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Assessment of the real estate benefits due to accessibility gains brought by a transport project: the impacts of a light rail infrastructure improvement in the Hauts-de-Seine department

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Abstract

This paper estimates the real estate benefits due to accessibility gains brought by a light rail infrastructure (the T2 tramway, in the Hauts-de-Seine). According to Urban Economics, the accessibility improvements resulting from a transport project will influence the residential location choices of households, and eventually the land rents at equilibrium will include the valuation of accessibility gains made by these households.

Apart from accessibility, housing choice also depends on other characteristics: internal characteristics and external (environmental) characteristics. To take into account all these determinants, we have estimated a hedonic price function of residential properties econometrically.

The data used are sales of residential dwellings in the Hauts-de-Seine department, population census and other sources, from 1993 to 2004, to take into account anticipation and learning effects.

The hedonic price function obtained allows us to measure implicit or "hedonic" prices of dwellings with a given group of characteristics, and isolates the pure effect of each characteristic on the price of a dwelling.

The results show that the T2 tramway accessibility improvements are capitalized into the housing prices. To measure this capitalization into real estate, we calculate the prices of dwellings with and without these accessibility gains. For the whole department, we estimate a capitalization around 3%.

Keywords: Accessibility; Hedonic function; Real estate values; Transport infrastructure.

1. Introduction

The purpose of this paper is to analyse the role of transport infrastructures in the formation of residential property values in urban areas. It focuses on the impact of

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accessibility gains on equilibrium prices[1], because we want to measure the added value of accessibility gains produced by a new transport infrastructure on residential property values. We have taken the case of the T2 tramway, opened in the Hauts-de-Seine department (France) in September 1997. This line was initially a railway[2], closed in 1993. Its layout cuts through wealthy neighbourhoods along the river Seine. It connects two major centres (La Défense in the North, and Issy-les-Moulineaux in the South). There was no significant additional urban quality improvement associated with its conversion, but this infrastructure noticeably improved accessibility in the department.

So we measure the effects of the tramway only by accessibility gains.

First, theoretical bases in urban economics and hedonic modelling to assess real estate benefits will be reminded. Then a description of the data used for this empirical work will be given. Then the construction of the accessibility indicators which capture the effect of the infrastructure will be presented and their values before and after the infrastructure improvement will be shown. Similarly, the changes in the explained variable housing prices will be put on maps. Finally, the results of the model will be displayed and discussed.

2. Theoretical bases

Our theoretical bases are urban economics and hedonic price theory.

Urban economics explains the functioning of a city by the behaviour of households relative to their choice of residential location. In the basic model (Alonso, 1964), the city is monocentric, all the jobs are located in the business centre, and the choice of a residential location by an economic agent results from a trade-off between expenditure for land area and transport costs to move to the centre, under budget constraints. This model was largely extended[3]: other variables may influence the choice of a location (amenities, neighbourhood externalities …), and the cities may be polycentric (so we use the concept of accessibility instead of transport costs to the centre).

According to urban economics, accessibility improvements resulting from a transport project will influence the residential location choices of households. Hence the demand for land occupation will be affected and land rents at equilibrium will include the valuation of accessibility gains made by these households. In this case we observe a "capitalization phenomenon".

Accessibility is not the only factor for the selection of a home: it is a heterogeneous good, with internal characteristics (surface area, equipment, type of dwelling …) and external characteristics (environment quality, school proximity ...).

To study the formation of housing prices, we will use hedonic price analysis to take all the characteristics into account. According to Sheppard (1999), this theory was initiated by Court (1939) and Griliches (1961), and popularized by Lancaster (1966) and Rosen (1974). It supposes that there are "implicit" competitive markets for each characteristic of heterogeneous goods, and the price of a characteristic is determined by the comparison of supply with demand for this characteristic in its implicit market. Therefore, the housing price is a function of "implicit" prices of the goods which characterize it.

[1] But not on the effects on supply and demand taken separately.
[2] Thus the space for the tracks already existed.
[3] See for example Fujita (1989), Papageorgiou (1990) or Henderson (1985).

Rosen recommends selecting the best specification of the hedonic function in an empirical way. Amongst the most common functional forms are the linear model and the logarithmic model (see for instance Follain and Jimenez (1985)). Cavailhès (2005) questions the constancy of the hedonic prices of residence characteristics, according to quantities, obtained with a linear model, "in particular because of the fixed costs of production (costs of construction) and of transaction, and because of indivisibilities for the consumer". On the contrary, the logarithmic form implies hedonic prices depending on quantities. We can also use the Box-Cox specification, generally considered as a more flexible functional form, adapted to estimate hedonic models, but its estimate is more complex than that of the models presented previously. In its simplest form (Box and Cox, 1964), we transform the dependent variable y in the following way: $\frac{y^{\lambda}-1}{\lambda}$. So the Box-Cox transformation allows us to estimate several types of models, while varying λ from 0 to 1. The parameter λ is chosen by the maximum likelihood method, and the form will be linear when $\lambda=1$, and logarithmic when $\lambda=0$.

Therefore, the hedonic estimate will enable us to have a function that will be used to calculate the price of the heterogeneous good, when modifying the quantities of the various characteristics which define it. Thus, if accessibility plays a role in the formation of residential property values in our study zone, we will be able to measure the effects on dwelling prices of the accessibility gains induced by the installation of the T2 tramway. To do this, we compare the dwelling prices observed with the tramway with the prices which we would have observed without the tramway, and these effects will be isolated from the influence of other factors[4].

3. The study perimeter and the data used

The perimeter of the study was defined as being the whole of the department of the Hauts-de-Seine, in the west of Paris (see Figure 1).

[4] We only use the first step of the hedonic method of Rosen (1974), because we only measure the impact of better accessibility on equilibrium prices. We don't explain how these effects come about, so we don't use the second step of this method to identify demand effects and supply effects (moreover, we don't have the necessary data to do this). For instance, Marchand and Skhiri (1995) and Kazmierczak-Cousin (1999) use the second step of this method.

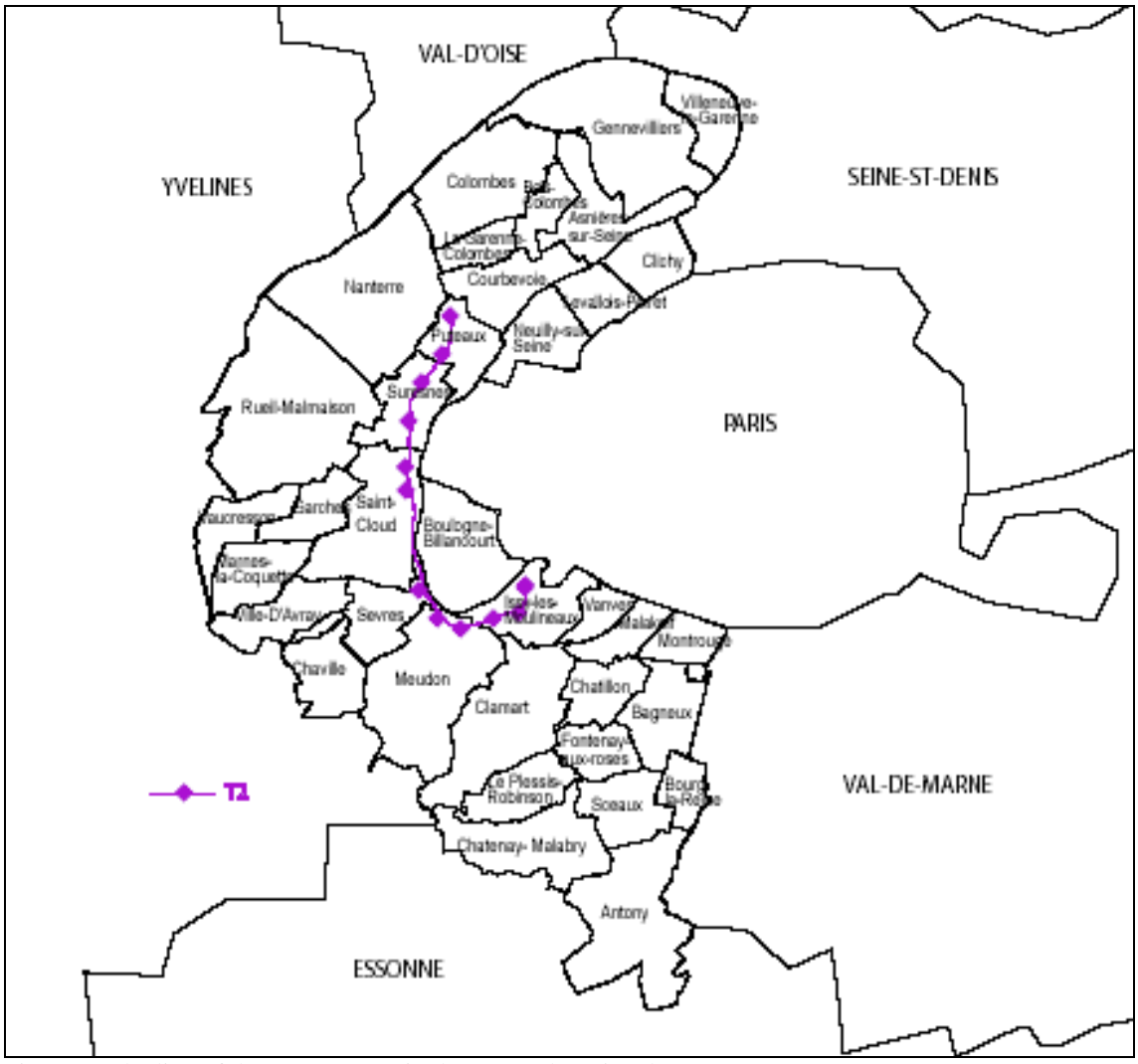

Figure 1: The line of the T2 tramway in the Hauts-de-Seine department.
Data Source: RATP

We chose a wide temporal dimension, from 1993 to 2004, in order to take into account the phenomena of anticipation of economic agents and learning effects.

The data used for the hedonic regression are sales of residential dwellings in the Hauts-de-Seine department, which include the prices and some internal characteristics of the dwellings ("CD-BIEN" data, provided by the DREIF).

We restricted ourselves to transactions relating to apartments, which account for 90% of the residences in the department, given the small number of transactions relating to single family houses and the low quality of the empirical results obtained with the latter. Here we consider a polycentric urban area, which is representative of our study zone. The households move towards all the centres, and a location is characterized by the whole of the potential destinations, and more precisely by the generalized total cost of transportation towards all these destinations. Therefore we built accessibility indicators, using matrices of generalized public transport time, from station to station, for the years 1996, 1997 and 2001[5], provided by RATP[6]. We deduced generalized public transport

[5] We do not have the direct monetary costs, but in an urban area they are negligible compared to non-monetary costs; moreover, fares are rather flat and the season ticket holding rate is high.
[6] Régie Autonome des Transports Parisiens (this is a public transportation company).

time from IRIS to IRIS[7], directly used in calculations of accessibilities. We have also built these indicators with road transport times given by the DREIF[8].

To these data we have added neighbourhood characteristics from the Population Census and other sources that contain external characteristics, located at the geographical level of the IRIS2000. So, some characteristics relating to dwelling comfort are only available at the neighbourhood level, and not at the transaction level: this should restrict the accuracy of housing price estimation, insofar as comfort plays a role in their formation, but this is presumably unrelated to the influence of accessibility on housing prices, which is our concern, and should not bias the estimation of real estate benefits derived from accessibility gains.

We also used the "SIRENE" data of INSEE9, acquired by INRETS10 and which contains information on employment and firms.

4. Construction of accessibility indicators

It is essential to build reliable indicators of accessibility, since they will enable us to make conclusions about the connection between modifications of these following T2, and the evolution of real estate prices. These indicators were calculated on the geographical level of the IRIS2000, and represent accessibility to all the IRIS of the Hauts-de-Seine.

We chose potential accessibility indicators for population, jobs and establishments. These indicators are based on spatial interaction models (see for example Schürmann *et al.* (1997) or Geurs and van Eck (2001)).

The formula is: $A_i=\sum_k O_k f(time_{ik})$ where

- i represents the IRIS taken into account, and k the other IRISs in the department
- $time_{ik}$ is the generalized transport time between the centre of IRIS i and the centre of IRIS k, expressed in minutes
- O_k represents the volume of population, jobs or establishments in the IRIS of the destination k
- $f(time_{ik})$ denotes the dissuasion function, decreasing in time, which we shall assume to follow a reciprocal form $f(time_{ik})=1/time_{ik}^{\beta}$ or a negative exponential form $f(time_{ik})=e^{(-\beta time_{ik})}$[11], β being a sensitivity parameter to transport time, between 0 and 1, and reducing the effect of travel time increase or decrease.

In order to choose the functional form and the β parameter[12], we have introduced the various accessibilities in a simple hedonic price model[13], and we kept the form and the β parameter giving the best explanatory capacity.

[7] The IRIS or IRIS2000 is an administrative segmentation in zones of 2000 inhabitants.
[8] Direction Régionale de l'Equipement en Ile-de-France
[9] Institut National de la Statistique et des Études Économiques
[10] Institut National de Recherche sur les Transports et leur Sécurité
[11] There are the two functional forms most usually used in studies (the inverse form gives Stewart-Warntz's measure (1958) and the exponential form gives Hansen's measure (1959) (Pooler (1995)).
[12] Normally the sensibility parameter is estimated empirically using a spatial interaction model, such as for example in Calzada and Le Blanc (2005). In this case, we must know the emissions and receptions (this is not our case).
[13]The simple model refers here to the fact that we only include the housing characteristics and the accessibility level of the zone in which it is located.

For accessibility by public transport, it is the negative exponential function with a low value for β, i.e. 0.01, whatever the opportunities: so in collective transportation, people are not very sensitive to a small variation in time. This value is close to that chosen by Spiekermann and Wegener (2007), 0.005, for accessibility by public transport.

Accessibility by road is not significant in the hedonic price model.

5. Description of study zone accessibility

The accessibility to jobs chart (Figure 2) shows the absolute levels of accessibility to jobs by public transport, in the "Hauts-de-Seine" department, before the opening of the T2 tramway (in 1996)[14].

The most accessible zones are located in the north around La Défense (Neuilly, Levallois, Asnières, Bois-Colombes, La Garenne-Colombes) and around Issy-les-Moulineaux (Boulogne, Vanves, and in the south of Issy, up to Châtenay-Malabry), as well as in the north of the department, where the number of jobs is quite high.

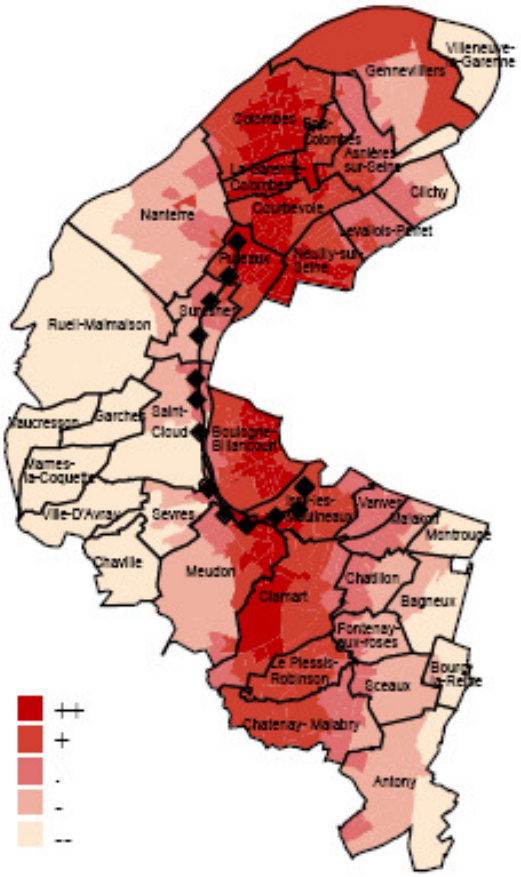

Figure 2: Accessibility to jobs, in 1996.
Data Sources: RATP and SIRENE

[14] Accessibilities to other opportunities are strongly correlated with accessibility to jobs, and the cartographic representations are very similar.

Figure 3 represents the accessibility gains due to the T2 tramway. These gains are supposed to be equal to accessibility gains between 1996 and 1997. Indeed, there were no important modifications of the public transport grid system between these two years, apart from the T2 tramway operation[15].

The most significant gains are located along the tramway line. There is a diffusion from Issy-les-Moulineaux to the south-east until Bagneux, to the south-west (Sèvres and Chaville), as well as to the north/north-west.

Thus the T2 tramway facilitated access to areas which were not very accessible.

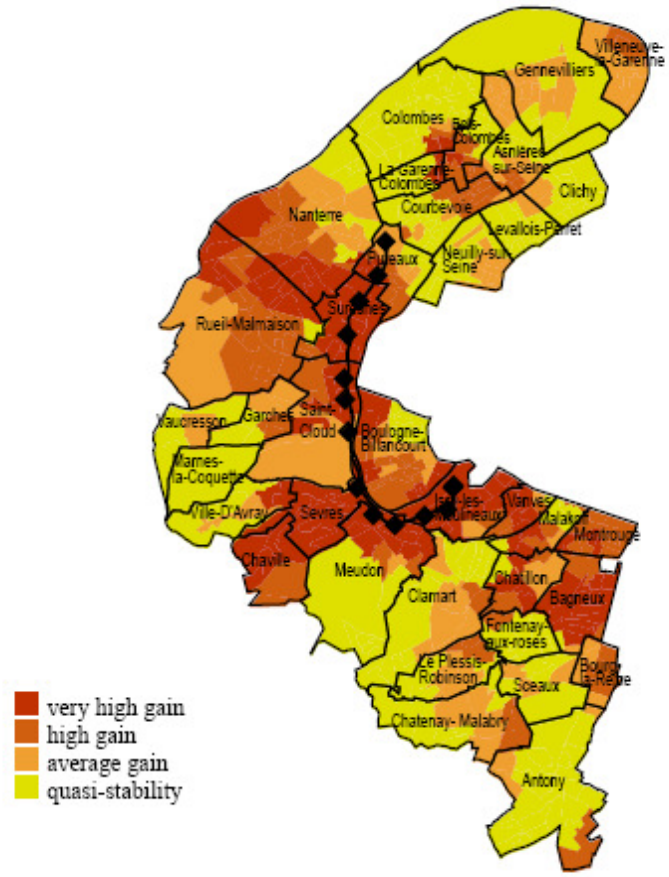

Figure 3: Gains of accessibility to jobs, by public transport, between 1996 and 1997.
Data Sources: RATP and SIRENE

6. Transactions in the Hauts-de-Seine department

Figure 4 shows the number of transactions relative to multi family residences in the department per year. This number increases from 1993 to 1999, with a decrease in 2000, and then another increase to 2004.

[15] That is why we observe small losses of accessibilities, considered as equal to 1 in the econometric regressions.

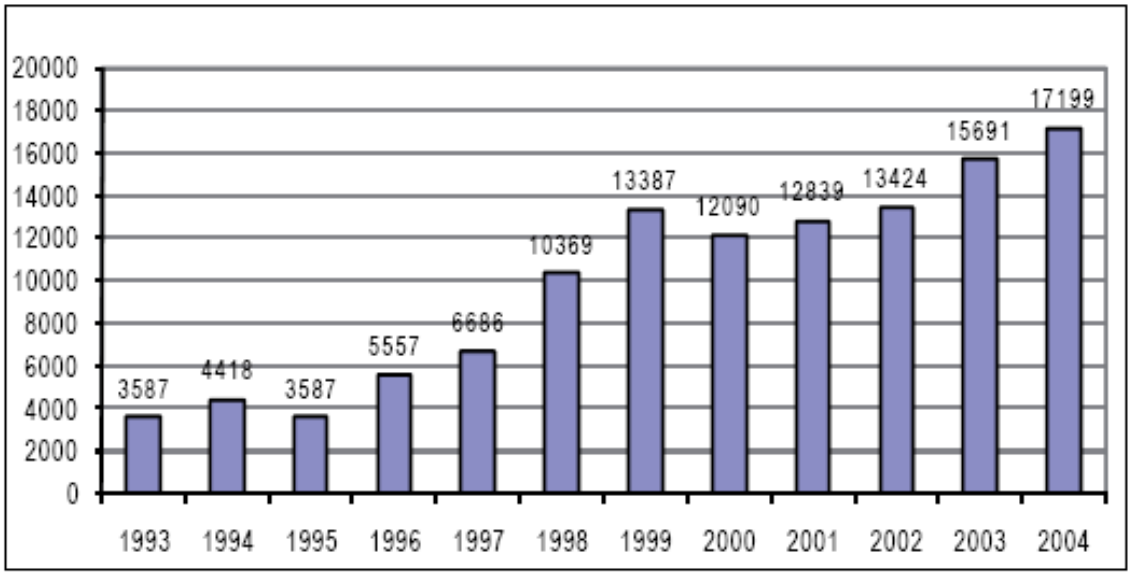

Figure 4: Number of transactions of collective residences, per year, over the period 1993-2004.
Data Source: CD-BIEN

Figure 5 represents the number of transactions between 1993 and 2004, and the average price per square meter. The transactions are especially numerous along the Paris border and in the north east of the department. Prices are especially high in the centre of the department.

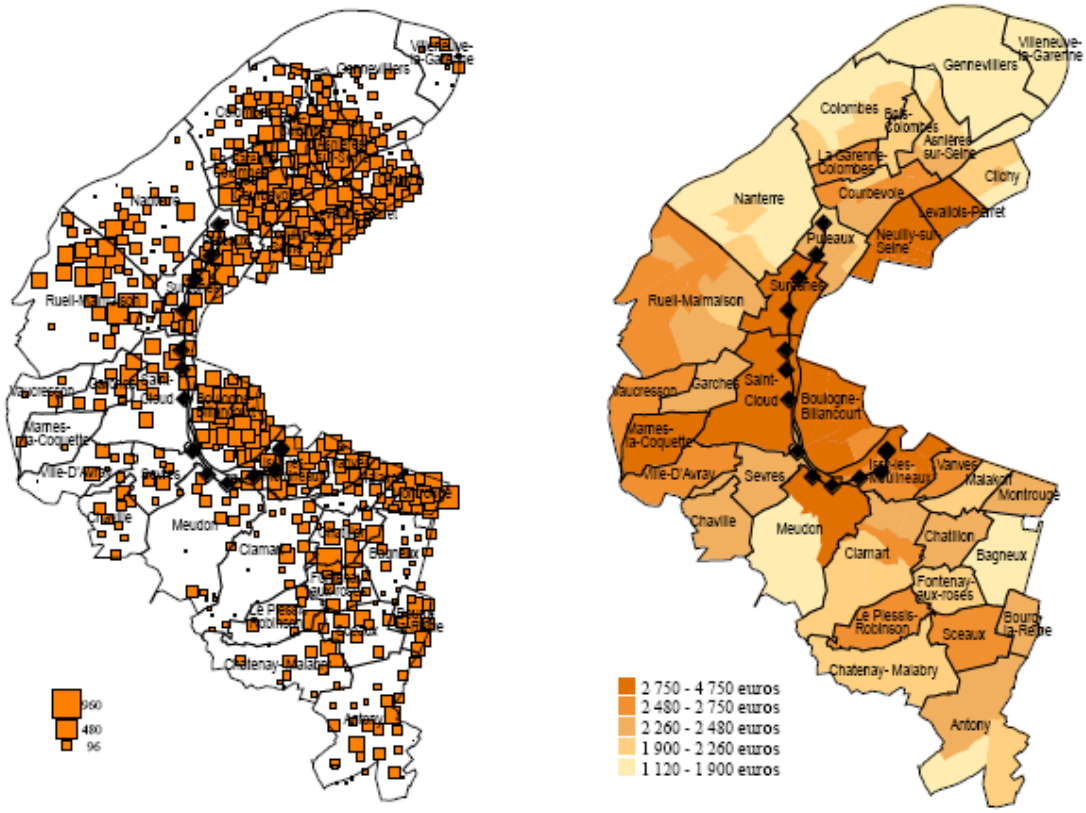

Figure 5: Number of transactions of collective residences and average price per square meter, over the period 1993-2004
Data Source: CD-BIEN

Finally the "average price chart" shows the trend of the average price per square meter between 1993 and 2004 (Figure 6).

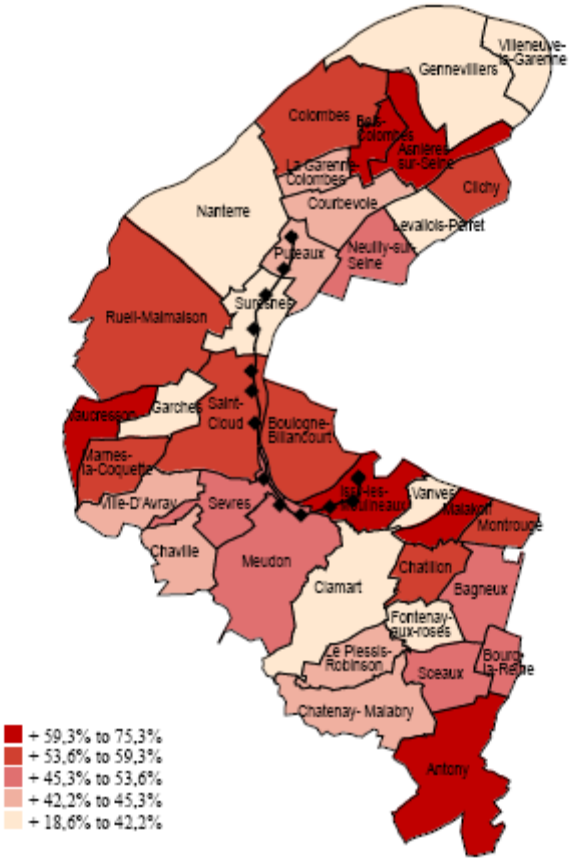

Figure 6: Evolution of the average price per square meter between 1993 and 2004.
Data Source: CD-BIEN

At first sight, it seems that there is no impact due to the T2 tramway, but we will see later that the results of the econometric analysis are different.

7. Results

We have econometrically estimated a hedonic price function for the collective residences, taking into account all the determinants of housing choice. The data used are sales of apartments in the Hauts-de-Seine department, which contain prices and internal characteristics of the housing, as well as the population census and other sources for the external features.

The chosen variables have to respect the parsimony principle, in order to avoid problems of multi-colinearity, but they have to be sufficiently numerous in order to avoid estimate biases that would occur if important variables were omitted. Cheshire and Sheppard (1995), for instance, insist on the importance of neighbourhood amenities variables.

In the first round, we limited ourselves to transactions carried out in 1996 and 1997, in order to measure the immediate effects of accessibility gains due to the T2 tramway on transaction values in 1997. Indeed, if the land and property markets worked

perfectly, there would be an immediate price adjustment. But the highlighted profits were negligible.

We then carried out the analysis over a longer period, from 1993 to 2004, in order to identify possible anticipation or persistence impacts, like McDonald and Osuji (1995), and Deymier (2005). Indeed, the buyers could have anticipated the implementation of the T2 tramway and incorporated the value of accessibility gains into prices before 1997. Reciprocally, the value of the accessibility gains may have impacted prices only after 1997, once the tramway was in place.

We tested a Box-Cox specification for the dependent variable in the hedonic regression for the apartments. We obtained a λ equal to 0.099. This parameter being close to zero, we chose the dependent variable in the logarithm form, so that the interpretation of the coefficients would be easier. We chose the best possible specifications for the explanatory variables: they are sometimes expressed in level or in logarithm, are introduced in polynomial form or are transformed into qualitative variables.

The variables chosen to explain the logarithm of the price of collective housing are:

- for the intrinsic features of the housing: building age, surface area and the surface area per room;
- transaction year, in order to take into account the evolution of the housing market;
- the neighbourhood characteristics of the IRIS: share of housing by comfort level, share of households by size and by socio-professional category of the head of the household, the smallest distance to a shopping centre;
- the taxation level of the municipality, considered in three different ways:
  - in model 1: we elaborate a synthetic qualitative variable with 5 modalities, mixing tax rates on dwellings and on the (built up) land value;
  - in model 2: we introduce the logarithm of the tax rate on the built up land value;
  - in model 3: we introduce municipality dummy variables; in this case, the local taxation variables cannot be retained, because there is a perfect correlation between the two kinds of variables; introducing these dummies also has some effect on the coefficients of neighbourhood characteristics, as these are linked to the municipality (though defined for a smaller area).
- accessibility to jobs[16], introduced
  - in levels for the year of transaction considered [17]
  - in variation (profit between 1996 and 1997), crossed with transaction year, in order to measure the capitalisation of this gain per transaction year.

In model 3, the accessibility to jobs in level cannot be retained, because there is a strong correlation with the municipality dummies. Indeed, if the accessibility variance is split into two components, between municipalities and within municipalities, the former component represents 88% of the total variance of the accessibility.

The three models are presented in Table 1. They have been estimated using the Ordinary Least Squares method[18], from 91,354 observations.

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[16] We have tested the three potential accessibilities by public transport, but the most significant is the accessibility to jobs; this result is in accordance with the urban economic theory.

[17] For the variable on accessibility by public transport to jobs, we only have the values of 1996, 1997 and 2001. So we consider that the level of accessibility between 1993 and 1995 equals that of 1996, and that the level between 2002 and 2004 equals that of 2001, and we interpolate between 1998 and 2000.

[18] The Hausman test permitted us to detect the presence of endogeneity in the surface area of housing. The best instruments for this variable are the composition of the household or the age of the purchaser. But we don't have these variables. The only variable that we have is the socio-professional category of the purchaser. But this instrument is not satisfying: the R-square of the regression of the housing surface

We have detected the presence of heteroscedasticity using the Gleisjer test, which we could not treat. So we use the White estimators (Greene (2003)) in order to estimate the variance and the t-statistics.

Note that the variables relating to the housing neighbourhood play a small role as compared with the internal housing variables: the model with only the internal housing characteristics explains 72% of the dependent variable inertia, and the model with the internal housing characteristics and the transaction year explains 79%.

The parameters obtained for the internal and external variables are not surprising; they confirm the results already obtained in the empirical literature[19].

The price increases with the age of the building, the total surface area and the surface area per room (evidence of higher quality buildings). The price varies with the year of transaction; we notice a decrease between 1996 and 1999.

The neighbourhood variables are significant too: prices are higher in IRISs where the share of one or two person households is significant, and prices are higher in IRISs where there is a significant share of households of a high social category. The price increases with the distance to a shopping centre (which are located in undesirable areas), and decreases with the level of municipality tax (consistently).

The current accessibility variable for the transaction year has a significant and positive impact on housing prices.

Concerning the effect of the accessibility gains, brought by the tramway between 1996 and 1997 on apartment prices, the results are quite surprising: the modalities of the gain variable, crossed with the transaction years 1993 and 1994, are not significant. In 1995, the effect is even negative. There is therefore no anticipation effect before 1996. Some explanations of this can be put forward. Work before the opening of the line may have generated additional congestion, making road accessibility worse along the corridor. Moreover, the former rail service had been transferred to buses that were caught up in the traffic, leading to a reduced public transport accessibility, even compared with the data used for the model estimation (since these data only considered theoretical bus scheduling). And overall, in 1995, there was a major public transport strike that particularly made accessibility worse as compared with the theoretical data used for modelling.

On the contrary, for transaction years from 1996, there is a positive impact of accessibility gains on prices, which continues until 2003 (the modality corresponding to the year 2004 is no longer significant).

There is therefore a progressive price adjustment over the years after 1996, and more particularly over the 4 years following the implementation of the T2 (the highest coefficients are over the period 1998-2001).

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on the instruments is 3%; and the R-square of the hedonic regression with instrumental variables falls from 86% to 37% for model 1, for example.

[19] See for instance Cavailhès (2005), Gravel *et al.* (2002), Özdilek *et al.* (2002), Cornuel *et al*. (2003).

Table 1: Hedonic regressions on sales of apartments between 1993 and 2004.

		Model 1			*Model 2*			*Model 3*		
VARIABLES		Coeff.	t-stat. (White)	Rate of induced variation	Coeff.	t-stat. (White)	Rate of induced variation	Coeff.	t-stat. (White)	Rate of induced variation
Constant		6.8544	48.67		7.4929	56.53		7.9897	162.71	
INTERNAL CHARACTERISTICS										
Construction year (dummy)	before 1914	-0.4151	-99.02	-33.97%	-0.4163	-99.26	-34.05%	-0.4339	-107.83	-35.20%
	1914 - 1947	-0.4494	-141.37	-36.20%	-0.4496	-141.53	-36.21%	-0.4326	-141.45	-35.12%
	1948 - 1969	-0.4064	-152.27	-33.39%	-0.4063	-152.47	-33.39%	-0.4020	-157.24	-33.10%
	1970 - 1980	-0.3285	-119.92	-28.00%	-0.3302	-120.81	-28.12%	-0.3144	-119.79	-26.98%
	1981 - 1991	-0.2327	-69.24	-20.76%	-0.2343	-69.35	-20.89%	-0.2212	-69.41	-19.84%
	after 1992 (reference)	-	-	-	-	-	-	-	-	-
Logarithm of the surface area		1.0813	537.03		1.0810	537.84		1.0795	561.67	
Logarithm of the surface area per room		0.0353	6.67		0.0305	5.79		0.0292	5.67	
YEAR OF TRANSACTION										
Transaction year (dummy)	1993	-0.3987	-33.03	-32.88%	-0.4215	-35.11	-34.39%	-0.4012	-35.03	-33.05%
	1994	-0.4098	-38.37	-33.62%	-0.4283	-40.18	-34.84%	-0.4186	-42.06	-34.20%
	1995	-0.4608	-41.49	-36.93%	-0.4763	-43.05	-37.89%	-0.4713	-45.45	-37.58%
	1996	-0.5381	-52.59	-41.61%	-0.5377	-52.30	-41.59%	-0.5571	-56.47	-42.71%
	1997	-0.5673	-71.12	-43.29%	-0.5713	-71.64	-43.52%	-0.5856	-78.37	-44.32%
	1998	-0.5731	-79.91	-43.62%	-0.5807	-80.57	-44.05%	-0.5875	-86.25	-44.43%
	1999	-0.5197	-72.92	-40.53%	-0.5269	-73.38	-40.95%	-0.5309	-79.10	-41.19%
	2000	-0.4529	-61.14	-36.42%	-0.4611	-61.82	-36.94%	-0.4527	-65.61	-36.41%
	2001	-0.3934	-54.84	-32.52%	-0.3991	-55.35	-32.91%	-0.3858	-58.18	-32.01%
	2002	-0.2917	-42.69	-25.30%	-0.2951	-43.08	-25.55%	-0.2779	-44.04	-24.26%
	2003	-0.1581	-23.90	-14.62%	-0.1590	-23.97	-14.70%	-0.1481	-24.19	-13.77%
	2004 (reference)	-	-	-	-	-	-	-	-	-
EXTERNAL CHARACTERISTICS										
Distribution of residences in the IRIS according to type of heating	Share of residences with individual central heating	0.4500	10.12		0.3282	7.32		0.5124	10.63	
	Share of residences with collective central heating	0.4130	9.93		0.2858	6.79		0.4025	8.97	
	Share of residences without central heating (reference)	-	-	-	-	-	-	-	-	-

VARIABLES		*Model 1*			*Model 2*			*Model 3*		
		Coeff.	t-stat. (White)	Rate of induced variation	Coeff.	t-stat. (White)	Rate of induced variation	Coeff.	t-stat. (White)	Rate of induced variation
Distribution of households in the IRIS according to size	Share of households of one person (reference)	-	-	-	-	-	-	-	-	-
	Share of households of two persons	-0.4355	-9.72		-0.3890	-8.69		0.1607	3.48	
	Share of households of three or four persons	-0.0075	-25.34		-0.0069	-23.52		-0.0075	-24.63	
	Share of households of more than four persons	-1.3837	-23.59		-1.3234	-22.63		-0.3608	-6.01	
Distribution of households in the IRIS according to the social and economic category of the person of reference	Share of households where the PR[20] is a farmer	-3.7054	-3.62		-3.1506	-3.03		2.6712	2.69	
	Share of households where the PR is independent	1.2958	35.93		1.1557	31.76		0.5411	13.84	
	Share of households where the PR is an executive (reference)	-	-	-	-	-	-	-	-	-
	Share of households where the PR is in an intermediate profession	-1.0604	-42.49		-1.0527	-42.35		-0.3133	-11.97	
	Share of households where the PR is an employee	-0.1732	-8.12		-0.1754	-8.29		-0.2253	-11.14	
	Share of households where the PR is a worker	-1.5499	-75.35		-1.5417	-75.14		-0.7793	-37.35	
	Share of households where the PR is a pensioner	-0.3047	-12.26		-0.3057	-12.39		-0.0595	-2.39	
	Share of households where the PR is without occupation	1.0128	18.55		0.8833	16.12		0.0610	1.10	
Municipality tax level (model 1 only)	very low	0.0247	7.31	2.50%	-	-	-	-	-	-
	low	0.0281	10.38	2.85%	-	-	-	-	-	-
	medium (reference)	-	-	-	-	-	-	-	-	-
	high	-0.0319	-9.21	-3.14%	-	-	-	-	-	-
	very high	-0.0525	-17.39	-5.11%	-	-	-	-	-	-
Logarithm of the tax rate on the built up land value (model 2 only)		-	-	-	-0.1223	-33.23		-	-	-
Municipality dummies (model 3 only)		-	-	-	-	-	-			
Nearest distance from a shopping centre	less than 1 km (reference)	-	-	-	-	-	-	-	-	-
	between 1 km and 1,5 km	0.0210	9.51	2.12%	0.0123	5.68	1.24%	0.0301	12.87	3.06%
	more than 1,5 km	0.0837	20.72	8.73%	0.0579	14.67	5.96%	0.0309	6.71	3.14%
Logarithm of accessibility to jobs for year of transaction		0.1076	10.50		0.0502	5.22		-	-	-
Logarithm of accessibility gains to jobs between 1996 and 1997, crossed with the year of transaction	1993	-0.0005	-0.27		0.0008	0.45		0.0004	0.26	
	1994	-0.0017	-1.12		-0.0005	-0.32		-0.0008	-0.52	
	1995	-0.0061	-3.68		-0.0049	-2.90		-0.0021	-1.36	

[20] Person of reference of the household

VARIABLES		*Model 1* Coeff.	t-stat. (White)	Rate of induced variation	*Model 2* Coeff.	t-stat. (White)	Rate of induced variation	*Model 3* Coeff.	t-stat. (White)	Rate of induced variation
Logarithm of accessibility gains to jobs between 1996 and 1997, crossed with the year of transaction	1996	0.0024	1.69		0.0016	1.11		0.0045	3.22	
	1997	0.0029	2.73		0.0025	2.30		0.0054	5.11	
	1998	0.0061	6.67		0.0059	6.39		0.0063	6.87	
	1999	0.0045	5.13		0.0040	4.53		0.0048	5.55	
	2000	0.0061	6.46		0.0058	6.10		0.0053	5.72	
	2001	0.0065	7.28		0.0068	7.60		0.0058	6.58	
	2002	0.0043	5.13		0.0044	5.19		0.0027	3.28	
	2003	0.0025	3.15		0.0024	2.98		0.0016	1.97	
	2004	0.0002	0.32		0.0000	-0.06		0.0001	0.11	
R^2			0.8626			0.8630			0.8803	
F			9969			10642			7221	
observations number			91354			91354			91354	

Once a hedonic price function is obtained, the added value due to the T2 tramway is calculated by taking into account housing prices with and without accessibility gains. The sum of observed differences measures the capitalization on housing prices for the whole of the department from 1996 to 2003. This amount cannot be diffused because it is not yet validated by RATP[21], but the added value could be approximately less than 5%.

The capitalization is not equally spread over the whole of the Hauts-de-Seine department (see Figures 7 and 8).

The highest capitalization is in the central zone of the department crossed by the T2, and the zone which extends towards the south west, where the accessibility gains between 1996 and 1997 were the highest. In volume, it is lower at the end points of the T2, but expressed as a percentage, capitalization is also high at the extreme south of the T2, around Issy-les-Moulineaux.

[21] We have a clause of confidentiality with RATP for this study.

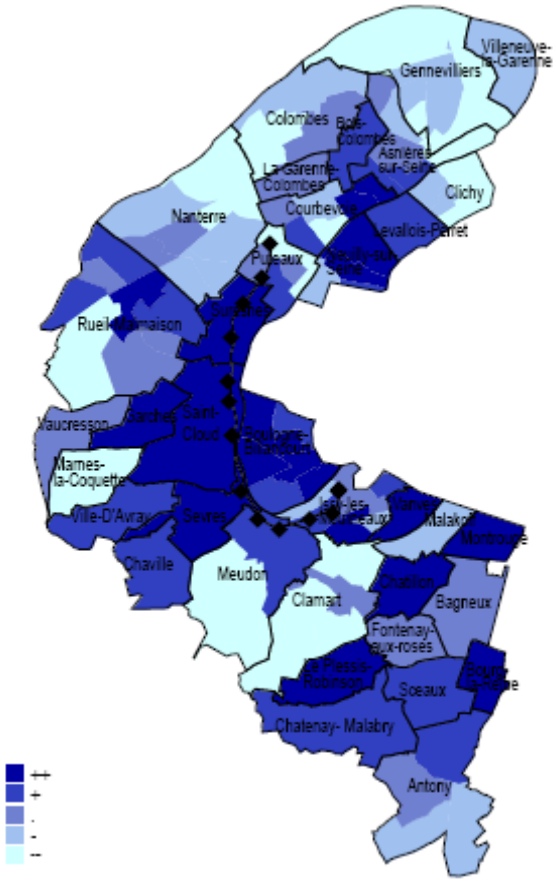

Figure 7: Volume of capitalization of accessibility gains per district on the sales of residential dwellings in the Hauts-de-Seine department, between 1996 and 2003.

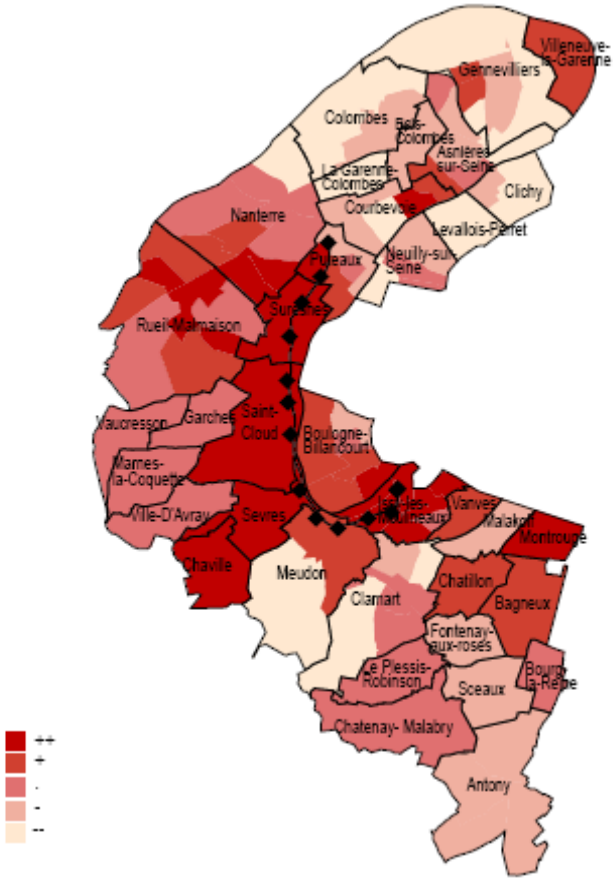

Figure 8: Percentage of capitalization of accessibility gains per district on the sales of residential dwellings in the Hauts-de-Seine department, between 1996 and 2003.

The implementation of the T2 had a positive and significant impact on the evolution of housing prices, through the accessibility gains to jobs, due to the infrastructure.

8. Conclusions

This research shows that hedonic models can yield significant accurate quantitative measurements of real estate benefits, provided by the accessibility gains of a new transport infrastructure. The main merit of the hedonic models is that they can separate the accessibility impacts from the many other variables, with a role in forging real estate prices. Their main drawback is that they are data intensive, they need a large amount of input that may be expensive to acquire, or that may not exist at the appropriate level of disaggregation: in that case, proxies must be found to take into account some relevant factors. Colinearity between some variables must also be checked.

This research also raises other questions that should be answered in future work. One of them is assessing the anticipation-delay feature of the impact: we have not detected any anticipation effect: is that true for all kinds of transport projects? On the contrary, our estimation shows that the consolidation of dwelling values took a few years after the infrastructure operation to be established. Methods for accurately estimating the total added value over this period should be refined. Other issues are related to the link between the real estate impacts of a new infrastructure and the type of context: are these

impacts dependent on the level of urbanisation, proximity to the city centre or CBD, the maturity of the public transport network in the city and so on? This promises fascinating but challenging studies for the future.

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