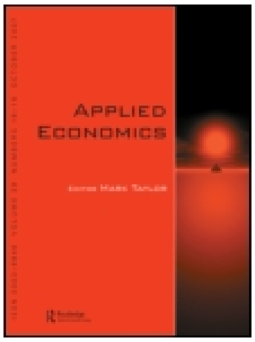

Applied Economics

ISSN: 0003-6846 (Print) 1466-4283 (Online) Journal homepage: https://www.tandfonline.com/loi/raec20

Measuring the social value of local public goods: an empirical analysis within Paris metropolitan area

Nicolas Gravel , Alessandra Michelangeli & Alain Trannoy

Applied Economics, 2006, **38**, 1945–1961

Routledge
Taylor & Francis Group

Measuring the social value of local public goods: an empirical analysis within Paris metropolitan area

Nicolas Gravel[a], Alessandra Michelangeli[b,*] and Alain Trannoy[c]

[a]*CSH (Delhi) and IDEP-GREQAM, 2, Aurangzeb Road, 110011 Delhi, India*
[b]*THEMA, Université de Cergy-Pontoise, 33, Bd du Port, 95011 Cergy-Pontoise, Cedex, France*
[c]*IDEP-GREQAM and EHESS, Centre de la Vieille Charité, 2, rue de la Charité, 13 002 Marseille Cedex, France*

A non-linear hedonic model is used to estimate the implicit marginal prices of 17 local public goods in a Paris suburban area on an original data set of some 8200 housing units. The results reveal a robust effect of local public school quality (measured both by the fraction of junior high school students that are at least two years behind grade level and the student/teacher ratio) on house prices. It is observed that housing owners' marginal willingness to pay for reducing commuting time is roughly similar for public transportation than for car transportation. Another noticeable result is the complete capitalization of local taxes at a discount rate of 3.5%. An illustration of the potential usefulness of the results for Cost–Benefit analysis is also provided.

I. Introduction

It is well-known that if a good is traded in a competitive market, the social value of a 'small' additional quantity of the good is measured by its market price, if the initial distribution of wealth, which gives rise to the competitive equilibrium, is considered optimal. A problem that arises when this principle is applied to the evaluation of 'small' public projects is that most goods supplied by such projects (such as quality of public schools, public parks, etc.) are not directly traded on competitive markets. Either for their intrinsic property (non-rivalry in consumption and non-excludability) or for exogenous political reasons, they belong to the category of public goods. How can the authority in charge of producing these goods obtain the relevant information about their social value?

When public goods are *local*, the '*hedonic*' or – more revealingly – *implicit* price theory popularized by Rosen (1974) provides an answer to that question. Recall that hedonic price theory views a housing as a bundle of utility-bearing characteristics, some of which being the public goods to which the occupation of the house give access. Accordingly, this theory interprets the price of a house as the market evaluation, by a *hedonic price function*, of the particular package of characteristics embodied in it. Although local public goods themselves are not traded on competitive markets, units of housing which give access to these local public goods are. Like for private goods, therefore, the increase in housing

*Corresponding author. E-mail: alexandra.michelangeli@eco.u-cergy.fr

Applied Economics ISSN 0003–6846 print/ISSN 1466–4283 online © 2006 Taylor & Francis
http://www.tandf.co.uk/journals
DOI: 10.1080/00036840500427213

price brought about by a 'small' increase in the quantity of a public good can be interpreted as the marginal social value of this public good and be used as such in cost-benefit analysis (see e.g. Scotchmer (1985; 1986) and Kanemoto (1988) for a complete discussion of the use of hedonic prices in cost–benefit analysis).[1]

Empirical estimations of housing hedonic prices functions including local public goods have been abundant in North America in the last 30 years (see Kiel and McClain (1996) or Lynch and Rasmussen (2001) for example). They have been much more rare in Europe (see however Cheshire and Sheppard (1995) and Ginsburgh and Waelbroeck (1998)) and this paper is primarily intended as a contribution toward closing the huge gap that separates North America from Europe in terms of empirical knowledge of the value attached by citizens to specific local public goods. In the authors' view, improving knowledge on this matter in Europe is a necessary step in understanding the differences between Europe and North America in terms of public good provision and financing.

A particular area where this comparison is likely to be instructive is *education*. Many hedonic studies performed in the USA[2] have found a *significant* negative relationship between the housing price and the pupil/teacher ratio at local public schools. This ratio is interpreted as an indicator of the 'objective' input devoted into the children's human capital production process by the public authorities. However, it is certainly not the only input of the human capital production function. Another input, which has been the object of a an important theoretical and empirical literature[3] is the quality of the 'peers' with whom the pupil interacts. However the American public school system makes the observed negative relationship between housing prices and pupil/teacher ratios somewhat difficult to interpret. This difficulty arises because, in the USA, public schools are managed and partially or wholly financed at the local (county or state) level. As a result, the across-county differences in public subsidies received by schools tend to be heavily correlated with the sociological characteristics of the counties. For this reason an observed relationship between housing prices and pupil/teacher ratios in the USA could in part reflect a concern for avoiding bad peers rather than a preference for smaller class sizes *per se*. Ideally, it would be appropriate to disentangle the household's valuation of the relative impact of the two inputs on human capital accumulation.

The data set and the institutional framework of the public school system in France enables these differing effects to be decomposed to some extent. The public school system is managed by the central government which pursues an egalitarian aim. As a result, differences between the public subsidies received by different schools are small and they tend to be slightly biased in favour of the relatively poor cities. These institutional features of the French public school system suggest that cross-cities variations in the pupil/teacher ratio are less likely to be related to variations in the quality of the 'peer group' in France than in the USA. As it happens, the data contains a plausible indicator of the academic quality of the peers that a given pupil will encounter when attending local public school and hence enable the peer group effects to be disentangled from the input effect.

Another kind of local public good that is likely to be valued differently in Europe and in the USA is *public transportation*. In Paris outskirts, 50% of inhabitants go to work by car, 28% use public transportation and 12% use both systems.[4] These figures are typically much higher than in US metropolitan areas. As it turns out, very few empirical hedonic studies have included variables that measure access to public or private transportation network. Given the role devoted to transportation in standard urban theory (see e.g. Fujita, 1999), this neglect is somewhat surprising.

In this paper an estimation of a hedonic price function is provided on an original data set of some 8200 observations on individual dwelling prices collected from the 33 largest cities of Val d'Oise (an administrative area that counts one million of inhabitants in the north-west of Paris) over the 1985 to 1993 period. By contrast to many studies in the literature, a large number (17) of public goods is included, among which are the quality of local public schools (measured both by the fraction of junior high school students that are at least two years behind grade level and the student/teacher ratio), geographical characteristics (distance from Roissy airport, geographic elevation of the location, the fraction of the city's area devoted to recreational land, etc.) and

[1] The *local* character of the information conveyed by empirical estimates of a hedonic price function, to which is adhered in the present paper, is worth emphasizing. Only under very specific assumptions (such as those considered in Bartik, 1987) can an estimation of the hedonic price function provide global information on preferences and technology. A thorough discussion of these issues is provided in Ekeland *et al.* (2004).
[2] See for instance Bogart and Cromwell (2000) and Black (1999).
[3] See e.g., Hanuscheck (1986), Arnott and Rowse (1987).
[4] *Source*: INSEE census 1999.

cultural/commercial infrastructure (number of historical buildings, playground fields, retail stores, public entertainment centres, etc. relative to the number of inhabitants). Also included are local tax rates on housing as well as measures of the commuting time (both by public transportation and by car) during rush hour. Also information on many housing-specific characteristics is available such as the size of the housing, the availability of a balcony, an equipped kitchen, and the like.

The plan of the rest of the paper is as follows. In the next section, the theoretical model is sketched. In the Section III, the data set and the estimation method are presented. Furthermore the results are discussed and interpreted. Section IV uses the hedonic estimates to examine an actual expenditure programme designed by the French government to reduce school delinquencies in a few cities covered by the sample and recall the conditions that enable partial derivatives of housing prices with respect to public goods characteristics to be interpreted as marginal social values of the public goods. Section V concludes.

II. Theoretical Model

The model described here is standard and is presented for the sake of completeness. Consider the problem of a household who chooses a quantity of a perfectly divisible private good (say money) and exactly one unit of housing. Alternative units of housing are assumed to be completely differentiated by their content in K implicit (but observable) characteristics. As in Rosen (1974), a unit of housing can thus be thought of as a vector in the non-negative orthant of the K-dimensional Euclidean space. It is further assumed that the number and variety of different cities and housing units is sufficiently large for the choice among city-specific and housing-specific characteristics to be assumed continuous 'for all practical purposes' (Rosen, 1974). This assumption is rather stringent in the context of location choice and should, at best, be seen as an approximation. The interpretation given to the empirical model estimated in this paper would *not* hold if the choice among alternative housing units was assumed to be discrete.

Let $\mathbf{X}$ denote the (closed and convex) set of all conceivable packages of the K characteristics. The household's preferences for the various combinations of private goods and housing characteristics are represented by a twice continuously differentiable strongly quasi-concave and weakly increasingly monotonic utility function $U : X \to \mathbb{R}_+$ with image u. Every unit of housing with combination of characteristics $c \in \mathbb{R}_+^K$ has a market price which can be thought of as the image of $\mathbf{c}$ under a function $h : \mathbb{R}_+^K \to \mathbb{R}_+$. The function h is commonly referred to as a *hedonic price function*. It assigns a price to every unit of housing as a function of its characteristics. It is assumed that h is strictly monotonically increasing and differentiable with respect to every characteristic. The household is assumed to act on the premises that h is given and independent from its location and housing-specific package choice.[5]

Taking the private good as the numéraire, and assuming that the household is initially endowed with y units of the private good, the decision problem faced by the household is:

$$\max_{(\mathbf{c},x)} U(\mathbf{c}, x)$$

subject to

$$x + h(\mathbf{c}) \leq y \quad \text{and} \quad (\mathbf{c}, x) \in \mathbf{X} \tag{1}$$

where $x \in \mathbb{R}_+$ denote the quantity of private good consumed by the household. Assuming that $\mathbf{X} \cap \{(\mathbf{c}, x) \in \mathbb{R}_+^{K+1} : x + h(\mathbf{c}) \leq y\}$ has a non-empty interior in $\mathbb{R}_+^{K+1}$ and given the properties of h and $\mathbf{X}$, it is clear that this program has a solution. A solution ($\mathbf{c}^*$, x^*) satisfies the first-order conditions

$$\frac{\partial U(\mathbf{c}^*, x^*)/\partial c_k}{\partial U(\mathbf{c}^*, x^*)/\partial x} = \frac{\partial h(\mathbf{c}^*)}{\partial c_k} \tag{2}$$

for every characteristic k chosen in strictly positive quantity in the interior of $\mathbf{X}$. As usual, the left-hand side of this equation is the marginal rate of substitution between the kth characteristic and the private good. It gives the maximal quantity of private good that the household is willing to give up in order to have access to an additional (arbitrarily small) amount of the kth characteristic. It gives the household's *marginal willingness to pay* for the kth characteristic which, at the households' optimal choice, is equal to the *hedonic price* $\partial h(\mathbf{c}^*)/\partial c_k$ of this kth characteristic.

III. Empirical Implementation of the Model

Since theory offers no guidance with respect to the form of the function h it is important to allow for some flexibility in the choice of the empirical

[5] Questions related to the existence and interpretation of $h(\cdot)$ in a (spatial) general equilibrium with production are beyond the scope of this paper and are not addressed. The reader may consult Mas-Colell (1975) and Ellikson (1979).

functional form (see e.g. Cropper *et al.* (1988) or Rasmussen and Zuehlke (1990) for further discussion on the issue). This is done by specifying a Box–Cox (1964) transformation of the dependent variable.[6] The empirical model estimated is therefore, for every observation $j = 1, \ldots, N$,

$$p_j(\lambda) = \sum_{k=1}^{K} \beta_k c_{kj} + \varepsilon_j \tag{3}$$

with

$$p_j(\lambda) = \frac{p_j^{\lambda} - 1}{\lambda} \quad \text{if } \lambda \neq 0$$
$$= \ln p_j \quad \text{otherwise}$$

where

- p_j denotes the price of the unit of housing j,
- c_{kj} denotes the quantity of the kth characteristics possessed by the jth housing (with the convention that $c_{1j} = c_{1i} = 1$ for all, $j = 1, \ldots, N$), and
- ε_j is a random term assumed to be identically, normally and independently distributed across observations with mean 0 and variance $\sigma_i^2 = \sigma_j^2 = \sigma^2$ for all i, j.
- $p_j(\lambda)$ will be later referred to as to the *transformed price*.

The empirical function (Equation 3) enables the first and second derivatives of the price with respect to the various characteristics to be calculated easily. From Equation 3, the first partial derivative of the housing price with respect to the kth characteristic in observation j is given by

$$\frac{\partial p_j}{\partial c_k} = \beta_k p_j^{1-\lambda} \tag{4}$$

which implies that the kth characteristic is a positive amenity if β_k is positive. The second partial derivative is given by

$$\frac{\partial^2 p_j}{\partial c_k^2} = (1 - \lambda)\beta_k^2 p_j^{1-2\lambda} \tag{5}$$

which implies that as long as λ is smaller than 1, the hedonic function is *convex* with respect to each characteristic, whatever the sign of β_k.

Equation 3 is estimated by maximum likelihood.[7] As shown by Dagenais and Dufour (1991) for general non-linear models and Spitzer (1984) for Box–Cox ones, hypothesis testing by mean of standard Wald criteria (Student tests) or Lagrange multiplier techniques is not invariant to measurement units. Likelihood ratio tests do not suffer from this problem. On the other hand likelihood ratio tests do not lead easily to confidence intervals. Therefore significancy tests are presented based on the likelihood principle and 95% confidence interval based on the Student distribution. The latter requires a correct computation of the variance–covariance matrix of the parameter estimates. In order to do that, a double length artificial regression is resorted to (see e.g. Davidson and McKinnon (1993) Chapter 14, pp. 492–99 for a thorough explanation of this method).

Data

The estimation of Equation 3 requires microdata on housing prices, housing-specific characteristics and amenity characteristics. The relative scarcity of reliable housing data sources in France made it necessary to build up a relevant data set. The study is limited to the sales housing market (rental market is not considered) and to the administrative area of Val d'Oise in the northern part of Paris greater metropolitan area, west of Roissy international airport (see Fig. A1 in Appendix). In order to obtain reliable information on local public goods this study is further restricted to the 33 cities of the Val d'Oise that had at least 10 000 inhabitants in the 1990 national census.

This limits the variability in the public goods characteristics. For this reason, the collection of data is spread on individual housing prices in each of these 33 cities on a nine years period (more precisely 1985 to 1993). For each city and for every year, data on local public goods, measured at the city level, were obtained from the relevant local public authorities. Data on housing prices were collected from adverts taken from free advertising local newspapers. These adverts record information on individual prices, the city where the housing is built, as well as on many housing-specific characteristics (e.g. the number of rooms, the presence of a parking lot, an equipped kitchen, etc.). Overall, 8192 observations were collected, allocated between the 33 cities and the nine years according to the demographic weight of each city in the area. There are at least three criticisms that could be made to the data set construction.

First, the spreading of the observations over nine years raises the question of the intertemporal stability of the hedonic price function h. This issue has been

[6] See however Dickie *et al.* (1997) for statistical evidence that flexibility of Box–Cox transformations of the dependent variable in hedonic analysis may not be as large as would be liked.
[7] Thorough explanations of estimation method can be found in Hyde (1999).

addressed by introducing time dummies in the list of regressors. The spreading of observations over time raises also some inter-pretative questions with respect to the relationship between housing's price at some period and the characteristic of the housing at that and subsequent periods. Clearly, the K characteristics of a housing should be distinguished by the time and, if necessary, the state of the world in which they are made available. When buying a dwelling, a household cares about the package of hedonic characteristics provided by the dwelling during the year of purchase but, also, during all subsequent years of existence of the dwelling. Yet, in the empirical specification (Equation 3) of the hedonic price function presented above, the price of a particular housing at some year is explained only by the value taken by the considered characteristics at that same year. This way of doing would be adequate if households purchasers were either holding stationary expectations about the future quantities of characteristics or holding rational expectations under the additional assumption that housing characteristics are random walks.

Second, it must be noted that the prices recorded in the data base are advertised – or *supply* – prices. Yet these advertised prices may behave differently from the housing prices at which units of housing were actually traded. Using advertised – rather than transaction – prices would not bias the estimation if the discrepancies between advertized and actual price were independent from the characteristics of the dwelling. Yet, there is no way to empirically verify whether this independence holds. Cheshire and Sheppard (1995) also use supply prices in their hedonic study. They send to the advertisers of their sample a questionnaire three months after the collection of the data to obtain additional information on the actual price at which the dwelling units were sold (if they were). They report a rate of response of some 40% and, for the houses that happened to be sold during the three months period, an average transaction price that is within a 1% interval of the average advertized price. Although the housing market considered in Cheshire and Sheppard is somewhat different from that considered here, their results suggest at least that, if it exists at all, the bias associated with the use of advertized price is not excessive.[8]

Third, the city level at which all amenities are measured may be considered inappropriate. As discussed at length in the literature, it would be preferable to measure public good and neighbourhood variables at the finest level of observability. Unfortunately, the data set does not allow for performing an analysis at a smaller level than the city one. Information on housing units does not typically mention the neighbourhood in which the unit is built. Moreover, many public amenities variables (e.g. tax rates) are only available at the city level.[9]

Variables

The list, description and definition of the 13 dwelling-specific variables and the 17 city specific amenity variables is given in Table A1 in Appendix. Table 1 provides descriptive statistics for the price and variables. This description is completed with a few additional comments on some of the public goods variables.

Education variables. As mentioned in the introduction, two variables are used to measure the quality of local public schools. The variable *Peer* is defined as the fraction of the total number of children registered in the three last years of junior high school who are at *least two years* behind their normal grade level (as determined by their birth rate). Assuming (plausibly given the uniform norms implemented by the French ministry of education) that the pass/failure policy of local school authorities does not exhibit systematic cross-city variations, this indicator measures the fraction of 'poorly performing' peers that a given child will interact with on a daily basis in a local public junior high school. It is an institutional particularity of the public school french system which motivates choice of the second year of the junior high school as the benchmark year to calculate the fraction of poorly performing peers. As explained by Cousin (1996, p. 60) the second year of junior high school is typically perceived to be the first year where failure is recognized to be a good method for sending to the pupil (or to the parents) a signal that can help in future orientation decisions (choosing a more applied school curriculum for instance). Hence until the first year of junior high school, parents have the right to

[8] It should also be noticed that advertised prices have one advantage over transaction prices reported to notaries: they are not subject to such understatements as reported transaction prices can be. In France, understatement of transaction prices reported to notaries is common as they enable the parties to reduce their tax payments (in France, housing purchase is taxed at a rate of some 8%).

[9] It should moreover be noticed that in France the average size of the city is much smaller than in the USA (the average city of the present sample is only 7.4 Km^2) For this reason, it may be expected that the inaccuracy of measuring amenities at the city level rather than at the neighbourhood one to be less severe in France than there would be in the USA.

Table 1. Summary statistics for the variables

Variable	Mean	Standard deviation	Minimum	Maximum
House's price	112 380.40	64 795.62	12 195.92	66 6202.20
Second room	0.964	0.185	0	1
Third room	0.885	0.318	0	1
Fourth room	0.682	0.465	0	1
Fifth room	0.396	0.489	0	1
Sixth room	0.163	0.369	0	1
Another room	0.084	0.412	0	6
Equipped kitchen	0.337	0.472	0	1
Parking	0.656	0.474	0	1
Balcony	0.274	0.446	0	1
House	0.555	0.496	0	1
Basement	0.580	0.493	0	1
Garden	0.384	0.486	0	1
Garden size	186.49	320.79	0	5700
Peer	17.99	5.55	6.37	36.47
Student/teacher	25.15	0.909	21.94	27.11
Ptransport	45.86	10.56	31	76
Ctransport	96.42	9.76	79	124
Acmotorway	3.430	2.78	0.885	13
Rnuisance	0.259	0.211	0	0.721
DistRoissy	26.74	10.11	6	45
Scenic	0.082	0.109	0	0.381
Elevation	0.103	0.085	0	0.304
Green	9.07	11.83	0.078	57.11
Monuments	0.210	0.429	0	2.37
Shopping	66.78	42.57	14.55	282.79
Auditoria	0.288	0.395	0	1.45
Playgrounds	0.841	0.774	0	3.88
Retax	15.15	4.87	6.49	28.22
Dtax	12.15	2.45	6.41	19.3
Poverty	33.67	6.91	20.7	55.24
Year 1986	0.102	0.303	0	1
Year 1987	0.117	0.321	0	1
Year 1988	0.110	0.313	0	1
Year 1989	0.116	0.321	0	1
Year 1990	0.126	0.332	0	1
Year 1991	0.110	0.313	0	1
Year 1992	0.100	0.301	0	1
Year 1993	0.106	0.308	0	1

object to a possible proposal of failure of their child made by the school authorities at the end of the year. Starting from the second year of junior high school, parents loose this opportunity. Interestingly enough, in other regressions not included in this present version, an alternative specification has been considered where the quality of peers is measured by the number of children registered in the first year who are at least two years backward. It turns out that the estimated coefficient of this second indicator of peer group effect (which exhibits only a modest correlation of 0.23 with the variable *Peer*) presents the wrong sign. It appears, therefore, that it is not the appropriate variable to measure the quality of the peers with whom the pupil interacts.

The second variable is the standard *Student/teacher* ratio calculated, for each city and year, on all public junior high-schools to which city resident are assigned by the public school zoning system. This variable is obviously a good proxy for the physical input of the human capital production function. It may be noticed on Table 1 that this variable exhibits very little variation across cities and years due to the egalitarian norms implemented by the French central authorities. The pupil/teacher ratios in junior high schools range from 21.9 to 27.1, with more than 85% of the observations lying between 24 and 26.5. It should be noted that *Student/teacher* is (slightly) negatively correlated with *Peer* (around 0.25) as well as with the variable that measure poverty (0.41) in the city (see below). This suggests that the national public school authorities allocate inputs across public schools in a way which partially attempt to compensate the unequal distribution of sociological characteristics across cities. (see also Trancart (1998, p. 49) for more evidence on this).

Accessibility. Three variables are considered that aim at capturing the accessibility of the city in which the dwelling is located. Two variables, *Ptransport* and *Ctransport*, measure the time (in minutes) required to commute from each of the 33 cities to Paris centre at morning rush hour using, respectively, public transportation and car transportation. Both variables are computed using information available in 1996.[10]

Both *Ptransport* and *Ctransport* are intended to measure the time required to commute from home to work. This rests on the 'monocentric' assumption that most inhabitants of Val d'Oise work in the centre of Paris. Although this assumption is not strictly true, it is worth keeping in mind that 40% of the jobs available in the Paris greater metropolitan area are located in the inner Paris, and that 22% of the inhabitants of Val d'Oise who work do so in the centre of Paris. It should also be noticed that, for historical reasons, the transportation network in France (both public and private) is concentrically organized around the city centre of Paris. Many people who commute between two points of the Paris greater metropolitan area must make an interconnection in the city centre of Paris. For this reason the commuting time from home to the city centre of Paris does capture a significant part of the commuting time of a much larger portion of the Val d'Oise workers than 22%.

The use of *two* distinct variables to capture what is often perceived as a *single* phenomenon could of course be questioned: The time taken to commute from home to work. Such a questioning is legitimate since, in each of the 33 cities covered in the sample, commuting time by public transportation is *smaller* than commuting time by car. If the time spent in commuting by car and the time spent in commuting by public transportation were perfect substitutes, commuting time by car would not be valued at all by the housing market. Pushed at the limit, if the two commuting times were perfect substitutes, there would not be observed any inhabitant of the Val d'Oise on the road network at the morning rush hours! As a matter of fact, the proportion of pure car users among the commuters from the outer ring of the metropolitan area of Paris (to which the Val d'Oise belongs) to Paris is only 19%.[11] Hence 81% of these commuters use at least once the public transportation system on some segment of the trip. Nonetheless, the fact that a significant portion of commuters do use the car despite the time difference suggest that the two transportation times are not perfect substitute. For this reason, it is chosen to keep them both in the regression. Keeping constant commuting time by public transportation, a positive impact could therefore be expected *a priori* of a marginal reduction of commuting time by car on dwelling prices.

Although commuting from home to work is an important component of the individuals' daily transportation activity, it is not the only one. People also commute to go shopping, to go on vacation, to visit friends and relatives, etc. Not all of this commuting is oriented toward the city centre of Paris. To account for other transportation facilities offered by the dwelling localization, the distance between the centre of the city in which the housing is built and the nearest (in kilometre) freeway entrance (*ACmotorway*) is also used as regressor. This variable is interpreted as a proxy for the accessibility of the dwelling in terms of overall road transportation. It might be thought that the proximity of a freeway, albeit convenient in terms of transportation facilities, can also be a source of pollution and noise. To account for this, among the regressors is also introduced the number of kilometres of highway that cross the area of the city in which the housing is built relative to the size of the city (*Rnuisance*).

[10] Commuting time by public transportation is calculated from the various networks of public transportation of the greater Paris metropolitan area (bus, suburban train, RER, and metro) using the official schedule of the public transportation companies (essentially the RATP and the SNCF) for the morning rush hour (7:00–9:00). This commuting time is the shortest that can be achieved when considering all possible combinations of itineraries. It includes the average time taken to commute (by car if necessary) from the various point of the city where the housing is built to the nearest access to the public transport network (train or RER station or bus depot) and the waiting time if any. Destination of commuting is assumed to be the subway and RER station of Chatelet-les Halles in the center of Paris.

Commuting time by car results from simulations performed on the road network of the Paris greater metropolitan area at morning rush hour. Times are computed under the assumption that the driver takes the fastest route to connect the centre of the city where he or she lives to Chatelet train station. It also includes the time required to park the car.

[11] The number comes from '*Enquête globale transports*', Syndicat des Transports Parisiens, 1997. This figure is different from those presented in the introduction which concern all commuters and not only those ones who from the suburbs commute to Paris.

Hence the derivative of the housing price with respect to *ACmotorway* measures the marginal willingness to pay of the dwelling's owner for improving access to the freeway system, *given the density of this highway system in the city where the dwelling is located.*

Environmental variables. In addition to *Rnuisance* which would fit naturally in this category, the physical distance between the centre of the city and Roissy's international airport which bounds the Val d'Oise on the east side has been introduced. This variable (*DistRoissy*) captures the (noise) nuisance associated with the geographic proximity of the airport.

Also considered are three variables that are intended to capture the aesthetic characteristics of the site on which the dwelling is located. One of these variables (*Scenic*) measures the length of scenic roads (expressed in metres relative to the area of the city) as recorded on a local Michelin touristic map (under the label 'picturesque stretch of road').[12] There is also a variable (*Elevation*) that is defined by the difference between the highest and the lowest point of the city relative to the city's (horizontal) area. Paris' region is rather flat and, for this reason, hills are much appreciated by residents. Finally, the last environmental variable (*Green*) is the fraction of the city land opened to recreational activities (that is, free from agriculture, road, and building).

The variable *Monuments* on the other hand, which measures, relative to the city's area, the number of historical buildings belonging to the national heritage, is intended to be a proxy for some aesthetic unmeasured 'charm' of the city. Finally, the variable Shopping, defined as the number of detailed shops per 10 000 inhabitants, captures the access to commercial facilities.

Public goods and taxes. Two variables gathered under this heading aim at capturing proximity of the dwelling to various intrinsically valuable public equipment (*Auditoria, Playgrounds*) which are mainly financed by local budgets.

High taxes are the usual counterpart of a generous public good provision even though local taxes are less tightly connected to local public good provision in France than they are in the USA. There are two local taxes paid by households in France: A tax on real estate (*taxe sur le foncier bati*) (*REtax*) paid only by the owner of the housing and a so-called dwelling tax (*taxe d'habitation*) (*Dtax*) paid by the household who lives in the dwelling (be it as landlord or as tenant).[13] Each of these two taxes is collected by applying a tax rate, chosen by the local public administration, to a dwelling-specific *administrative tax base* that bears no clear relationship with the dwelling's market value.[14] Since tax liabilities are not observed, the analysis proceeds by regressing housing on the two tax rates (along with the other housing characteristics). Although not completely pure from a theoretical point of view, this procedure enables nonetheless to account to some extent for the capitalization of the taxes in the housing value. Furthermore knowledge of the *sample average* administrative tax base provides an indirect way of testing the degree of tax capitalization. More specifically, the procedure enables it to be checked if the estimated hedonic price of either tax rate corresponds to a capitalization of the future taxes liabilities brought about by a marginal increase in the tax rates *evaluated at average value of the administrative tax base*. Assuming that a purchaser of a unit of housing expects a marginal increases in the current tax rate to remain in effect for ever, this procedure enables, in effect, to infer the *implicit discount rate* used by the household to calculate the present value of its future tax liabilities. This 'revealed' discount rate can then be compared with the discount rate used in the literature to test explicitly for tax capitalization.

Sociological and neighborhood variables. The variable *Poverty* is defined as the fraction of the households living in the city who are exempt from the (national) income tax. This variable is interpreted as a proxy for factors that enter into the production of several public goods supplied by a city and which may be correlated with some of the public goods. The problem with an empirical specification such as Equation 3 is that it neglects many public goods by putting them in the error term ε_j. Yet these omitted characteristics are likely to be correlated with the amenities integrated in the empirical analysis. The reason for this is that many local public goods of a given city (observed and unobserved) are *produced* by a set of *common* production factors. An example of factors that enter jointly in the production of several public goods is the distribution of sociological attributes (poverty rate, average income, average level of education, etc.) within the population of a particular city. Typically, it would be expected that cities with favourable distribution of sociological

[12] The map used is the 1998 edition of the Michelin map no. 101 (outskirt of Paris: 1 cm = 530 metres).
[13] A household who owns the housing in which it lives pays both taxes.
[14] See Acosta and Renard (1993, pp. 57, 127) for more details.

attributes to exhibit better performance in terms of public safety, school success, quality of the neighbourhood, etc. than cities with less favourable distributions of these attributes. The fraction of the households who are free from income tax liabilities is therefore interpreted as summary statistics for the distribution of sociological traits.

A crime variable is also tested but it turned out to have no significant impact on housing prices. The weakness of the influence of crime on housing price is common in many hedonic studies (see for instance Lynch and Rasmussen, 2001). It appears therefore that city is not the appropriate level of measurement of criminal acts.

Results

The results obtained from estimating Equation 3 with the independent variables of Table A1 are presented in Table 2.

The best functional form for the hedonic price function is obtained for $\lambda = -0.1287$. As indicated by the value of the likelihood ratio test, this functional form is significantly different from the linear ($\lambda = 1$) or the log-linear ($\lambda = 0$) form. In accordance with the prediction of the theoretical urban hedonic literature (see e.g. Anderson, 1985; Sheppard, 1999), it implies an overall *convexity* of the hedonic price function with respect to the housing characteristics (in particular, marginal willingness to pay for a given characteristic is increasing with respect to the quantity of this characteristic).

As can be noticed, all housing characteristics behave in an *a priori* predictable way.

Focusing on public amenities variables, it is first noticed that, on these 17 variables, 16 are significant at the 1% confidence level and one at the 5% (student/teacher ratio). All in all, the 25 variables used in the model account for 82% of the variance of the transformed housing price.

Table 3 gives the empirical estimates of hedonic prices for the urban amenities.[15] They correspond to the partial derivative of the hedonic price function in the case of continuous variables, and to the discrete price difference in the case of discrete variables at the average housing of the sample. Table 3 also gives, for all variables expressed in continuous units, the absolute value of the 'hedonic elasticity' of the amenity measured at the average housing (the percentage variation in housing price brought about by a 1% variation in the amenity).

For school variables, it is noticed that both are significant. The estimated marginal willingness to pay for reducing by one point the fraction of poorly performing peers at school is 255 € (or 1417 € per point of standard deviation). Reducing class size by one pupil is valued 854 € by the owner of the average housing of the sample (or 785 € *per* point of standard deviation). Summing these two effects, it is obtained that the owner of the average housing is willing to pay some 2200 € for reducing by one point of standard deviation the two indicators of school quality considered herein. This should be compared with the marginal willingness to pay of 3948 $ for a one point of standard deviation amelioration in test score at primary schools obtained by Black (1999) in wealthy suburbs of Boston. It should be mentioned also that, when interpreted in a human capital perspective, these figures suggest that the impact of poorly performing peers and/or student/teacher ratio on the (future) human capital of the child is modest. Take for instance the 1417 € that the owner of the average household is willing to pay for reducing by one point of standard deviation the fraction of poorly performing peers that its child will encounter at public high schools. Assuming that this amount corresponds to the actualization at a discount rate of 3.5% of future earning losses brought about by such an exposure to 'bad peers' and that the active life starts at 25 and ends at 65, such a hedonic price is consistent with a yearly earning loss of... 65.3 €.

Transportation variables provide interesting results. Reducing either car or public transportation time by one minute increases housing price. The value of reducing by one minute the time taken to reach the city centre of Paris is higher for public transportation than car (345 € by public transportation, 276 € by car) but the difference is not statistically significant. An interesting exercise is to estimate the value of an elementary unit of time revealed by the hedonic price of *Ptransport*. Assuming that an average working individual will commute 230 days per year forever, and using a discount rate of 3.5%, the hedonic price of 345 € associated with a one minute reduction in commuting time is consistent with a value of the minute of some 5 cents (3 € for an hour). This figure, which is about half the net French minimum wage rate, suggests either that the discount rate used is too low or that individuals tend to consider that commuting time has less disutility than the time spent to work. The convexity of the hedonic price function entails that the marginal willingness to pay is decreasing at a decreasing rate, which is consistent with the predictions of classical models of the monocentric city. If the generalized transportation cost (pecuniary and time cost) is linear or concave

[15] Hedonic prices for private characteristics can be provided upon request.

Table 2. Estimation results

Variable	Coef.	Std err.	95% Confidence interval	
Lambda	−0.128**	0.011	−0.151	−0.106
C	5.917**	0.310	5.307	6.526
Second room	0.066**	0.009	0.048	0.085
Third room	0.049**	0.007	0.036	0.063
Fourth room	0.034**	0.005	0.024	0.044
Fifth room	0.034**	0.005	0.024	0.044
Sixth room	0.032**	0.005	0.022	0.043
Another room	0.023**	0.003	0.016	0.031
Equipped kitchen	0.017**	0.002	0.012	0.023
Parking	0.017**	0.002	0.011	0.022
Balcony	0.011**	0.002	0.007	0.016
House	0.043**	0.006	0.031	0.055
Basement	0.004**	0.001	0.001	0.007
Garden	0.006**	0.002	0.002	0.010
Garden size	0.000 06**	0.000 01	0.000 04	0.000 08
Peer	−0.0005**	0.0002	−0.0009	−0.0002
Student/teacher	−0.002*	0.0008	−0.003	−0.0003
Ptransport	−0.0008**	0.0001	−0.001	−0.0004
Ctransport	−0.0006**	0.0002	−0.001	−0.0002
Acmotorway	−0.002**	0.0004	−0.002	−0.001
Rnuisance	−0.032**	0.005	−0.043	−0.020
DistRoissy	0.0006**	0.0001	0.0003	0.0009
Scenic	0.029**	0.009	0.010	0.048
Elevation	0.039**	0.011	0.016	0.062
Green	0.0002**	0.000 09	0.000 04	0.0004
Monuments	0.008**	0.002	0.004	0.012
Shopping	0.0001**	0.000 02	0.000 08	0.0001
Auditoria	0.023**	0.003	0.015	0.031
Playgrounds	0.004**	0.001	0.002	0.006
Retax	−0.001**	0.0003	−0.002	−0.001
Dtax	−0.001**	0.0004	−0.002	−0.0009
Poverty	−0.001**	0.0002	−0.002	−0.001
Year 1986	0.025**	0.004	0.017	0.034
Year 1987	0.050**	0.007	0.035	0.064
Year 1988	0.075**	0.010	0.054	0.096
Year 1989	0.108**	0.015	0.078	0.138
Year 1990	0.136**	0.019	0.099	0.174
Year 1991	0.148**	0.020	0.107	0.189
Year 1992	0.146**	0.020	0.106	0.186
Year 1993	0.138**	0.019	0.100	0.176
Number of observations		8192		
Log likelihood		93 428.6		
Test H_0	Restricted lgL	$\chi^2(1)$	Pr > χ^2	
Lambda = −1	−99 565.396	5513.25	0.000	
Lambda = 0	−93 491.246	125.31	0.000	
Lambda = 1	−97 670.453	8483.73	0.000	

Notes: **Coefficient significantly different from zero at the 0.01 level.
*Coefficient significantly different from zero at the 0.05 level.

with respect to the distance to the central business district (CBD), then the equilibrium market rent curves are strictly convex with respect to the distance to the CBD (see e.g. Fujita, 1999 p. 57). This interpretation must of course be taken with a grain of salt since the convexity observed here concerns to the commuting time, while the prediction of the theory is about the physical distance.

Another interesting result is the significant hedonic price of 857 euros attached to a one kilometre reduction in the distance from the nearest freeway entrance (given the density of the highway network in the city where the dwelling is built). The significant hedonic price of 1881 euros attached to a kilometre reduction in the density of this network (given the distance from the nearest freeway entrance) is even

Table 3. Hedonic price of urban amenities

Variable name	Hedonic price (Euros)	Elasticity (%)
Peer	255	0.0659
Student/teacher	854	0.2212
Ptransport	345	0.1631
Ctransport	276	0.2744
Acmotorway	857	0.0302
Rnuisance	1881	0.0050
DistRoissy	275	0.0756
Scenic	168	0.0001
Elevation	225	0.0002
Green	98	0.0091
Monuments	482	0.001
Shopping	59	0.0404
Auditoria	4105	0.0121
Playgrounds	733	0.0063
REtax	718	0.1119
Dtax	773	0.0967
Poverty	670	0.2322

more interesting. It reveals that the nuisance created by highway (given access) is more important (in absolute value) than the benefit which results from improving access (given nuisance).

Living one kilometre away from Roissy airport increases the value of the average housing by some 275 euros.

The four environmental and geographical variables *Scenic, Elevation, Green, and Monuments* are significant but their contribution to price seems rather modest.[16]

The hedonic price of adding one auditorium in the (virtual) city in which the average dwelling is built (4105 euros, roughly 4% of the price of the average housing) might look high at first glance. It is difficult to believe that it is the representative dwelling purchaser's intrinsic preference for music, theatres, etc. which accounts for a willingness to pay of 4105 euros just to live in a city which possesses one more showroom than the average city. A possible explanation is that the fact for a city to have or not an auditorium is a proxy for other unmeasured amenities. This explanation finds some support in the fact that more than one-half of the cities covered by the sample (precisely, 19 out of 33) do not have any auditorium.

An interesting result is the strong capitalization effect of local tax rates. For increasing by one point the dwelling tax rate (with respect to the real estate tax rate) leads to a reduction of 773 euros (resp. 718 euros) in the value of the average housing unit. In terms of the earlier discussion, if the tax rates are applied on a unit of housing of average *administrative* value, and under the assumption that a one point increase in the tax rate is expected by the household to last forever, (the average estimate of the negative capitalization of 773 euros (resp. 718) reveals a discount rate of 3.7% (resp. 3.2%). The difference between the two rates is not statistically significant. These figures fall down a plausible confidence interval of the actual real interest rates on mortgage loans observed for that period; in terms of Palmon and Smith's (1998) methodology, these results indicate a *full capitalization of taxes* at a real discount rate of 3.5%. They suggest the existence of an almost complete 'Laffer effect'. If tax authorities were to base their local tax rate on the market (rather than administrative) value of the housing, then increasing tax rates would have virtually no effect on the expected future government tax revenues.

IV. Policy Implications of the Results

In this section, it is shown how, under specific assumptions, hedonic prices of public goods provide exact measures of their social marginal values and the hedonic estimates are used to evaluate some public programmes aimed at reducing school failure in poor cities. First recall the condition under which the sum of hedonic prices for a public good taken over the inhabitants of a particular city provides an exact measure of the social value attached by the population of the city for a small improvement in the available quantity of this public good.

Assume that there are H households who make the same decision as that of the representative household examined in Section II (indexing by $i \in \{1, \dots, H\}$ their utility functions and consumption sets and denoting by $\hat{y}_i$ the wealth of household i). All these households face the same hedonic price function $h(\cdot)$.

[16] For these variables, the hedonic price associated with an increase of the numerator of the variable equal to one unit in computed (with the exception of *Elevation* for which an increase of the numerator equal to 10 metres is considered). So the hedonic price of one more kilometre of scenic roads in the (virtual) city in which the average dwelling is built is obtained (or the hedonic price of one more hectare of green space or of an additional monument). The same method of computation for the variables *Auditoria and Playgrounds* is used.

Since every household's optimal choice of characteristics package depends upon wealth only (given $h(\cdot)$), household i's indirect utility function $V_i : \mathbb{R}_+ \to \mathbb{R}_+$ with image v_i is defined by

$$V_i(\hat{y}_i) = \max_{(\mathbf{c},x)} U_i(\mathbf{c}, x)$$

$$\text{subject to } x + h(c) \leq \hat{y}_i \quad \text{and} \quad (\mathbf{c}, x) \in \mathbf{X}$$

Assume now that the distribution of incomes across households is considered optimal with respect to the social evaluation function $S : \mathbb{R}_+^H \to \mathbb{R}_+$ defined by

$$S(y_1, \ldots, y_H) = W(V_1(y_1), \ldots, V_N(y_H))$$

where $W : \mathbb{R}_+^H \to \mathbb{R}_+$ is a continuously differentiable and increasingly monotonic Bergson–Samuelson social welfare function. This assumption amounts to asserting that observed $(\hat{y}_1, \ldots, \hat{y}_H)$ are (interior) solutions of the following program

$$\max_{y_1, \ldots, y_H} S(y_1, \ldots, y_H) \quad \text{subject to} \quad \sum_{i=1}^{H} y_i \leq \sum_{i=1}^{H} \hat{y}_i \tag{P}$$

and, therefore, satisfy first order conditions

$$\frac{\partial W(V_1(\hat{y}_1), \ldots, V_N(\hat{y}_H))}{\partial v_i} \frac{\partial V_i(\hat{y}_i)}{\partial y_i} = \frac{\partial W(V_1(\hat{y}_1, \ldots, V_N(\hat{y}_H))}{\partial v_t} \frac{\partial V_i(\hat{y}_t)}{\partial y_t} = \lambda$$

for every household i and l where λ is some real non-negative constant (the Lagrange–Kuhn–Tucker multiplier associated to the constraint in the program (P)).

Assume that it is required to evaluate the social value of a 'small' project consisting of an increment of dc_k in the quantity of the amenity k in some city j. Letting H^j denote the number of households who optimally choose to locate in city j, the social value ΔW of such a project at households's initial optimal choice is approximated by

$$\Delta W = \sum_{i=1}^{H^j} \frac{\partial W(V_1(\hat{y}_1), \ldots, V_N(\hat{y}_N))}{\partial v_i} \frac{\partial U_i(\mathbf{c}_i^*, x_i^*)}{\partial c_k} dc_k$$

From the first order conditions of households maximization programs, this can be written as

$$\Delta W = \sum_{i=1}^{H^j} \frac{\partial W(V_1(\hat{y}_1), \ldots, V_N(\hat{y}_N))}{\partial v_i} \frac{\partial Vi(\hat{y}_i)}{\partial y_i} \frac{\partial h_i(\mathbf{c}_i^*, x_i^*)}{\partial c_k} dc_k$$

which, given the optimality of income distribution and ordinality of social welfare measurement, amounts to

$$\Delta W = \sum_{i=1}^{H^j} \frac{\partial h_i(\mathbf{c}_i^*, x_i^*)}{\partial c_k} dc_k$$

In a continuous context with optimal distribution of incomes therefore, summing the implicit marginal prices of local public goods produced by a 'small' project over all occupied housings built in the location where the project is implemented provides an exact measure of the social value of the project. It is worth emphasizing the strength of the condition that observed households incomes are optimally distributed with respect to the same social welfare function as that used to appraise the value of public projects. This condition amounts to using in project evaluation the same ethics as that who considers the actual income distribution to be 'just' (or socially optimal). This particular ethic may not command widespread support.

Given this *proviso*, this formula can be applied and compute the social benefit that a reduction of one unit in some local public good could bring about in the cities. This is done in Table 4 for the variable *Peer* in a few poor cities of Val d'Oise in which the French Ministry of the city affairs has launched a large expenditure programme. Column 3 in Table 4, evaluates the sum of marginal willingness to pay for a one point reduction in *peers* taken over all landlords of every concerned city. These benefits, although significant, underestimate the total benefits that the inhabitants of the city would obtain out of the policy since they take no account of households who do not own their housing.[17] These figures can be compared with the government capital spending in these cities for local public schools that appear in column 4. It is of course difficult to appraise these figures without further information on the technology used by the government to convert public fund into reduction of behind grade levelness at school. However, and unless an extremely high rate of

[17]On the other hand, it is worth recalling that housing prices used in this study are supply prices and not transaction prices. It is also probably worth recalling that these figures are obtained from the sale (rather than the renting) market. These two states of affairs suggest an overestimation of the marginal willingness to pay.

Table 4. Cost–Benefit comparisons of public spending for reducing school failure

	(1)	(2)	(3)	(4)	(5)	(6)
	% of owners 1990 census	Number of housing units 1990 census	Table benefit of a permanent reduction of school failure by one point (in thousand of euros)	Total public spending including capital expenditures 1993 (in thousand of euros)	Annual benefit of a reduction of school failure by one point (in thousand of euros)	Public spending excluding capital expenditure 1993 (in thousand of euros)
Argenteuil	43	34 113	3520	3441	123	77
Bezons	44	9423	1040	980	36	25
Garges les Gonnesses	34	12 842	820	2640	29	75
Goussainville	58	7940	1349	1464	47	33
Persan	36	3402	2645	1251	93	14
Saint Ouen l'Aumône	43	6101	553	927	19	16
Sarcelles	33	17 607	1237	1407	43	42
Villiers le Bel	39	9102	656	1182	23	45
Total	–	–	11 820	13 291	414	327

Notes: (1) (2): INSEE CENSUS 1990.
(3): $(1) \times (2) \times$ MWP for the city.
(4) (6): Financial appendix: Town contract 1994–1998 Sources: Mission-Ville Département du Val d'Oise.
(5): $(3) \times 0.035$.

conversion of government money into reduction of school failure is assumed, it must be recognized that government spending is very modest in most of the cities with respect to the estimation of the benefits aimed. Column 5 and 6 make the same kind of comparison in annual terms using the discounted rate revealed by the capitalization of tax rate in the empirical model. Here again, government spending seems modest relative to the estimation of the benefits.

V. Conclusion

This study reveals a few noticeable facts. In Paris metropolitan area, dwelling prices appear to be sensitive to both public and car transportation. At a discount rate of 3.5%, the willingness to pay of the owner of the average housing of the sample used in this study for reducing marginally her commuting time to work is consistent with an hourly value of this owner's time of some three euros, a figure that is much lower than the value of the minimum wage for the reference years. The second important results revealed by this study is the clear capitalization of local taxes. Furthermore, the empirical results support the view that the quality of local public schools affects significantly housing price. It appears that both objective inputs and *peer* group effects affects significantly house price when control is made for other neighbourhood variables such as the poverty rate. The importance of the estimates of the social marginal value of avoidance of bad peer is worth stressing. In an average city counting 25 000 landlords, a policy leading to a reduction of 1% in the number of children who fail at school has a social marginal value of some 6.375 million of euros.

Acknowledgements

We gratefully acknowledge the financial support from the 'Direction Générale de l'équipement du Val d'Oise' as well as from the programme 'Action concertée incitative Villes' of the Ministère de l'enseignement supérieur et de la recherche. We thank also Stéphane Bujeau and Jean-François Guillaume for their competent research assistance, André de Palma and Cedric Fontan for providing us the data about transportation time costs and Richard Arnott and Nancy Wallace for helpful comments and Fabrice Barthélémy for a thorough discussion about DLR.

References

Acosta, R. and Renard, V. (1993) *Urban Land and Property Markets in France*, UCL Press, London.

Anderson, J. E. (1985) On testing the convexity of the hedonic price function, *Journal of Urban Economics*, **18**, 334–337.

Arnott, R. and Rowse, J. (1987) Peer group effects and educational attainment, *Journal of Public Economics*, **32**, 287–305.

Bartik, T. J. (1987) The estimation of demand parameters in hedonic prices models, *Journal of Political Economy*, **95**, 81–88.

Black, S. E. (1999) Do better schools matter? Parental valuation of elementary education, *Quarterly Journal of Economics*, **114**, 578–599.

Bogart, W. T. and Cromwell, B. A. (2000) How much is a neighborhood school worth, *National Tax Journal*, **47**, 280–305.

Box, G. E. P. and Cox, D. R. (1964) An analysis of transformations, *Journal of the Royal Statistical Society*, Ser. B, **26**, 211–52.

Cheshire, P. and Sheppard, S. (1995) On the price of land and the value of amenities, *Economica*, **62**, 247–67.

Cousin, O. (1996) Construction et Evaluation de l'Effet Etablissement, *Revue Française de Pédagogie*, **115**, 59–75.

Cropper, M. L., Deck, B. L. and McConnell, K. E. (1988) On the choice of functionnal form for hedonic price function, *Review of Economics and Statistics*, **70**, 668–75.

Dagenais, M. G. and Dufour, J. M. (1991) Invariance, nonlinear models, and asymptotic Tests, *Econometrica*, **59**, 1601–15.

Davidson, R. and McKinnon, J. G. (1993) *Estimation and Inference in Econometrics*, Oxford University Press, New York.

Dickie, M., Delorme, J. R. and Humfrey, J. M. (1997) Hedonic prices, good-specific effects and functional form: inferences from cross-section time series data, *Applied Economics*, **29**, 239–49.

Ekeland, I., Heckman, J. J. and Nesheim, L. (2004) Identification and estimation of hedonic models, *Journal of Political Economy*, **112**, 60–109.

Ellikson, B. (1979) Competitive equilibrium with local public goods, *Journal of Economic Theory*, **21**, 46–61.

Fujita, M. (1999) *Urban Economic Theory, Land Use and City Size*, Cambridge University Press, Cambridge. paperback reprint.

Ginsburgh, V. and Waelbroeck, P. (1998) The EC and real estate rents in Brussels, *Regional Science and Urban Economics*, **28**, 497–511.

Hanushek, E. A. (1986) The economics of schooling: production and efficiency in public schools, *Journal of Economic Literature*, **24**, 1141–77.

Hyde, S. K. (1999) Likelihood based inference on the Box–Cox family of transformations: SAS and Matlab programs, *Technical Report*, Mathematical Sciences, Montana State University.

Kanemoto, Y. (1988) Hedonic prices and the benefit of public projects, *Econometrica*, **56**, 981–89.

Kiel, A. K and McClain, K. T. (1996) House price recovery and stigma after a failed siting, *Applied Economics*, **28**, 1351–58.

Lynch, A. K. and Rasmussen, D. W. (2001) Measuring the impact of crime on house prices, *Applied Economics*, **33**, 1981–89.

Mas-Colell, A. (1975) A welfare analysis of equilibrium with differentiated commodities, *Journal of Mathematical Economics*, **2**, 263–95.

Palmon, O. and Smith, B. A. (1998) A new approach for identifying the parameters of a tax capitalization model, *Journal of Urban Economics*, **44**, 299–316.

Rasmussen, D. W. and Zuehlke, T. W. (1990) On the choice of functional form for hedonic price functions, *Applied Economics*, **22**, 431–38.

Rosen, S. (1974) Hedonic prices and implicit markets: product differentiation in pure competition, *Journal of Political Economy*, **82**, 34–55.

Scotchmer, S. (1985) Hedonic prices and cost/benefit analysis, *Journal of Economic Theory*, **37**, 55–75.

Scotchmer, S. (1986) The short run and the long run benefits of environmental improvements, *Journal of Public Economics*, **30**, 61–81.

Sheppard, S. (1999) Hedonic analysis of housing markets, in *Handbook of Regional and Urban Economics*, Vol. 3 (Eds) P. Cheshire and E. Mills, North-Holland, New York, pp. 1595–635.

Spitzer, J. J. (1984) Variance estimates in models with the Box–Cox transformation: implications for estimation and hypothesis testing, *Review of Economics and Statistics*, **66**, 645–52.

Trancart, D. (1998) L'Evolution des disparités entre colléges publics, *Revue Française de Pédagogie*, **124**, 43–53.

Appendix

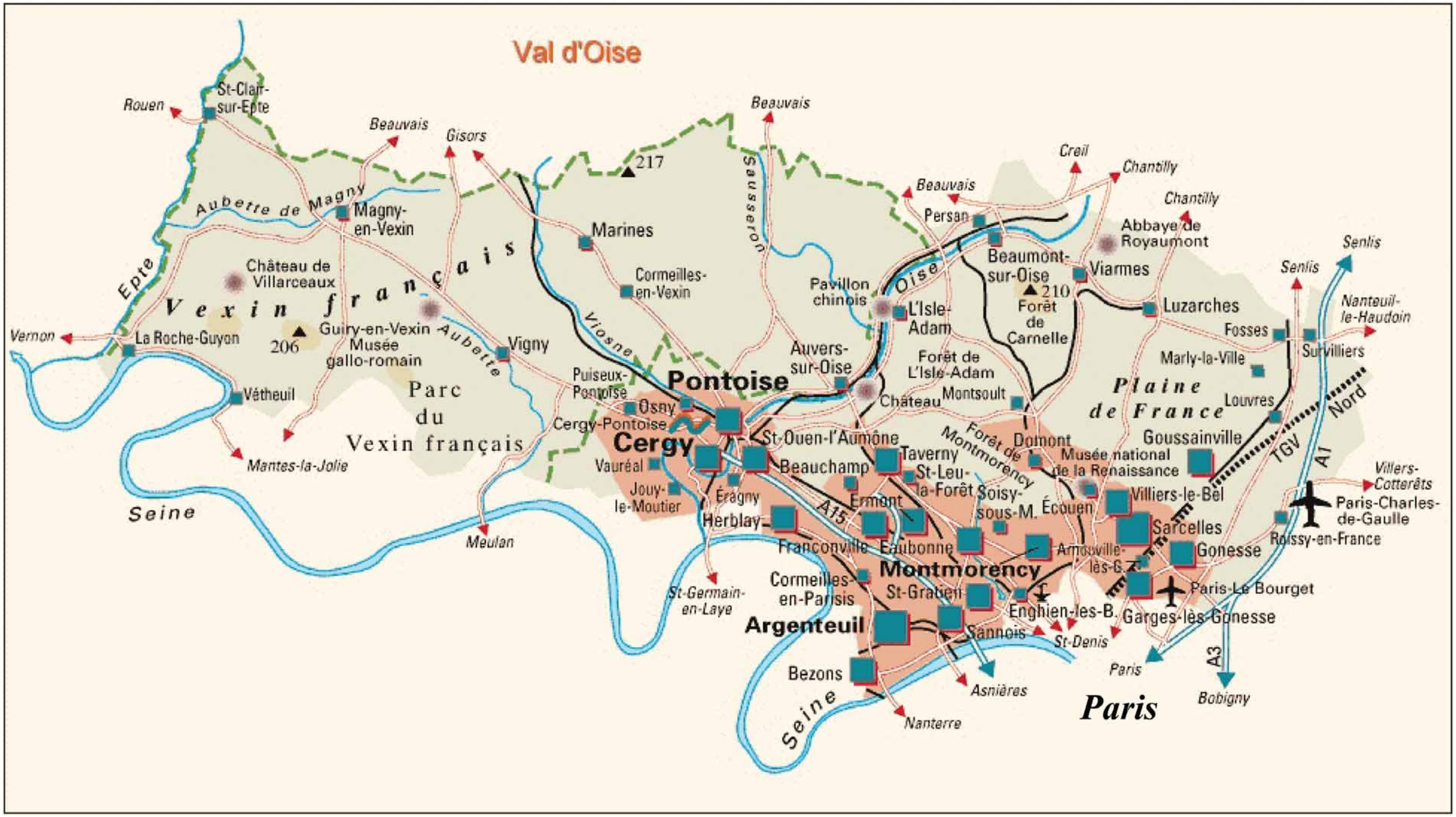

Fig. A1. Map of Val d'Oise

Table A1. Variable description

Variable name	Definition	Unit of measurement	Source
(A) Private variables			
Price	price of the housing divided by a price index	continuous (euros)	free newspapers adds
Second room	whether or not the housing has a second room	dummy	free newspapers adds
Third room	whether or not the housing has a third room	dummy	free newspapers adds
Fourth room	whether or not the housing has a fourth room	dummy	free newspapers adds
Fifth room	whether or not the housing has a fifth room	dummy	free newspapers adds
Sixth room	whether or not the housing has a sixth room	dummy	free newspapers adds
Another room	number of rooms above 6	discrete	free newspapers adds
Balcony	whether or not the housing has a balcony	dummy	free newspapers adds
Kitchen	whether or not the housing has an equipped kitchen	dummy	free newspapers adds
Parking	whether or not the housing has a parking	dummy	free newspapers adds
House	whether or not the housing is a house or an apartment in a collective building	dummy	free newspapers adds
Basement	whether or not the housing has a basement	dummy	free newspapers adds
Garden	whether or not the housing has a garden	dummy	free newspapers adds
Garden size	Size of the garden	continuous (m^2)	free newspapers adds
(F) Education variables			
Peer	fraction of the high school pupils who are at least two years backward in the three last years of high school	percent (average over the public schools in the city)	Ministry of education
Pupils/teacher	average number of pupils per class in public high schools	percent (average over the public schools in the city)	Ministry of education
(B) Accessibility			
Ptransport	time taken by public transportation to commute between the city centre and the centre of Paris in the morning rush hour	Minutes	I.A.U.R.I.F (96)
Ctransport	time taken to commute by car between the city and the centre of Paris in the morning rush hour	Minutes	I.A.U.R.I.F (96)
ACmotorway	distance between the city centre and the nearest freeway entrance	Km	computation by the authors
(C) Environmental and geographic variables			
DistRoissy	distance between the city and Roissy airport	km	computation by the authors
Rnuisance	lenght of the highway network relative to the city territory	km/km squared	computation by the authors
Scenic	lenght of scenic roads relative to the area of the city	km/km squared	Michelin's map, ed.1998, n.101
Elevation	difference between the highest and the lowest point in the city relative to the area of the city	m/m squared	computation by the authors

(*Continued*)

Table A1. Continued

Variable name	Definition	Unit of measurement	Source
Green	hectares of the city land open to public as natural space relative to the area of the city	per cent	Inventaire des terrains ouverts au public, Val d'Oise I.A.U.R.I.F 1990
Monuments	Number of historical buildings per km squared	continous	Inventaire communal INSEE 1998
Shopping	number of salaried workers in retail stores per 10 000 inhabitants	continous	Unemployment insurance office of the Paris metropolitan area
(E) Public goods and taxes			
Auditoria	number of auditoria per 10 000 inhabitants	continous	National census (1981 and 1990)
Playgrounds	number of playgrounds per 10 000 inhabitants	continous	National census (1981 and 1990)
REtax	rate of the tax on real estate	per cent of the administrative value of the housing	Tax authorities
Dtax	rate of the dwelling tax	per cent of the administrative value of the housing	Tax authorities
(G) Sociological and neighborhood variables			
Poverty	fraction of households who do not pay income taxes	per cent	Tax authorities