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Physical Real Estate : A Paris Repeat Sales Residential Index

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Physical Real Estate:
A Paris Repeat Sales Residential Index

Abstract

In this paper we present the repeat sales index methodology developed by Case and Shiller (1987) and its estimation problem. We particularly describe the problem arising from the time intervals construction for the estimation.

We then apply this methodology to the Paris residential market. We use the CD-BIEN database that contains more than 220 000 repeat sales transactions for residential properties in the Paris area covering the period 1973-2001 period. This index based on returns is compared to the official one used in France for Paris based on single prices, the Notaires/INSEE index.

We then underline the robustness of in the index estimation according to its periodicity by the way of the return and volatility estimation. The index sensibility to the time period is studied in the last part. We conclude that i) the estimation is quite robust whatever the estimation period is, and ii) this index is significantly different from the official residential index for Paris.

Key words: Real estate indexes, repeat sales indexes

Résumé

Nous présentons dans ce document de travail la méthodologie de construction d'indice immobilier par les ventes répétées, élaborée par Case et Shiller (1987), ainsi que les problèmes d'estimation qu'elle soulève. Nous nous interrogeons notamment sur l'influence de la période choisie dans l'estimation de l'indice.

Nous appliquons ensuite cette méthodologie pour créer un indice pour l'immobilier d'habitation à Paris. Nous utilisons pour ce faire, une base de données qui contient plus de 220 000 observations de ventes de biens immobiliers en région parisienne sur la période 19873-2001. Cet indice fondé sur des taux de rendement est comparé à l'indice de prix officiel utilisé en France pour Paris, l'indice Notaires/INSEE.

Nous mettons en lumière la robustesse de l'estimation de l'indice quant à la périodicité choisie à partir de l'estimation du rendement et de la volatilité. La sensibilité de l'indice au choix de la période sur laquelle il est estimé est également étudié dans la dernière partie. Nous en concluons que d'une part l'estimation est robuste quelle que soit la période choisie pour la réaliser et que d'autre part, l'indice calculé par la méthode des ventes répétées est significativement différent de l'indice officiel de l'immobilier d'habitation à Paris.

Mots-clés : indices immobiliers, indices de ventes répétées.

JEL Classification Code: C20, G00

Introduction

Every real estate investor faces an objective difficulty concerning the measurement of real estate investment performance and risk. The reasons explaining this difficulty are numerous: an absence of centralised trading, or even price lists, a low degree of buildings or apartments turnover in investor portfolios, a lack of transparency in transactions, the heterogeneity and indivisibility of real estate properties, and a tradition of confidentiality in the industry.

The official index for Paris is a hedonic one based on transaction prices. We can use this index to have an estimation of the price return by comparing the index value at two different dates. For instance, the price return in capital between December 1985 and December 1991 are the following: Notaires/INSEE 249%.

But, to be able to study price return in capital directly we will use repeated sales. Case and Shiller (1987) generalize the work of Bailey, Muth and Nourse (1963) and thus provide the first approach of repeat measures methods for construction of real estate indices. The approach first begins by stating that the price of say good *i* at date *t* is a function of four terms: the good's quality at date *t*, the value of the underlying global real estate index at date *t*, a random walk variable linked to good *i* at date *t* and an error term, here again linked to good *i* at date *t* (modelled as a white noise; idiosyncratic risk).

The main merit of this model based on repeat sales, is that is does not presuppose any mechanical form for the behaviour of the underlying real estate index. Since 1987, the model has attracted a lot of attention and has given rise to a number of improvements or critics (see for instance Gatzlaff and Haurin 1997 about the bias in the selection of repeat sales). One of the improvements was to use simultaneously the information on the single sales and on the repeated sales and this is the way of the hybrid models (Englund, Quigley & Redfearn, 1998; Meese & Wallace, 1997).

According to the purpose of the present paper, we will simply refer to the general methodology and apply the model to data for Paris and its surrounding area.

The repeat sales approach, developed by Case and Shiller (1987) is based on the assumption that building quality stays unchanged between two sales; this can be accepted if we consider that the building quality in mean has not significantly changed as suggested by Thion, Faverger and Hoesli (2001) in a previous work on a French dataset.

We will develop the Case and Shiller repeat sales approach in the section 1. The data available to estimate the Paris WRS sales index will be presented in section 2. The estimation results and robustness analysis will be the subject of the section 3. In section 4 we will compare this index to the French one in an index perspective and in section 5 the comparison will be made on a return and volatility point of view. The last section gathers our concluding remarks.

1. Repeat sales Methodology

1.1 Model Description

The Weighted Repeat Sales (WRS)[1] of Case and Shiller (1987) starts by introducing the «intrinsic » price of good *i* ($i = 1,\ldots, n$), p_{it} at date *t*. By defining $P_{it} = \ln\left(p_{it}\right)$ as the natural logarithm of the good's price, at *t*, and $I_t = \ln(i_t)$ as the property index at *t*, the model states the following:

$$P_{it} = I_t + H_{it} + N_{it} \qquad (1)$$

where

[1] The principles of this method date back to Bailey, Muth and Nourse (1963).

- H_{it} is a Gaussian random walk that represents asset i's own trend. By construction, $E\left[H_{it} - H_{it}\right] = 0$ and $E\left[H_{it} - H_{it}\right]^2 = (t - t)\, s_H^2$. What's more, H_{it} is non correlated with I_t, for all i and t.
- N_{it} is a white noise, and models the property market's imperfections. By assumption $E\left[N_{it}\right] = 0$ and $E\left[N_{it}\right]^2 = s_N^2$. What's more, N_{it} is uncorrelated with either I_t, or $H_{jt'}$ for all j and all t, except when $i = j$ et $t = t'$.

The sale price of asset i V_{it} is defined as the sum of the asset plus it quality. By denoting Q_{it} the quality of asset i at date t, we have:

$$V_{it} = P_{it} + Q_{it}$$

The difference in value for asset i between date t and t can we written as:

$$V_{it} - V_{it} = I_{it} - I_{it} + Q_{it} - Q_{it} + H_{it} - H_{it} + N_{it} - N_{it}$$

which becomes, when one assumes that the asset's quality is unchanged[2]:

$$V_{it} - V_{it} = P_{it} - P_{it} = I_{it} - I_{it} + H_{it} - H_{it} + N_{it} - N_{it}$$

so, the difference in value for asset i between date t and t is the difference of the log of index plus $H_{it} - H_{it} + N_{it} - N_{it}$ which represents the idiosyncratic terms.

How can we then estimate the real estate using a repeat sales dataset?

1.2 Econometric Modelling

Let us start by restating the asset's change in value:

$$V_{it} - V_{it} = \left[(1 \times I_t) + (-1 \times I_t)\right] + H_{it} - H_{it} + N_{it} - N_{it} \qquad (2)$$

We should then notice that the dates t and t are dependent on the observation time period in the dataset (daily, monthly, annually, …). How can we take account of the time?

1.2.1 Time Intervals

The overall period of analysis may be sliced into S subperiods. We then observe the two dates t and t in one of those subperiods:

Periods	1	2	3	4	5	…	s	s+1	…	S-1	S
Time	1		t				t				T

---

[2] See Case and Shiller (1987).

By aggregating the observations (a buy or sell transaction) by subperiod, one may construct a discontinuous series. The discontinuity depends on the time length $\overline{t}_s - \underline{t}_s$ (what's more the quality of the resulting index will in fact depend on the number of observations n_s for each sub period s). Hence, for every transaction i, the relationship given in (2) may be approximated by[3] when using S sub periods:

$$V_{it} - V_{it} = \sum_{s=1}^{S} \Phi_s D_{is} + H_{it} - H_{it} + N_{it} - N_{it}$$

where $D_{is} = \begin{cases} 1 & \text{if } t(i) \in \left[\underline{t}_s, \overline{t}_s\right[\\ -1 & \text{if } t(i) \in \left[\underline{t}_s, \overline{t}_s\right[, \\ 0 & \text{Else} \end{cases}$

with $t(i)$ and $t(i)$ the acquisition and resell dates of asset i. Φ_s is the parameter to be estimated.

Note that if two distinct transactions i' and i are such that $t \in \left[\underline{t}_s, \overline{t}_s\right[$ and $t \in \left[\underline{t}_s, \overline{t}_s\right[$, the value for $D_{i'}$ will be identical to D_i.

1.2.2 Model Details

Denote by e_i the error term associated to asset i. One refers to date (t) for the acquisition date and to (t) as the resell date (recall that $H_{it} - H_{it} + N_{it} - N_{it}$). To estimate the price index, we will use the following equation[4] :

$$i \in \{1,..,n\},\ V_{it} - V_{it} = \sum_{s=2}^{S} \Phi_s D_{is} + e_i$$

hence, for all s = 2, ..., S, the value $\hat{\Phi}_s$ will be an estimator for I_s, i.e. an estimator of the logarithm of the period s price index. One may therefore construct the time matrix in the following way:

$$\begin{array}{c} \textit{Subperiod} \quad 1 \quad 2 \qquad s \qquad S \\ \begin{bmatrix} 0 & -1 & \cdots & 1 & \cdots & 0 \\ & & \cdots & & \cdots & \\ \vdots & \vdots & & \vdots & & \\ 0 & 0 & \cdots & -1 & \cdots & 1 \\ \vdots & & & \vdots & & \vdots \\ -1 & 0 & \cdots & 1 & \cdots & 0 \end{bmatrix} \begin{array}{l} t \in \left[\underline{t}_2, \overline{t}_2\right[, t \in \left[\underline{t}_s, \overline{t}_s\right[\quad \textit{for observation } 1 \\ \\ \\ t \in \left[\underline{t}_s, \overline{t}_s\right[, t \in \left[\underline{t}_s, \overline{t}_s\right[\quad \textit{for observation } i \\ \\ t \in \left[\underline{t}_1, \overline{t}_1\right[, t \in \left[\underline{t}_s, \overline{t}_s\right[\quad \textit{for observation } n \end{array} \end{array}$$

Denote by

- D the matrix containing the last S-1 columns (sub periods) of the above matrix,

[3] Note that by construction we will include transaction i in our analysis only if $t(i)$ and $t(i) \notin \left[\underline{t}_s, \overline{t}_s\right[$.

[4] The dependent variables of D_{is} are perfectly collinear (they sum up to 0). What's more the model is without a constant.

- Φ is the vector, of dimension *S*-1, of parameters to be estimated (for our index),
- *R* the vector or log returns.

The model is thus simply:

$$R = D\Phi + \mathbf{e}, \text{ where } \mathbf{e} \sim N(\mathbf{0}, \Sigma) \qquad (3)$$

The form of the variance-covariance matrix being quite particular, only the diagonal is non null (refer to the assumptions temporal and cross section correlation).

1.2.3 Estimation steps

The estimation of the heteroscedastic regression model (3) is based on three ordinary least squares regressions. After running on OLS regression to get a consistent estimator vector (see step 1), we can estimate the parameters defining the heteroscedastic function (developed in step 2) and then we get a feasible weighted least squares (FWLS) of the parameters (in step 3).

Step 1

The variance-covariance matrix Σ being unknown, the first step is to obtain a consistent estimator of the error terms e_i by running the following regression:

$$R = D\Phi + \mathbf{e}, \text{ where } \mathbf{e} \sim N(\mathbf{0}, s^{2}\mathrm{I}) \qquad (4)$$

Step 2

The second step consists in regressing the residuals' squared values $(\hat{e}_i)^2$ on a constant and on variable[5] $[t - t]$, in order to obtain estimated values of s_N^2 and s_H^2:

$$(\hat{e}_i)^2 = a + b\left[t(i) - t(i)\right] + res, \quad i \in \{1,..,n\}$$

This regression enables us to identify the variances of our two random variables, since:

$$(\hat{e}_i)^2 = \left[(V_{it} - V_{it}) - (I_t - I_t)\right]^2$$

Given the original specification, we may also write:

$$\left[(P_{it} - P_{it}) - (I_t - I_t)\right]^2 = (H_{it} - H_{it})^2 + (N_{it} - N_{it})^2 + 2 \times (H_{it} - H_{it})(N_{it} - N_{it})$$

thus

$$E\left[(P_{it} - P_{it}) - (I_t - I_t)\right]^2 = E\left[(H_{it} - H_{it})^2\right] + E\left[(N_{it} - N_{it})^2\right] + E\left(\left[(H_{it} - H_{it})(N_{it} - N_{it})\right]\right)$$

since the last term is zero given the assumption for model (4), we have:

$$\begin{aligned} e_i^2 &= E\left[(H_{it} - H_{it})^2\right] + E\left[(N_{it} - N_{it})^2\right] \\ &= E\left[(H_{it} - H_{it})^2\right] + E\left[(N_{it})^2 + (N_{it})^2 - 2N_{it}N_{it}\right] \\ &= s_N^2(t - t) + 2s_H^2 - 2E(N_{it}N_{it}) \\ &= 2s_N^2 + s_H^2\left[t(i) - t(i)\right] \end{aligned}$$

[5] This variable represents the holding period duration and it is expressed in the same unit as the original time unit of the data.

This shows how the regression of the squared residuals on a constant term and on a time variable $\left[t - t\right]$ enables us to estimate values for s_N^2 and s_H^2 given by $\hat{s}_N^2$ and $\hat{s}_H^2$ obtained by the following equation

$$\left(\hat{e}_i\right)^2 = 2\hat{a} + \hat{b}\left[t(i) - t(i)\right] = 2\hat{s}_N^2 + \hat{s}_H^2\left[t(i) - t(i)\right]$$

Using these values, we may then estimate matrix Σ of model (3). Indeed, given the fact that only the diagonal terms are non zero, one has[6]

$$\hat{\Sigma}_{ii} = 2\hat{s}_N^2 + \hat{s}_H^2\left[t(i) - t(i)\right],\ i \in \{1,..,n\} \qquad (5)$$

estimation of

$$\begin{cases} \Sigma_{ii} = & 2s_N^2 + s_H^2\left[t(i) - t(i)\right] & \forall i = 1,\ldots,n \\ \Sigma_{ij} = & 0 & \text{si } i \neq j \end{cases} \qquad (6)$$

Step 3

The third step consists on estimating the model (3), by using a special form of the variance-covariance matrix Σ as defined in (6). The procedure consists of using weighted least squares in which the diagonal terms of the variance-covariance matrix of the errors terms vector $\mathbf{e}$ are the values given in (5).

1.2.4 Index Construction

The estimate of the index will depend on the way the time period is subdivided in sub periods[7]. We typically obtain period values for the WRS index (month, semester…) depending on the value chosen for S[8]. Whatever $s = 1,\ldots,S$, $\hat{\Phi}_s$ will be the estimator for the log of the index I_s. We have then

$$\ln\left(p_{it} / p_{it}\right) = \hat{\Phi}_s, \text{ if } t(i) \in \left[\underline{t}_s, \overline{t}_s\right[,\ t(i) \in \left[\underline{t}_1, \overline{t}_1\right[$$

By construction for two transactions i and i' where $t \in \left[\underline{t}_1, \overline{t}_1\right[$ and $t \in \left[\underline{t}_s, \overline{t}_s\right[$, the estimate of the log-return is similar, $\ln\left(p_{it} / p_{it}\right) = \ln\left(p_{i't'} / p_{i't'}\right)$. The log-return of the index over the same period of is similar.

This in turn gives the result for the index:

$$\begin{cases} \hat{i}_s = 100\, e^{\hat{\Phi}_s},\ \forall s = 2,\ldots,S \\ \text{with the initial reference being } i_1 = 100 \end{cases}$$

2 The database

2.1 The CD-BIEN database

The CD-BIEN database contains nearly all property transactions signed in front of a notary since 1990 for Paris and its surrounding area (which includes the Hauts-de-Seine, Seine Saint-Denis and Val de

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[6] Recall that this estimation is different for each transaction i whenever the transactions dates $t(i)$ and $t(i)$ differ.

[7] Transactions i take place over T units of time (weeks, months, quarters…). It is therefore equivalent to either specify the number of periods S or the time length of the period in units (the smallest period being the one contained in the original transactions data).

[8] To the comments made in *Footnote 7*, one may add that the index also depends on the nature of the returns initially observed or used in the estimate. This has to do with the way one constructs vector R in model (4). Based on monthly transactions, one may construct returns for higher periods of time.

Marne). This market is the most active in France and represents more than a quarter of the country's residential property market.

Such a database is unique in Europe. At the end of 2001, it contained more than 890 000 transactions since 1990 and 760 000 for housing sector. It is now updated every quarter. One very important aspect of this database is that around a quarter are repeat sales transactions, i.e. for a given recorded transaction, the notary also recorded the price and the date at which the apartment was previously purchased.

For each transaction in the database, a number of characteristics are given: the location, the type of property sold (housing, offices, retail…), the type of seller, acquirer, eventually but unfortunately not always the surface, the floor, …

One may also note that the data provided in the database is not exhaustive, since the average ratio of the number of recorded transactions and the total number of actual transactions is 70%. The main reason for this is that not all transactions in this area are recorded in from of a notary located in the given area. Indeed buyer and seller may agree to record the transaction in another region.

For a number of transactions, the previous transaction date as well as price is also provided. All these elements are sourced back to the notaries themselves and can therefore be considered reliable, except where inevitable keying mistakes do indeed occur. Concerning the prices provided, they relate to the price on the acquisition act, excluding stamp duty.

2.2 Repeat Measures Transactions

From the CD-BIEN database, we extracted 229 450 transactions for which we had the information on both the initial price and date (post 1st of January 1973) at which the properties had been bought as well as the price and date for the following resale[9]. These "complete" transactions represent around 25% of the total number of transactions.

Having at our disposal both the initial price of the property $P(T_1)$ as well as its resale price $P(T_2)$, we may calculate 229 450 price returns in capital $R = P(T_2)/P(T_1)$.

In order to compute the return linked to a repeat sale, one needs the previous transaction date and price, as well as the corresponding information for the subsequent transaction. We therefore extracted all transactions whose resell date was between the 01/01/1990 and 31/12/2001 and whose previous acquisition (date and price) was also included in the database. The transactions were either residential, office, retail or mixed used (residential & professional). We have for the residential sector 220 680 repeated sales (with the first transaction dated back to as early as 01/01/1973). Each transaction will thus have the following characteristics recorded:

- General location (French « Département »),
- Registration number,
- Date of 1st transaction, T_1
- Price of 1st transaction, $P(T_1)$
- Resell date, T_2
- Resell price, $P(T_2)$

We have transactions not only for Paris ("department" 75) but for three other neighboured "departments" (92, 93 and 94). They correspond to a geographically area called the "Petite Couronne" (PC).

Figure 1 represents the distribution of transaction dates for repeat sales in the CD-Bien database (*date1*, *date2*, and the total number of transactions). As can be seen, starting in January 1973, the database does

[9] We have to note an important feature concerning the database's structure: we only observe those transactions whose second transaction has taken place after 1990. We will come back to this point and point out where it may be cause of concern in the course of the analysis presented below.

contain an increasing number of acquisitions for which we do have a resell price and date. However, it does not contain any resell date prior to June 1994.

This particular feature of the CD-bien database may potentially induce a form of bias in the sense that the proportion of long holding period transactions is over-represented in the data. Variable *date1's* distribution illustrates, to a certain extent, the real estate market's activity. The graph's observation leads us to a time partition into three broad phases: a relatively low but increasing volume of apartment acquisitions from 1973 to the mid-1980s, a moderate increase in market activity (acquisitions) from 1985 to 1990, followed by a brutal decline in acquisitions coinciding with the real estate bust of 1991, with the mention that the slow acquisitions activity has lasted till the end of 1998.

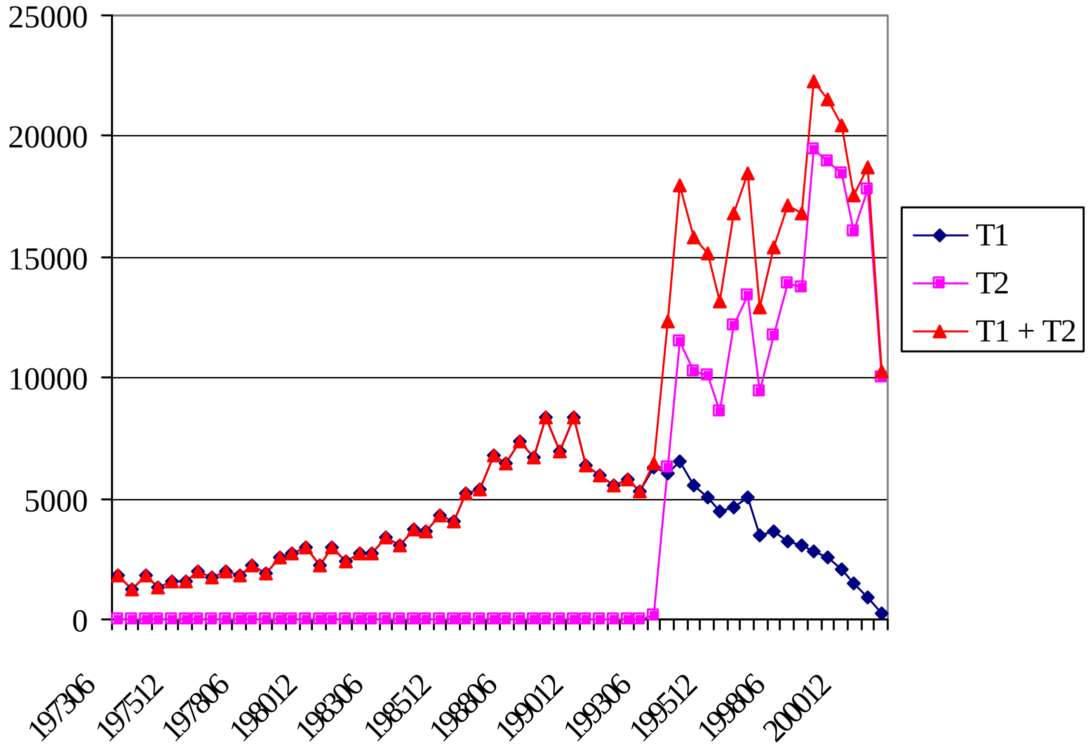

Figure 1: Temporal structure of the database

3 Residential WRS index for Paris and the "Petite Couronne"

3.1 WRS index for the period 1973-2001

As mentioned in 2.2, we can estimate the residential index for: Paris, PC and Paris & PC. Those three estimations results are presented in details in *Appendix A*. For each, we have the three steps (see section 1.2.3), where the first corresponds to the OLS estimation, the second one to the variance estimation, and the last one to the FWLS estimation.

For instance, for the Paris & PC residential index, we can estimate the index for the whole period 1973-2001. We have on the first step of the estimation procedure an R^2 of 53.8%. The second step enables us to estimate the variance of the error term[10]. At the end, the third step is just a FWLS according to the heteroscedasticity estimated at the previous step. As there is no constant term in this regression model (the constant is transformed) we will not interpret the R^2. The estimated index is shown in *Figure 2*. The

[10] $\hat{\Sigma}_{ii} = 0.097142 + 0.004591 \times [t(i) - t(i)]$

decrease in 1990 after the bubble is more pronounced for the Paris index then for the Paris & PC index (see *Figure 3*).

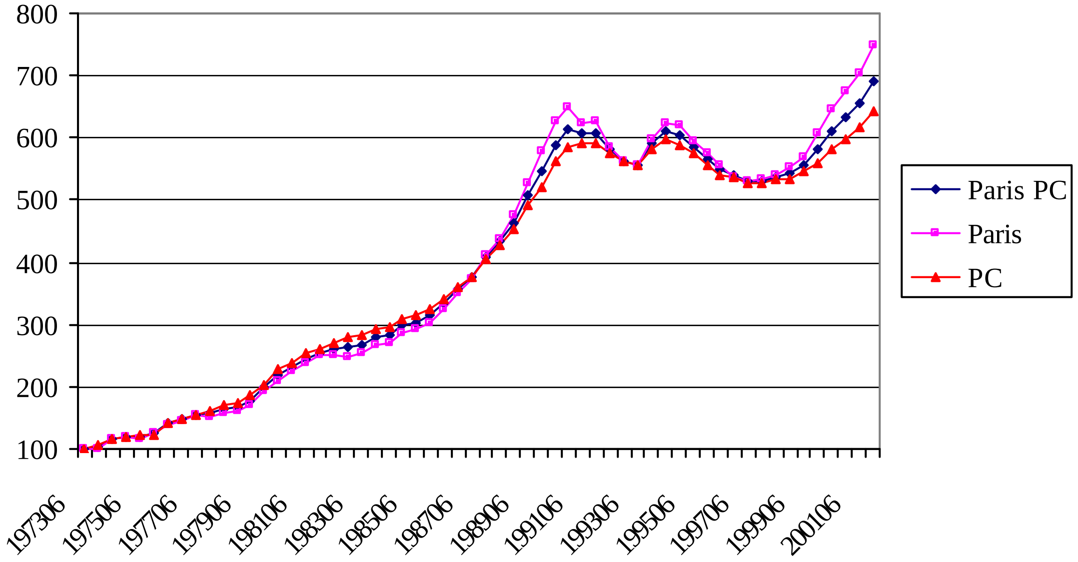

Figure 2: Paris & PC residential WRS index for 1973 to 2001

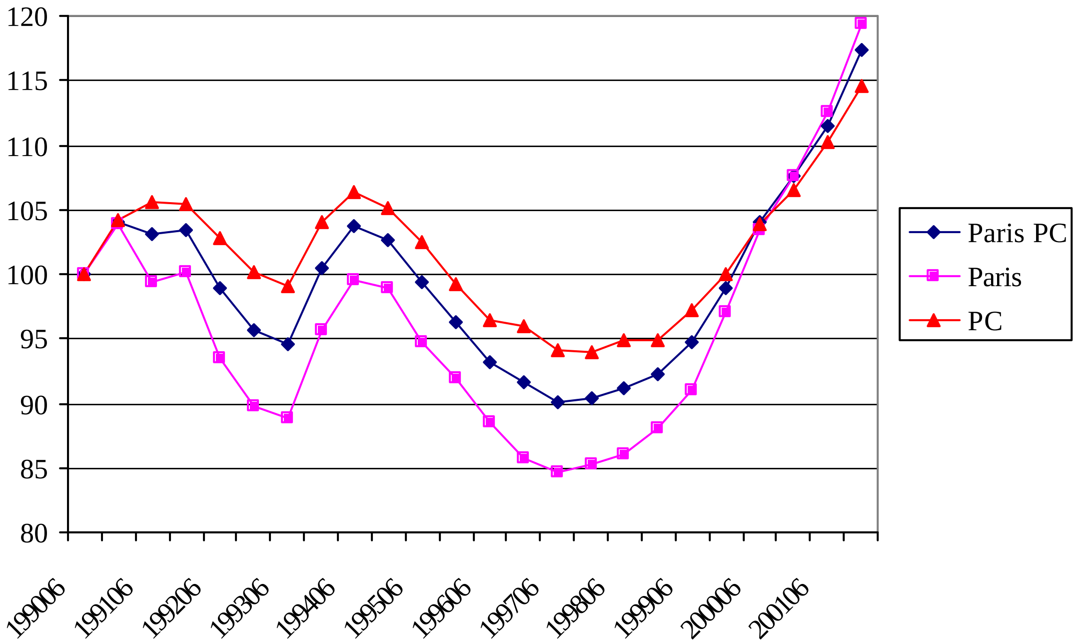

Figure 3: Paris & PC residential WRS index for 1973 to 2001 – base 100 in 1990

3.2 Robustness

We have seen that the temporal structure of the database is quite particular. Does the index change according to the beginning date? We consider three potential dates 1973, 1982 and 1990 for the beginning of the index. We take 1982 because this is date where the Notaires/INSEE index begins and 1990 because to diminish the bias of our repeated sales dataset.

We define "WRS 73-YY" the residential Paris & PC index estimated with data covering the period (19)73 to YY (00 for 2000 and 01 for 2001). The *Figure 4* shows the three indices according to the evolution of WRS 73, that is to say a value of 100 in 1973:06. There is no significant modification except a less increase in the period 1993612 to 1994:06 for the WRS 73-90 index (see *Figure 5*). This is due to the fact that we have not for this index transactions with first sale date before 1990, and there were at this date sells of such goods. As the price returns were in mean better than those observed for the other goods, we observe this feature.

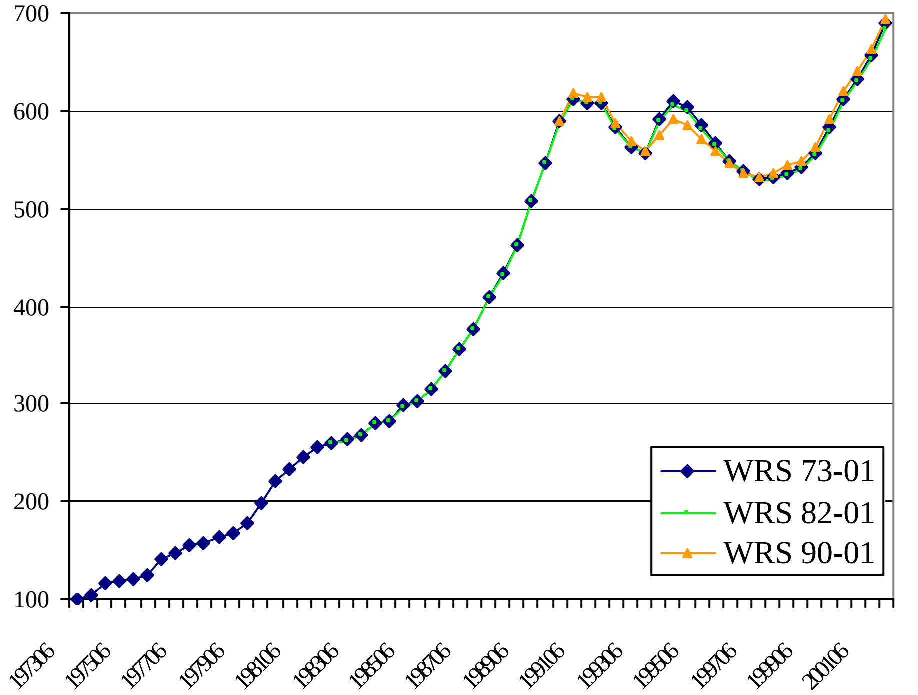

Figure 4: WRS Paris & PC as a function of the beginning period – base 100 in 1973

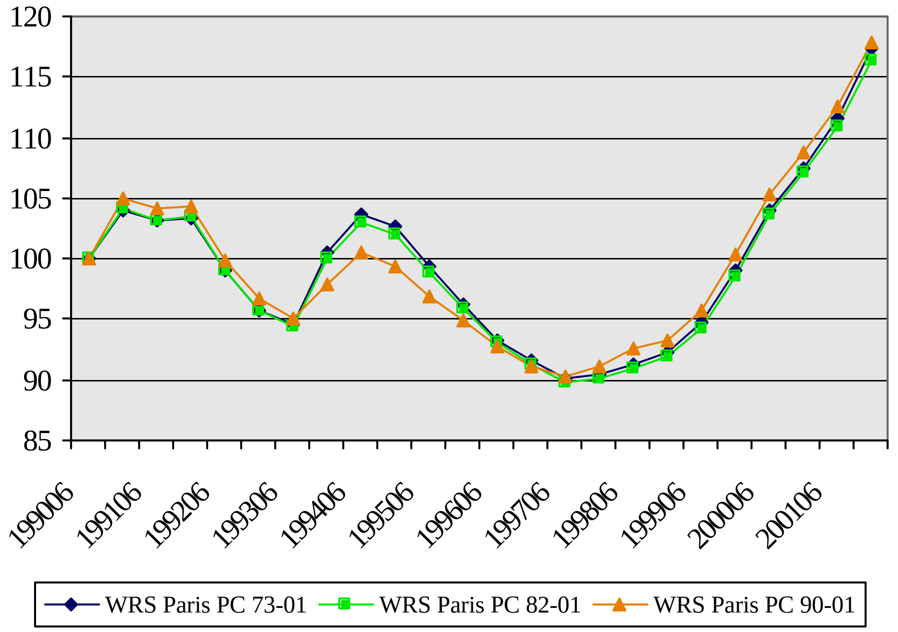

Figure 5: WRS index as a function of the beginning period –base 100 in 1990:06

3.3 Reversibility

As it is underlined in the literature (see for instance Shiller 1998), this kind of index is not stable in the sense that information today changes the past values of the index, in other words, the whole index[11]. We then compare for different ending periods the estimate index. In *Figure 6* we can see the transactions with a resale date lying between 1996 to 2001 modify the index. If this modification seems not to be significant before 1989, it appears more influential after this date. These modifications are detailed in *Figure 7* where we study for the period 1990-2001 the modification of the index year by year. The three indexes 73-01, 73-00 and 73-99 are the same from 1995. Before this date, the estimation differs from one to another. More generally, new observations lead to a bigger bubble in 1990 (a higher value of the index), a less fall in 1994 (a higher value of the index), and a less increase in 1995 (a smaller value of the index).

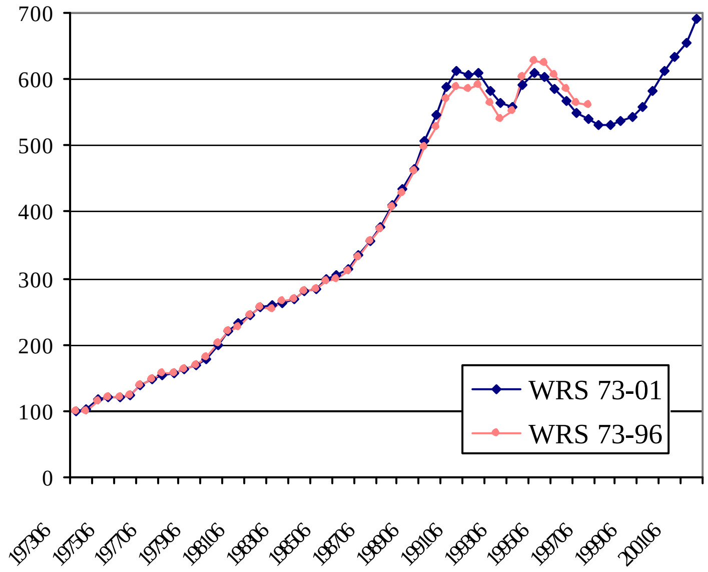

Figure 6: Reversibility in the WRS Paris & PC index

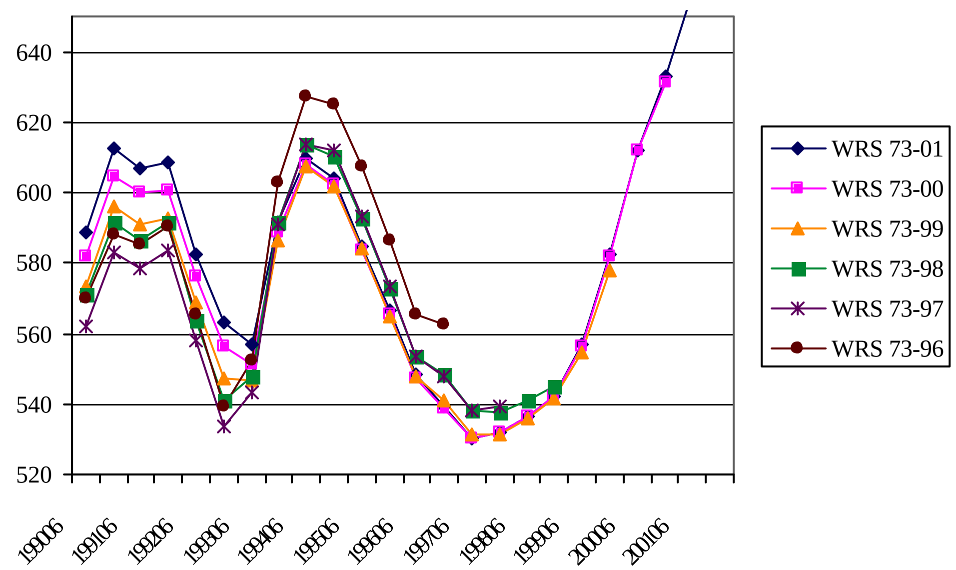

Figure 7: Reversibility in the Paris & PC WRS index – the after bubble period

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[11] This can be analysed in a estimation point of view. As we use all the observations to estimate the coefficients $\hat{\Phi}_s$ on each subperiods (by the way of the inverse of the matrix $X'X$), we modify the estimation with new information.

3.4 Sample

We can see in *Figure 8* that the WRS is quite robust to the number of observations. This is due to the fact that even in the 25% sample, there is still enough observations in each period. However if the number of observations becomes two small, the periodicity should be changed[12].

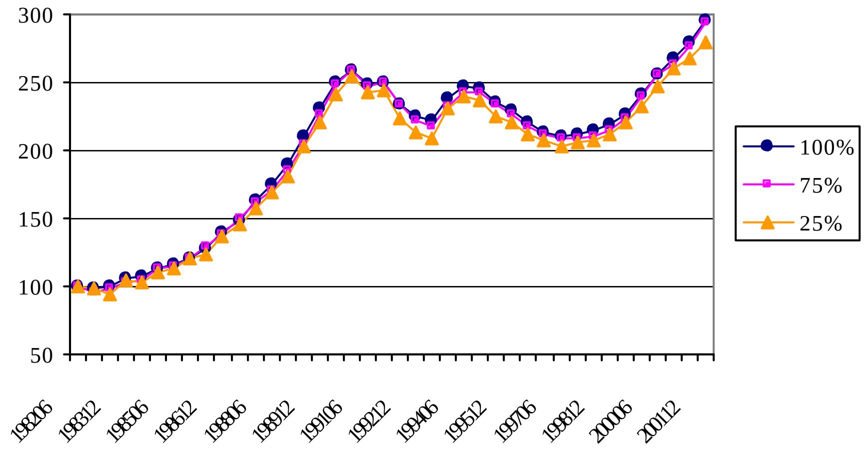

Figure 8 : WRS robustness according to the sample size

3.5 Periodicity

If we shorten the period, we have naturally less observations in each period which implies a higher variance of the estimate. In fact there is a trade-off between the periodicity and the precision of the estimate. The smaller the periodicity is, the smaller the precision (the volatility is over-estimated). In the following figure we reduce the sample size to simulate the period reduction[13].

For the WRS estimation, we construct a semi-annual index which corresponds to the Notaires/INSEE periodicity.

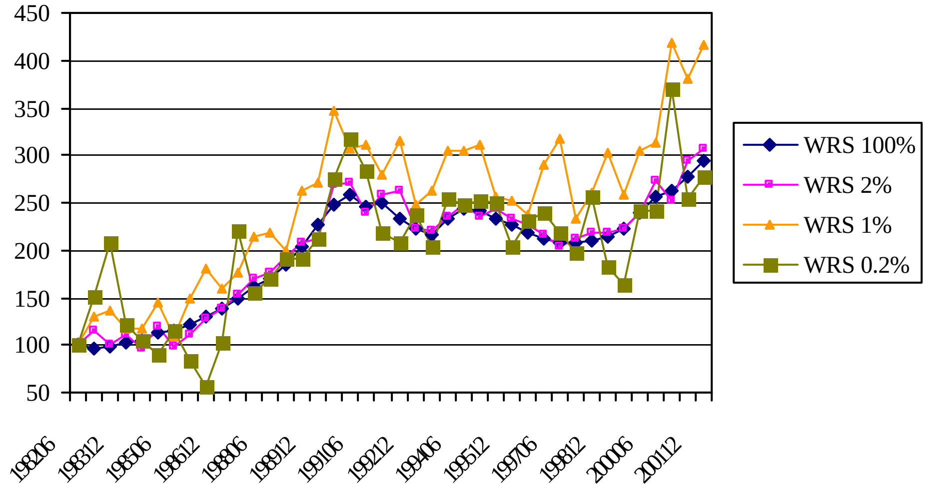

Figure 9 : WRS robustness according to the sample size simulated by the sample size

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[12] As seen in section 5 the volatility becomes higher with smaller sample (for 100% s = 0.0641, for 50% s = 0.0669, and for 25% s = 0.0719).

[13] If we reduce the period to one month, it is not possible to construct the Paris WRS index because for some periods there are no observations in our database.

4 Comparison of Paris residential index

We should notice that the Notaires/INSEE index is computed for goods which are more than 5 years old, unoccupied, so we should use the same structure for the WRS index: we do not have the building age and the occupation status of the building at the purchase date (David et al., 2002). Hence, the WRS index will be computed on all the repeat sales transactions available. Moreover, the Notaires/INSEE index begins in 1982. We will then use WRS 82 (which is not very different from WRS 73 as seen in 3.2). Since the WRS index can be computed to date back to early 1982, it seems interesting to analyse the way it behaved relatively to the Notaires/INSEE (*Figure 10*). The French property market experienced a severe downturn in the early 1990s, preceded by a very steep price rise. This phenomenon appears quite clearly in the Notaires/INSEE index, whereas the WRS index exhibits a much lower slope (even if it indeed plots a handsome rise during the late 1980s). Note that the Notaires/INSEE index depicted in a rather exaggerated manner this fast growth.

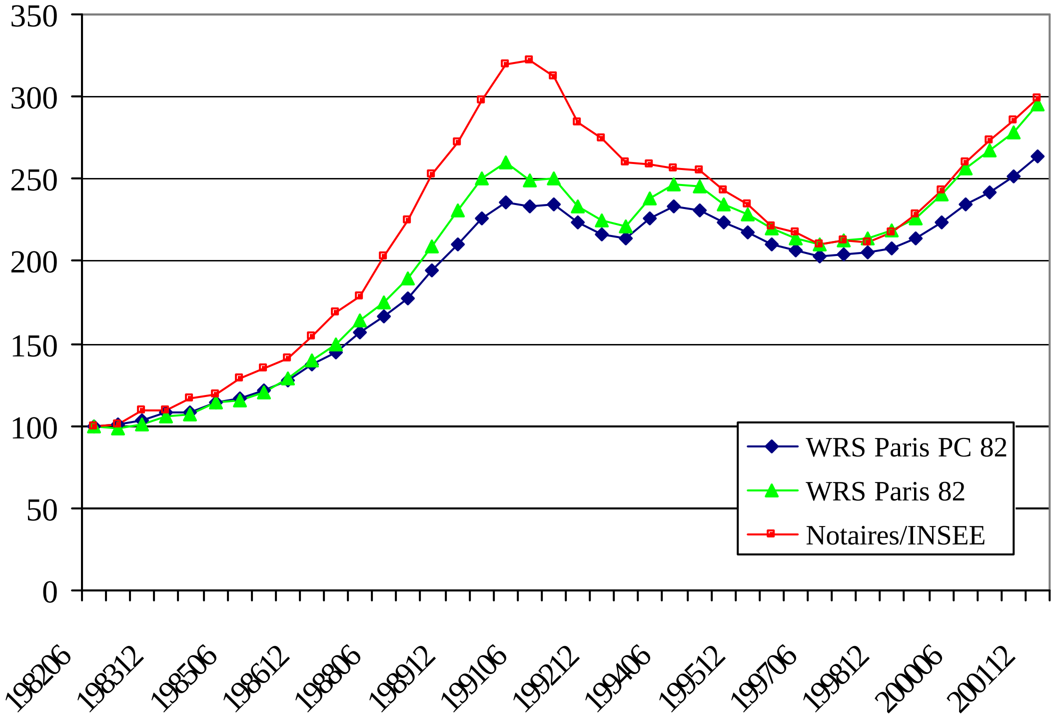

Figure 10: Comparison of Paris residential indices from 1982-2001

An explanation of this feature may be that the Notaires/INSEE index is based on prices. The WRS index is closer to the data and is based on price returns. From the return we deduce the price evolution which gives us the index. Note finally that the Notaires/INSEE index moves away from the WRS index only during the 1987-1994 period which is precisely the time when the so called "real estate bubble" formed and deflated. This can simply be explained by the fact that during this period even if the prices were higher the returns behaved differently. This is described in Baroni, Barthélémy and Mokrane (2001). The Notaires/INSEE index for direct residential property investment in Paris clearly seems to be more volatile than the WRS index which is based on repeat measures transactions. Over the whole period 1982-2001, the Notaires/INSEE volatility is also higher than the WRS one (see section 5). If we look at the WRS Index only for Paris, it is closer to the Notaires/INSEE index and its volatility is higher than the Paris & PC index. This result was expected because it is well known that the Paris "intra muros" market is more volatile than the Paris region one.

During the period July 1991 to July 1995, which professional investors term the "market crisis", the WRS index captures the severity of the downturn. One notable feature which is present in the WRS index and absent in the Notaires/INSEE index is the reaction that appears during the year 1993.

The fact that this rebound period is absent from the Notaires/INSEE index points out that it is no-repeat transactions that have aggravated the downturn and made the crisis last longer. In other terms, it looks as if long-term investors (holding periods longer than 20 years) accepted selling properties at rather low prices.

The WRS model is by construction sensitive to the number of transactions in any given time period. The WRS index seems to be particularly moving during the period 1990 to 1994, a period for which the Notaires/INSEE index does not seem to experience similar moves. From July 1993 to July 1994, these two indices show an opposite movement which can only be interpreted by a small number of repeat transactions during this period (*Figure 1*). *Figure 11* shows the same feature at the beginning of 1998, although with less accuracy.

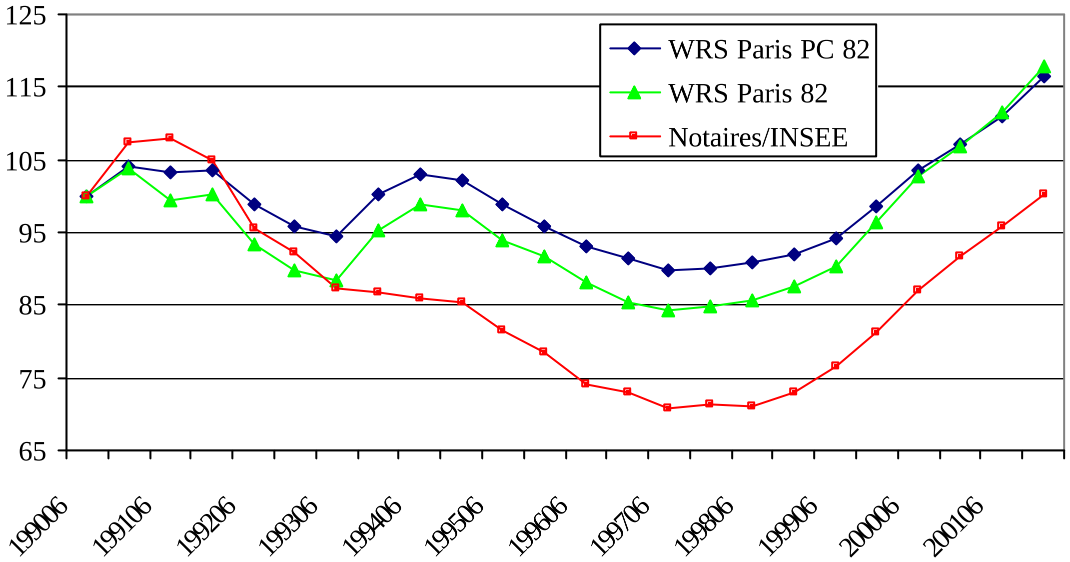

Figure 11 : Comparison of Paris residential indices from 1982-2001- based 100 in 1990:06

5 Risk and Return

This section extends the analysis to the nature of the return and risk (standard-deviation) characteristics of physical real estate through the two indices. Assuming that real estate log-returns $\ln(p_{it} / p_{it})$, are indeed normally distributed, enables us to consider that WRS index follows standard geometric brownian motion dynamics. The estimated model for R_S is hence a diffusion process whose instantaneous expected mean is m where: $m = m + \frac{1}{2}s^2$, and variance is s^2 (*m*, resp. s, being the historical average, resp. standard-deviation, of log-returns).

We sum up the measures of average return, instantaneous mean and volatility by comparing with empirical estimates. Note that the empirical measures of moments yield much higher estimates of the average capital returns than the estimates provided by the indices. This is probably linked to the fact that indices incorporate a time series cumulative aspect that is not present in the raw data for which an *x*% return in the early 1990s is treated in the same manner as a similar *x*% return in the late 1990s. All those results are presented in *Table 1*. We have respected the structure of the Notaires/INSEE index which is a semi annual index[14]. Hence, all those values are annualised.

[14] With a periodicity of two months and three months, the Paris WRS volatility is respectively 0.0699 and 0.0562 .

Annualised moments (%)	*Average return (m)*	*Instantaneous mean (μ)*	*Standard deviation (s)*	*Sharpe ratio*
WRS Paris & PC	*4.88*	*1.51*	*4.07*	*0.19*
WRS Paris	*5.53*	*5.75*	*6.41*	*11.47*
Notaires/INSEE	*5.93*	*6.21*	*7.45*	*16.24*
Empirical estimates	*4.54*	*7.60*	*24.73*	*10.51*

Table 1: Annualised return and volatility for the two indices (1982-2001)

Moreover, comparing the above results to inflation behaviour during the 1982-2001 period confirms the traditional view that real estate is a hedge for inflation risk. Indeed, average inflation was 5.72% annually which is very close. What's more, note in Table 2 the strong correlation between WRS index and inflation during the 1982-2001 period. This feature is present to a lower extent if one uses the Notaires/INSEE.

	Notaires/INSEE Index	*WRS Housing Index*
Price Index	0.756	0.892

Table 2: Correlation with price index (1982-2001)

Conclusion

Our study, grounded in observed transactions prices and dates, shows there is an alternative to the Notaires/INSEE Index to describe the evolution of real estate prices in Paris. The indices do not give similar results and they do not seem to tell the same history, even if they use the same original database. The methodologies are very different. The WRS index takes into account the unique character of each apartment, but as a repeat sales index does not include single transactions. The Notaires/INSEE index, more complete in terms of transactions, stays a mean price index. The biggest differences between the two indices appear more clearly in "bubble" or "crisis" periods. In fact, in these periods, long holding periods transactions have a more important weight in WRS index than in Notaires/INSEE and have in some extent a smoothing rule, because they are integrated inside the index computing through a return rate. At reverse during "normal" period, WRS index shows more volatility than Notaires/INSEE, because its methodology "forces" the index to pass through every transaction without any smoothing effect.

We think such Repeat Sales Index could be a substantial help for investors on the Paris property market, especially for long-term strategies. It is able to capture both specific and systematic risk and to integrate the investor behaviour. However, both Notaires/INSEE and WRS do not have any predictability capacities. Our focus is now to propose a repeat sales methodology that could have this capacity.

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Appendix A: WRS estimation results for the period from 1973 to 2001 – semi-annual index

Step 1:

	Paris & PC		Paris		PC	
Obs	218 102		98 863		119 239	
R2	0.538		0.547		0.533	
Date	**estimates**	***s.e.***	**estimates**	***s.e.***	**estimates**	***s.e.***
197312	0.008521	*0.022801*	0.045177	*0.015624*	0.008521	*0.022801*
197406	0.145079	*0.020780*	0.153386	*0.014181*	0.145079	*0.020780*
197412	0.165810	*0.022632*	0.180186	*0.015358*	0.165810	*0.022632*
197506	0.156538	*0.021988*	0.187438	*0.014708*	0.156538	*0.021988*
197512	0.232950	*0.021893*	0.220476	*0.014738*	0.232950	*0.021893*
197606	0.326616	*0.020661*	0.340526	*0.013889*	0.326616	*0.020661*
197612	0.379669	*0.020768*	0.388290	*0.014337*	0.379669	*0.020768*
197706	0.433629	*0.020346*	0.437542	*0.013845*	0.433629	*0.020346*
197712	0.426007	*0.020930*	0.452411	*0.014233*	0.426007	*0.020930*
197806	0.453822	*0.019829*	0.496092	*0.013519*	0.453822	*0.019829*
197812	0.480386	*0.020497*	0.522820	*0.013987*	0.480386	*0.020497*
197906	0.541323	*0.019197*	0.580644	*0.013106*	0.541323	*0.019197*
197912	0.658624	*0.018975*	0.688812	*0.012941*	0.658624	*0.018975*
198006	0.744535	*0.018696*	0.791569	*0.012719*	0.744535	*0.018696*
198012	0.821586	*0.020042*	0.849652	*0.013541*	0.821586	*0.020042*
198106	0.865086	*0.018623*	0.902408	*0.012675*	0.865086	*0.018623*
198112	0.918834	*0.019200*	0.940625	*0.013224*	0.918834	*0.019200*
198206	0.921317	*0.018906*	0.958315	*0.012918*	0.921317	*0.018906*
198212	0.912440	*0.018810*	0.970075	*0.012951*	0.912440	*0.018810*
198306	0.931315	*0.018170*	0.988434	*0.012413*	0.931315	*0.018170*
198312	0.987488	*0.018381*	1.034150	*0.012611*	0.987488	*0.018381*
198406	0.995902	*0.017717*	1.042103	*0.012204*	0.995902	*0.017717*
198412	1.057842	*0.017905*	1.097101	*0.012257*	1.057842	*0.017905*
198506	1.074872	*0.017391*	1.113355	*0.011915*	1.074872	*0.017391*
198512	1.115883	*0.017655*	1.151958	*0.012019*	1.115883	*0.017655*
198606	1.179541	*0.017012*	1.207882	*0.011605*	1.179541	*0.017012*
198612	1.258539	*0.017050*	1.275125	*0.011573*	1.258539	*0.017050*
198706	1.327714	*0.016589*	1.332053	*0.011251*	1.327714	*0.016589*
198712	1.420576	*0.016613*	1.413282	*0.011313*	1.420576	*0.016613*
198806	1.485530	*0.016473*	1.471445	*0.011153*	1.485530	*0.016473*
198812	1.565603	*0.016593*	1.537407	*0.011260*	1.565603	*0.016593*
198906	1.668533	*0.016328*	1.629341	*0.011022*	1.668533	*0.016328*
198912	1.763859	*0.016654*	1.705164	*0.011218*	1.763859	*0.016654*
199006	1.845300	*0.016373*	1.779259	*0.011022*	1.845300	*0.016373*
199012	1.881875	*0.016986*	1.819195	*0.011328*	1.881875	*0.016986*
199106	1.838892	*0.017103*	1.810878	*0.011425*	1.838892	*0.017103*
199112	1.845302	*0.017112*	1.812239	*0.011529*	1.845302	*0.017112*
199206	1.775641	*0.016955*	1.767293	*0.011457*	1.775641	*0.016955*
199212	1.737557	*0.017061*	1.736123	*0.011583*	1.737557	*0.017061*
199306	1.721076	*0.016572*	1.720860	*0.011313*	1.721076	*0.016572*
199312	1.801186	*0.015515*	1.784065	*0.010665*	1.801186	*0.015515*
199406	1.840263	*0.015197*	1.815753	*0.010434*	1.840263	*0.015197*
199412	1.833068	*0.015260*	1.806638	*0.010495*	1.833068	*0.015260*
199506	1.792217	*0.015314*	1.773136	*0.010521*	1.792217	*0.015314*
199512	1.758274	*0.015466*	1.739902	*0.010621*	1.758274	*0.015466*
199606	1.719217	*0.015274*	1.705267	*0.010467*	1.719217	*0.015274*
199612	1.686294	*0.015152*	1.689254	*0.010433*	1.686294	*0.015152*
199706	1.669260	*0.015503*	1.671161	*0.010646*	1.669260	*0.015503*
199712	1.677594	*0.015314*	1.671236	*0.010527*	1.677594	*0.015314*
199806	1.679950	*0.015262*	1.675725	*0.010464*	1.679950	*0.015262*
199812	1.708164	*0.015260*	1.688602	*0.010462*	1.708164	*0.015260*
199906	1.737769	*0.015117*	1.713430	*0.010357*	1.737769	*0.015117*
199912	1.797133	*0.015115*	1.754991	*0.010377*	1.797133	*0.015115*
200006	1.860337	*0.015147*	1.803381	*0.010403*	1.860337	*0.015147*
200012	1.899232	*0.015240*	1.835964	*0.010481*	1.899232	*0.015240*
200106	1.940061	*0.015243*	1.868795	*0.010442*	1.940061	*0.015243*
200112	2.001010	*0.015834*	1.920886	*0.010835*	2.001010	*0.015834*

Step 2:

	Paris & PC		Paris		PC	
Parameters	**estimates**	**s.e.**	**estimates**	**s.e.**	**estimates**	**s.e.**
CONSTANT	0.089820	*0.004461*	0.106455	*0.006985*	0.089820	*0.004461*
Duration	0.004278	*0.000199*	0.004717	*0.000304*	0.004278	*0.000199*

Step 3:

	PARIS & PC		PARIS		PC	
Obs	218 102		98 863		119 239	
R2	0.426		0.439		0.422	
Date	**estimates**	***s.e.***	**estimates**	***s.e.***	**estimates**	***s.e.***
197312	0.039230	*0.020646*	0.002962	*0.029769*	0.075525	*0.028269*
197406	0.150247	*0.018676*	0.141115	*0.027059*	0.156283	*0.025458*
197412	0.177547	*0.020132*	0.163019	*0.029340*	0.188953	*0.027296*
197506	0.185152	*0.019214*	0.152329	*0.028369*	0.207862	*0.025785*
197512	0.217410	*0.019182*	0.226858	*0.028158*	0.205642	*0.025860*
197606	0.337922	*0.018068*	0.321680	*0.026548*	0.348095	*0.024352*
197612	0.386983	*0.018537*	0.375808	*0.026572*	0.400184	*0.025539*
197706	0.436896	*0.017879*	0.430637	*0.025961*	0.440991	*0.024333*
197712	0.450336	*0.018265*	0.421537	*0.026540*	0.474960	*0.024845*
197806	0.494694	*0.017359*	0.449220	*0.025158*	0.536323	*0.023671*
197812	0.520553	*0.017854*	0.476819	*0.025873*	0.561196	*0.024349*
197906	0.580065	*0.016762*	0.538447	*0.024252*	0.617120	*0.022896*
197912	0.688121	*0.016517*	0.656680	*0.023928*	0.714431	*0.022537*
198006	0.789533	*0.016229*	0.740493	*0.023554*	0.831116	*0.022112*
198012	0.846632	*0.017080*	0.817066	*0.024958*	0.868730	*0.023141*
198106	0.899680	*0.016085*	0.861439	*0.023349*	0.931788	*0.021915*
198112	0.938649	*0.016626*	0.916381	*0.023885*	0.962432	*0.022871*
198206	0.954780	*0.016236*	0.915160	*0.023472*	0.989719	*0.022202*
198212	0.967842	*0.016212*	0.907948	*0.023294*	1.029237	*0.022299*
198306	0.986978	*0.015625*	0.928904	*0.022590*	1.038810	*0.021368*
198312	1.031797	*0.015768*	0.984607	*0.022719*	1.076418	*0.021629*
198406	1.040327	*0.015331*	0.991678	*0.022017*	1.089808	*0.021094*
198412	1.092972	*0.015330*	1.052883	*0.022115*	1.129609	*0.021008*
198506	1.109876	*0.014980*	1.069231	*0.021589*	1.146635	*0.020546*
198512	1.146982	*0.015031*	1.108638	*0.021779*	1.177667	*0.020527*
198606	1.204449	*0.014633*	1.173530	*0.021157*	1.228907	*0.020020*
198612	1.272111	*0.014576*	1.253378	*0.021146*	1.283086	*0.019896*
198706	1.327569	*0.014279*	1.319937	*0.020706*	1.328412	*0.019505*
198712	1.408977	*0.014307*	1.414471	*0.020694*	1.400413	*0.019573*
198806	1.466821	*0.014158*	1.478540	*0.020548*	1.452232	*0.019336*
198812	1.533523	*0.014218*	1.558986	*0.020600*	1.508847	*0.019436*
198906	1.623749	*0.014019*	1.659853	*0.020368*	1.592056	*0.019145*
198912	1.698464	*0.014147*	1.754369	*0.020585*	1.652917	*0.019298*
199006	1.772277	*0.013986*	1.834796	*0.020345*	1.724261	*0.019092*
199012	1.811979	*0.014185*	1.872656	*0.020750*	1.765186	*0.019302*
199106	1.803541	*0.014232*	1.828959	*0.020796*	1.778688	*0.019371*
199112	1.805493	*0.014274*	1.836580	*0.020761*	1.777361	*0.019472*
199206	1.761843	*0.014205*	1.767809	*0.020615*	1.752069	*0.019404*
199212	1.728205	*0.014252*	1.726948	*0.020620*	1.725290	*0.019505*
199306	1.717080	*0.014055*	1.715914	*0.020268*	1.714731	*0.019281*
199312	1.777215	*0.013676*	1.790155	*0.019641*	1.763271	*0.018818*
199406	1.808187	*0.013537*	1.829586	*0.019448*	1.785804	*0.018618*
199412	1.798458	*0.013574*	1.823219	*0.019485*	1.773649	*0.018682*
199506	1.765820	*0.013591*	1.780874	*0.019520*	1.749144	*0.018699*
199512	1.734152	*0.013652*	1.750838	*0.019617*	1.715988	*0.018777*
199606	1.701918	*0.013562*	1.712973	*0.019502*	1.688139	*0.018641*
199612	1.684818	*0.013541*	1.681348	*0.019429*	1.682914	*0.018644*
199706	1.667719	*0.013677*	1.667465	*0.019653*	1.663877	*0.018811*
199712	1.671011	*0.013605*	1.676357	*0.019535*	1.662192	*0.018721*
199806	1.680182	*0.013569*	1.684652	*0.019510*	1.672009	*0.018652*
199812	1.690871	*0.013569*	1.707402	*0.019512*	1.672364	*0.018650*
199906	1.717511	*0.013507*	1.740842	*0.019424*	1.695651	*0.018565*
199912	1.761930	*0.013520*	1.804572	*0.019425*	1.724078	*0.018596*
200006	1.811649	*0.013541*	1.867711	*0.019453*	1.762513	*0.018626*
200012	1.844819	*0.013595*	1.908368	*0.019520*	1.786653	*0.018707*
200106	1.881359	*0.013579*	1.952963	*0.019535*	1.821048	*0.018659*
200112	1.932083	*0.013858*	2.012319	*0.019961*	1.860829	*0.019022*

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