.294	0.300	-0.949	0.322	1.668	-0.587	-0.052
22	109.612	107.762	105.810	-0.735	1.738	-0.455	4.596	3.527	4.035
23	112.762	108.953	110.026	2.873	1.105	3.984	1.789	0.748	1.676
24	110.220	107.053	106.437	-2.255	-1.744	-3.262	2.018	-0.051	0.715
25	116.270	111.066	111.248	5.489	3.748	4.520	2.912	1.211	1.570
26	118.658	113.868	113.969	2.054	2.523	2.445	3.862	2.367	3.934
27	111.884	108.362	105.885	-5.709	-4.835	-7.093	-0.430	-1.698	-3.184
28	113.874	107.084	107.729	1.779	-1.180	1.741	-1.362	-3.499	-3.499
29	115.069	109.968	108.668	1.050	2.693	0.872	-1.669	-0.744	-1.372
30	108.615	104.435	105.503	-5.609	-5.031	-2.913	-6.580	-5.754	-5.833
31	110.565	105.091	105.888	1.795	0.628	0.365	-1.122	-3.248	-1.153
32	111.144	106.786	106.175	0.524	1.613	0.271	0.954	-0.140	0.210
33	112.897	109.278	108.681	1.577	2.335	2.360	2.240	3.171	2.246
34	118.273	113.621	113.208	4.762	3.973	4.165	7.901	5.437	6.991
35	117.390	112.728	112.378	-0.746	-0.785	-0.733	4.105	3.465	2.138
36	120.141	111.944	113.260	2.343	-0.696	0.785	9.001	4.569	6.410
37	120.764	113.818	113.922	0.519	1.674	0.585	3.865	2.478	2.404
38	117.667	108.865	110.119	-2.564	-4.351	-3.339	-0.835	-4.393	-3.378
39	113.607	109.886	108.002	-3.451	0.938	-1.922	1.540	1.406	1.999
40	110.721	104.630	105.908	-2.541	-4.784	-1.939	-2.769	-2.292	-1.690
41	106.369	103.828	102.556	-3.930	-0.766	-3.165	-7.561	-5.583	-5.625
42	108.637	104.003	105.241	2.132	0.168	2.619	0.020	-0.414	-0.248
43	112.048	108.958	107.597	3.140	4.765	2.238	1.342	3.680	1.614
44	113.901	108.689	108.840	1.653	-0.247	1.155	2.481	1.783	2.510
45	121.693	114.420	114.993	6.841	5.273	5.653	7.791	4.705	5.808
46	120.020	111.231	113.733	-1.374	-2.788	-1.096	1.477	-2.103	0.464
47	115.823	110.253	109.061	-3.497	-0.879	-4.107	-1.335	-2.196	-2.951
48	115.348	108.450	108.765	-0.411	-1.636	-0.271	-3.989	-3.122	-3.968
49	115.490	109.609	108.346	0.123	1.069	-0.386	-4.367	-3.698	-4.895
50	110.685	106.093	104.934	-4.160	-3.208	-3.149	-5.934	-2.547	-4.708
51	110.573	104.547	105.569	-0.101	-1.457	0.605	-2.670	-4.859	-2.252
52	106.538	102.836	101.786	-3.649	-1.637	-3.584	-3.778	-1.715	-3.893
53	115.099	108.250	110.074	8.036	5.265	8.143	8.207	4.259	7.331
54	117.924	113.807	112.863	2.454	5.134	2.534	8.548	9.427	7.242
55	117.565	112.891	111.808	-0.304	-0.805	-0.935	4.924	3.609	3.914
56	122.715	112.576	114.780	4.380	-0.279	2.658	7.738	3.576	5.458
57	119.214	112.544	112.178	-2.853	-0.029	-2.267	-2.037	-1.640	-2.448

A measure that can be used to compare these indexes more precisely is a root-mean-square measurement. This is a simple way of measuring how closely two indexes move together. The measure is calculated as

$$D_{ij} = \left[\frac{1}{57} \cdot \sum_{t=1}^{57} (I_i^t - I_j^t)^2 \right]^{1/2}$$

where i and j refer to any two of the indexes.

The results are displayed in Table 11. There are two points worth noting about these results. First, both corrections appear to be accounting for compositional shifts, but the overall-weights index is doing this much more effectively. Second, the two corrections appear to be substantially different from each other; indeed, the two corrections are as different from each other as the first correction is from the standard mean index. This seems to indicate that the overall-weights index is a more accurate measure of house-price changes. The variation between the two corrections could be arising because of the high variance problem due to small sample sizes in the overall-weights index; or, in the case of the price-ratio-adjusted index, because the assumption of all regions having equal rates of house-price changes is incorrect.

Table 11: Root Mean Square Measure of Indexes

Standard Mean Index and Overall-Weights Index:	D = 14.99
Standard Mean Index and Price-Ratio-Adjusted Index:	D = 8.05
Overall-Weights Index and Price-Ratio-Adjusted Index:	D = 14.02

C. The General Hedonic Index

This method of constructing a price index also attempts to isolate pure price changes from measured price changes due to compositional shifts. It is similar to

Correction 2 above, except in this case compositional shifts are controlled for through regression techniques, rather than by "standardizing" sale prices. Furthermore, it controls for compositional distortions arising from all housing characteristics for which data is available, not just distortions caused by changes in the relative importance of various regions. A hedonic regression is therefore employed as explained in Section 1. Specifically, the model used here is

$$\ell n P_i = \alpha + \sum_{l=1}^{4} \beta^l \cdot X_i^l + \sum_{k=1}^{5} \gamma^k \cdot S_i^k + \sum_{h=1}^{6} \lambda^h \cdot A_i^h + \sum_{j=1}^{19} \delta^j \cdot T_i^j + \varepsilon_i \tag{6}$$

where P_i is the sale price of "observation" i, where each observation is a given house in a given time period. (This explains why there are no time subscripts in equation (6).) Each X_i^l (l=1,2,3,4) is one of a set of four observable house characteristics (size, number of bedrooms, number of bathrooms, and annual total taxes), each S_i^k (k=1,2,...,5) is one of a set of five style dummy variables as defined in Table 2, each A_i^h (1,2,...,6) is one of a set of six age dummy variables as defined in Table 4, and each T_i^j (1,2,...19) is one of a set of 19 dummy variables denoting the quarter in which the dwelling was sold.

Note the absence of subscripts denoting the region in which the house is located; this is because a separate version of equation (6) is estimated for each of the ten regions. Thus, each of the parameters (α, β^l, γ^k, λ^h and δ^j) will have different estimated values in each region. Given the estimates for each region's regression, the index of house prices for region n is given by

$$I_{3n}^j = \exp\{\alpha_n + \delta_n^j\} \tag{7}$$

• *Results: The Hedonic Versus the Quarterly Mean*

In the case of the hedonic index, equation (6) is estimated (for each region) using quarterly rather than monthly data. Thus, the complete sample offers 19 quarterly observations on the house-price index for each of the 10 regions. In order to compare the

Table 12. Quarterly Standard Mean Index

Qtr	Region 1	Region 2	Region 3	Region 4	Region 5	Region 6	Region 7	Region 8	Region 9	Region 10
1	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
2	110.27	96.69	106.13	102.88	105.63	102.20	98.46	103.86	101.70	106.64
3	106.96	95.74	104.75	101.27	106.17	99.83	102.72	115.78	92.92	102.42
4	114.22	100.60	99.55	104.89	103.61	105.72	100.66	97.70	98.37	105.34
5	121.07	101.80	102.92	108.71	115.55	104.90	105.34	109.33	108.10	108.33
6	136.71	98.65	106.85	111.51	108.25	104.81	100.16	101.70	116.77	112.96
7	98.51	98.51	101.42	109.18	106.43	105.38	99.61	105.13	100.19	104.38
8	115.60	101.83	103.50	110.18	108.59	109.48	99.37	99.38	103.66	104.93
9	112.79	100.67	107.55	112.01	114.40	108.62	111.51	102.14	106.86	108.42
10	106.45	96.16	103.72	109.00	110.29	107.69	94.57	102.65	114.55	99.70
11	103.71	94.71	103.82	109.49	109.83	109.53	100.53	103.63	96.34	102.73
12	121.82	93.58	111.00	115.68	118.38	111.80	105.36	105.30	106.36	109.45
13	110.91	93.37	105.48	110.34	116.44	112.72	101.14	104.82	105.93	108.33
14	103.80	92.13	100.69	109.50	108.92	106.32	95.48	100.24	88.86	96.84
15	113.95	101.72	113.70	115.42	118.25	109.81	97.86	96.15	98.52	102.55
16	106.98	98.97	111.39	114.61	113.20	109.26	96.21	102.11	102.11	105.15
17	100.55	93.71	101.16	109.59	109.97	110.51	98.58	100.69	97.47	102.98
18	116.32	95.99	105.55	110.90	114.42	106.43	102.38	100.40	102.06	102.28
19	115.93	98.64	118.36	116.14	119.15	115.08	99.52	105.73	96.05	109.80

Table 13. Quarterly Hedonix Index

Qtr	Region1	Region 2	Region 3	Region 4	Region 5	Region 6	Region 7	Region 8	Region 9	Region 10
1	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
2	99.55	99.38	104.28	102.20	104.96	101.28	101.43	100.30	105.37	101.86
3	99.31	99.77	105.21	102.35	106.22	99.23	95.90	106.43	94.34	99.89
4	102.45	101.15	101.72	100.76	105.04	103.36	98.88	98.48	106.76	100.37
5	111.45	101.72	101.08	107.49	107.94	102.24	95.18	102.28	104.65	102.87
6	108.38	100.77	103.11	105.22	110.53	103.35	102.02	104.83	104.47	103.25
7	101.47	100.03	101.60	105.11	107.55	104.65	100.14	103.82	106.41	101.86
8	103.40	100.78	101.94	106.98	109.35	106.29	100.86	102.30	106.46	102.22
9	108.73	100.31	99.25	103.22	110.20	105.82	99.08	100.32	104.68	98.16
10	99.89	95.11	99.30	105.98	106.58	105.71	95.61	104.60	111.99	96.43
11	98.50	96.39	95.55	100.73	104.55	103.43	98.64	96.08	99.17	92.27
12	99.90	94.97	97.08	101.67	105.23	103.45	100.04	104.63	102.65	93.84
13	102.55	95.02	96.84	99.97	101.20	100.50	96.38	101.95	99.15	95.57
14	94.99	89.88	92.03	97.18	100.64	98.02	92.66	99.05	95.62	88.58
15	98.49	97.32	92.31	98.40	102.36	98.72	91.40	96.77	87.73	90.48
16	98.60	96.29	93.21	98.79	101.25	95.91	85.98	90.64	95.22	89.98
17	93.12	92.37	89.55	96.09	98.72	96.33	85.21	95.07	91.35	89.13
18	95.51	91.86	87.55	95.13	99.38	98.54	87.44	93.02	91.29	88.80
19	99.72	96.09	91.71	98.06	100.16	96.64	87.17	95.50	94.34	90.95

Table 14. Rates of Change of Quarterly Mean Index

Qtr	Region 1	Region 2	Region 3	Region 4	Region 5	Region 6	Region 7	Region 8	Region 9	Region 10
1	--	--	--	--	--	--	--	--	--	--
2	10.27	-3.31	6.13	2.88	5.63	2.20	-1.54	3.86	1.70	6.64
3	-3.00	-0.98	-1.30	-1.57	0.51	-2.32	4.32	11.47	-8.63	-3.96
4	6.79	5.07	-4.97	3.58	-2.41	5.90	-2.00	-15.61	5.86	2.85
5	5.99	1.20	3.39	3.64	11.53	-0.77	4.65	11.91	9.89	2.84
6	12.92	-3.10	3.82	2.57	-6.32	-0.09	-4.92	-6.98	8.02	4.28
7	-27.94	-0.15	-5.08	-2.09	-1.68	0.54	-0.56	3.37	-14.20	-7.59
8	17.35	3.37	2.05	0.91	2.03	3.89	-0.23	-5.47	3.46	0.52
9	-2.43	-1.13	3.91	1.66	5.35	-0.79	12.21	2.77	3.09	3.33
10	-5.62	-4.49	-3.56	-2.69	-3.59	-0.85	-15.19	0.50	7.19	-8.05
11	-2.57	-1.50	0.09	0.45	-0.42	1.71	6.31	0.95	-15.89	3.04
12	17.46	-1.20	6.91	5.65	7.79	2.07	4.80	1.61	10.40	6.54
13	-8.96	-0.22	-4.97	-4.62	-1.64	0.83	-4.01	-0.46	-0.41	-1.02
14	-6.41	-1.33	-4.54	-0.76	-6.46	-5.68	-5.60	-4.37	-16.11	-10.61
15	9.78	10.41	12.92	5.40	8.57	3.28	2.50	-4.08	10.88	5.90
16	-6.12	-2.70	-2.04	-0.69	-4.27	-0.50	-1.69	6.20	3.64	2.54
17	-6.01	-5.32	-9.18	-4.39	-2.86	1.14	2.47	-1.39	-4.55	-2.07
18	15.68	2.43	4.34	1.19	4.05	-3.69	3.85	-0.29	4.71	-0.68
19	-0.33	2.76	12.14	4.73	4.14	8.13	-2.80	5.31	-5.88	7.36

Table 15. Rates of Change of Quarterly Hedonic Index

Qtr	Region1	Region 2	Region 3	Region 4	Region 5	Region 6	Region 7	Region 8	Region 9	Region 10
1	--	--	--	--	--	--	--	--	--	--
2	-0.45	-0.62	4.28	2.20	4.96	1.28	1.43	0.30	5.37	1.86
3	-0.25	0.40	0.89	0.14	1.20	-2.03	-5.45	6.11	-10.47	-1.93
4	3.17	1.38	-3.32	-1.55	-1.11	4.17	3.11	-7.46	13.16	0.48
5	8.79	0.57	-0.63	6.69	2.76	-1.08	-3.74	3.86	-1.98	2.49
6	-2.76	-0.93	2.02	-2.12	2.39	1.08	7.18	2.49	-0.17	0.37
7	-6.38	-0.73	-1.47	-0.10	-2.69	1.26	-1.84	-0.96	1.86	-1.35
8	1.90	0.74	0.33	1.78	1.67	1.57	0.73	-1.46	0.05	0.35
9	5.16	-0.47	-2.64	-3.51	0.78	-0.45	-1.77	-1.94	-1.67	-3.97
10	-8.13	-5.18	0.05	2.67	-3.28	-0.10	-3.49	4.27	6.98	-1.76
11	-1.40	1.35	-3.77	-4.95	-1.91	-2.16	3.17	-8.15	-11.45	-4.31
12	1.43	-1.48	1.60	0.94	0.65	0.02	1.42	8.90	3.51	1.70
13	2.65	0.06	-0.24	-1.68	-3.83	-2.85	-3.66	-2.56	-3.41	1.83
14	-7.37	-5.41	-4.97	-2.79	-0.56	-2.46	-3.86	-2.85	-3.55	-7.31
15	3.68	8.28	0.30	1.26	1.71	0.71	-1.36	-2.30	-8.25	2.15
16	0.11	-1.06	0.98	0.39	-1.09	-2.85	-5.93	-6.33	8.54	-0.56
17	-5.55	-4.07	-3.93	-2.73	-2.50	0.44	-0.89	4.88	-4.07	-0.94
18	2.57	-0.55	-2.23	-1.00	0.68	2.30	2.61	-2.15	-0.06	-0.38
19	4.40	4.60	4.76	3.08	0.78	-1.93	-0.31	2.66	3.34	2.42

hedonic index with the standard mean index, it is therefore necessary to construct a standard mean index using quarterly, rather than monthly, price averages. We call this the quarterly mean index.

Index values are shown in Tables 12 and 13, and the rates of change of the index are in Tables 14 and 15. Diagrams 7 through 10 show the index and its rate of change only for Regions 3 and 10 (all other regions are excluded for brevity). It is clear that the hedonic index is a more stable index than the quarterly mean index; it is characterized by smaller quarter-to-quarter fluctuations. It also appears to show a falling price trend, something that none of the other indexes show. This downward price trend begins at about 1990-91. Over the same time the quarterly mean index shows a price trend that is constant or slightly rising.

Table 16 compares the root-mean-square measurement of the hedonic index with that of the quarterly mean index. The numbers are all quite high relative to those values in Table 11. Since the root-mean-square value measures the "closeness" of the index to the standard mean index, the high values in Table 16 (compared to those in Table 11) suggest that the hedonic index does a considerably better job at accounting for compositional shifts (of all kinds) than do the two corrections discussed above.

Table 16: Root Mean Square Measure of Indexes

(Quarterly Mean Index Versus the Hedonic Index)

Region 1:	42.67
Region 2:	9.06
Region 3:	21.49
Region 4:	14.63
Region 5:	18.72
Region 6:	14.31
Region 7:	27.54
Region 8:	26.20
Region 9:	36.09
Region 10:	18.05

Other than the theoretical problems discussed in Section 1, the hedonic index can be problematic for practical reasons. Its major disadvantage is its complexity. It requires considerably more data than the previous indexes, which require nothing more than observed prices and quantities from each region in each period, and also requires more sophisticated techniques. Thus, although the hedonic index appears to be superior to the standard mean index (or to Corrections 1 and 2), some price in terms of increased complexity must be paid.

4. Conclusions

Each index has its own advantages; but each also has its own problems. It is difficult to directly compare the hedonic index with the previous three indexes because it is operating on a slightly different sample. Since the hedonic index was constructed quarterly for each region, whereas the other indexes were constructed monthly for the entire data set, it is not possible to make direct comparisons. However, there are some observations that can reasonably be made.

First, each index provided lower or about equal estimates of house-price changes compared to the standard mean index. Also, the hedonic index provides the lowest period-to-period fluctuations in house-price changes. If the hedonic method were used on all the data, as were the first three methods, the same result would likely have been found.

Second, the results of the overall-weights and price-ratio-adjusted indexes indicate that compositional bias is significant. Correcting for this reduces the large period-to-period fluctuations in the index. Furthermore, the performance of the hedonic index indicates that housing characteristics other than just region should also be accounted for when constructing house-price indexes, because compositional shifts in these other characteristics have a significant effect. However, even though the root-mean-square results confirm this, they also indicate that region is the most important factor for which to correct when constructing retail housing price indexes.

Third, the price-ratio-adjusted index, which did not correct for compositional shifts by adjusting sales proportions, demonstrates roughly the same estimates of monthly house-price changes as the standard mean index. This indicates that the assumption of uniform inflation rates across regions is incorrect. Therefore, this method is not the best alternative for correcting a standard mean index. Given the results, the overall-weights index appears superior to the price-ratio-adjusted index in controlling for compositional shifts.

Fourth, the hedonic index provides lower period-to-period fluctuations when compared to the quarterly standard mean index. In fact, it is the only index that demonstrates a clear price trend. It is interesting to note that, while all other indexes show prices rising on average over time, the hedonic index demonstrates a downward price trend after about 1990. One explanation for this could be due to the recession that occurred in Canada starting in 1991, a recession that was particularly acute in Montreal. Recessions always affect construction in general, particularly new housing, but they affect used-home sales as well. One possible reason why the hedonic index shows prices falling over this period, while the standard mean index shows them to be rising, is because the recession was associated with the sales of houses with more expensive characteristics (other than the house's region). If this is the case, then some explanation is needed for why expensive houses represent a disproportionate amount of house sales during a recession. Providing such an explanation is well beyond the scope of this paper.

Overall, it is difficult to say which index method is best. It does, however, appear that the first correction of the standard mean index, the overall-weights index, is better at correcting for compositional shifts than the second correction, the price-ratio-adjusted index. The hedonic method is the most accurate, although it is the most difficult to use. It is much more stable than the standard mean index. Also, it appears to detect trends in prices that are contrary to all the other indexes. Thus it seems to be the most accurate method, and the best at controlling for compositional shifts.

References

Bailey, M.J., R.F.Muth and H.O.Nourse (1963), "A Regression Method for Real Estate Price Index Construction", *Journal of the American Statistical Association*, 19:3, 933-942.

Case, B. and J.M.Quigley (1991), "The Dynamics of Real Estate Prices", *Review of Economics and Statistics*, 73:3, 50-57.

Case, B., H.O.Pollakowski and S.M.Watcher (1991), "On Choosing Amongst House Price Index Methodology", *The American Real Estate and Urban Economics Association*, 19:3, 286-307.

Clapp, J.M., C.Giaccotto and D.Tirtiroglu (1991), "Housing Price Indices: Based on All Transactions Compared to Repeat Subsamples", *Journal of the American Real Estate and Urban Economics Association*, 19:3, 270-285.

Dale-Johnson, D. (1982), "An Alternative Approach to Housing Market Segmentation Using Hedonic Price Data", *Journal of Urban Economics*, 11, 311-332.

Ferri, M.G. (1977), "An Application of Hedonic Indexing Methods to Monthly Changes in Housing Prices: 1965-1975", *American Real Estate and Urban Economics Association Journal*, 5:4, 455-462.

Goodman, A.C. (1978), "Hedonic Prices, Prices Indices, and Housing Markets", *Journal of Urban Economics*, 5, 471-484.

Haurin, D.R., P.H.Hendershott and D.Kim (1991), "Local House Price Indexes: 1982-1991", *American Real Estate and Urban Economics Association Journal*, 19:3, 451-471.

Mark, J.H. and M.A.Goldberg (1981), "Alternative Housing Price Indices: An Evaluation", *Journal of American Real Estate and Urban Economics Association*, 12:1, 31-49.

Palmquist, R. (1980), "Alternative Techniques for Developing Real-Estate Price Indexes", *Review of Economics and Statistics*, 62, 442-448.

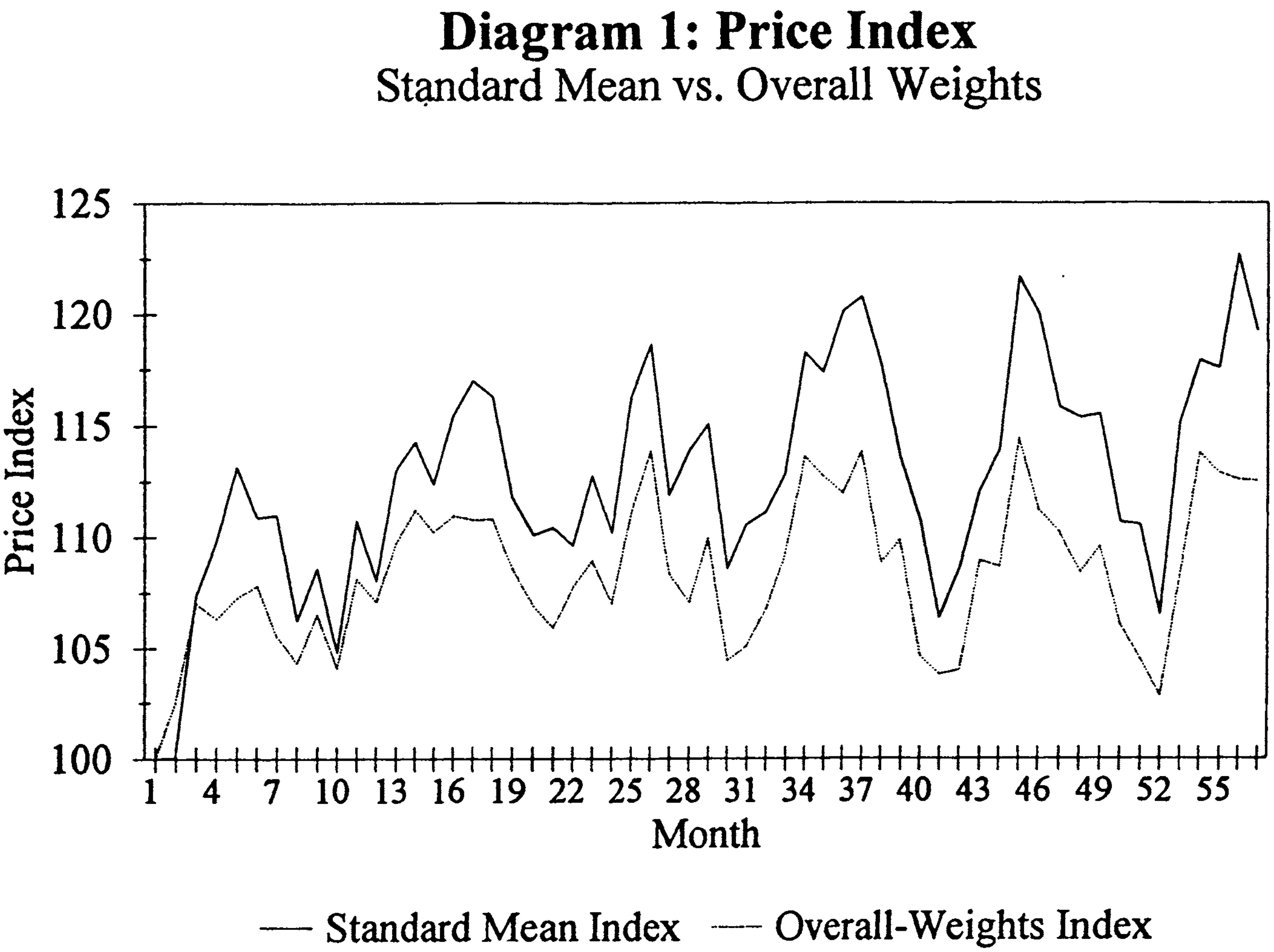
Diagram 1: Price Index
Standard Mean vs. Overall Weights
125
120
115
110
105
100
Price Index
1 4 7 10 13 16 19 22 25 28 31 34 37 40 43 46 49 52 55
Month
— Standard Mean Index
— Overall-Weights Index

Diagram 2: Price Index

Standard Mean vs. Price-Ratio Adjusted

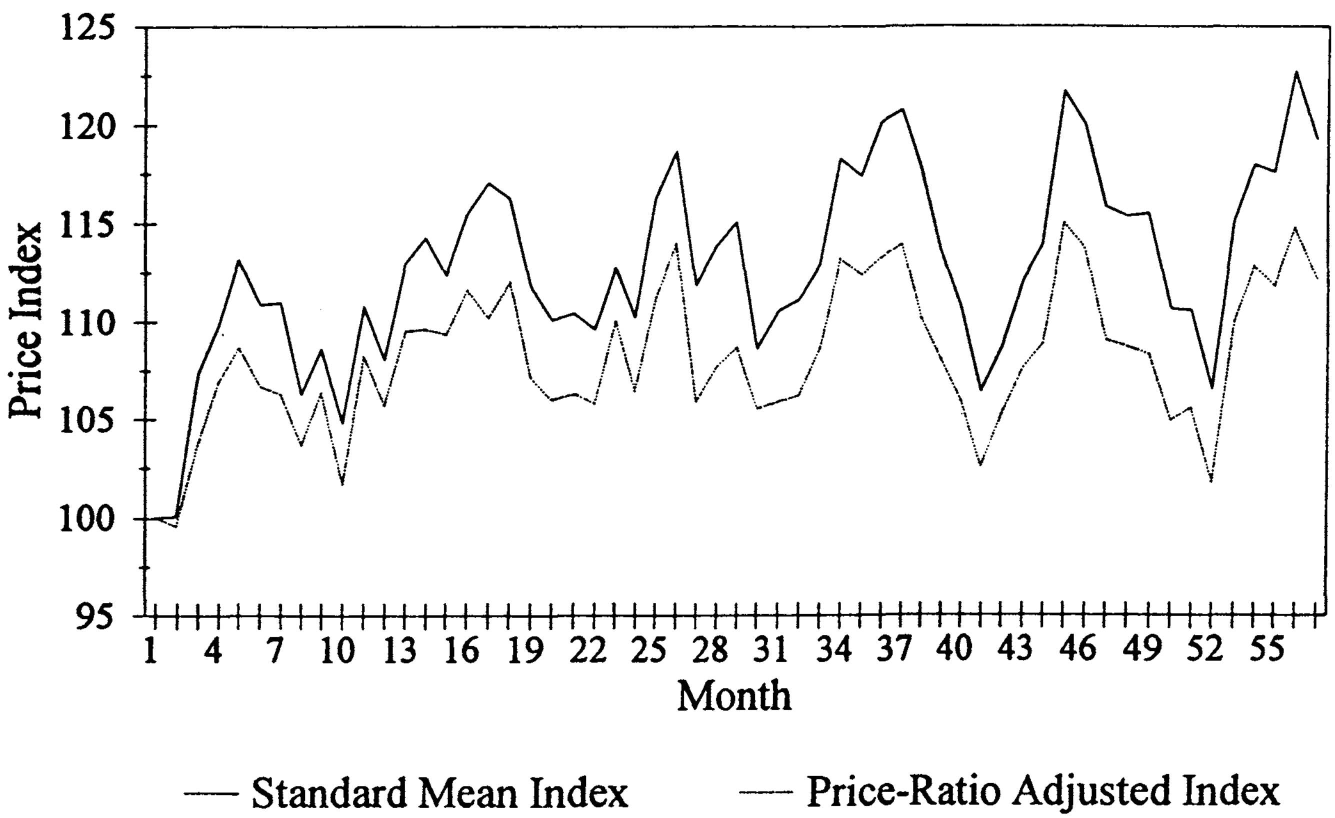

Diagram 3: Price Index
Overall-Weights vs. Price-Ratio Adj

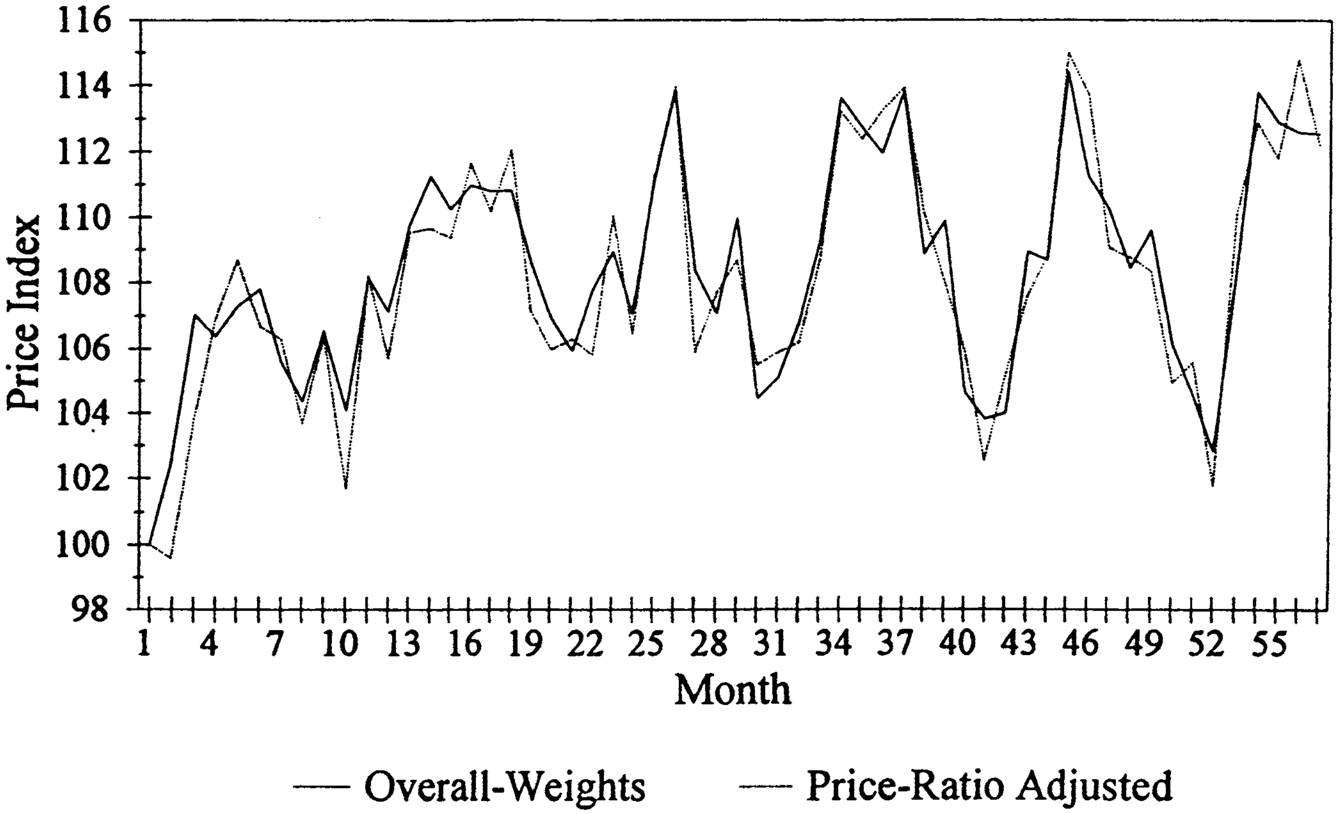

Diagram 4: Monthly Inflation

Standard Mean vs. Overall-Weights

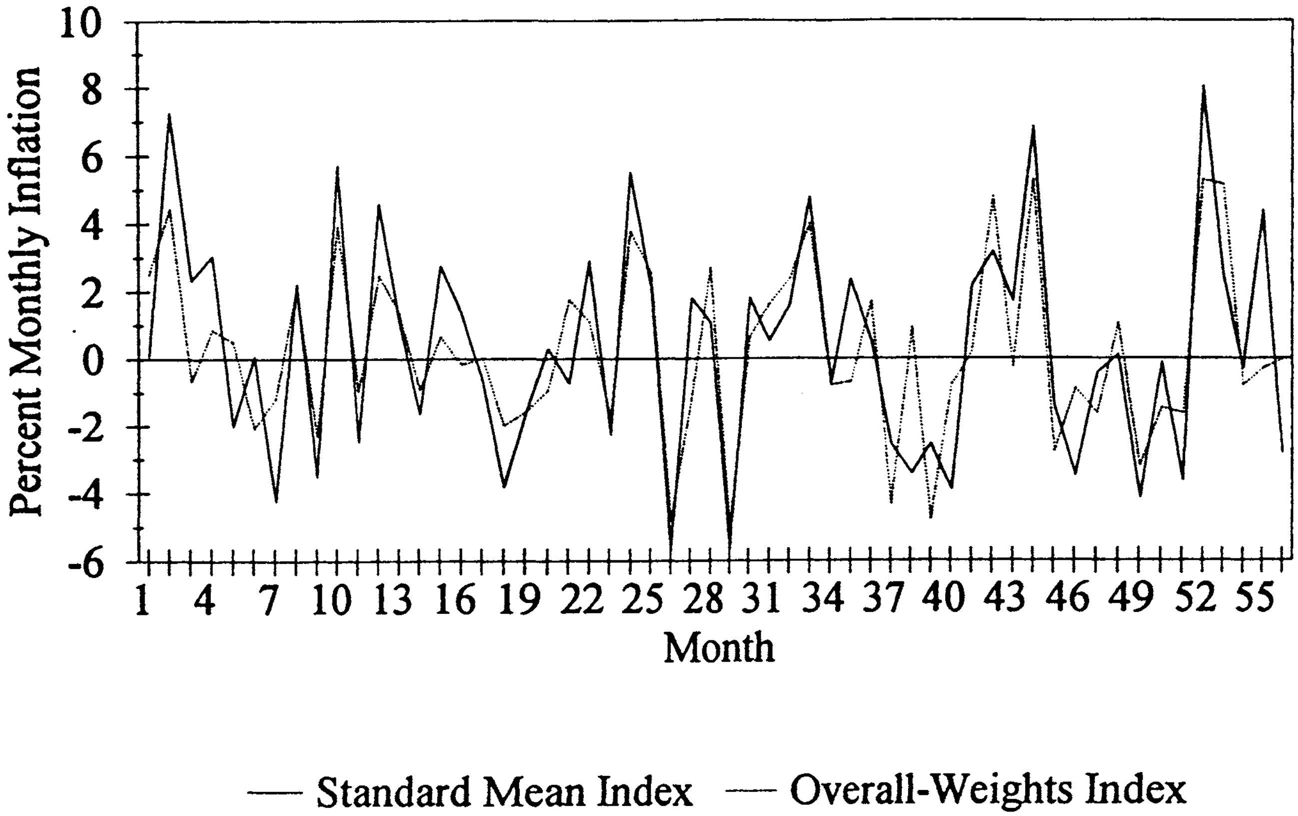

Diagram 5: Monthly Inflation

Standard Mean vs. Price-Ratio Adjusted

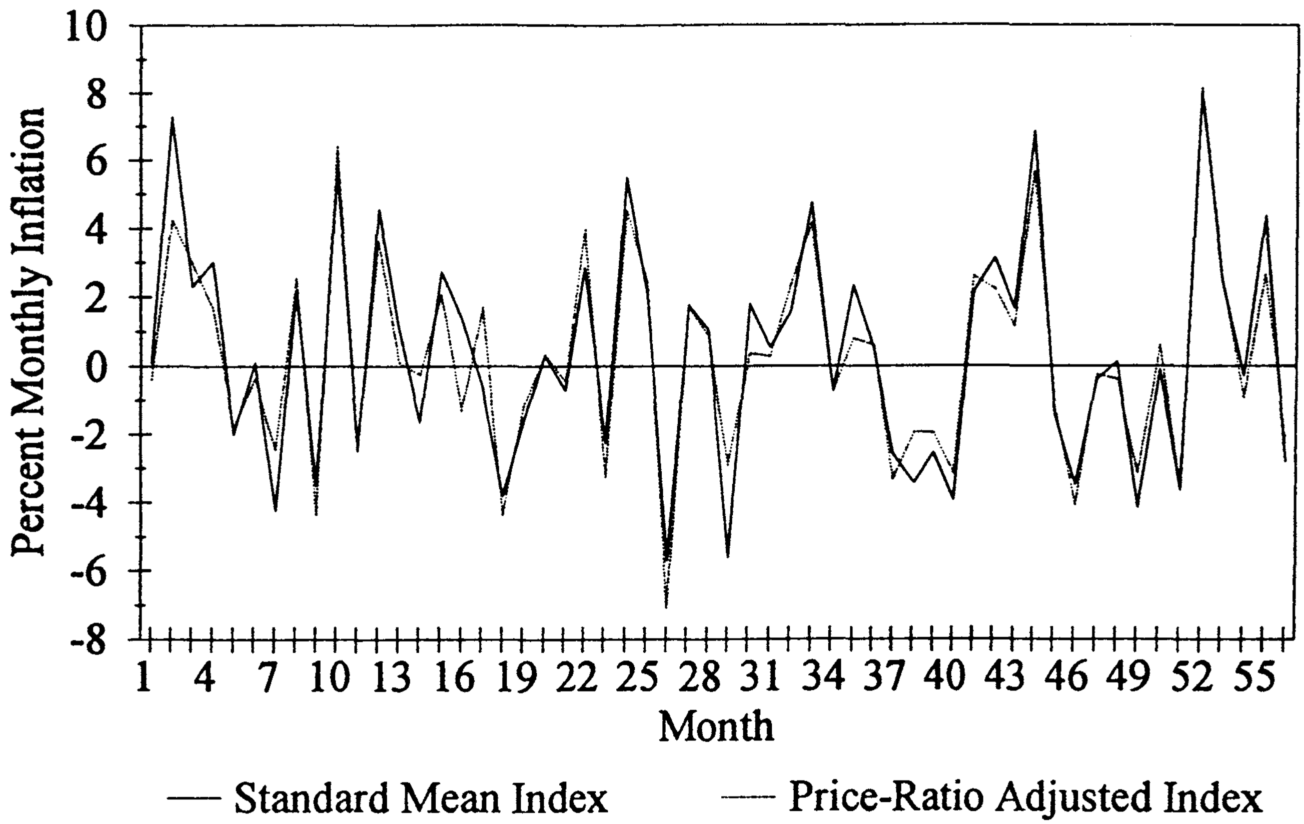

Diagram 6: Monthly Inflation

Overall-Weights vs. Price-Ratio Adj

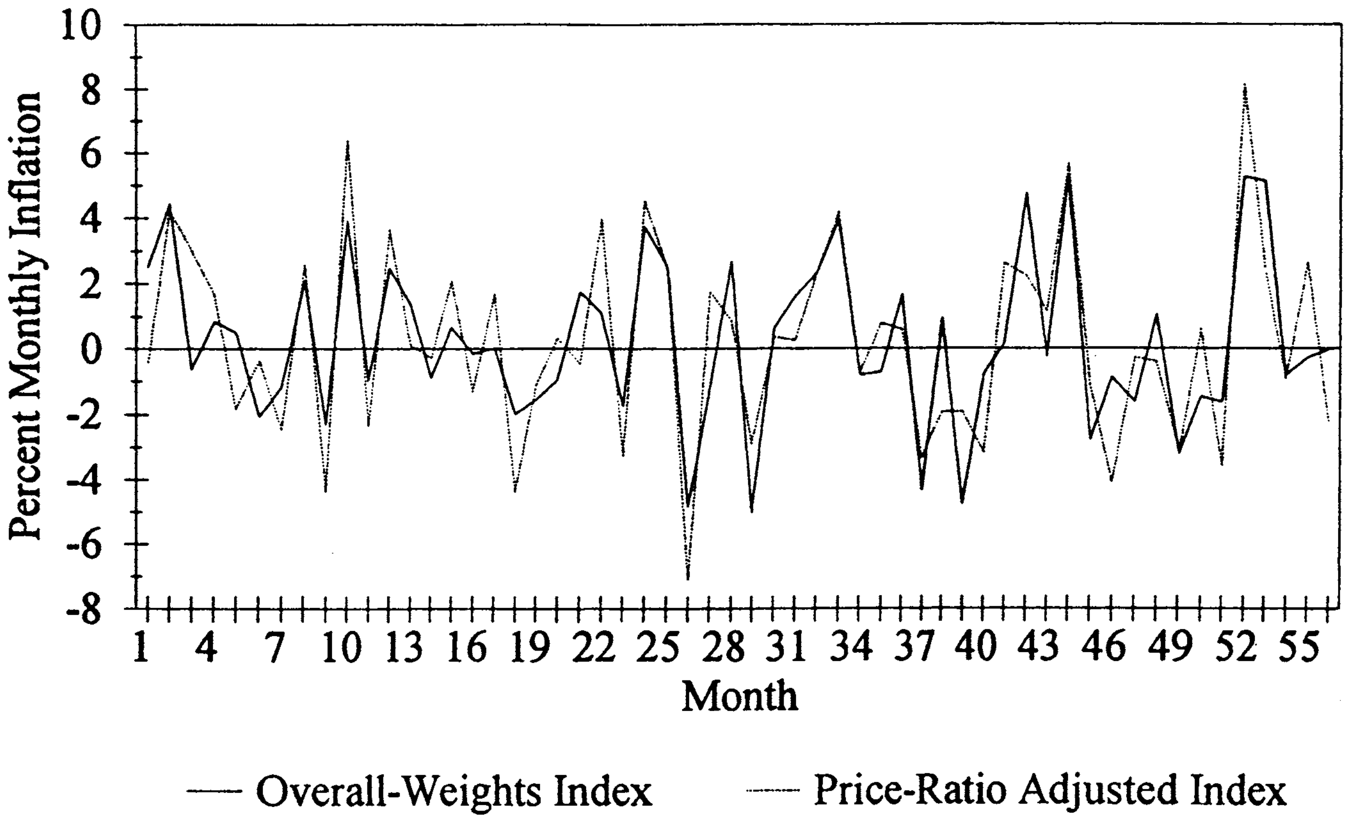

Diagram 7: Region 3 Price Index
Quarterly Mean vs. Quarterly Hedonic

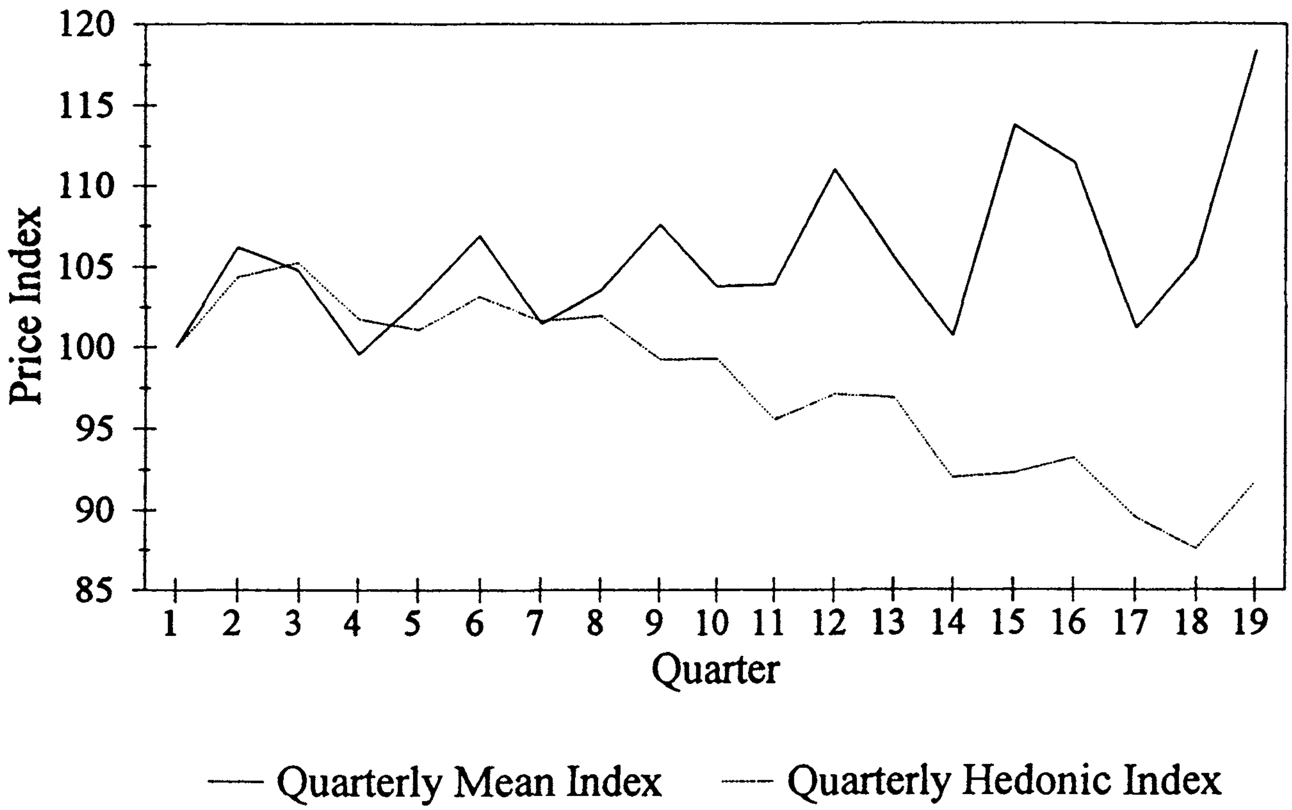

Diagram 8: Region 10 Price Index
Quarterly Mean vs. Quarterly Hedonic

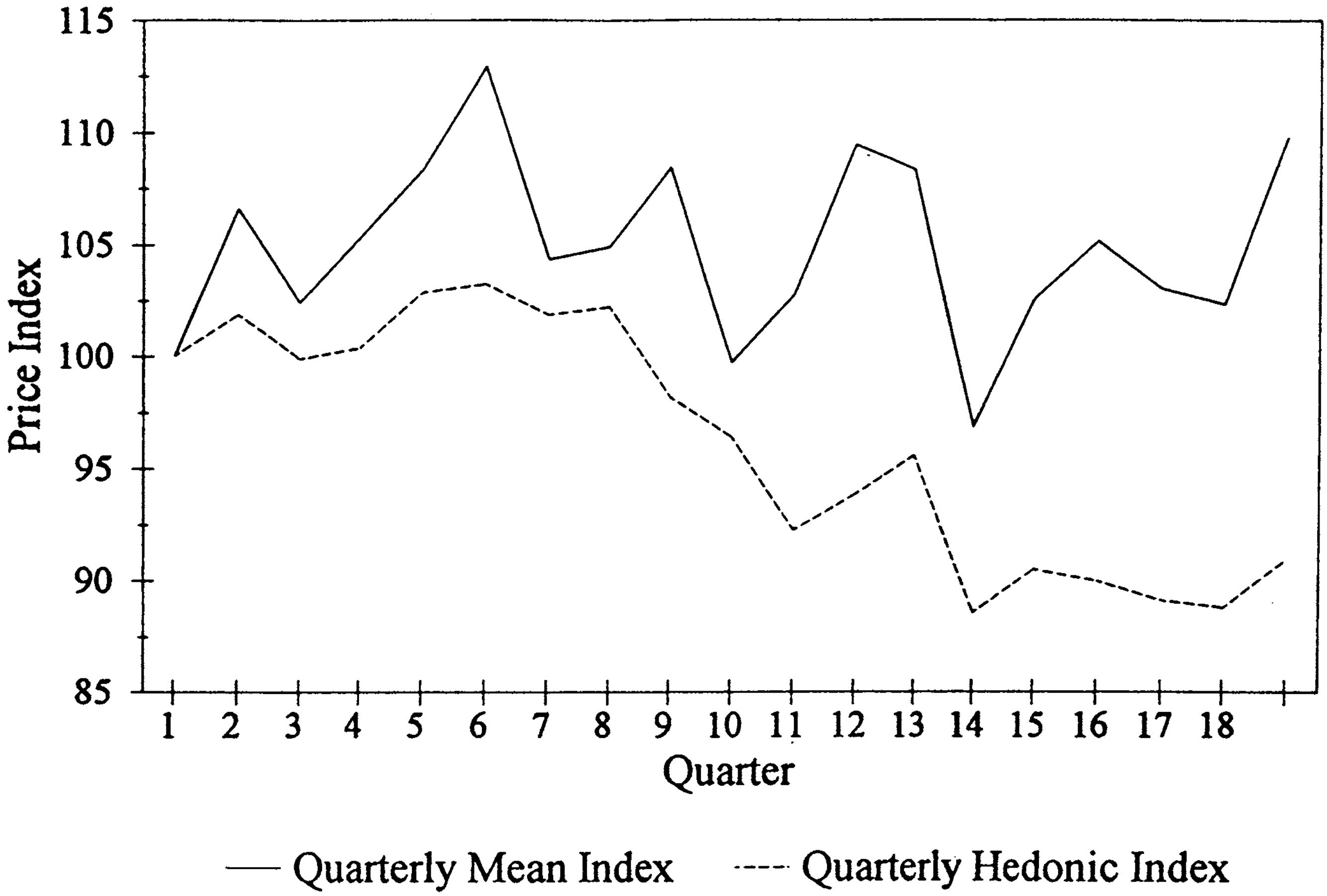

Diagram 9: Region 3 Quarterly Infltn

Quarterly Mean vs. Quarterly Hedonic

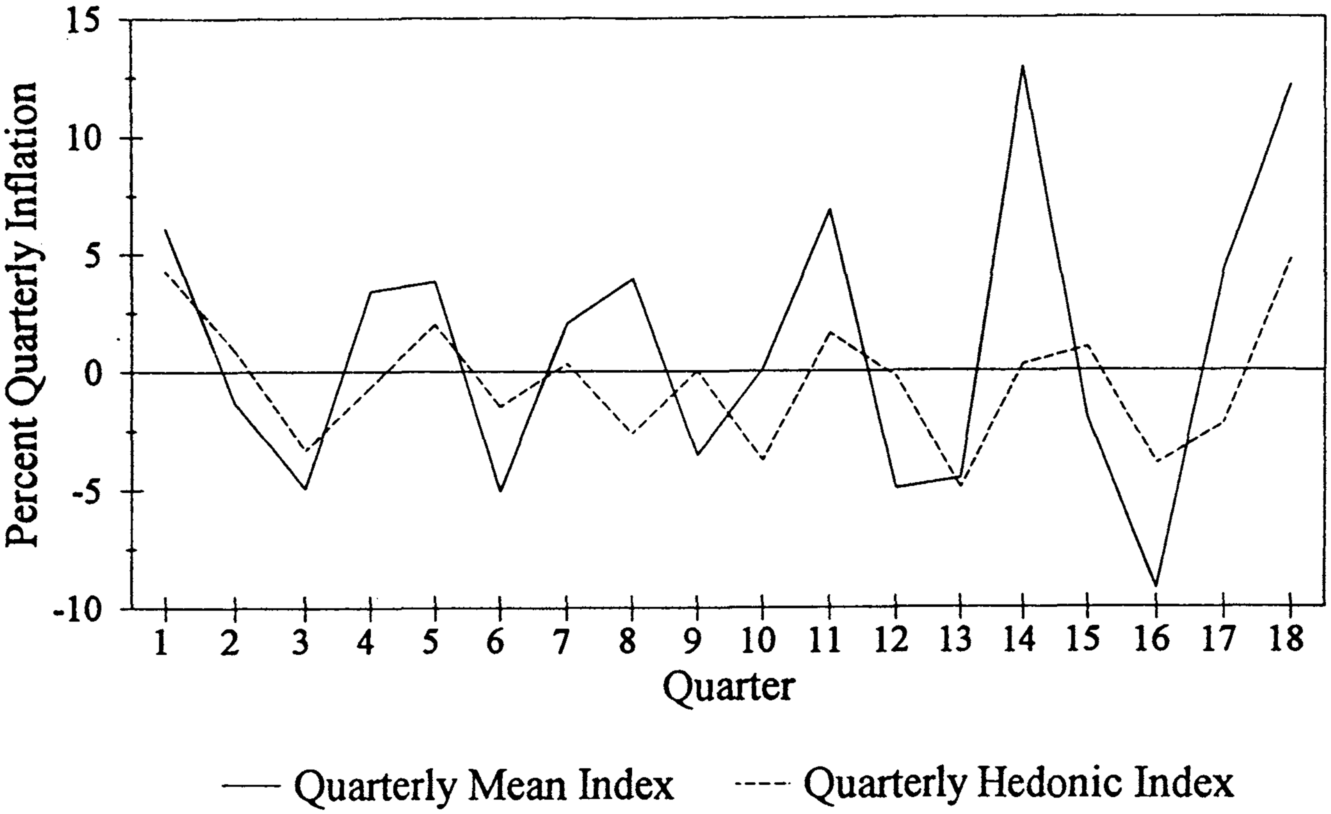

Diagram 10: Region 10 Quarterly Infltn
Quarterly Mean vs. Quarterly Hedonic