**Abstract**

Residential house price indices are generally constructed at a relatively coarse level of geographic aggregation due to limitations in index construction methodologies. Most commonly, these geographic units correspond to a municipal region. However, a high degree of price heterogeneity occurs within-city. Accurate indices constructed at the suburb or neighbourhood level would allow for a better understanding of within-city price dynamics. This paper investigates the application of matching procedures to develop indices across relatively small geographic areas. Contributions to the literature include adjustments for a non-constant reference housing stock in matched sample indices, and the application of coarsened exact matching (CEM) procedures to residential house price data. I also take advantage of the properties of a the simulated randomised controlled trial arising from matching procedures to check for systematic correlations of changing reference housing stock characteristics and property prices.

**Introduction**

The markets for residential housing and housing services are crucial components of most economies. Very nearly all economic agents find it necessary at some stage in their lives to dedicate a not insubstantial proportion of their income to the consumption of housing services. And, as a consequence, some of the most important decisions made by those agents revolve around whether to continue to rent, or to purchase a house for the first time; whether to consume the housing services generated by that asset themselves, or to sell them to someone else. Equally important, are those agents’ decisions concerning the purchase of additional houses as investments, if and when to rent them, improve them (and to what extent), or to sell down the stock of houses they currently own.

Unsurprisingly, there are a large number of stakeholders involved in either housing, or housing-peripheral markets that have an interest in the price dynamics of the housing stock. The construction, real estate, finance, and other housing service industries; prospective purchasers, and current homeowners, along with policy makers and the authorities whose responsibility it is to allocate and collect taxes associated with the ownership and sale of properties; all closely monitor the movements in house prices at a variety of levels of geographic aggregation.

Policy is often developed across a country because of house prices. Sometimes used as a proxy for an economic development measure etc.

Policymakers often target problems that are endemic to a region, territorial authority, municipality etc.

For many stakeholders though, the nuances of within-city price dynamics play an important role in their decision making.

Additionally, methods that improve the robustness of measures of price change in smaller geographic areas will potentially improve measures constructed over larger areas.

The literature largely converges in its use of price indices as the tools with which to capture changes in price through time. However there is considerably less consensus around the methods by which those indices are constructed. In motivation, a price index is an attempt to isolate the changes in price through time, from corresponding changes in quantity or quality. Specifically, a price index is defined as a table, one dimension of which is time and the others, if any, may be geographical regions, property types (semi-detached, detached, apartment, etc), circumstances of transaction (purchase of a new-build, first-time buyer, freehold, etc).

It may be most useful to begin by defining an index within the context of house prices. Produced below is an example of a two-way index compiled annually using the unweighted means of the natural log of sale prices of all sales, grouped by an administrative area of a relatively small size known as an area unit (AU). This naïve index is intended to capture the expected sale price of a home in each geographic area (but does not currently control for any property specific characteristics). I have used data comprising of a complete set of sales records in the city of Dunedin, New Zealand from 2000 to 2015. The below table is truncated for clarity in the discussion of motivation.

Table 1: A house price index for four area units in Dunedin from 2000 to 2005

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Year | | | | | |
| Region | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 |
| Opoho | 100.0 | 102.3 | 116.6 | 134.7 | 170.9 | 180.9 |
| Forrester Park | 100.0 | 130.3 | 112.3 | 146.7 | 154.6 | 180.2 |
| North East Valley | 100.0 | 112.9 | 109.1 | 130.5 | 171.1 | 187.8 |
| Pine Hill | 100.0 | 105.2 | 109.8 | 138.1 | 170.2 | 184.2 |

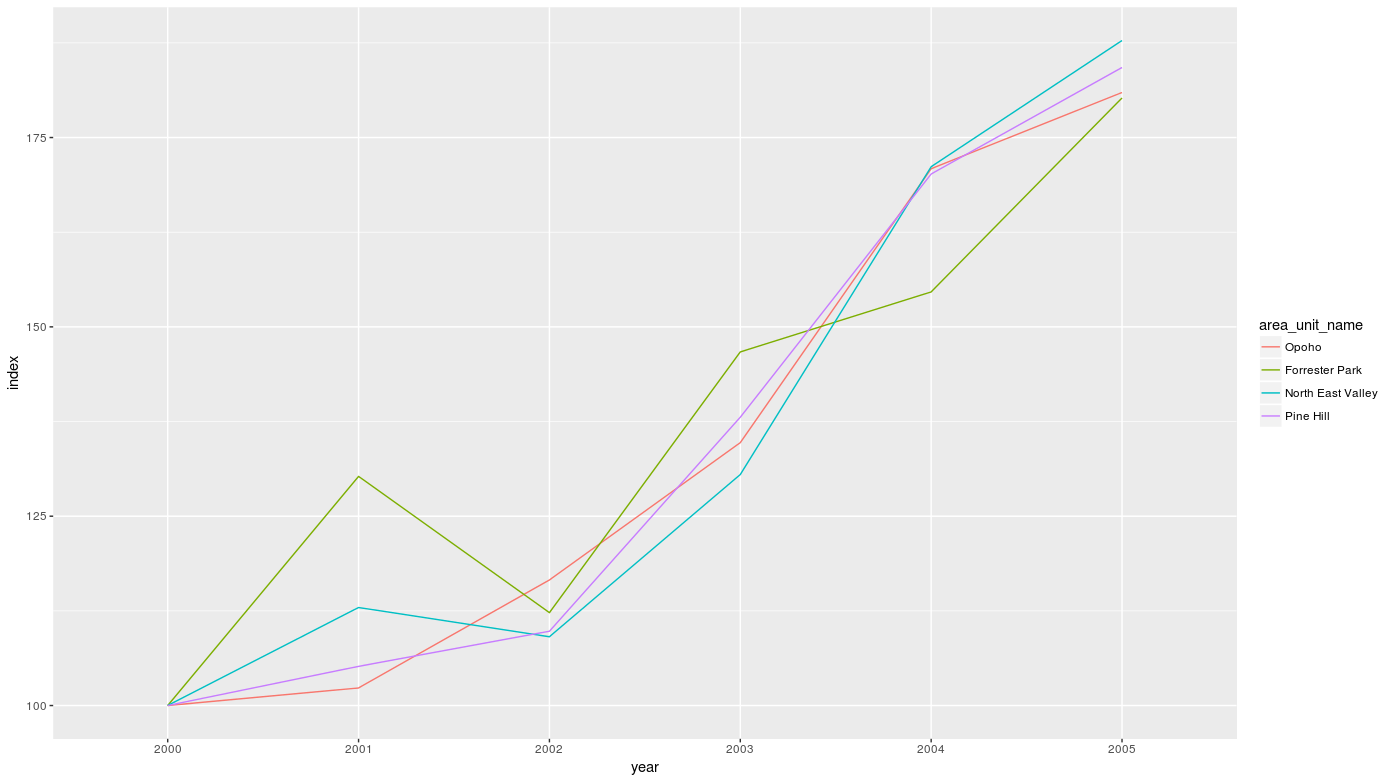


Figure 1: A house price index for four area units in Dunedin from 2000 to 2005

Briefly consider only the suburb of Opoho (the first row in the table). Each index entry (e.g. 134.7) is interpreted as a comparison of the house price in the year concerned (2003) with the reference year (2000) in each area unit. In describing these comparisons it can be said that house prices have increased by 34.7% over the period in question. Likewise, it might also be said that a house sold in the reference year (2000) for price *v* might be expected to sell for 1.347*v* in the comparison year (2003). Under certain conditions these two statements can be considered equivalent. However this is not true more generally. The first statement compares the average prices across the two periods. The second concerns the change in value of a single property or subset of properties. In order to interpret the information provided by the index correctly it is important to clearly define the framework in which indices are constructed.

A house price index is associated with the *housing stock* that exists within a given geographic area. The housing stock is defined as the set of all dwellings the serve the purpose of the primary residence of a single household. The boundaries of the definition of ‘dwellings’ are, of course, not absolute. Generally there will be criteria that arbitrate whether the housing stock will include dwellings that are still in the process of construction, but with some parts habitable; that are in a desolate state (and would fail a regulatory inspection) but are still occupied, and that apart from being used as a home are also used for pursuing business or trade.

Likewise, the definition of the term ‘household’ is not absolute. In most real-estate literature the term ‘single-household’ is a characteristic associated with a dwelling rather than its occupants. Typically, in countries with comprehensive residential property records, this is a classification that is formulated administratively.

These terms provide a foundation from which the purpose of a house price index can begin to be clearly specified. The most common intended purpose of an index is to track the exogenous price changes in the entire housing stock. It can be expected that an index derived from a straightforward comparison of the means in each year might achieve such a purpose under well-defined conditions.

Consider the ideal housing stock for such an index. This geographic unit would contain dwellings that were homogenous in their observable characteristics. They would for instance, sit on equally sized plots, have identical footprints, layouts, architectural details; be constructed of the same materials; have identical views, gardens and access to amenities. Fortunately this dystopian arrangement is observable only in Stepford, Connecticut and Disney villages. Clearly though, one of the defining characteristics of real estate in general is exclusivity and immutability with respect to location. Thus, a variable capturing the distance of the dwelling from a town centre (or similar) would provide a degree of variation that, it might be imagined, would have a material impact on price. Likewise the dispositions of the buyer and seller at the time of the transaction and their relative skills in the process of negotiation would impact the transaction price, as would the quantity of other nearby dwellings available for sale at the time. Further, assume that each unit sells exactly once in each period and that all sources of price variation are invariant with respect to time.

Returning to the example of the suburb of Opoho and assuming that it exhibited the characteristics of the ideal housing stock enumerated above, a comparison of the mean sale price in the reference year (2000) and the year of interest (2003) would yield and index that could be interpreted equally as the average price of houses increasing 34.7%, and that any (homogenous) dwelling unit could be expected to sell for 1.347 times its sale price in the reference year.

First, the index number would be derived from the mean sale price of the entire housing stock (the population parameter). That is, the number of dwellings sold in each year given by *n* would be equal to the number of dwellings in the housing stock *N* (every dwelling is sold once in each period). Thus the comparison of the population means, given by .

If we had transaction data for the entire housing stock in each year (i.e. every dwelling changed hands each year). All housing characteristics were time invariant (no improvements, depreciation, changes etc). And all dwelling characteristics were equal to the mean of each covariate. Then the straightforward comparison of the means in each year would yield an index number that captured only the exogenous price changes through time. It would also yield an index that could equally be interpreted as the change in the average house price and the change in value of a single property (or subset of properties).

As stated previously, each entry in an index gives a comparison of the price in a given year with the *reference year*. In the above table the reference year is 2000. This is implied by the entries in the first column equal to 100.0. For these first entries a straightforward comparison of the (two identical) means is coherent and uncontroversial in interpretation.

This is precisely equivalent to the comparison of the hypothetical mean sale price of the housing stock in the reference year to itself.

Straightforward comparisons of the mean sale prices in any two years (like those in Table and Figure 1) are problematic if the properties sold differ systematically through time. For example, smaller properties may have become relatively more sought after because of an increase in the number of small (single-member) households and the reduced availability of such properties.

A comparison of like with like is desirable. However, what constitutes a similarity in properties is difficult to specify. A residential property has a multitude of salient attributes, and many of them are not recorded in a typical database. Among them are not only the attributes of the structure but the (size, design and structural quality of the building, insulation and heating, state of disrepair and decoration), but also of the location (employment and leisure opportunities, quality of schools, the local rates of taxation, and absence of crime and dilapidation), environment (level of pollution, including noise), surroundings and neighbourhood (garden and other land that belongs to the property, fencing, access to the roads and local services) and the general ambience.

Some of these attributes are difficult to measure or assess, and their perceived importance, as well as the attributes themselves, may change over time. Every property is subject to wear and tear (including occasional catastrophic damage), but also to maturation (development of good relationships amongst neighbours; growth of trees and hedges in the gardens and common spaces), and properties occasionally undergo renovation. Substantial structural changes to a property are subject to local authority approval, and so are recorded but not necessarily included in the analysed database. Non-structural changes are generally not documented, although they be more costly and more material than changes subject to the consent process. There is also the presence of purchaser preferences that might be attributable to fashions and these may have a stronger effect in some periods (and locations) than others. Further, the circumstances and disposition of buyers and sellers and their skills in the process of negotiating a transaction have an impact on the sale price, as does the availability of similar properties for sale at the time. In brief, it is difficult to establish that two properties, as assets, are alike, even if they are adjacent, were constructed at the same time, and have (or originally had) the same design.

Notwithstanding, an index attempts to compare the sale prices of a typical property, or collection of properties, if they were sold in one year as well as in the other. It might be argued that such a comparison would be more appropriate if the outcome of the second transaction was not informed by the first, however, prior sale prices often play an important role for both the buyer and seller in the process of negotiating a subsequent transaction. While this might mean an index is less informative with respect to the changes in value of the asset fundamentals it also would fail to accurately capture that element of the negotiation over the subsequent transaction sale price. Fortunately, we can largely disregard this path of inquiry as ‘blinding’ in this manner is impossible to arrange.

The collection of properties for which the index is intended is called the reference housing stock (RHS). For example the RHS for the index in Table 1 is the set of all residential properties that sold (at least once) in the year 2000. It may be practical to define a reference housing stock that is much smaller, but it is essential that it is a good representation of the overall housing stock, akin to a random sample. The properties sold in subsequent years need not necessarily satisfy this criterion.

This difference is sometimes described in the literature as sample bias. And, the history of index development could be considered the development of techniques to arbitrate that bias.

\*\*Because housing is highly heterogenous and a composite good with low turnover frequency the measurement of those price dynamics are not straightforward.\*\*

Because there is no way to benchmark the accuracy with which an index quantifies the true magnitude of price changes with respect to changes in time alone, the criteria by which we assess the quality of an index consist largely of tests of reasonableness and consistency. One of the reasons for such a high degree of methodological diversity in the indexing literature is that the characteristics of the asset class of interest in this paper exhibit qualities that hamstring efforts to accurately isolate price movements from nuisance parameters as they change through time.

These qualities fall broadly into two groups. First, units of housing are highly heterogeneous. The economics literature generally considers houses to be composite goods. That is, each market-level transaction represents a trade of a bundle of attributes specific to that property. Naturally, one response is to control directly for heterogeneity across attributes using a hedonic regression. One of the main problems with this approach is that it is particularly sensitive to the model specification. Housing units, arguably, posses a large number of relevant attributes. Many of which cannot be or are not measured accurately if at all.

Second, units of housing sell relatively infrequently

Despite the fact that the literature on the construction of indices often treats these as seperate problems, these can in fact be expressed formally as the same problem i.e. sample selection bias is just omitted variables i.e. changing preferences over characteristics is a variable that enters the Z matrix because it's obviously not measured so can't be in X and isn't in u because it's correlated with y through time.

\*\*Discuss some of the general difficulties with computing indices. Specifically sample restricted computation.\*\*

\*\*So most indexing is computed at a higher level of aggregation. MSA in the US. City level in the NZ (Grimes etc).\*\*

House price indices are most commonly constructed at the metropolitan area level. They are generally of use to real estate industry participants. For example the collateral value of the underlying asset value of a mortgage can be easily calculated by using a price index to inflate or deflate either an original estimate of value or market-level transaction price. Mortgage lenders can assess the risk associated with collateral. Homeowners can monitor the value of their assets. House price indices are a measure of the return to a representative unit of housing or the return to the average homeowner etc. It represents a tradeoff between more complex estimation methods for something that's easy to use because it allows you to produce an estimate of value/risk associated with highly dimensional and heterogenous assets.

\*\*But comparable policy is enacted across a smaller scale within cities. people might also be interested in this.\*\*

\*\*In the intra-city context, one of the most important aspects of housing is location. Specifically, exclusivity and immutability.\*\*

\*\*There is an extensive theoretical literature on the structure of the relationship between location and price (sometimes distance and price in less computationally sophisticated models). This is mostly expressed as a land bid-price curve because of the relative homogeneity of land.\*\*

\*\*Is there literature on how or if that structural relationship within cities changes over time?\*\*

\*\*At least intuitively, that system has both policy and organic components. Isolating and measuring the impacts of those components in the time dimension is important in informing the decisions of policy makers and of interest to all other housing market stakeholders.\*\*

\*\*The nature and drivers of that system are difficult to measure. That is because of the aforementioned housing stock heterogeneity, tunrover infrequency etc etc.\*\*

In this context it is important to have a reliable measuring tool which also works well in the time dimension. Sample sizes are almost always a tradeoff betwen geographic resolution and time resolution. Some literature on development of geographic price indexing at an within-city level.

Review of indexing methods at a high spatial resolution. Some methods fall apart entirely and others have properties that are made better or worse by area restriction.

#Other rando thoughts

In New Zealand there is some evidence to suggest that incentive structures around retirement savings have created a bias towards investing in housing as a method of storing and building wealth. Cite Andrew Coleman perhaps.

Sample selection bias – eliminated with matching (can I subset to simulate this?)

Average treatment effect assuming vs time series hedonic pricing model.

Estimates of changes in shadow price of attributes changes over time. Fisher index etc.

Obviously the matching process itself is a Laspeyres analog, observing the change in prices on the bundle of first period quantities. That is, the change in price of the representative first period house.

Hedonic regression – Time dummy vs Characteristic method.

An index is an empirical method of tracking the movements of a single dimension of a composite good or bundle of goods while holding the other dimensions constant. Historically, price and the relative quantities of goods in the bundle of interest have been the dimensions of interest. More recently, prompted by significant quality changes over relatively short spaces of time in electronic goods, indexes have been developed for quality.

Important to recognize that the change in price of a representative unit of housing is not the same as the return to the representative, sampled homeowner. One fixes the ‘quantity’ of the characteristics to a base period while the other allows for a change in the mix of housing characteristics. That is, the representative homeowner may change their preferences for and the quantity mix of housing attributes they hold from period to period.

It’s important to recognize that there is no guarantee that SPAR will produce a constant-quality price index as the generated appraisal values allow for changes in the shadow prices and quantities of different housing attributes. This is an explicit result of determining the appraisal values using a hedonic method and would be at least an implicit outcome of any aggregation of housing attributes into a one-dimensional price attribute.

Recently, the house price indexing literature has started to adopt matching approaches to solve some of the model dependence problems associated with hedonic regressions.

What are the two main indexing problems? Sample selection bias. Omitted variables bias. These two this are the same.

**Data**

Analysis was carried out on a data set that contained records of all sales of single household residences in the Dunedin area from the beginning of 2000 to the end of 2018.

The data were obtained from Corelogic, who collect and maintain a database of real-estate information and make that information available for purchase. It should also be noted that Corelogic provide the estimates of property values used by local authorities to allocate property taxes (rates) and publish a proprietary set of market indices that are widely used by the real-estate industry. That is to say that the data used for this research is, at least in its initial form, identical to the data underlying some crucial metrics that are in widespread use by the real-estate industry.

There are some caveats of course. First, the dataset purchased did not contain the full set of variables that Corelogic collect on property transactions. The variables purchased were limited to those that, in some form, would be used in the matching procedures or subsequent parametric analyses. This was based on a priori beliefs about whether the variables would have a substantial net impact on the quantity of interest (the sale price). The literature generally supports the idea that a not insubstantial portion of residential property values are driven by a large set of unobservable characteristics. This set of unobservable but significant drivers of variation in sale price would therefore be more problematic in the analysis than observable but insignificant controls. Given the limits of the budget and additional cost associated with purchasing a greater number of variables, it seemed reasonable to exclude any that would not be considered to have a significant impact on price regardless of whether they could be observed. Additionally, the matching process itself is a technique designed specifically to reduce sensitivity to model specification. By using matching as non-parametric data pre-processing it reduces the need for a comprehensive set of control variables in the estimation of the quantity of interest. Thus, the results should be robust to the exclusion of those variables in any case.

Second, There were a number of observations in the data that contained missing or incorrectly coded values. These were excluded at the outset from any subsequent analysis. Specifically, observations considered to have incorrectly coded values were defined as being those that had a zero value associated with the land area or building area variables. Neither of these necessarily constitutes a coding error. For instance, a zero value in the building area variable might be interpretable as an empty lot. Likewise, a zero value in the land area variable might be interpretable as the sale of a leasehold property. However, independently checking a subset of these observations revealed that the majority of these cases appeared to be genuine errors. In any case, neither empty lots nor leasehold properties were units of interest in this analysis and so were excluded.

Table: Summary of missing or zero values by variable.

The dataset obtained from Corelogic contained 34081 observations from the 01/01/2000 to the 12/09/2018. After filtering a total of 1052 observations for missing and ‘incorrectly coded’ variables the dataset used for analysis had n = 33029 observations.

Within this data set the were thirty area units. Area units are a standardised administrative unit of geography determined at the national level based loosely on population densities. In this analysis indices were compiled at the area unit level. Indices were compiled annually with a total of 15 periods. Below is a summary of the sample sizes arising from these scale divisions in the space and time dimensions.

Table: Sample sizes by area unit and year.

TALK ABOUT VARIABLES AND MEASUREMENT

DATA CHAPTER FOR FLOODING

For the analysis of the impact of the 2015 flooding event in South Dunedin the data previously described were further restricted in the following ways. The major change was that student areas were removed from the analysis. This excluded an additional 4381 transactions, reducing the total number of observations from 33029 to 28648.

**Beltrán A., Maddison D., Elliott R.J.R.**

**Assessing the Economic Benefits of Flood Defenses: A Repeat-Sales Approach**

**Risk Analysis, 2018**

Economic theory suggests that, other things being equal, properties located within a [floodplain](https://www.sciencedirect.com/topics/earth-and-planetary-sciences/flood-plains) should suffer a price discount. A survey of the existing evidence nonetheless reveals that this price discount lies anywhere between − 75.5% to a + 61.0% price premium. In this paper we summarise and explore the wide variation in the results to obtain ‘best’ estimates with which to guide policy. Results from our [meta-analysis](https://www.sciencedirect.com/topics/earth-and-planetary-sciences/meta-analysis) comprising 37 published works and 364 point estimates indicate marked differences between studies according to when and where they were conducted. For [coastal regions](https://www.sciencedirect.com/topics/earth-and-planetary-sciences/coastal-regions) the results show that properties located in the floodplain command higher prices; this finding is however likely to be caused by a high correlation between omitted coastal amenities and flood risk. There is moreover, evidence that publication bias affects the [coastal flooding](https://www.sciencedirect.com/topics/earth-and-planetary-sciences/coastal-flooding) literature. Results from meta-regression analyses intended to uncover sources of heterogeneity confirm that controlling for time elapsed since the most recent flood is especially important. For inland flooding the price discount associated with location in the 100-year floodplain is − 4.6%. Although other estimates are defensible, we suggest this figure be used as a rule of thumb to determine the benefits of flood relief projects to households.

# **Forgetting the Flood? An Analysis of the Flood Risk Discount over Time**

We examine whether property price differentials reflecting flood risk increase following a large flood event, and whether this change is temporary or permanent. We use single-family residential property sales in Dougherty County, Georgia, between 1985 and 2004 in a difference-in-differences spatial hedonic model framework. After the 1994 “flood of the century,” prices of properties in the 100-year floodplain fell significantly. This effect was, however, short-lived. In spatial hedonic models that explicitly incorporate both linear and nonlinear temporal flood-zone effects, we show that the flood risk discount disappeared between four and nine years after the flood, depending upon the specification. (JEL Q51, Q54)