Hedonic Housing Price Indices: The Turinese Experience

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This study presents the methodology used by the Agenzia del territorio to produce real-estate indices for the analysis of the housing market in the Turinese area districts. The importance of an index is highlighted by the fact that a significant percentage of national wealth is the property sector. To this end, we use a rich and detailed database on transaction prices which allows us to study the dynamics of the residential housing market through the estimation of hedonic price indexes for Turin. This study carried out an hedonic methodology, not yet applied in Italy, on data collected and aggregates in homogeneous areas for the city of Turin. The results obtained appear to be of valid significance in the ratios, also in terms of values. Home price increased 40 percent from first semester of 2003 through the second semester of 2007. [JEL Classification: D49, D69, C4, R2]

1. - Introduction

This work is based on two independent assumptions. A rapid review of the real estate indices available at the international level highlights a lack of information about the general Italian real

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estate market and, on the other hand, notable attention given to hedonic regression (Eigslsperger, 2006). Hedonics are the "most intellectually satisfying of the various quality-adjustment methods because (they) appeal to an underlying economic structure rather than opportunistic proxies" (Hulten, 2003). The idea is to detect the quality of a product or, in other words, «the potential contribution to the welfare and happiness of its purchaser and the community» (Court, 1939) through a characteristic's vector. Real estate price indices have recently played a crucial role in contributing to both capacity and inflationary pressures. A high percentage of national wellness is based on the real estate sector and how dynamic house prices affect investment decision, financial order, inflation and working mobility. In Italy, surprisingly, there is no official real estate market index. This anomaly was reported by Eurostat (1999), and it created a lot of problems for the statistic agency (Boskin *et* al., 1998), but also for the Central Bank (Cannari, 2006) because it could not base its decisions on an official index. Some nations use housing price indices in the national budget, as a deflator of the indices on residential construction and in order to determine the value of the housing stock. We decided to use the Territory Agency's tools to analyze Turin's real estate market. These tools were also used by literature. The Territory Agency both manages the updating of the real estate data bank and is a technical organ of the Financial and Economic Ministry that analyzes real estate prices and a lot of other characteristics. Using the bases of hedonic method, we analyzed the elementary prices derived by extraction of the OMI relevation card. For every six months, we derived a vector of characteristics compatible with what literature says, and then, valued the regression coefficients and extracted the real estate index for the city of Turin. This index covers the gap in the current estate specialistic literature, in fact the hedonic approach has not yet been applied in Italy. Despite the abundance of information provided by the current literature, it is not easily used. In fact, price variations influence budget and also sellers' and buyers' investment decisions, which, in turn, influence price stability in the Euro area. The rest of the paper is organized as follows.

Section 2 defines the housing price indexes. Data and the econometric specification of the hedonic function is presented in Section 3. Section 4 shows the results of the hedonic regression. Section 5 concludes.

2. - Housing Price Indices

There are several methods for constructing house price indices. Some of these methods were created decades ago but the problem is open. The variation in the median (or average) sale price is often used to measure price changes. The index formula, so-called Dutox index, is easily understood and available for most areas in Italy. The index is sensitive to quality changes because a house is not a homogeneous product[1]. In the real estate market, matched methods are so called repeat sales methods. They estimate price trends from transactions for houses that have been sold more than once over the period (Bailey *et* al., 1963; Ashenfelter and Graddy, 2003).

The main advantage of the repeat sales approach is reproducibility and the main disavantage of the approach is as follows:

(a) It does not use all of the available information on housing unit sales;

(b) It does not allow for changes in the implicit price of particular charateristics over time (Diewert, 2003);

(c) It does not take into account repairs or renovations in the housing units;

(d) It does not take into account depreciation of the housing units.

The repeat sales model, advanced by Bailey *et* al., (1963) was first used as an alternative method of analyzing the hedonic price

[1] The median price is immune from measurement errors in the upper quantile or the lower quantile, however the model is unable to reflect the price changes in the upper quantile. Median price is used in several studies (MARK J. - GOLDBERG M., 1984; WANG F. - ZORN P., 1997) in the index calculated from the US Real Estate Association, instead average price is used in studies available in Italy. This index is known to be sensitive to quality changes (CASE B. - SHILLER R., 1987).

index. If the assumption of unchanged house charateristics is not violated the repeat sales method may be expressed as:

(1) $$p_{it+s} - p_{it} = \sum_{t=1}^{T} \beta_t D_{it} + (\varepsilon_{it+s} - \varepsilon_{it})$$

where P_{it} is the sales price of house unit i at time t and D_{it} is a set of time dummy variables, we assume the characterisctics and the implicit prices of the same housing unit do not change over the time. When the assumption of unchanged house charateristics is not violated, the repeat sales method is not needed to estimate characteristics. However the disavantages are the non randomness of the sample, reductions in sample size, and selectivity. The repeat sales method holds quality constant by mesuring the same asset in two periods. The selection corrected repeat-sales index estimates whether a housing unit is sold twice or not. I_{it} is an indicator variable which takes the value of 1 if the housing unit is sold at time and zero otherwise.

(2) $$\text{prob}(I_{it} = 1) = \Phi(\gamma_0 + \sum_{k=1}^{K} \gamma_k Z_{kit})$$

where Φ is the standard normal distribution; Z_{kit} is the relevant hedonic charateristics vector of the housing unit i at time t (k = 1,…, K) and γ is a set of parameters. The second step is to find the Mills *ratio* parameter:

(3) $$\lambda_{it} = \frac{\phi(\gamma Z_{it})}{\Phi(\gamma Z_{it})}$$

is included in hedonic regression to obtain unbiased price indices correcting for the non randomness of the sample:

(4) $$p_{it+s} - p_{it} = \sum_{t=1}^{T} \beta_t D_{it} + \chi(\lambda_{it+s} - \lambda_{it}) + (\varepsilon_{it+s} - \varepsilon_{it})$$

A hedonic price index uses a hedonic function in some way (Triplett, 2004). Most research hedonic price indices have used the time dummy variable method (Gordon 1990; Griliches, 1990; Triplett, 2004) which allows shadow price and price index to be simultaneously estimated (Locatelli and Zanola, 2003). The hedonic price model attributes an implicit price to each of the time-invariant and time-varying characteristics of the item. A set of charateristics is identified for a regression of the price of the house i such that:

$$\ln P_{it} = \beta_0 + \sum_{i=1}^{K} \beta_i X_{it} + \sum_{j=1}^{T} \gamma_j D_j + \varepsilon_{it} \tag{5}$$

where ln p_{it} is the logarithm of the price of house i sold in period t; β is the implicit price, X is a vector of charateristics; ε_{it} is the random error term; D_j is a dummy equal to 1 when a sale occurs in semester j, 0 otherwise. The social valuation of house charateristics does not change over time. The regression coefficient γ is the logarithm of the price index at the time t, so the price index at time t is:

$$I_t = I_{t-1}[\exp(\gamma_t - \gamma_{t-1})] \tag{6}$$

If the assumption of unchanged house charateristics over time is violated only the data of two periods are pooled into regression. The model is such as:

$$\ln P_{it} = \beta_0 + \sum_{i=1}^{K} \beta_i X_{it} + \gamma_j D_j + \varepsilon_{it} \tag{7}$$

The adjacent period regression is preferred because of the possible presence of structural change across time. Structural change and coefficients instability from one cross section to another are due to technological innovations or changes in consumer preferences. In the real estate market, it is reasonable to suppose that constructive technology and tastes do not change so quickly (Li, 2006). Chow test can be used to test if structural change is present. Triplett (2004) noted that the index number formula implied by the dummy variable method can be derived from the expression for the regression coefficient for the time variable because the index formula depends on the functional form for the hedonic function. The first hedonic price index, introduced by the US Census Bureau in 1968, was a characteristic price index. The charateristic price method uses the implicit characteristic prices (the regression coefficients from the hedonic function) in a conventional weighted index number formula (Triplett, 2004). Housing buyers want the location and living area, and the number of bathrooms contained in the housing unit. This interpragetion of the characteristic price index method only requires that the quantities of characteristics are the variables that buyers want and use and that sellers produce and market. The linear model is such as:

(8)
$$\ln P_{it} = \beta_0 + \sum_{i=1}^{K} \beta_i X_{it} + \varepsilon_{it}$$

where *p* is price of housing unit at time *t, X* is a set of charateristics, the regression coefficients are the implicit prices and the constant is the price of the housing unit without characteristics held in the regression equation. The Laspeyres price index is:

(9)
$$I = \beta_0 + \sum_{i=1}^{K} \beta_i X_{it} \beta_0 + \sum_{i=1}^{K} \beta_i X_{it-1}$$

In a weighted index number formula, weights are quantities of characteristics in the sample (Li, 2006; Triplett, 2004) or in a typical or average housing unit, or more correctly, the total quantity of characteristics purchased by the index population. The regression is carried out for each period and coefficients are allowed to change over the time. When the hedonic price surface is nonlinear, because a characteristic does not have a single market price and different buyers pay different prices for characteristics depending on their preferences, the characteristics price index is biased. Griliches (1971) called this method a "price-of-characteristics index". The method has several advantages (Triplett, 2004):

— the index number formula. The index number formula is separated from the form of the hedonic function. In the time dummy method the form of hedonic index depends on the empirical relation between prices and charateristics (Rosen, 1974).

— the time dummy method constrains the hedonic coefficients to be unchanged over the time periods included in the regression. Schultze and Mackie (2002) urge the statistical agencies to avoid putting resources into the dummy variable method.

A Chow test can be used to investigate if hedonic coefficients differ statistically across the periods.[2] According to Silver and Heravi (2001), the main problems are:

(a) we must estimate a number of parameters equal to the number of characteristics;

(b) if, reducing the number of parameters reduces the number of classes of characteristics, the variance of coefficients analyzed inevitably increases;

(c) Theory provides little guidance to help determine the appropriate functional form and the characteristics vector for hedonic equations.

The hedonic method controls for quality by using multiple regressions; the problems are to determine the charateristics vector, instability of coefficients from one cross section to another, specification of the hedonic functional form (Knight *et* al., 1995). The disavantages of repeat-sales is the non randomness of the sample, reductions in sample size, and selectivity. Case and Quigley (1991) go beyond two approaches (hedonic and repeat); this metodology combines information on repeat sales with hedonic approach to capture the variation of prices within the repeat sales model and the serial correlation. Case and Shiller (1987) developed the method that involves two steps. The first is to estimate a repeat sales equation and the second uses the residuals to correct for heteroskedasticity using Generalzated Least Squares[3]. Empirical evidence in the real estate market indicates that hybrid models are unbiased (Case and Szymanoski, 1995). However, when the sample is too small and does not represent the population of properties, or when there is more than

[2] Empirical evidence in the real estate market indicates that all of three hedonic methods (pooled, adjacent, characteristic) produce almost identical results (LI W. *et* AL., 2006).

[3] US Office of FHEO uses a modified version to construct house price indices.

one sale repeated during the time period, even the hybrid models tend to produce distorted results. (Hwang and Quigley, 2004). Carter Hill *et* al. (1997) extended this approach by assuming the hypothesis about the first order autoregressive properties of errors in the repeat model.

3. - Hedonic Approach

Griliches (1971) proposed to use the technique of the hedonic regression in order to fix the prices to varying quality; from then, began a discussion about whether traditional methods should be replaced by hedonic methods in the work of the statistic agencies. In 1939 Andrew Court published the first article on hedonic housing price indices. Hedonic indices have been subsequently adopted in varying countries in the field of electronics and real estate. A hedonic function is a regression and explanatory variables are based on the notion that the transaction observable is a bundle of lower order transactions that determine the value of the bundle. The definition of hedonic indices of price can be pursued in various ways; typically the studies use one regression with dummy variables. The time dummy variable method was the major method employed for hedonic price indices, however, Griliches's original paper was the first to produce hedonic indices by methods other than the dummy variable one. The first hedonic price index was introduced by the US Census Bureau in1968 and in the national budget in 1974. We can use hedonic with heterogenous goods. There are a number of studies that have used hedonic approach to estimate the value of goods such as automobiles (Griliches, 1971), PCs (Triplett, 1990; Berndt, 1993), houses, (Blackley *et* al., 1986; Laferrere, 2006; Vinhay and Lall, 2006; Li, 2006), paintings (Berndt *et* al., 1995; Chanel, 1996; Candela and Scorcu, 1997; Locatelli-Biey, and Zanola, 2003), human capital wage from the labour economics (Griliches, 1990), wines (Nerlove, 1995; Combris *et* al., 1997). Environmental characteristics distinguish a particular category of attributes; from which emerges the necessity to know the willingess to pay for improvements in environmental quality. In our case the market is that one of real estate. According to Rosen (1974) each good is characterized by the set

$$x_k = \{x_1, ..., x_k\} \tag{10}$$

of all its characteristcs. The assumpion underlaying the theory is that: notion of a homogeneous good is an "idealtype" in the sense of Max Weber. Goods, as such, empirically do not exist but there are only variants of the idea of a certain good. Under the hedonic hypothesis, a good is:

(a) characterized by the set of model which fit under a same hedonic regression equation;

(b) identified with the set of all variants *j* whose prices can be explained by characteristics $x_k = \{x_1,\ldots,x_k\}$ and the parameters $\beta = \{\beta_0,\ldots,\beta_k\}$ typical of a regression function (Brachinger, 2002).

This definition is adapted to the real estate market. Following a remarkable variability of the national real estate market and, particularly, Torino, due to historical, cultural and urban planning reasons, we see meaningful price variations due to the variation, sometimes, of one characteristic. For example, the price of a store on Via Roma depends on the side of the road where it is. Formally the functional relationship if between price *p* and characteristics *x* is as follows:

$$p = f(x_k) \tag{11}$$

From the first order conditions associated with a solution of problem we differentiate the hedonic function according to: P=constant (= P_a) we have:

$$\frac{\partial P}{\partial x_k}(x) = \frac{\partial f}{\partial x_k}(x)(k = 1, ..., k) \tag{12}$$

The coefficient shows the increment to the price of a good arising from a one unit increase in characteristic x_k (other variables in the regression constant). To explain what we want to say, we show a simplified representation of one possible specification of the hedonic housing function:

$$\text{price}_{\text{houseunit}} = f([\text{livingarea}],[\text{location}],[\text{piano}]) \quad (13)$$

Rosen (1974) represents a perfect competitive market in which consumers and producers interact to form the equilibrium prices. In order to analyze this market and to understand the behaviors of the consumers, we consider the consumers' choices for every single characteristic and therefore divide this market in many implicit markets. From the action between consumers and purchasers, on these implicit *n - markets*, we define a matrix of the prices in which it expresses the equilibrium's price in the every single characteristic's market. The main problems are:

(a) Determine the charateristics vector x typical for each good;

(b) Coefficients are unstable from one cross section to another;

(c) Specify the hedonic functional form $f(x_k)$.

The applicable procedures in the determination of the needed variables are different: to choose on the base of the economic theory of the market; to use same variables used in previous studies; to implement methods statistically in order to try to extrapolate from the data the behavior of the actors on the market[4]. Second the coefficients regression can be unstable from one cross section to another. The third problem of the economic model relates to the choice of the functional form and implies one decision on the way to express the variables; it must use the linear form, or transform the variable ones in order to better succeed to identify the relation that elapses between price and the characteristics. The functional form has a determining impact on results and deserves therefore one particular reflection.

[4] The first two procedures bring up similar results based on the existing literature with the advantage of being able to confront results with analogous studies.

3.1 *Estimating the Hedonic Prices*

To calculate the hedonic price index researcher uses a procedure in two steps. First, the investigator must estimate a hedonic function and in the second part, the investigator decides how to use the hedonic function to calculate a price index. In analyzing the hedonic function, the first step is to choose the variables to utilize as characterisctics and obtain a precise dataset. To obtain unbiased estimates of house price indices the regression should be specified correctly with respect to both functional form and independent variables. The hedonic method is a technique to control for the heterogeneous nature of properties; it recognizes that properties are composite products. While attributes are not sold separately, regressing the sale price of housing units on their various characteristics yields the marginal contributions of each charateristic. For example, an estimated hedonic function for houses might be:

(14) $$P_{it} = c_0 + c_1(\text{sup})_{it} + c_2(\text{ZonaOMI})_{it} + c_3(\text{piano})_{it} + u_{it}$$

In this example, the price of the house unit depends on its living area, measured in square meters, its location, and the level, u_{it} is the random error term. The economic theory underlying hedonic functions rests on the hedonic hypothesis: heterogeneous goods are a set of characteristics that are outputs for producers and commodities for consumers. Under hedonic hypothesis, one does not buy a housing unit as a "box"; one buys the bundle of characteristics that the producer packages into the box and «the potential contribution ... to the welfare and happiness of its purchaser and the community» (Court, 1939). Rosen (1974) developed the output theory for producers in a competitive industry focusing on product differentiation in pure competition. Obviously this assumption implies that also the construction costs depend on the characteristics; in fact the urban planning instruments put into effect preview the possibility to build up to a million cubic meters and uncertain number of homes. To estimate hedonic price indices, researchers need the estimated regression coefficients, c_1, c_2, and c_3 from equation *(14)*. The classical assumptions for the error term will be reasonable if all the price observations are independent.

(15)
$$E(u \mid X) = 0$$
$$Cov(u \mid X) = \sigma^2 I$$

In practice, this assumption may not be fulfilled because some of the prices may be correlated. The main problem is to constrain the hedonic coefficients to be unchanged over the time periods included in the regression. The regression coefficient, when the regressions are estimated by OLS, indicates how much the price of a housing unit changes if this house is endowed with an additional unit of the characteristic. The equation *(14)* is the linear approach; the regression coefficient indicates how much the price of a housing unit changes if this house is endowed with an additional unit of the living area. If the relationship between price and characteristics is such as that:

(16)
$$\ln P_{it} = c_0 + c_1 \ln(\text{sup})_{it} + c_2 (\text{ZonaOMI})_{it} + c_3 \ln(\text{piano})_{it} + u_{it}$$

the regression coefficient indicates the partial elasticity, how many percent the price changes if the sup_{it} (living area) changes by one percent. The regression coefficients are not the implicit price of characteristics. A hedonic function is a relation between the prices of different varieties of a housing unit and the quantities of characteristics in them. The regression coefficients are often called implicit prices or characteristics prices, because they indicate the prices charged and paid for an increment of one unit of, *i.e.*, living area. If a characteristic is desired by the users, one does not expect a negative sign in the hedonic function. *Coeteris paribus*, for estimating regression coefficient c_i it is better to have less correlation between charateristic x_i and the other independent variables (Wooldridge, 1999, page 96). In the regression model, explanatory variables in equation *(16)* are correlated with the price. Multicollinearity arises when there are statistical dependencies among explanatory variables in a regression. Multicollinearity is a problem stressed in hedonic studies, for a review see Shultze and Mackie (2002). In several studies, hedonic regression standard errors blow up and coefficients are unstable from one cross section to another. According to Triplett (2004) instability in hedonic functions is often caused empirically by data errors combined with multicollinearity, missing variables and proxy variables. The first requirement for absence of multicollinearity is absence of technical relations among the characteristics that restrict possibilities for changing one characteristic without concomitant increases or decreases in the other characteristics. The second requirement is absence of economic relations among regression variables. Gujarati (1995) gives as a regression of electricity use on income and house size, where income and house size are usually correlated. Absence of multicollinearity in the universe also requires absence of correations among explanatory variables in the sample. When the living area increases, there are no technical reasons to increase the number of bathrooms or luxury items. However, usually, consumer preferences are similar. When certain house characteristics are considered desirable by the buyer, housing unit sales will tend to cluster in the center of the characteristics' area. Finally, on the buyers' side, the sample based only on market transactions, over-represents the most requested homes, those with two or three rooms. It is correct to say that multicollinearity is a problem but large samples and data cleaning often reduce it.

3.2 *Functional Forms in Hedonic Studies*

In the history on hedonics a few number of functional forms have been used (Triplett, 2004). The linear form is often used to preliminary approach but the semilog and the double log are most common forms in study about real estate. The functional forms considered in this paper are listed as follows:

(a) Linear Model:

(17) $$P_{it} = \beta_0 + \sum \beta_{it} (X)_{it} + u_{it}$$

(b) Semilog Model

(18) $$\ln P_{it} = \beta_0 + \sum \beta_{it} (X)_{it} + u_{it}$$

(c) Log-linear Model

(19) $$\ln P_{it} = \beta_0 + \sum \beta_{it} \ln(X)_{it} + u_{it}$$

The most simple approach is the linear; the regression coefficient β_k (k=1,...,K) indicates how much the price of a good changes if this good is endowed with an addictional unity of the x_k characteristic.

(20) $$\beta_k = \frac{\partial P(x)}{\partial x_k} (k = 1,..., K)$$

In this model, obviously, the regression coefficient β_k indicates the growth rate because the price vectors are shown in logartimic form.

(21) $$\beta_k = \frac{\partial P(x)}{\partial x_k} 1P(x)(k = 1,..., K)$$

In the third approach (double log) the regression coefficient β_k indicates the partial elasticity, how many percent the price changes if the x_k characteristic changes by one percent.

(22) $$\beta_k = \frac{\partial P(x)}{\partial x_k} x_k P(x)(k = 1,..., K)$$

The theory of hedonic functions shows that the form of the hedonic function is entirely an empirical matter[5]. Rosen showed conclusively why theory cannot specify the best fitting functional form for hedonic functions (1974). The semilog and the log-linear model are preferred because it is relatively easier to interpret the coefficients. Triplett (2004) argues that choosing a functional form

[5] Econometric textbooks reported as a criteria for choosing among functional forms the Box-Cox test (BOX G.E.P. - COX D.R., 1964) but the empirical evidence shows as the usually used forms all are rejected statistically by the test (TRIPLETT J., 2004).

to reduce heteroskedasticity is not correct because heteroskedasticity does not bias the expected values but the standard errors. Heteroskedasticity, not constant variance in the residuals, violates one of the basic assumptions for OLS methods. The hedonic function estimates the relation between the prices of housing units and the characteristics embedded in them and an inappropriate functional form biases our estimates of the hedonic indices. Halvorsen and Pollakowski (1981) proposed a criteria based on quadratic Box-Cox functional form. Often in the first step researchers use the linear form where coefficients are implicit prices. Rosen (1974) showed that the linear form should be used only for divisible goods. On the buyers' side consumer should be indifferent from one housing unit with living area of 80 m^2 or two with living area of 80 m^2. According to several studies in real estate hedonic we tested the semilogaritmic form on available data.

4. - Results

4.1 *The City of Turin: Why?*

Turin is the fourth city in Italy for people and for residential real estate market after Rome, Milan and Naples. It constitutes, by itself, the 40.5% of the whole province whith 490.698 housing units, the number of normalized transactions represent 46% of the whole province with a NTN of 16,284. Table 1 shows the comparison of stock and NTN of six main italian cities.

TABLE 1

STOCK AND NTN OF SIX MAIN ITALIAN CITIES

	Stock	NTN
Rome	1,313,637	41,368
Naples	415,063	9,847
Milan	789,822	24,689
Genoa	323,611	8,537
Palermo	309,518	7,569
Turin	490,698	16,274

4.2 *Data and Variables*

Data as reported in the Osservatorio del Mercato Immobiliare (OMI) Agenzia del Territorio for the city of Turin. Since 2002 OMI has collected semester data in more than 1,500 Italian municipalities using standardized housing information data. The data span from 2003 to 2007 and the survey is task of Agenzia of Territorio[6] using also data from real estate associations. OMI has collected several prices: the selling price, the estimated price and the offer price. We use only actual selling price according to the law 243/2006. The collected data has the advantage of being unbiased in that it is not influenced by the individual owner as in the Inquiry of National Gross Income of the Bank of Italy. The main problem is the possibility of selection bias. The following list gives a description of original data and the process of variable construction.

(*a*) *Location classification:*

(*a*1) *Downtown core*: includes central zones except San Salvario between Corso Roma, Regina Margherita, Corso Inghilterra;

(*a*2) *San Salvario*: The characteristics of the houses located at San Salvario are peculiar but we have the problem about number of observations;

(*a*3) *North Semi-Central*: includes San Donato, Porta Palazzo, Duchessa Iolanda, Palermo;

(*a*4) *South Semi-Central*: includes Valentino, Dante, San Secondo, Galileo Ferraris, De Gasperi, Michelotti, Crimea, San Paolo, Spina1, Marmolada, Duca d'Aosta;

(*a*5) *North Suburban*: includes Spina 3, Euro Torino, Madonna di Campagna, Spina 4, Docks Dora, Rebaudengo, Corona, Barca Bertolla, Vanchiglia;

(*a*6) *South Suburban*: includes Zara, Carducci, Unità d'Italia, Lingotto, Santa Rita, Mirafiori North, Mirafiori South, Pozzo Strada and Aereonautica Parella;

(*a*7) *Hill*: includes only data from Hill; in the data set, 89% of resale detached houses are located in Hill suburb.

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[6] For more information see: *www.agenziateritorio.it*

The variables *North Suburb* is omitted since it is used as a base category.

(*b*) *Housing Type*: the original data includes detached house and condominium. Only condominium is included for the hedonic index. Detached houses data is omitted since observations are only for location Hill.

(*c*) *Dummy variables*: there are location dummy variables and proxy for various features. They includes new house, old house, park, green, penthouse;

(*d*) *Continuous variables*: There are 5 continuous variables, namely, living area, age and sqrage, number of flats, number of lift. House price has negative quadratic relationship with age of the unit, thus both variable of age and root squared are used.

Data are cleaned by the following procedure.

(*a*) create a new data set which includes only detached houses in the City of Turin.

(*b*) drop observations if sold price is less than 30,000 euros or greater than 1,000,000 euros.

(*c*) drop observations if living area is less than 30 smq.

(*d*) drop observations if the number of flats is greater than 25.

The data span from 2003 to 2007, I^{st} semester with a total of 3,199 observations. See Table 13 for the datailed description of variables and sample information.

Formally, our specification is given by:

$$
\begin{aligned}
\text{(23)}\quad \ln P_{it} &= \beta_0 + \beta_1 2003:I + \beta_2 2003:II + \beta_3 2004:I + \beta_4 2004:II + \\
&+\beta_5 2005:I + \beta_6 2005:II + \beta_7 2006:I + \beta_8 2006:II + \beta_9 2007:I + \\
&+\beta_{10}\,\text{sup tot} + \beta_{11}\text{npiano} + \beta_{12}\text{attico} + \beta_{13}\text{eta} + \\
&+\beta_{14}\text{sqreta} + \beta_{15}\text{nascen} + \beta_{16}\text{newhouse} + \beta_{17}\text{ordhouse} + \\
&+\beta_{18}\text{park} + \beta_{19}\text{verde} + \beta_{20}\text{servizi} \\
&+\beta_{21}\text{centro} + \beta_{22}\text{salvario} + \beta_{23}\text{semnord} + \\
&+\beta_{24}\text{semsud} + \beta_{25}\text{persud} + \beta_{26}\text{collina} + \varepsilon_{it}
\end{aligned}
$$

4.3 *Analysis of Results*

In this section the relationships among variables are examinated. Criteria for comparing results R-squared, root-MSE, F-Test, p-value, t-test and Breush Pagan test for heteroskedasticy. The Chow test is used to investigate for structural changes across time. We test the pooled and the adjacent time dummy method. Criteria for comparing functional forms includes R-squared, root-MSE, F-Test. Finally, hedonic semilog model pooled and charateristic are computed and compared with average data.

4.3.1 Correlations

Table 3 shows the correlation matrix between *suptot, nflat, penthouse, sqrage, n_ascen, new_house, ord_house, park, green, services*. The dependent variable is included to see how independent variables follow the price movement. Our observations include:

(*a*) The correlation coefficient between *newhouse* e *sqrage* is reasonable 29.35%;

(*b*) The living area has not any relashionship with all other independent variables;

(*c*) The correlation coefficient between *suptot* e *valmq* is low maybe because the price for meter is in the regression model;

(*d*) The correlation coefficient between *valmq* and *newhouse* 33.79%;

(*e*) The correlation coefficient between *green* and *sqrage* 24.28 is less reasonable.

Multicollinearity does not seem to pose a serious problem in this study. The highest value of correlation is between *park* and *green* 46,31%; we think location with more park have reasonable more green indeed in the hill suburb the correlation coefficient between *park* and *green* is 52.12%. The number of observations in the data set is not the problem. The possible reason may be the accuracy of the data set and the procedure to clean data, which reduces the multicollinearity among the independent variables.

For example Table 8 shows the correlation matrix for the first semester of 2007.

4.3.2 Comparing Hedonic and Median Index

Table 4 shows the sample information, the minimum price is 950 euros and the maximum is 6,000 euros. Table 5 shows the results for the pooled regression for the semilog model. Robust standard errors of the estimated coefficients accounting for heteroskedasticity are obtained, Table 12 shows the results of Breusch-Pagan test. For the dummy variables all the individual *t*-statistics are significant at the 5% significance level. All the location dummy variables have negative signs because Periferica nord is used as a base category. Using as a criteria the *p - value* the regression coefficients are statistically significant at the level of 95% except *san_salvario*; we think it for the small observation's number. All the coefficients have expected signs except the variable *green*. *R-squared* is 0.5885 and *R-squared adjusted* is 0.5887 are moderate. After we run an adjacent year regression which includes one time dummy variable that distinguishes the two periods with the same results. Table 7 shows, for example, the period 2006:II-2007:I. Some coefficients are not statistically significant probably relation to size of the sample (1,070). The semilog model best fits the data as it is shown in Table 9 and in Table 10. Based on Chow test as reported on Table 11 there are not structural changes on data so we can use pooled semilog method. Graph 2 shows the trends of the hedonic housing price index obtained with semilogartimic pooled and characteristics price method (Fisher and Laspeyres formula) and the results are reported in Table 6. All of these three hedonic methods produce identical trends, but Laspeyres price index imposes the upper limit consistent with the literature. The average index absorbs the variations and between 2005 and 2007 is lower than hedonic which better controls for the quality variation. The variation of the prices in the considered period turns out to be 40.01% and it does not seem to arrest itself, in spite of the forecasts of the analysts not even in first semester

2007. Comparing the results with panel data of "Consulente Immobiliare" of il Sole24ore, Nomisma we see some relevant difference, the comparision of housing price indexes are reported in Graph 3. The data of Osservatorio di Torino are the highest, Nomisma and OMI the lowest.

5. - Conclusions

This paper brings together two assumptions: the notable attention given by the statistic agency to hedonic methods and the public database information. We tested both time dummy and characteristic price, highlighting the likeness of both methods. The semilogaritmic form best fit to data, according to main hedonic studies of the real estate sector, it gives similar results both with dummy method and pooled method. It appears obvious, for the application of a real estate price index, the necessity of an extension to the regional and national level. The possible lines of development of this study are the production of batteries of indices at the provincial level and tested the robustness of the data and adopted a system of weights we can produce indices for the residential field on a national level. Finally, it could be interesting to test the local spatial effect with spatial models and to test the spatial correlation between the error terms.

APPENDIX

FIGURE 1

THE CITY OF TURIN: LOCATION CLASSIFICATION

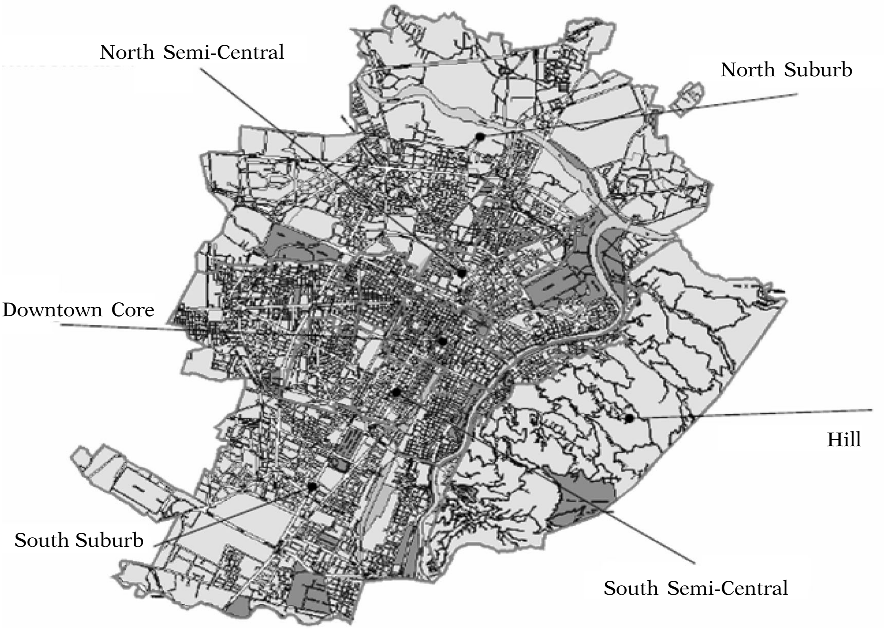


TABLE 2

SAMPLE INFORMATION I: NUMBER OF OBSERVATIONS

Total	2003:I	2003:II	2004:I	2004:II	2005:I	2005:II	2006:I	2006:II	2007:I
3,199	133	400	270	440	187	264	234	401	790

TABLE 3

SAMPLE INFORMATION II: CORRELATION MATRIX (OBS=3,199)

	green	service	park	sqrage	elevator	newhouse	ordhouse	flat	Suptot	valmq
Green	1.00									
Service	-.210	1.00								
Park	.463	-.196	1.00							
Sqrage	-.242	.216	-.155	1.00						
Elevator	.125	.008	.118	-.170	1.00					
newhouse	.013	-.019	.082	-.293	.073	1.00				
ordhouse	-.097	-.004	-.187	.208	-.070	-.868	1.00			
Flat	-.005	.123	.216	.029	.304	-.010	.003	1.00		
Sunto	.114	.100	.064	-.104	.071	.051	-.023	-.005	1.00	
Valmq	-.028	-.136	-.227	-.243	.125	.337	-.165	.007	.158	1.00

TABLE 4

SAMPLE INFORMATION III: VARIABLE SUMMARY

Variables	Summary	Value
Valmq	Media	1,875.08
	Std.dev	645.43
	Minimum	945.00
	Maximum	6,469.00
suptot	Media	103.85
	Std.dev	78.10
	Minimum	12.00
	Maximum	360.00
Flat	Media	0.14
	Std.dev	0.10
	Minimum	0.00
	Maximum	11.00
penthouse	Media	0.25
	Std.dev	0.15
	Minimum	0.00
	Maximum	1.00
elevator	Media	0.06
	Std.dev	0.04
	Minimum	0.00
	Maximum	8.00
age	Media	29.91
	Std.dev	0.89
	Minimum	1.00
	Maximum	112.00
green	Media	0.47
	Std.dev	0.49
	Minimum	0.00
	Maximum	1.00
Services	Media	0.37
	Std.dev	0.29
	Minimum	0.00
	Maximum	1.00

TABLE 5

REGRESSION RESULTS FROM SEMILOG MODEL

Robust standard errors,
Number of obs = 3,199
F (22, 1884)=12246
Prob > F = 0.00000
R-squared = 0.5887
Adj R-squared = 0.5885
Root MSE = .23261

lnp	Coef.	Robust. Std. Err.	*t*	*P*>|*t*|	(95% Conf.	Interval)
2003:I	-.0869587	.0419532	-2.07	0.038	-.1692383	-.0046791
2003:II	-.2110567	.0359539	-5.87	0.000	-.2815703	-.1405431
2004:I	-.2347592	.0362724	-6.47	0.000	-.3058975	-.1636208
2004:II	0.0498288	.0375026	2.33	0.016	-.0237222	.1233798
2005:I	0.28999	.004089	10.43	0.000	.36578	.381657
2005:II	.1295655	.0359353	5.16	0.000	.0590882	.2000427
2006:I	.1171842	.0372957	3.14	0.002	.044039	.1903293
2006:II	.1594054	.0333753	3.22	0.000	.093949	.2248618
2007:I	.2372293	.0332466	7.14	0.000	.1720253	.3024333
downtowncore	.5146694	.0186165	27.65	0.000	.4781583	.5511804
salvario	.0035176	.052569	0.07	4.57	-.099582	.1066171
semnord	.0295014	.0203731	2.45	0.000	-.0104548	.0694576
semsud	.3226514	.0169452	19.04	0.000	.2894181	.3558848
persud	.1291854	.0151755	8.51	0.000	.0994228	.158948
hill	.466898	.052706	4.55	0.000	.3635298	.5702662
green	-.0026776	.0127632	-4,67	0.000	-.0277092	.022354
services	.0641992	.0268181	-2.39	0.017	-.1167956	-.0116028
sqrage	.0191794	.0039893	-4.81	0.000	-.0270034	-.0113554
elevator	.0802965	.0093784	8.56	0.000	.0619034	.0986897
newhouse	.4002738	.0330003	12.13	0.000	.3355528	.4649948
ordhouse	.2053156	.0300877	3.06	0.000	.1463069	.2643243
nflat	.0133284	.0027578	4.83	0.000	.0079197	.018737
suptot	.000049	.0000591	3.4	0.000	-.0000669	.000165

TABLE 6

HOUSING PRICE INDEXES, (SEMILOG MODEL), 2003:I=100

Semester	Pooled	Laspeyres	Fisher	Average
2003:I	100	100	100	100
2003:II	101.05	101.56	101.45	107.7
	(0.000)	(0.001)	(0.000)	(0.000)
2004:I	99.69	99.45	98.99	107.00
	(0.000)	(0.000)	(0.000)	(0.000)
2004:II	117.88	118.02	117.34	108.70
	(0.015)	(0.016)	(0.005)	(0.000)
2005:I	124.41	125.01	124.45	113.60
	(0.000)	(0.000)	(0.000)	(0.000)
2005:II	119.66	118.89	118.23	115.60
	(0.000)	(0.000)	(0.000)	(0.000)
2006:I	129.54	129.89	129.23	118.60
	(0.000)	(0.000)	(0.000)	(0.000)
2006:II	129.95	128.56	130.11	118.60
	(0.000)	(0.000)	(0.000)	(0.000)
2007:I	140.10	140.23	140.99	123.20
	(0.000)	(0.015)	(0.000)	(0.000)

TABLE 7

REGRESSION RESULTS FROM THE ADJACENT SEMILOG MODEL, 2006:II-2007:I

Source	SS	df	MS				
					Number of obs		1,070
					F(16,1053)		= 47.49
Model	355.340.278	16	22.087.674		Prob > F		= 0.0000
Residual	492.412.281	1.053	.0467628		R-squared		= 0.4192
					Adj R-squared		= 0.4103
Total	847.752.559	1.069	.079303326		Root MSE		= .21625
lnp	Coef.		Std. Err. *t*	*t*	*P*>*t*	(95% Conf.	Interval)
2007:I	.0609323		.0183047	3.33	0.001	.0250145	.0968501
downtown core	.3488262		.0254604	13.70	0.000	.2988674	.398785
semnorth	-.0296465		.022776	-1.30	0.134	-.074337	.0150449
semsouth	.1881311		.0227844	8.26	0.000	.143423	.2328391
persouth	.1031405		.0178192	5.79	0.000	.0681753	.1381056
hill	.3090382		.0794665	3.89	0.000	.1531076	.4649689
green	.0342603		.0176815	1.94	0.053	-.000434	.0689552
services	.1351831		.0885559	1.53	0.08819	-.038583	.3089493
park	.0067596		.0266773	0.25	0.55555	-.045587	.0591064
age	-.002252		.0016179	-1.39	0.113	-.005426	.0009227
sqrage	.0181407		.0161916	1.12	0.182	-.0136308	.0499122
elevator	.1160204		.0129566	8.95	0.000	.0905968	.141444
newhouse	.6851298		.0905598	7.57	0.000	.5074317	.8628279
ordhouse	.5030128		.0889615	5.65	0.000	.3284509	.6775748
nflat	.0124516		.0033858	3.68	0.000	.0058078	.0190953
suptot	.0003837		.0001765	2.17	0.030	.0000374	.0007301
cons	6.521.559		.1332402	48.95	0.000	6.260.113	6.783.006

TABLE 8

CORRELATION MATRIX 2007:I

	green	services	park	sqrage	elevator	newhouse	ordhouse	nflat	suptot	valmq
green	1.000									
services	-.087	1.000								
park	0.230	-.121	1.000							
sqrage	-.1676	0.215	-.167	1.000						
elevator	0.732	0.264	.281	-0.213	1.000					
newhouse	0.005	-0.636	0.259	-0.248	.005	1.000				
ordhouse	-.002	0.427	-.033	0.169	0.004	-0.098	1.000			
nflat	0.001	0.496	-.006	-0.003	0.225	-0.042	0.310	1.000		
suptot	0.204	-.0981	.112	-0.211	0.205	-0.009	0.085	0.804	.000	
valmq	0.132	-0.010	0.147	-0.134	0.216	0.202	-0.2633	0.114	0.184	.000

TABLE 9

MODEL SELECTION STATISTICS

Period	Parameter	linear	semilog	Loglin
2003:I-2003:II	R-squared	0.6885	0.6817	0.682
	Adj R-squared	0.664	0.6566	0.6569
	Root MSE	360.36	0.2548	0.2547
	F	28.05	27.17	27.21
2003:I-2004:II	R-squared	0.8482	0.8653	0.8663
	Adj R-squared	0.8399	0.858	0.859
	Root MSE	269.57	0.1734	0.172
	F	102.79	118.21	119.18
2004:I-2004:II	R-squared	0.7214	0.7031	0.6982
	Adj R-squared	0.7037	0.6943	0.679
	Root MSE	434.74	0.2696	0.2718
	F	40.79	37.3	36.43
2004:II-2005:I	R-squared	0.6331	0.4916	0.4812
	Adj R-squared	0.6002	0.446	0.4346
	Root MSE	448.58	0.2673	0.2701
	F	19.21	10.77	10.33
2005:I-2005:II	R-squared	0.8429	0.8266	0.8471
	Adj R-squared	0.8311	0.8136	0.8356
	Root MSE	257.69	0.1337	0.1256
	F	71.55	63.57	73.87
2005:II-2006:I	R-squared	0.7554	0.7544	0.759
	Adj R-squared	0.7408	0.7398	0.7447
	Root MSE	312.954	0.1544	0.153
	F	51.87	51.61	52.91
2006:I-2006:II	R-squared	0.5941	0.6193	0.6124
	Adj R-squared	0.5768	0.6031	0.5958
	Root MSE	329.06	0.1586	0.1601
	F	34.3	38.13	37.03
2006:II-2007:I	R-squared	0.4015	0.4192	0.4174
	Adj R-squared	0.3924		0.4085
	Root MSE	452.24	0.2165	0.2165
	F	44.15	42.07	47.15

TABLE 10

REGRESSION RESULTS FOR STUCTURAL FORMS

	2003:II	2004:I	2004:II	2005:I	2005:II	2006:I	2006:II	2007:I
Semilog	0.110	-0.034	0.243	-0.097	0.204	0.028	0.014	0.061
	(0.000)	(0.010)	(0.000)	(0.009)	(0.010)	(0.015)	(0.000)	(0.000)
Lin	-140.23	-35.75	325.91	-284.62	-18.57	15.51	40.16	163.16
	(0.000)	(0.016)	(0.000)	(0.000)	(0.008)	(0.000)	(0.000)	(0.000)
Loglin	-0.097	-0.032	0.283	-0.103	-0.040	0.026	0.017	0.062
	(0.000)	(0.000)	(0.000)	(0.015)	(0.016)	(0.000)	(0.000)	(0.000)

TABLE 11

CHOW TEST FOR STRUCTURAL CHANGE

	2003:I-2003:II	2003:II-2004:I	2004:I-2004:II	2004:II-2005:I	2005:I-2005:II	2005:II-2006:I	2006:I-2006:II	2006:II-2007:I
Semilog	27.17	118.21	37.3	10.77	63.57	51.61	38.13	47.49
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

Table 12

HOUSING PRICE INDEXES (SEMILOG MODEL), 2003:I=100

	2003:I-2003:II	2003:II-2004:I	2004:I-2004:II	2004:II-2005:I	2005:I-2005:II	2005:II-2006:I	2006:I-2006:II	2006:II-2007:I
Semilog	19.24	8.51	31.49	19.51	0.14	0.81	9.95	13.43
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.016)	(0.015)	(0.000)
Linear	8.82	4.11	24.46	12.71	2.91	1.06	11.47	13.32
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Loglinear	16.89	10.39	35.89	21.72	0.15	0.73	10.28	14.00
	(0.011)	(0.010)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

GRAPH 2

HOUSING PRICE INDEXES (SEMILOG MODEL), 2003:I=100

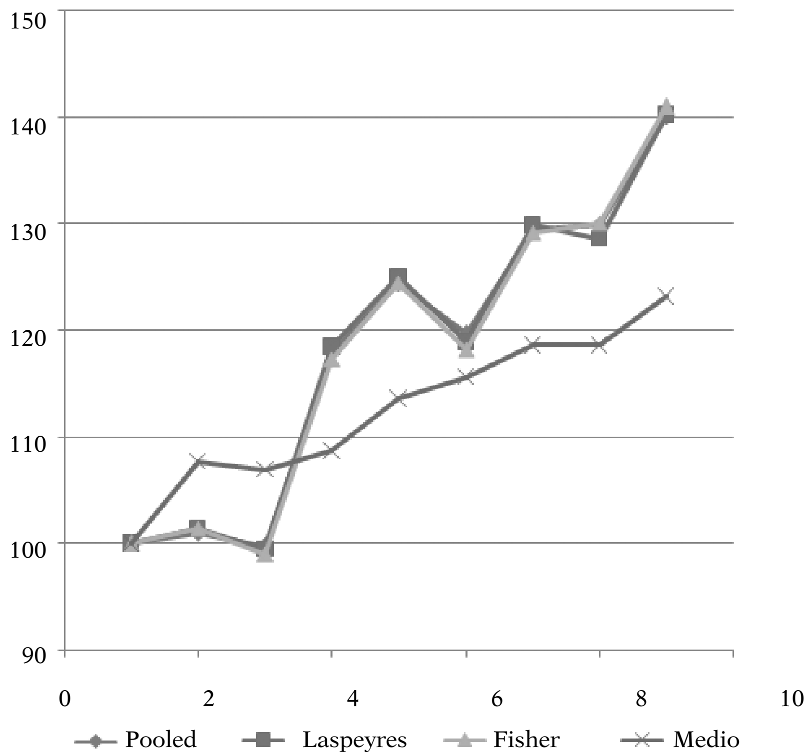


TABLE 13

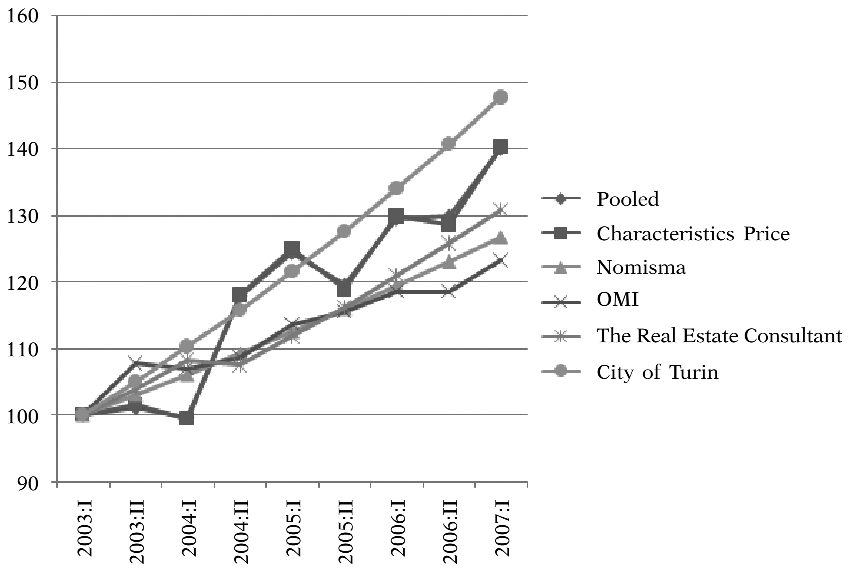
VARIABLE DESCRIPTION

Variable	Description
price	Sale price
valmq	Sale price for sqm (euro/sqm)
Tot surface	Total square footage in the unit (mq)
nflat	number of flat
penthouse	If flat is penthouse=1, otherwise=0
age	age of housing unit
sqrage	roor squared of housing unit
elevator	If the unit is in a property building with an elevator
newhouse*	If unit's age is zero=1, otherwise=0
ordhouse	If the conservation of unit is normal=1, otherwise=0
park	If number of garage is not zero=1, otherwise=0
green	If unit has an indoor or outdoor green (500m)=1, otherwise=0
services	If shopping center or kindergarten or school is nearby (500m) =1, otherwise=0
downtown core**	If unit is located at Downtown core=1, otherwise=0
salvario	If unit is located at San Salvario=1, otherwise=0
North Semi-Central	If unit is located at North Semi-Central=1, otherwise=0
South Semi-Central	If unit is located at South Semi-Central=1, otherwise=0
South Suburb	If unit is located at South Suburb=1, otherwise=0
hill	If unit is located at Hill suburb=1, otherwise=0
2003:I	If unit is sold in the first semester 2003=1, otherwise=0
2003:II	If unit is sold in the second semester 2003=1, otherwise=0
2004:I	If unit is sold in the first semester 2004=1, otherwise=0
2004:II	If unit is sold in the second semester 2004=1, otherwise=0
2005:I	If unit is sold in the first semester 2005=1, otherwise=0
2005:II	If unit is sold in the second semester 2005=1, otherwise=0
2006:I	If unit is sold in the first semester 2006=1, otherwise=0
2006:II	If unit is sold in the second semester 2006=1, otherwise=0
2007:I	If unit is sold in the first semester 2007=1, otherwise=0

**Note*: The variable oldhouse is omitted since it is used as a base category.
***Note*: The variable North Suburb is omitted since it is used as a base category.

GRAPH 3

COMPARISION OF HOUSING PRICE INDEXES FOR TURIN CITY



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