SHOULD ANY NEW LIGHT RAIL LINE PROVIDE REAL ESTATE GAINS, OR NOT? THE CASE OF THE T3 LINE IN PARIS

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ABSTRACT

This paper presents a research to assess real estate gains brought by a new light rail infrastructure: the T3 tramway line in Paris opened in December 2006. Based on comprehensive geolocated data, it mainly focuses on econometric hedonic modelling where accessibility gains are included besides other intrinsic and extrinsic variables. In spite of different specifications, no model yielded any significant effect of the new line. Finally, the rationale for such an outcome is discussed, and by comparison with other studies, the factors for a new line to provide significant gains are listed.

Keywords: light rail, Paris, accessibility, hedonic models, real estate gains, land rents

1. OBJECTIVE

1.1. Introduction

This paper presents the outcomes of a study aimed at evaluating the impact of the T3 tramway line in Paris on housing real estate prices.

The study is part of a series of studies by IAU Ile-de-France and IFSTTAR (ex INRETS) on the evaluation of real estate impacts of transport infrastructures or policies (T1 tramway line, Nguyen-Luong, 2006; T2 tramway line, Boucq & Papon, 2007; RER E, Nguyen-Luong, 2006;

Zones 30 in Paris, Glachant, Bureau & Nguyen-Luong, 2008). These studies on the one hand are conducted in a context where public funding is becoming scarcer and where the government is searching for new sources of public transport project funding. One possible source would be taxing part of real estates gains brought by new infrastructures, though it raises technical and juridical issues beyond the scope of this research. On the other hand, such studies may help at improving transport and land use models, such as SIMAURIF (De Palma & Nguyen-Luong, 2004 à 2008), that simulates two-way effects between transport infrastructure and land use in the middle-long run, in particular households and jobs location and land and real estate rents, which include « wider benefits », i.e. positive externalities beyond classical time gains.

The study was conducted in six phases: (1) bibliographic synthesis, (2) data collection, (3) field survey passed to real estate agents, (4) descriptive analysis, (5) estimation and validation of a hedonic regression price model, (6) summary of five studies on the real estate effects of a new transport infrastructure in Ile-de-France. This paper will focus on the outcomes of the hedonic model.

1.2. Bibliographic synthesis

One question is whether the effects of infrastructures on land and/or real estate rents are positive and significant. The detailed literature review is skipped here. According to the comprehensive review by Deschamps (2008), since the 1950's, study results have been very variable. The outcomes depend on infrastructure type, distance to infrastructure, period taken into account, and urban dynamics. The author points out the following methodological flaws.

The spatial level of analysis should not be at the municipality level but more accurate to seize household preferences, distance to transport services and other amenities, and the housing micro-markets; data should be individual transactions and not aggregated; price data should be real sale prices and not the price displayed before bargaining; anticipation effects are rarely taken into account; the most important variable, accessibility, is often imperfect (often linear where a more complex form would be needed) and its parameter has decreased over time; statistical methods do not always allow accurate measurement of a very small time gain effect; besides transport variables, two other variable types should be integrated in the price model intrinsic variables (surface area, building age, lift...) and extrinsic variables (proximity to urban amenities, neighbourhood social characteristics); colinearity and space heterogeneity between variables may induce cumulative effects that may produce counter intuitive outcomes. This research attempted, as far as possible, to overcome these issues.

In spite of hardly comparable studies as each case is different, and in spite of varying accessibility effects on housing prices (in nature and intensity), one consensus emerges: when transport effects are significant, they are low.

2. DATA/METHODOLOGY

2.1. The T3 tramway line

The T3 tramway line was opened to operation on December 16, 2006, replacing a former bus line. Its main characteristics are: 7.9 km length, 17 stations, 26 minutes travel time between terminus stations, 115,000 travellers per day on average in 2010 (double the previous bus line), 5:00 a.m. to 12:30 a.m. operation, 16.5 km/h commercial speed (compared to 14.5 for the previous bus line), 7 metro lines and 37 bus lines in direct transfer, lawn grown on 70% of the lay-out.

The study area is set 4 km apart both sides of the tramway line, partly covering 8 Paris *arrondissements*, 7 municipalities in county Hauts-de-Seine (Boulogne, Issy-les-Moulineaux, Vanves, Malakoff, Châtillon, Montrouge, Bagneux) and 5 municipalities in county Val-de-Marne (Arcueil, Gentilly, Villejuif, Le Kremlin-Bicêtre, Ivry-sur-Seine), including the line corridor defined 400 meters apart both sides of the tramway line.

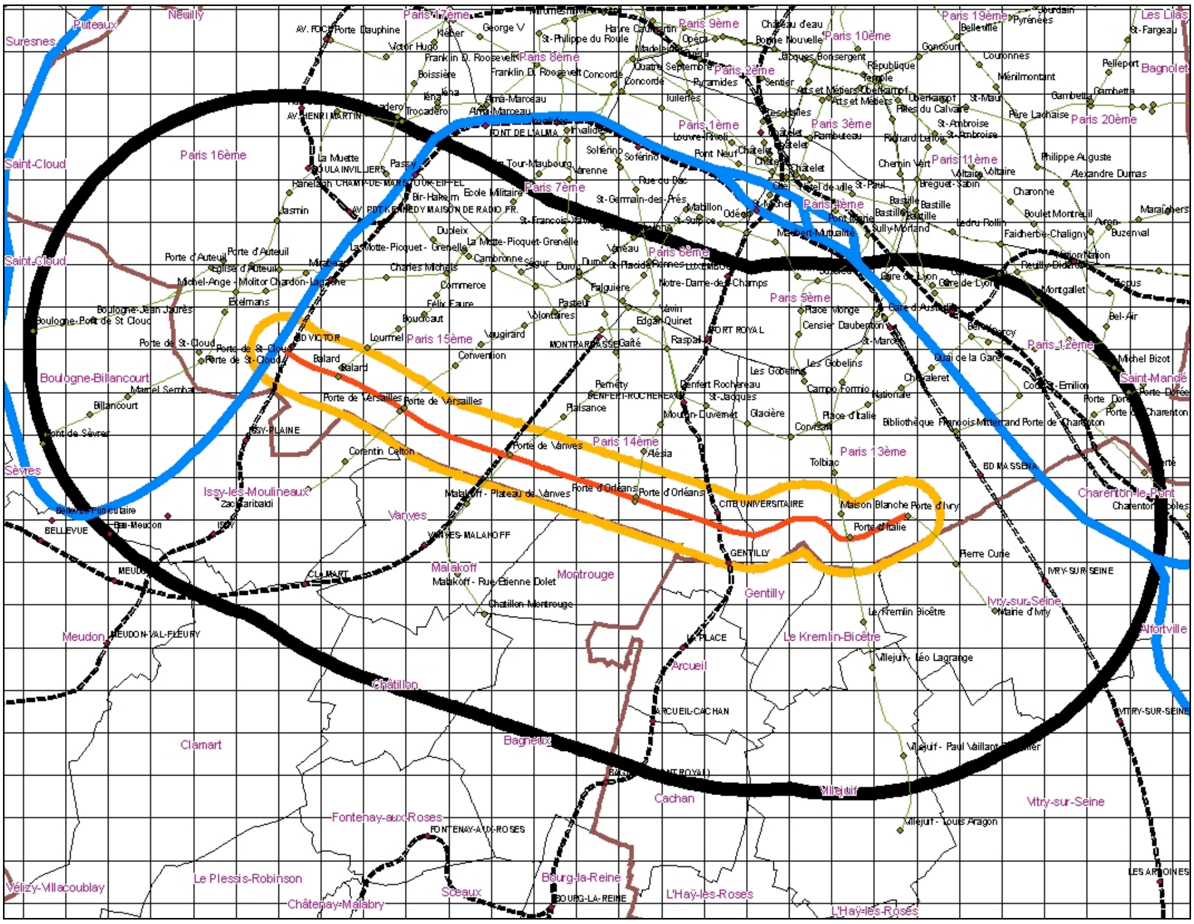

Figure 1 – T3 situation map (red line), 400 m line corridor (yellow), first 3km study perimeter (black), SIMAURIF model grid

The T3 line is being extended end of 2012 from Porte d'Ivry to Porte de la Chapelle with 25 new stations.

A recent cost-benefit analysis of the T3 tramway (Prud'homme et al., 2011) finds that the new line produced a ne loss for travellers, as increase in road congestion offsets time savings to public transport users.

2.2. Real estate data source

The richest possible data were used for this research. All collected transaction data were geolocated at the postal address. Historically in France in this type of study, transaction data were at the municipality level, or recently at the IRIS area level (defined with population of 2000 inhabitants, T2 study by INRETS, Boucq, 2008) or at the street level (T1, RER E and Green neighbourhoods studies by IAU Ile-de-France, Nguyen-Luong, 2006). Such an accurate location allows computing precisely extrinsic variables such as distances to amenities.

This database takes into account only the properties on the transaction market (for sale). It excludes properties outside this market (for rent): council housing and privately rented flats. The database is BIEN from the Paris Notary Chamber who detains the exhaustive transaction data from 1990 to today. The great pro of this base is that all transactions are geolocated with Lambert II coordinates XY at their postal address. Seven years, from January 1, 2002 to December 31, 2008 were included, five years before tramway operation and two years after.

2.3. Methodology

This data enable two kinds of analysis. On the one hand, a descriptive and cartographic analysis in time and space compares means and standard deviations before/after and close/remote from the infrastructure. The evolution of average prices per m2 in the tramway corridor (400 meters) and more remote areas (up to 4 km) or control zones along the same boulevard but where the T3 tramway does not operate (yet) is tabulated. On the other hand, an econometric analysis of prices of the hedonic regression type enables to quantify ceteris paribus the effect of each factor by controlling other determinants of the explained variable. Here, the main determinants of real estate transaction prices are identified to isolate the specific impact of the T3 tramway.

2.4. Unfavourable economic trend

An additional concern has occurred during the study, as the real estate crisis burst in 2008-2009. A study by the Paris Notary Chamber showed that the number of housing sales in the region Ile-de-France plummeted by 40% in the first term of 2009 as compared to previous year. This fall concerned all housing categories: old flats (-41%), new flats (-46%), old houses (-44%) and new houses (-56%). Prices also fell in the same time, although in 2010 they recovered the previous increasing trend. Thus, for the first time since the second term of 1998, old flats in Paris city have recorded a decrease in annual variation (-1,0% at 6360 euros/m2 vs. +9,4% in the first term of 2008). The fall is higher in inner suburbs (-5%) and in outer suburbs (-8%). This price decrease did not ease descriptive comparisons before/after and the interpretation of the econometric analysis results.

2.5. Real estate data 2002 to 2008

The database on the study area includes 162,032 transactions (or sales or transfers) of flats between 01/01/2002 and 31/12/2008. Table 1 shows the distribution of flat transactions by year on the study area:

Table I – Number of transactions per year in the study area

Years	2002	2003	2004	2005	2006	2007	2008	Total
Number of transactions	22 468	22 673	24 663	26 172	23 851	23 143	19062	162 032

The available fields are: reference number, transfer date, transfer price, municipality code, street type, street name, floor number, new or old, liveable surface area, number of rooms, lift, garage, building period (9 classes), previous transfer date, previous transfer price, X, Y.

2.6. Other collected data

RATP provided data from an October 2009 origin-destination survey. To sum up, 14 stations out of 17 are mainly for servicing local destinations. The other three are more oriented as transfer stations with metro (line 4 and 13) or RER (line B).

RATP also provided official service scheduling that were used to compute accessibility changes. But according to a report by the Accounting Court in May 2009, the observed travel time for the entire line is 28.7 minutes (corresponding to 16.5 km/h) vs. 26 minutes (corresponding to 18.2 km/h) in the official timetable. According to RATP, the lower speed was reported in the morning peak hour, and was due to patronage above forecast (115,000 vs. 100,000 pax per day).

3. ECONOMETRIC ANALYSIS

3.1. Hedonic modelling principles

To study the effect of a transport infrastructure on real estate prices, hedonic modelling is generally used (for example DREIF, 2002; Deymier, 2005; Boucq, 2008).
This method is particularly suited as properties are heterogeneous goods, and their price depends on their characteristics, intrinsic and extrinsic. Intrinsic characteristics are those that belong to the property itself (surface area, number of rooms, number of bathrooms...), and extrinsic characteristics are those of the environment where the property is located (socio-demographics, proximity to local public facilities such as schools and hospitals, or local transport conditions.

To measure the possible effects of the T3 tramway on real estate prices, a hedonic price model based on the founding work by Rosen (1974) is built. The hedonic function will provide an estimation of properties as a function of their characteristics.

Once this function is estimated, the fictive price of properties if the tramway had not been put in operation, and the price of properties taking into account the tramway service can be computed. The difference is the gain brought by the tramway implementation, as the hedonic function provides a measurement of one single variable modification impact on prices, everything else being equal, and enables to separate the tramway effect from other price determinants.

3.2. Hedonic model description

The estimated model is based on Rosen's formulation (1974):

$F(p) = X1\beta1 + X2\beta2 + \varepsilon$

With p housing price vector, and F(.) hedonic function, supposed in a first step to be of the Box-Cox form. It is assumed that characteristics are desirable and that agents' choices obey the utility maximization principle. X1 and X2 are characteristics observation matrices (X1 intrinsic and X2 extrinsic). ε is an independent and identically distributed error term vector.

Thus each composite good basket (X1, X2) corresponds to a market price p estimated by hedonic function F(.).

3.3. Model variables

According to data availability, the following fifty or so explanatory variables were tested.

A) Intrinsic characteristics: building period, liveable surface area, number of rooms, average surface area per room, floor number, lift, number of garages.

B) Transfer characteristics: current transfer year, current transfer month, previous transfer year, dummy "transfer after Olympiades station opening (June 2007)".

C) Extrinsic characteristics are classified into 7 categories.

1) Address: municipality, *arrondissement* if Paris city, neighbourhood if Paris city (80 neighbourhoods), street type (14 types avenue, boulevard etc.), orientation with respect to the T3 line (6 classes: north, south, north-east, south-east, north-west, south-west).

2) Proximity (after the land use data), i.e. distances to the nearest facility of each type: woods and forests, leisure parks, gardens and parks, habitat gardens, shopping malls, all shopping

facilities, sheltered sport facilities, middle schools, high schools, higher education, hospitals, cemeteries, great cultural facilities, transport infrastructure more than 25 meters wide.

3) Dummies whether the property belongs to a particular land use polygon: single family housing, single family housing residence, rural housing, multi family low rise row housing, multi family high rise row housing, multi family high rise detached housing, prisons, other habitat, activities in mixed urban fabric, facilities for water, sewage, energy and industry.

4) Other proximity variables, i.e. distances to the nearest facility of each type: metro station excluding Olympiades, SNCF and RER train station, passenger railways, ZAC urban development zone, T3 tramway line or station, Châtelet station, gare de Lyon station, Montparnasse station, Saint-Lazare station.

5) Other dummies: property within 500 meters (respectively 200 meters, between 200 and 400 meters) from Olympiades station, address on *boulevard des Maréchaux* (we do not know whether the flat windows faces or not the boulevard).

6) Variables linked to INSEE blocks crossed with land use: percentage of natural area in block, percentage of industry in block, percentage of tertiary activity in block, number of jobs per block.

7) Socio-economic variables linked to IRIS population zones (INSEE): percentage of persons aged 60 and over in IRIS, percentage of couples with 3 children or more in IRIS, percentage of households by household size (1, 2, 3, 4 and over) in IRIS, percentage of households the head of which belong to a particular socio-professional category (farmer, retailer/craftsman/business boss, executive, intermediary profession, employee, worker, retired, without professional activity) in IRIS, percentage of foreigners in IRIS population, percentage of unemployed among IRIS working population, percentage of higher education degrees in IRIS, population aged 20 and over, percentage of dwellings lacking one comfort element (WC, shower or bath, heating).

D) Accessibility variables (« log sum ») to jobs. The accessibility of one zone is the weighted sum of jobs located in all zones, weighted by a function of transport time, computed as:

$$A_i = \sum_j E_j . \exp(-\lambda . T_{ij})$$

Where
Log(Ai): accessibility to jobs of zone i by public transport;
Ej: number of jobs in zone j (source regional job survey ERE 2001);
Tij: public transport travel time between i and j (source STIF);
λ: parameter (equals 0.27 from project SIMAURIF).

This accessibility variable is computed in three ways: in level before the T3 tramway operation (travel times 2005), in level after the T3 tramway operation (travel times 2008), with the same job structure, in variation induced by the T3 tramway computed as the difference between the two levels before and after. However some approximations were needed to get the 2005 travel times as there were not readily available, which may weaken the results attached to the accessibility gain variable.

Different processing of missing values were needed, including imputation by modelling, imputation by hierarchical hot-deck, or inclusion of an "unknown class" for class variables.

3.4. Study period and anticipation effects

If the real estate market were perfectly working, prices would immediately adjust after one property characteristic modification. So, if it were true, and if the public transport accessibility to jobs played a determinant role in property price forming in our study area, the T3 tramway induced accessibility modifications would entail an immediate price adjustment as soon the T3 tramway is put in operation. But the market does not perfectly function and immediate tramway effects may be nearly not existent, because household might have anticipated the tramway implementation and incorporate accessibility gains in sale prices before the tramway operation began.

Reversely, the accessibility gain value might have been incorporated in the prices only after operation began. McDonald & Osuji (1995), Boarnet & Chalermpong (2001), Smersh & Smith (2000), Yiu & Wong (2005), Deymier (2005), or else Boucq (2008), measure effects before or after the concerned infrastructure building. These authors all show the existence of anticipation effects, and sometime learning effects, but no consensus emerges about the number of years after which tramway effects continue. This may depend on the geographical area, the situation before tramway operation such as good public transport service or not, information provided to households on the project, or other not manageable elements. So we choose a wide enough analysis period to detect these possible anticipation or learning effects, taking into account data availability: 2002 to 2008, 5 years before operation and 2 years after (2008 was the last available year at the start of the study).

4. RESULTS

Three different models were performed:
- Model 1 is a hedonic model without taking into account the T3 tramway.
- Model 2 takes into account the T3 tramway by introducing distance between dwelling unit and T3 line as an additional explanatory variable.
- Model 3 takes into account the T3 tramway by introducing accessibility to jobs, in level before the tramway operation, and in variation induced by the tramway.

Several formulations were tested for each of these models, to best grasp the effect of the T3 tramway on housing prices. Only the most relevant formulation will be presented here.

4.1. Results of model 1 without taking into account tramway T3

Figure 2: coefficients and statistics of model 1 (model 1c)

	Intrinsic explanatory variables	Coefficient	Standard error	t-stat	Pr > |t|	Variation rate
	Constant	8,477	0,031	274	<,0001	
	logarithm of surface area	0,994	0,001	759	<,0001	
	logarithm of surface area per room	-0,047	0,001	-39	<,0001	
	before 1969	-0,042	0,002	-21	<,0001	-4%
	1970-1980	-0,020	0,003	-7	<,0001	-2%
	1981-1991	0,016	0,004	4	<,0001	2%
	1992-2000	0,091	0,004	21	<,0001	10%
	2001-2008	0,241	0,003	72	<,0001	27%
building period	unknown (reference)	0,000	.	.	.	.
	basement or ground floor without lift	-0,066	0,006	-10	<,0001	-6%
	basement or ground floor with lift	-0,046	0,008	-6	<,0001	-4%
	first floor without lift	-0,022	0,006	-4	0,0003	-2%
	first floor with lift	-0,008	0,006	-1	0,1976	-1%
	2nd floor without lift	0,012	0,006	2	0,0563	1%
	2nd floor with lift	0,020	0,006	3	0,0025	2%
	3rd floor without lift	0,018	0,006	3	0,0034	2%
	3rd floor with lift	0,033	0,006	5	<,0001	3%
	4th floor without lift	0,021	0,006	3	0,0009	2%
	4th floor with lift	0,043	0,007	7	<,0001	4%
	5th floor without lift	0,030	0,006	5	<,0001	3%
	5th floor with lift	0,051	0,007	8	<,0001	5%
	6th floor without lift	0,014	0,007	2	0,0404	1%
	6th floor with lift	0,051	0,007	7	<,0001	5%
	7th, 8th or 9th floor	0,043	0,006	7	<,0001	4%
	10th floor or above	-0,018	0,007	-2	0,0134	-2%
floor number	unknown floor without lift	0,136	0,006	21	<,0001	15%
crossed with lift presence	unknown floor with lift (reference)	0,000	.	.	.	.
	0	-0,180	0,004	-47	<,0001	-16%
	1	-0,062	0,004	-17	<,0001	-6%
number of garages	2 or more (reference)	0,000	.	.	.	.
	January 2002	-0,644	0,009	-68	<,0001	-47%
	February 2002	-0,633	0,010	-65	<,0001	-47%
	March 2002	-0,639	0,010	-67	<,0001	-47%
	April 2002	-0,632	0,009	-67	<,0001	-47%
	May 2002	-0,592	0,009	-63	<,0001	-45%
	June 2002	-0,597	0,009	-65	<,0001	-45%
	July 2002	-0,579	0,009	-65	<,0001	-44%
	August 2002	-0,562	0,010	-55	<,0001	-43%
	September 2002	-0,563	0,009	-62	<,0001	-43%
	October 2002	-0,566	0,009	-60	<,0001	-43%
	November 2002	-0,555	0,010	-54	<,0001	-43%
	December 2002	-0,543	0,009	-58	<,0001	-42%
	January 2003	-0,523	0,010	-55	<,0001	-41%
	February 2003	-0,528	0,010	-55	<,0001	-41%
	March 2003	-0,514	0,010	-54	<,0001	-40%
	April 2003	-0,512	0,009	-55	<,0001	-40%
	May 2003	-0,497	0,010	-51	<,0001	-39%
	June 2003	-0,473	0,009	-52	<,0001	-38%
	July 2003	-0,464	0,009	-53	<,0001	-37%
	August 2003	-0,441	0,010	-42	<,0001	-36%
	September 2003	-0,438	0,009	-49	<,0001	-35%
	October 2003	-0,439	0,009	-47	<,0001	-36%
	November 2003	-0,433	0,010	-43	<,0001	-35%
	December 2003	-0,407	0,009	-44	<,0001	-33%
	January 2004	-0,384	0,009	-41	<,0001	-32%
	February 2004	-0,401	0,010	-42	<,0001	-33%
	March 2004	-0,391	0,009	-42	<,0001	-32%
	April 2004	-0,370	0,009	-39	<,0001	-31%
	May 2004	-0,359	0,009	-38	<,0001	-30%
	June 2004	-0,343	0,009	-39	<,0001	-29%
	July 2004	-0,328	0,009	-38	<,0001	-28%
	August 2004	-0,306	0,010	-30	<,0001	-26%
	September 2004	-0,309	0,009	-35	<,0001	-27%
	October 2004	-0,301	0,009	-33	<,0001	-26%
	November 2004	-0,276	0,010	-28	<,0001	-24%
	December 2004	-0,288	0,009	-32	<,0001	-25%
	January 2005	-0,274	0,009	-30	<,0001	-24%
	February 2005	-0,267	0,009	-29	<,0001	-23%
	March 2005	-0,260	0,009	-28	<,0001	-23%
	April 2005	-0,245	0,009	-26	<,0001	-22%
	May 2005	-0,235	0,009	-26	<,0001	-21%
	June 2005	-0,217	0,009	-25	<,0001	-20%
	July 2005	-0,198	0,009	-23	<,0001	-18%
	August 2005	-0,177	0,010	-18	<,0001	-16%
	September 2005	-0,166	0,009	-19	<,0001	-15%
	October 2005	-0,163	0,009	-17	<,0001	-15%
	November 2005	-0,160	0,009	-17	<,0001	-15%
	December 2005	-0,159	0,009	-18	<,0001	-15%
	January 2006	-0,143	0,009	-15	<,0001	-13%
	February 2006	-0,137	0,009	-14	<,0001	-13%
	March 2006	-0,139	0,009	-15	<,0001	-13%
	April 2006	-0,139	0,009	-15	<,0001	-13%
	May 2006	-0,119	0,009	-13	<,0001	-11%
	June 2006	-0,114	0,009	-13	<,0001	-11%
	July 2006	-0,088	0,009	-10	<,0001	-8%
	August 2006	-0,064	0,010	-6	<,0001	-6%
	September 2006	-0,086	0,009	-9	<,0001	-8%
	October 2006	-0,076	0,009	-8	<,0001	-7%
	November 2006	-0,065	0,010	-6	<,0001	-6%
	December 2006	-0,078	0,009	-9	<,0001	-7%
	January 2007	-0,067	0,009	-7	<,0001	-7%
	February 2007	-0,058	0,010	-6	<,0001	-6%
	March 2007	-0,049	0,009	-5	<,0001	-5%
	April 2007	-0,048	0,010	-5	<,0001	-5%
	May 2007	-0,039	0,009	-4	<,0001	-4%
	June 2007	-0,029	0,009	-3	0,0013	-3%
	July 2007	-0,031	0,009	-4	0,0004	-3%
	August 2007	-0,035	0,010	-3	0,0005	-3%
	September 2007	-0,017	0,009	-2	0,0577	-2%
	October 2007	-0,011	0,009	-1	0,2446	-1%
	November 2007	-0,006	0,010	-1	0,5682	-1%
	December 2007	-0,002	0,009	0	0,8072	0%
	January 2008	0,012	0,009	1	0,2038	1%
	February 2008	0,006	0,010	1	0,5092	1%
	March 2008	0,010	0,010	1	0,2957	1%
	April 2008	0,017	0,010	2	0,0665	2%
	May 2008	0,023	0,010	2	0,0202	2%
	June 2008	0,031	0,009	3	0,001	3%
	July 2008	0,037	0,009	4	<,0001	4%
	August 2008	0,037	0,011	3	0,0008	4%
	September 2008	0,037	0,009	4	<,0001	4%
	October 2008	0,029	0,010	3	0,0026	3%
transfer year and	November 2008	0,007	0,011	1	0,5432	1%
month	December 2008 (reference)	0,000	.	.	.	.
	avant 1970	-0,068	0,005	-13	<,0001	-7%
	1971-1980	-0,011	0,004	-3	0,0077	-1%
	1981-1990	0,013	0,004	3	0,0006	1%
	1991	0,032	0,006	6	<,0001	3%
	1992	0,042	0,006	7	<,0001	4%
	1993	0,048	0,005	9	<,0001	5%
	1994	0,049	0,005	10	<,0001	5%
	1995	0,045	0,005	8	<,0001	5%
	1996	0,053	0,005	11	<,0001	5%
	1997	0,053	0,005	11	<,0001	5%
	1998	0,058	0,005	13	<,0001	6%
	1999	0,062	0,004	14	<,0001	6%
	2000	0,064	0,004	15	<,0001	7%
	2001	0,063	0,004	15	<,0001	6%
	2002	0,041	0,004	10	<,0001	4%
	2003	0,022	0,004	5	<,0001	2%
	2004	0,026	0,004	6	<,0001	3%
	2005	0,039	0,004	9	<,0001	4%
	2006	0,008	0,005	2	0,1173	1%
	2007	-0,005	0,006	-1	0,4296	0%
previous transfer	2008	-0,029	0,008	-4	0,0002	-3%
year	unknown (reference)	0,000	.	.	.	.

	Extrinsic explanatory variables	Coefficient	Standard error	t-stat	Pr > |t|	Variation rate
	Alfortville	0,131	0,008	17	<,0001	14%
	Arcueil	0,154	0,010	15	<,0001	17%
	Bagneux	0,145	0,009	15	<,0001	16%
	Boulogne-Billancourt	0,528	0,007	76	<,0001	70%
	Bourg-la-Reine	0,214	0,023	9	<,0001	24%
	Cachan	0,092	0,009	11	<,0001	10%
	Charenton-le-Pont	0,389	0,009	42	<,0001	48%
	Châtillon	0,253	0,007	34	<,0001	29%
	Clamart	0,272	0,008	33	<,0001	31%
	Fontenay-aux-Roses	0,227	0,020	11	<,0001	26%
	Gentilly	0,226	0,011	21	<,0001	25%
	Haÿ-les-Roses (L')	0,065	0,047	1	0,1661	7%
	Issy-les-Moulineaux	0,421	0,007	58	<,0001	52%
	Ivry-sur-Seine	0,136	0,007	20	<,0001	15%
	Kremlin-Bicêtre (Le)	0,210	0,009	23	<,0001	23%
	Maisons-Alfort	0,183	0,015	12	<,0001	20%
	Malakoff	0,387	0,008	46	<,0001	47%
	Meudon	0,316	0,009	36	<,0001	37%
	Montrouge	0,405	0,007	58	<,0001	50%
	Paris01Q1	1,390	0,055	25	<,0001	302%
	Paris03Q2	0,927	0,089	10	<,0001	153%
	Paris03Q3	0,911	0,023	40	<,0001	149%
	Paris04Q1	1,363	0,153	9	<,0001	291%
	Paris04Q2	0,844	0,014	62	<,0001	133%
	Paris04Q3	0,859	0,012	73	<,0001	136%
	Paris04Q4	1,166	0,016	75	<,0001	221%
	Paris05Q1	0,875	0,011	77	<,0001	140%
	Paris05Q2	0,794	0,011	71	<,0001	121%
	Paris05Q3	0,891	0,011	83	<,0001	144%
	Paris05Q4	0,939	0,013	73	<,0001	156%
	Paris06Q1	1,055	0,012	86	<,0001	187%
	Paris06Q2	1,047	0,012	85	<,0001	185%
	Paris06Q3	0,968	0,010	94	<,0001	163%
	Paris06Q4	1,128	0,015	74	<,0001	209%
	Paris07Q1	1,094	0,012	93	<,0001	199%
	Paris07Q2	1,067	0,013	80	<,0001	191%
	Paris07Q3	0,924	0,011	83	<,0001	152%
	Paris07Q4	0,916	0,010	91	<,0001	150%
	Paris08Q1	1,096	0,017	63	<,0001	199%
	Paris08Q4	0,832	0,133	6	<,0001	130%
	Paris11Q2	0,665	0,019	35	<,0001	94%
	Paris11Q3	0,668	0,009	75	<,0001	95%
	Paris11Q4	0,645	0,008	84	<,0001	91%
	Paris12Q1	0,570	0,009	60	<,0001	77%
	Paris12Q2	0,623	0,008	79	<,0001	86%
	Paris12Q3	0,586	0,011	52	<,0001	80%
	Paris12Q4	0,653	0,009	77	<,0001	92%
	Paris13Q1	0,610	0,011	58	<,0001	84%
	Paris13Q2	0,490	0,009	55	<,0001	63%
	Paris13Q3	0,585	0,008	78	<,0001	80%
	Paris13Q4	0,702	0,010	71	<,0001	102%
	Paris14Q1	0,857	0,010	83	<,0001	136%
	Paris14Q2	0,719	0,010	74	<,0001	105%
	Paris14Q3	0,707	0,008	87	<,0001	103%
	Paris14Q4	0,690	0,008	84	<,0001	99%
	Paris15Q1	0,698	0,008	87	<,0001	101%
	Paris15Q2	0,737	0,009	81	<,0001	109%
	Paris15Q3	0,767	0,009	88	<,0001	115%
	Paris15Q4	0,742	0,008	90	<,0001	110%
	Paris16Q1	0,730	0,008	88	<,0001	108%
	Paris16Q2	0,817	0,009	88	<,0001	126%
	Paris16Q3	0,817	0,010	80	<,0001	126%
	Paris16Q4	0,856	0,010	83	<,0001	135%
	Paris20Q4	0,590	0,017	35	<,0001	80%
	Saint-Cloud	0,346	0,011	31	<,0001	41%
	Saint-Mandé	0,473	0,014	34	<,0001	60%
	Saint-Maurice	0,368	0,014	27	<,0001	44%
	Sèvres	0,216	0,019	11	<,0001	24%
Paris	Vanves	0,362	0,008	43	<,0001	44%
neighbourhood or	Villejuif	0,116	0,007	17	<,0001	12%
municipality	Vitry-sur-Seine (reference)	0,000	.	.	.	.
	avenue	0,015	0,005	3	0,0048	2%
	boulevard	0,001	0,006	0	0,7961	0%
	passage, place, quai	0,019	0,006	3	0,004	2%
	rue	0,008	0,005	1	0,1476	1%
	square,villa,voie,route	0,026	0,007	4	0,0003	3%
Street type	allée, cité, impasse or other (reference)	0,000	.	.	.	.
	Percentage of natural area in block	0,012	0,006	2	0,043	
	Percentage of higher education degrees in IRIS	0,210	0,014	16	<,0001	
	Percentage of foreigners in IRIS population	-0,242	0,021	-12	<,0001	
	Percentage of households in IRIS where head is retailer/craftsman/business boss	0,383	0,030	13	<,0001	
	Percentage of households in IRIS where head is without professional activity	0,205	0,035	6	<,0001	
	Percentage of hh. in IRIS where head is employee	0,066	0,015	4	<,0001	
	Percentage of hh. in IRIS where head is worker	-0,208	0,023	-9	<,0001	
	Percentage of persons aged 60 and over in IRIS	0,111	0,016	7	<,0001	
	MOS single family housing	0,055	0,004	14	<,0001	6%
	MOS multi family low rise row housing	0,020	0,003	8	<,0001	2%
	MOS multi family high rise detached housing	-0,025	0,002	-11	<,0001	-3%
	woods and forests	-0,016	0,002	-7	<,0001	
	gardens and parks	-0,004	0,001	-7	<,0001	
	sheltered sport facilities	0,007	0,001	6	<,0001	
	higher education	-0,009	0,001	-7	<,0001	
	hospitals	-0,004	0,001	-6	<,0001	
	cemeteries	0,011	0,001	10	<,0001	
	great cultural facilities	-0,025	0,001	-17	<,0001	
	habitat gardens	-0,002	0,001	-2	0,1076	
logarithm of	all shopping facilities	0,005	0,001	5	<,0001	
distance to	ZAC urban development zone	0,008	0,001	12	<,0001	
	logarithme of distance to St Lazare station					
	address on boulevard des Maréchaux	-0,085	0,010	-9	<,0001	-8%
distance to	1) 0-200m before	0,028	0,017	2	0,0975	3%
Olympiades station	2) 0-200m after	0,024	0,032	1	0,4492	2%
and transfer	3) 200-400m before	0,043	0,013	3	0,0009	4%
before/after	4) 200-400m after	0,084	0,022	4	0,0002	9%
Olympiades	5) > 400m (reference)	0,000	.	.	.	.

In a first step, a Box-Cox specification for hedonic function F(.) was tested. The Box-Cox parameter maximizing likelihood is close to zero. So, the logarithm form (log-log) was retained for the dependant variable, following methodology by Ahamada et al. (2007).

The estimated model is:

$$\ln(p) = X1\beta1 + X2\beta2 + \varepsilon$$

Where p is housing price vector, X1 intrinsic characteristics observation matrix, and X2 extrinsic characteristics observation matrix. ε is an independent and identically distributed error term vector. Estimated coefficient vectors β1 and β2 are given in figure 2.

The logarithm specified model is estimated by the ordinary least squares method. Table 2 presents global tests statistics.

Table 2: global statistics of model 1c

number of observations	161299
R2	0.8781
R2 adjusted	0.8779
degrees of freedom	231
F	5021

Model 1c is globally very significant, and the share of variance is close to 88%. As in the literature, intrinsic variables, in particular the dwelling unit surface area, play a preponderant role on price determination. Transfer year and month also play an important role. As this variable is in the linear form in a logarithmic model, its effect is multiplicative, which allows taking into account the housing market inflation in price formation. Among extrinsic variables, municipality of neighbourhood plays an important role as well, and this variable captures other price determinants that are linked to the neighbourhood and that are not directly observable.

The effects of explanatory variables on housing prices are not surprising, and support the empirical literature (e.g. Cavailhès (2005), Gravel et al. (2002), Özdilek et al. (2002), Cornuel et al. (2003), Bowes & Ihlanfeldt (2001), Boucq (2008)).

Let's interpret the results by variable category.

Intrinsic variables

Housing price increases with the dwelling unit surface area, in a quasi-proportional way (estimated elasticity 0.994±0.001, the significant small gap with one gives a premium to small flats). The number of rooms was not included in the model, as it is strongly correlated with surface area (linear correlation coefficient 0.86), and the most significant variable of the two was retained. However, another variable, built from the previous two, was added: average surface by room, not too much correlated with surface area (linear correlation coefficient 0.23). Marchand & Skhiri (1995) also had a similar specification by retaining the number of rooms and the surface area per room. In the retained model, this variable plays a significant and negative role on the dwelling price determination. Thus, everything else being equal, in particular surface area, housing price decreases with average surface area per room, which means that it increases with the number of rooms, for a given surface area.

Housing price decreases with remoter building period. As compared with dwellings with missing building period, the variation rate induced by a building before 1980 is negative but small (-4% before 1969, -2% for 1970-1980); it is positive and small for period 1981-1991 (+1.5%), and then increases rather strongly for period 1992-2000 (+9.5%) and very strongly for period after 2001 (+27%).

These results are consistent with those by Cavailhès (2005), who estimates a hedonic model for rents in 1996, whole of France, Paris, and each urban area size. In Paris, the highest rents are obtained for the building period after 1989, followed by 1982-1989. In their model, Marchand & Skhiri (1995) introduce building age, in a continuous form, by means of a quadratic function. They get a negative parameter for building age and a positive one for squared building age: the negative effect of building age is decreasing, which is consistent with our results.

The effect of a lift on flat prices varies according to the floor level. So the floor variable was crossed with the dummy lift for flats up to 6th floor. Beyond, the number of dwellings without lift is too small to get robust results. Lift is systematically valued (figure 3) and prices increase with floor level up to the fifth floor without lift, and up to sixth floor with a lift. Then price decreases with floor level, particularly for flats located on the 10th floor or above.

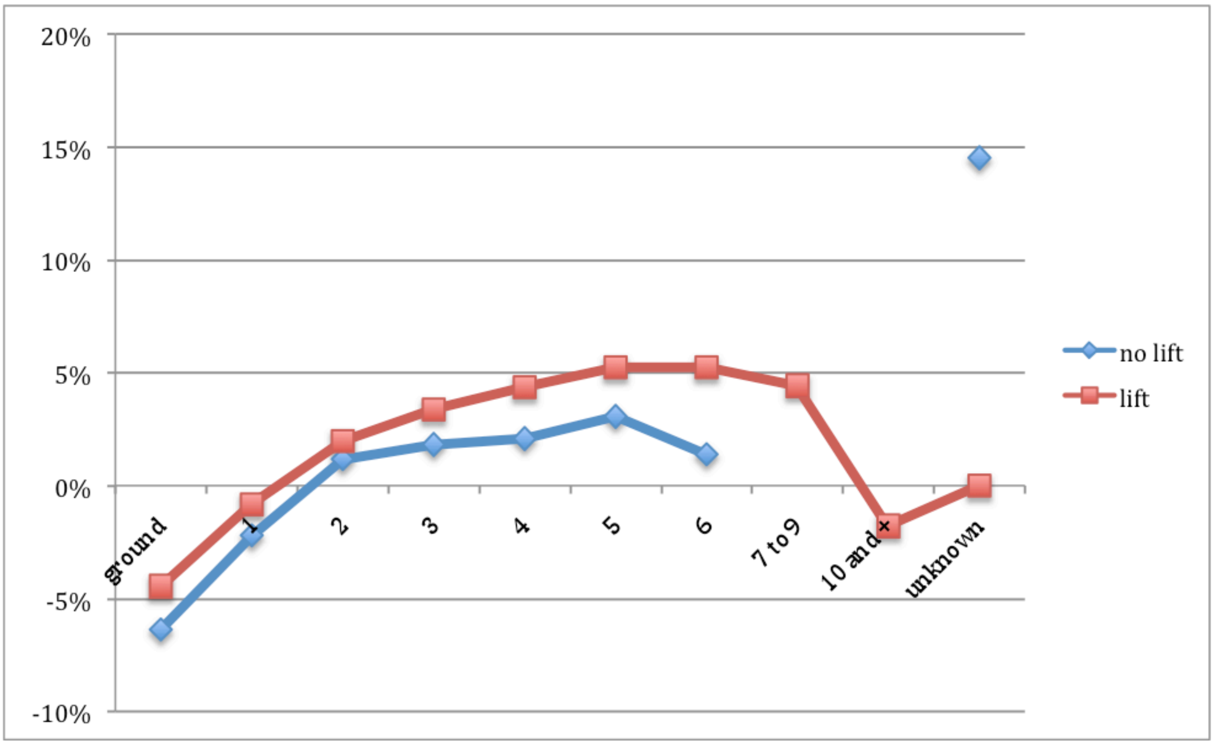

Figure 3: percentage change according to floor level and lift (model 1c, reference: with lift, floor unknown)

A last, the dwelling price increases with the number of garages: compared to dwellings with two garages or more, the variation rate induced by the lack of garage is -16,5%, and -6% for dwellings with only one garage.

Variables relative to transfer dates

Figure 4 represents the variation rate induced by transfer month and year, compared with December 2008. Price is all the higher as transaction is more recent, but for the last three months of 2008 when a slight decrease is observed. The variation rate increases rather steadily between January 2002 and July 2008, from -47% to +3,8%. Then follow three plateau months, then a decrease.

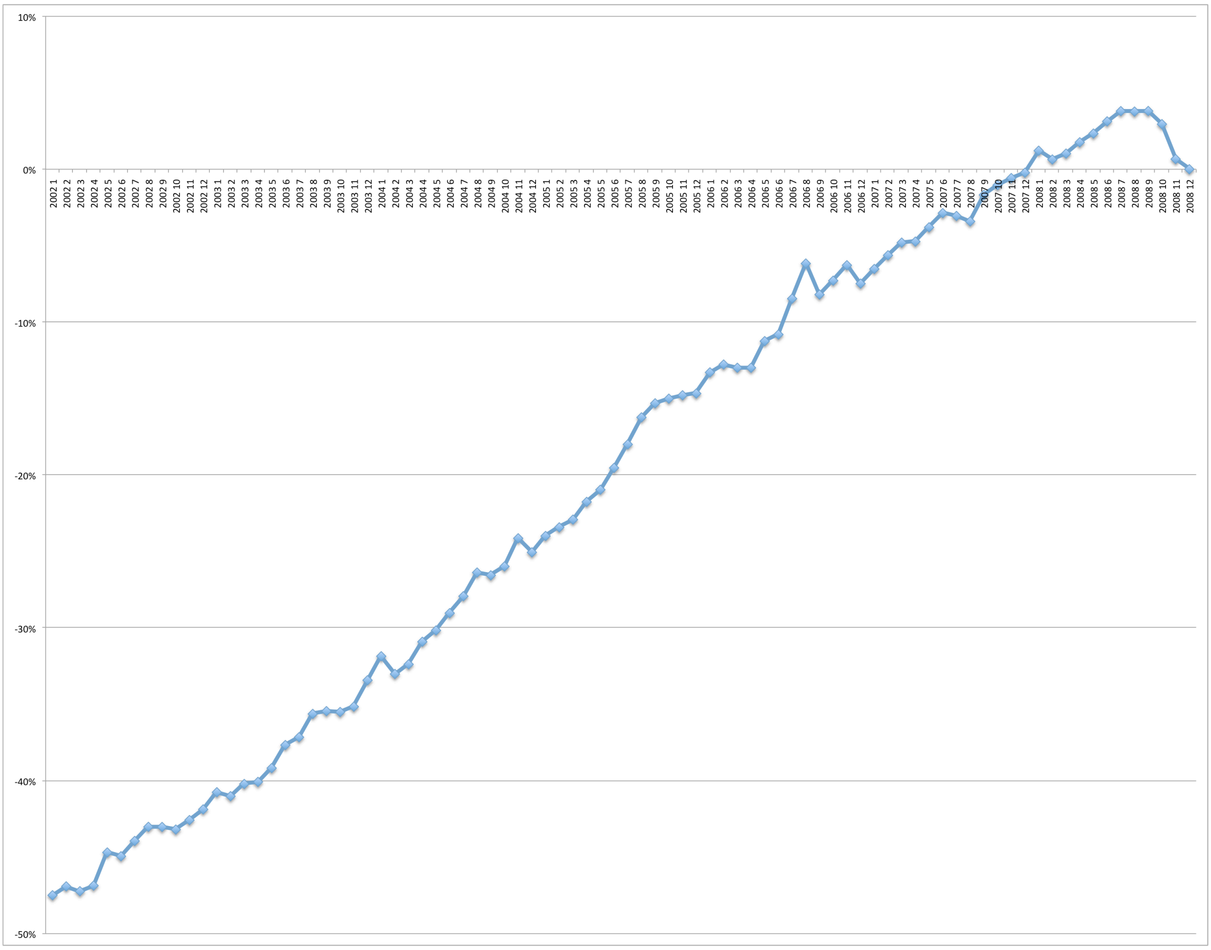

Figure 4: variation rate induced by transfer month and year (model 1c, reference: December 2008)

The dwelling price also varies according to the previous transfer year, but with a weaker range than that induced by the current transfer year. Until 2001, the more recent the previous transfer is, the highest the price is. The trend is reversed from 2002: price is all the lowest as previous transfer is recent, but for a small peak in 2005.

Extrinsic variables

Neighbourhood (in Paris) or municipality plays an important role in real estate price determination. Variation rates induced by the sold unit geographical location strongly vary from one neighbourhood or one municipality to another: rates range from 0% for reference Vitry-sur-Seine to 300%. Paris is systematically more valued than other municipalities, and in Paris some neighbourhoods are more valued than others, in particular neighbourhood Saint-Germain-l'Auxerrois (1st neighbourhood in 1st *arrondissement*), neighbourhood Saint-Merri (1st neighbourhood in 4th *arrondissement*), neighbourhood Notre-Dame (4th neighbourhood in 4th *arrondissement*), and neighbourhood Saint-Germain-des-Prés (4th neighbourhood in 6th *arrondissement*), with a variation rate above 200%.

As in Glachant et al. (2008), street type also impacts prices, but for more robustness some items with small sample size and similar price effects were grouped together. Among street types with large sample size, avenues, which represent 16% of transactions, are the most valued. Boulevards, with 7% of transactions, are the less valued, in particular *boulevard des Maréchaux* (8% of addresses are located on a boulevard).

As far as the land use variables are concerned: real estate prices are higher for properties located in a single family housing or multi family low rise row housing polygon, and lower for those located in a multi family high rise detached housing one. Moreover, housing price increases with proximity to some green space: woods and forests, gardens and parks, and habitat gardens. Price also increase with proximity to some local public facilities such as hospitals, higher education institutions and great cultural facilities, which confirms the local public goods capitalization hypothesis by Tiebout (1956). Reversely, price increases with the remoteness to cemeteries, sheltered sport facilities, ZAC urban development zone and all shopping facilities. This last point can look surprising, but it was already present in Boucq (2008) and could be explained by the fact that shopping facilities are often located in undesirable or unfavoured areas.

Proximity in a 200 meters radius to Olympiades metro station has no effect on dwelling prices before or after the station opening in end June 2007. On the contrary, in a 200-400 meters ring around the station, housing price was significantly higher before station opening (by some 4,5%), and this price difference doubled after the station opening. But the before/after difference is not significant at the 95% threshold.

As far as the IRIS population zone characteristics are concerned, those with a high proportion of high social category (retailers, craftsmen, or business manager), higher education degrees, unemployed, persons aged over 60, are more valued. Reversely, zones with a high share of foreigners, or workers, are less valued.

Finally, housing price is higher in blocks with natural space.

4.2. Results of model 2 taking into account tramway T3 with distance

When distance to the T3 tramway is introduced in the preceding model, the distance to the line is more significant than that to the nearest T3 station and is retained. As the effect of the distance on prices is not continuous, distance is introduced as a class variable. The intervals must be short enough for accuracy, but not too much out of sample size concerns. Distance is oriented by making the distinction of which side of the line the dwelling unit is located. As this oriented distance to the T3 line is highly correlated to the distance to the centre of Paris, which strongly impact prices within each neighbourhood, the distance to the centre of Paris is also introduced in the model (the best centre used is the one with the most significant effect among several tested: gare St Lazare). The oriented distance to the T3 line is then crossed with the transaction date dummy before/after T3 operation.

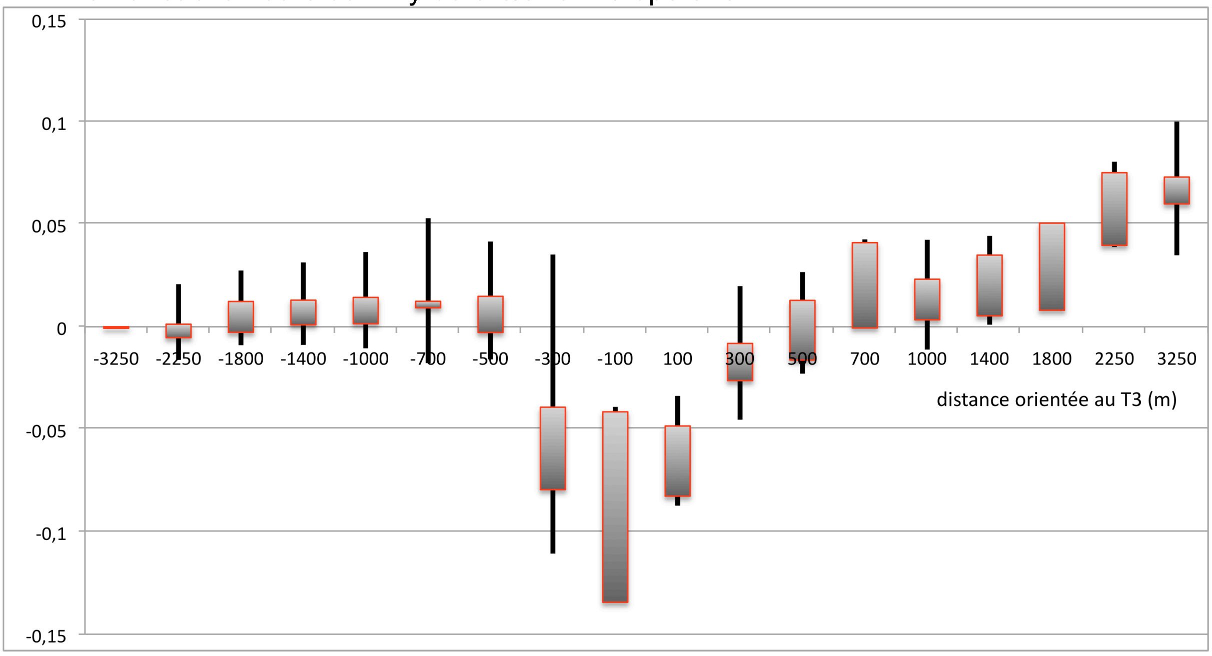

Figure 5: confidence bars at 95% level of parameters of oriented distance classes to the T3 line, before and after operation (model 2.3c, reference: over 2500 metres South)
Figure 5 reads as follows: the confidence bar before operation is the black bar emerging at the bottom of the rectangle; the confidence bar after operation is the black bar emerging at the top of the rectangle; if the rectangle is white, the after bar is significantly above the before bar; if the rectangle is black, both bars overlap in the rectangle.

The parameters of oriented distance classes are slightly higher after operation as compared to before operation for nearly all distance classes, but that below 200 meters South of the line. Apart for this class, the gap is higher in the South. However, if the model error margin is taken into account, no gap is significant at the 95% threshold (figure 5).

4.3. Results of model 3 taking into account tramway T3 accessibility gains

Accessibility to jobs (in logarithm) is introduced in the model, as well as accessibility gains induced by T3 operation (also in logarithm), crossed with transaction year to take into account anticipation or learning effects. Moreover, distance to T3 is introduced in four classes (less than 200 metres and 200 to 400 metres crossed with North and South), which are also crossed with the dummy transaction before/after T3 operation. Accessibility gains get significant negative but small effect only in 2002 and 2005 (figure 6).

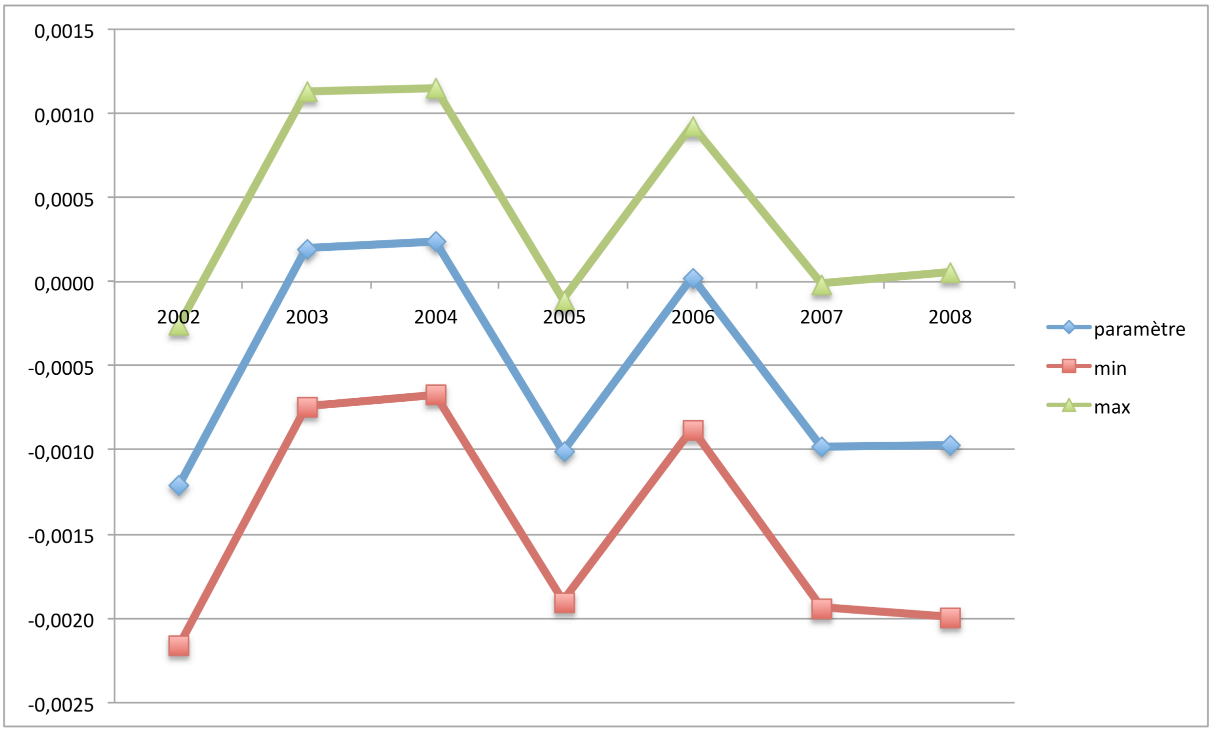

Figure 6: elasticity of dwelling prices to T3 accessibility gains, according to transaction year, and confidence interval at the 95% level.

4.4. Estimation of real estate gains

A price increase by 5% was observed in the 200 to 400 metres strip south of the T3 line after its operation began, and by a lower rate beyond, but this increase is not significantly different from zero. On the contrary, a weak significant negative effect of the T3 accessibility gain was detected in 2002, 2005 and 2007, but it is difficult to attribute it to the T3 with certainty.

Thus, it is not possible to compute real estate gains or losses brought by the T3 that would be statistically significant and reliable as regards their causality. However, the most comprehensive and accurately located data were used for all transactions passed in a 4000 meters radius from the T3 from 2002 to 2008; no better data could have been used. It can be concluded that it is not possible to detect any effect of the operation of the T3 tramway on the dwelling values.

5. CONCLUSIONS/IMPLICATIONS

At the end of this study, three main conclusions can be cleared.

First, from a methodological point of view, the study implemented state of the art data and statistical methods. Methodological data weaknesses, often pointed out in the literature, were corrected and cannot be used to explain inaccurate or uncertain outcomes, but for one variable (the public transport accessibility gain to jobs) that was computed with a complex but approximate manner due to a missing piece of data. Hedonic modelling is a powerful statistical method, but must be handled with rigour by skilled econometrists. It consisted in testing some fifteen explanatory models in a log-log functional form by incrementally introducing regressors and avoiding statistical biases from spatial autocorrelation and multicolinearity. Some fifty variables, not counting crossed variables, were taken into account. They can be classified into four categories: intrinsic variables, extrinsic non-transport variables, transfer date variables, and accessibility variables.

Hedonic modelling is essential to quantify the specific effects of a new infrastructure on real estate prices, and its use gets a consensus in the scientific community. However, it is important to beforehand carry out a descriptive space-time and cartographic descriptive analysis of geolocated data, which is not always done in such studies, and to pass in parallel a qualitative survey to real estate agents who detain a thorough knowledge of the local context and of the demand evolution before/after infrastructure operation. Thus, descriptive analysis, econometric analysis and qualitative analysis are additional approaches.

Then, from the point of view of the study statistical results, the retained econometric models are very significant, with some 88% of variance explained. They evidence the main determinants: dwelling surface area, economic trend and neighbourhood. They also set the role of many other intrinsic and extrinsic characteristics of the sold unit. The share of intrinsic variables amounts to about three quarters of the price. These results are robust and parameters vary little if the model specifications are changed.

As far as transport variables are concerned, including the distance to the T3 tramway route, models clearly show depreciation next to the route (some 5% less than 200 metres North et 400 metres South). But the existence of this depreciation does not mean that the cause is the T3, given the historical image of the area. Besides, the observed ceteris paribus price evolutions after the T3 operation in different stripes along the route are not significant, though they are positive from 200 meters South of the line (+5% 200 to 400 metres, +3% 600 to 800 metres), in spite of the real estate crisis that struck more suburban areas than Paris.

As regards the T3 induced accessibility gain, it looks correlated with a weak and significant loss in 2002, 2005 and 2007, or after operation compared with before operation, in the order of magnitude of one thousandth of the value of the concerned dwellings. But it is unlikely that those losses be due to the anticipation of accessibility variation brought by the tramway, or to a relative disappointment about its quality of service after its operation. Other effects may have been captured by this variable, such as the hindrance from the works before the tramway operation, or the decrease in road traffic fluidity during the works and after operation. Anyway, the tramway time gain compared with the previous PC1 bus service is low (less than 4 minutes from one end to another), and it is consistent with other studies selected from the literature not to observe in this case any sensitive effect on prices. Finally, the outcome is that no significant effect of the T3 tramway operation on real estate prices was proven.

Nevertheless, it could have been expected that the environment and landscape improvement would have brought a gain in the vicinity of the line. But this was not observed in 2007 and 2008, two years only after the T3 began operation. Maybe it is due to a difficult real estate situation, and the following years may show an increase in the area attractiveness. But a new evaluation will be needed to know it.

Finally, concerning the general problematic of the impact of a new infrastructure on residential real estate prices, the synthesis of five studies conducted in Île-de-France since 2006 can now forge an opinion answering the recurrent question of the real estate gain induced by public transport. Thus, eight factors were found intervening to change the effects of a new infrastructure on residential real estate prices:

1. New infrastructure type: heavy (metro, RER), light (tramway, bus in dedicated lane);
2. Existence of previous transport supply and level of service of this previous supply;
3. Distances from dwelling to stops (station) and to line;
4. Distinction flat / house (especially on the periphery);
5. Local context (area image and history, social typology, density, dynamism);
6. Lay-out refurbishing during infrastructure construction;
7. General real estate situation trend;
8. Period taken into account before (anticipation) and after (learning effect) operation (short, medium or long term time effects).

The existence of a likely more or less significant real estate gain depends on the crossing of these eight factors. For example, in the case of the T3 as well as the one of the T1 where accessibility gains are low compared with previous situation, the serviced area not thriving and suffering a downgraded image, we proved that there was no significant impact on real estate price two years on, particularly as it occurred during a real estate crisis period. The lay-out refurbishing was not sufficient to change the boulevards image, and many more years will be needed to observe an urban renewal in the area next to the T3. Conversely, at the same time, the extension of the M14 metro line to Olympiades station generated dwelling price increases near the station as compared with not serviced control areas as an anticipation and just after the station operation began. In the case of the T2 that serves a corridor with no previous relevant service, even without any particular urban renewal program, there was a real accessibility gain that on its own induced real estate gains in thriving municipalities. In the case of Green/quiet neighbourhoods in Paris, it is the environmental gain that triggered slight real estate gains, independently from any accessibility gain or loss dimension. But as in the case of the vicinity of the RER E stations, discrepancies on these gains are large, since each neighbourhood constitutes a specific real estate market the evolution of which strongly depends on the local context.

However, three invariants are evidenced in those five studies: if real estate gains show up, they differ according to dwelling type (flat/house), they are not induced in the immediate proximity of stations, but beyond 200 metres on average whatever the kind of infrastructure, and it is higher for a heavy mode than for a light mode.

This study finally supports the idea that the recovery of real estate gains cannot be applied in an authoritarian and uniform manner in a pre-designated area around all public transport project stations. All landowner near a new station would be entitled to legally dispute the payment of an additional fixed tax. He/she just needs to request the government to prove that his/her property actually benefited from real estate gains, when scientific studies do not converge on the topic and our conclusions discuss the modulation of the real estate gains according to the aforementioned eight factors. Indeed, the Grand Paris public transport network changed its mind about it. At the very beginning (2008), it forecast to fund itself in significant proportions and in the long run through land and real estate valuation in a 1500 metres radius around new stations. Finally, after the public debate in January 2011, this potential financial source just disappeared from the project funding scheme. Surely, it was considered as too random and uncertain, thus not likely to be secured. The recognition of scientific studies in this field finally won over system mindset.

At last, it seems necessary to set the means for a genuine suited and designed data collection process of before/after situations, over several years, each time a new transport infrastructure is built, for example by creating specific observatories, if new infrastructure effects on real estate prices are to be actually measured, by making the distinction between pure accessibility gains benefits, and those induced by the urban refurbishing provided with the line creation.

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