The price of climate: french consumers preferences reveal spatial and individual inequalities

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THE PRICE OF CLIMATE: FRENCH CONSUMER PREFERENCES REVEAL SPATIAL AND INDIVIDUAL INEQUALITIES

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Summary: We use the hedonic price method to study consumer preferences for climate (temperature, very hot or cold days, and rainfall) in France, a temperate country with varied climates. Data are for (i) individual attributes and prices of houses and workers and (ii) climate attributes interpolated from weather stations. We show that French households value warmer temperatures while very hot days are a nuisance. Such climatic amenities are attributes of consumers' utility function; nevertheless, global warming assessments by economists, such as the Stern Review Report (2006), ignore these climatic preferences. The social welfare assessment is changed when the direct consumption of climate is taken into account: from the estimated hedonic prices, we calculate that GDP rises by about 1% for a 1 °C rise in temperature. Moreover, heterogeneity of housing and households is a source of major differences in the individual effects of climatic warming.

Key Words: Price of climate, Hedonic method, France

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I. INTRODUCTION

We investigate the hedonic prices of climate in France.[1] First, we show that climate change impacts GDP through the capitalization of such prices in land rents and/or wages; this cannot be ignored, then, when assessing the macroeconomic effects of warming. Second, in France, people are not equal when it comes to warming: inequalities appear between individuals depending on their characteristics.

Consumers' climatic preferences are ignored in the global warming debate. Yet there are grounds for believing that, in their private behavior, inhabitants of temperate countries put a positive value on warmer temperatures, while very hot or very cold days are a nuisance: empirical studies converge toward these two findings. Such climatic amenities and nuisances are attributes of consumers' utility functions. Several consequences follow from this.

First, at the macroeconomic level, allowing for the value of these attributes modifies economic welfare. In particular, the non-egalitarian effects of global warming might be greater than the effects sometimes estimated (see Stern *et al*., 2006): inhabitants of temperate countries (e.g. France, U.K.), where the mean temperature will rise, will see their welfare increase whereas inhabitants of hot countries (e.g. Mexico, Egypt), where heatwaves will be more marked, will see their welfare decline. These direct effects must be taken into account in global warming assessment, otherwise the international climate negotiations would be distorted.

Second, at the microeconomic level, the contradiction between private optimum and social optimum might be greater than in the standard case (congestion, pollution, etc.) because, as global warming improves the private optimum of consumers in temperate countries while diminishing the global social optimum, the two effects have opposite signs. It will therefore be more difficult to get citizens in temperate countries, which are big producers of greenhouse gases, to accept public policies combating global warming. These private effects must be taken into account in public announcements and campaigns to heighten awareness of the hazards of warming. Otherwise, such talk would be given little credence by people who feel an improvement in their own private welfare.

Thirdly, individuals are not equally affected by warming. Warming does not have the same effect for someone in an apartment or in a detached house, or for someone in the city or in the country. The elderly and the young do not have the same demand for climatic goods. This diversified behavior must also be taken into account in policies for combating warming or they shall not attain their targets.

Here we study consumer preferences for climate (mean annual temperatures, mean January and July temperatures, summer heatwaves, coldest winter days, annual and monthly rainfall) in France. We use the hedonic price method (Rosen, 1974) to determine the price of climatic attributes, which are capitalized in wages and/or land rents. This enables us to assess the increase

[1] This research was financed by the French *Ministère de l'Emploi, de la Cohésion sociale et du Logement*. It uses data from Housing Surveys by the *Institut national de la statistique et des études économiques* (INSEE).

in welfare brought about by a rise in temperatures. We use individual data from housing surveys by the French National Institute for Statistics and Economic Studies (INSEE). Econometric estimates are made on real-estate values (owner-occupiers and tenants) and on wage-earners. Climatic variables are required for the entire country to be matched with these data. They are obtained by interpolation by local regression and kriging of readings from weather stations. Section 1 summarizes the economic literature on climate and presents the micro-economic analysis. The econometric models, economic and climatic data are covered in Section 2. The results are presented and discussed in Section 3. Section 4 concludes.

II. CLIMATE IN ECONOMICS

1. The hedonic price of climate

To the best of our knowledge, estimations of the hedonic price of climate date back to Hoch and Drake (1974). Prominent work was done in the domain by Cragg and Kahn (1997; 1999). In many other studies since Henderson (1982), climatic attributes are variables selected to measure among other things the quality of life or to control for spatial heterogeneity (e.g. Blomquist *et al.*, 1988). Recently, debate about climate change has led to examination of the effects of climate on welfare at a global scale (Maddison, 2003; Rehdanz and Maddison, 2005). The effect of climate on population migrations also has a long history (Graves, 1976; 1980; Graves and Linneman, 1979). Cheshire and Magrini (2006) have recently shown the impact of climate on the growth of urban populations in Europe.

The findings show that January and July temperatures command significant hedonic prices (capitalization in wages is negative for winter and positive for summer), as is generally the case with rainfall, wind speed, and hours of sunshine. In the U.S., a variation of one standard deviation in any one of these attributes accounts for 2% to 3% of wages.

Little work has been done in Europe. In a study of Italy, Maddison and Bigano (2003) conclude that July temperatures and January rainfall have a negative effect on welfare and that the number of days of clear skies has a significant effect in Milan. Maddison (2001) shows that mean annual temperatures and rainfall are significant in a housing-price function in the U.K. Rehdanz and Maddison (2008) show that German households prefer warmer winters with less rainfall.

It should be noted that such research is seldom conducted on individual data, so there is no way of telling whether or not the results are sensitive to the characteristics of housing or households.

2. Economic valuation of climatic warming

Nordhaus (1991; 1992) pioneered the economic valuation of warming by developing climatic-economic models, which were rapidly followed by others. The Stern Review Report (Stern *et al.*, 2006) also relies on a climatic-economic model (Hope, 2006). Time is at the core of these studies, whether for very long-term climatic changes or for inter-temporal economic reasoning. The aim is to compare the damage and prevention costs so as to find an optimal policy pathway for reducing greenhouse-gas emissions.

The conclusions broadly converged until recently: emission-reducing policies are required and the optimal pace is to implement them slowly today, and then intensify them progressively over time. The Stern Review (Stern *et al.*, 2006) conclusions are the other way around: highly restrictive measures should be taken immediately. The crux of the divergence is the discount rate. We shall steer clear of this debate. The divergence also relates to the economic agents' capacity to adapt (Mendelsohn *et al.*, 1994).

3. The welfare

Climate, which is an attribute of the consumer utility function, must be allowed for when calculating social welfare, regardless of the indirect market costs and benefits generally used in cost-benefit analysis of warming. In this way, the two strands of the literature just discussed can be unified.

Rosen (1979) and Roback (1982) provide foundations for the reasoning, which are summarized by Gyourko *et al*. (1999) in this way. Let the program of a consumer *j* at location *k* be: $\max U = U(Z_j, S_j, A_k, \alpha_j)$, under the constraint: $Z_j + R_k S_j = W_k$ where *R* is the land rent, *S* the area of a residential lot, *A* a climatic amenity, *W* income, and α_j are characteristics specific to consumer *j*. The indirect utility function *V* is $V_{jk} = V_j(W_k, R_k, A_k)$, and at the optimum: $V^* = V_{jk}$.

Let also a firm's profit be: $\pi_{jk} = pY_j(M_j, L_j, S_j, A_j, \beta_j) - p_M M_j - W_k L_j - R_k S_j$, where *Y* is output and *p* its price, *M* is capital input and p_M its price, *L* labor, *S* land, and β_j are characteristics of firm *j*. The indirect profit function is: $\Pi_{jk} = \Pi_j(W_k, R_k, p, p_M, A_k)$, and at the optimum $\Pi^* = \Pi_k$.

Wages and rents at equilibrium are determined from the utility and profit functions. From the first order conditions, it is easy to obtain the variations in wages and rents with amenities (indexes denote partial derivatives), which are:

$$\frac{\partial W}{\partial A} = \frac{\frac{1}{V_W}\left(-V_A + V_R \frac{\Pi_A}{\Pi_R}\right)}{1 - \frac{V_W}{V_R}\frac{\Pi_R}{\Pi_W}} \text{ (indeterminate sign) and } \frac{\partial R}{\partial A} = \frac{-\frac{V_A}{V_R} + \frac{V_W}{V_R}\frac{\Pi_A}{\Pi_W}}{1 - \frac{V_W}{V_R}\frac{\Pi_R}{\Pi_W}} > 0 \quad (1)$$

Land values rise with amenities. The sign is indeterminate for wages: if the amenity does not affect firms' productivity (Π_A=0), the amenity is negatively capitalized in wages. If the amenity has positive productivity, the change in wages is indeterminate, and rents increase more than in the previous case.

If warming is an amenity in temperate countries, an increase in temperature *ceteris paribus* entails an increase in consumer's utility because consumers enjoy a greater quantity of this good. To maintain their utility at the same level the government has to collect a tax, which swells the public purse. Otherwise, tenants pay more (cf. (1)) and landowners receive more rent, which is imputed to the households item in the National Accounts. In both cases, the climatic amenity is reflected by a gain in GDP brought about by warming.

This effect depends on consumer preferences and firms' technology levels, on assumptions about international trade, and on the initial level of temperature: all things been equal, GDP will rise in a temperate country, which is sensitive to warming, and will decrease in a hot country, which is negatively affected.

III. METHODS AND DATA

1. Econometric issues

First, the identification problem is well-known in hedonic literature: the second step of Rosen's method (1974) is required to estimate the supply and demand functions (see especially Brown and Rosen, 1982), except if supply is price-inelastic (Freeman, 1979), which is the case of climate attributes.

Second, some explanatory variables may be endogenous (Epple, 1987), particularly in a housing equation, when the purchaser simultaneously chooses the price (dependent variable) and the quantity of certain attributes (e.g. the living space). Thus, we use the instrumental method, using personal characteristics of the households as instruments, as theory suggests (Epple, 1987). Their exogeneity is tested by Sargan's method, and the endogeneity of the covariate(s) is tested by Hausman's method. The main equation is then estimated by the 2SLS.

Thirdly, there are many and strong correlations among climatic variables (see Appendix 1). If multicollinearity occurs (detected by the *condition number*), we use a second estimation procedure, Partial Least Squares (PLS, Wold 1985), which may be thought of as an intermediate procedure between OLS and principal component regression (Stone and Brooks, 1990). We used a modified version of this algorithm (Bastien *et al*., 2005), and a bootstrap approach to determine the distribution of the PLS estimators of regression coefficients, and to calculate mean confidence intervals.

Finally, the spatial autocorrelation between the residuals cannot be tested because the data are anonymous: their spatial distribution is unknown.

2. The economic data

The economic data are mainly from housing surveys conducted by the INSEE. The climatic variables and the spatial variables (see below) were matched with these surveys by the INSEE.[2]

The Mincer-type wage equation (Mincer, 1962) was obtained from individual income data of people in dwellings surveyed in 2002. After excluding state employees and extreme wages, the sample comprised 19,063 people. The endogenous variable is the logarithm of the annual wage earned in the 12 months preceding the survey. The explanatory variables are (cf. the descriptive statistics in Appendix 2): age, sex, socio-occupational category, employment rate, employment contract type, highest diploma, nationality, and country of birth.

For housing, we selected households that had moved in recently (within the last four years). Four equations were estimated for buyers and tenants crossed with detached houses and apartments. We had a total of 9,640 buyers of single-detached houses, 2,658 buyers of apartments, 3,447 tenants of single-detached houses and 8,615 tenants of apartments. The data were deflated into €2002. The explanatory variables are (cf. descriptive statistics in Appendix 2): detached housing or housing in apartment blocks, survey year, floor space, garden area for detached houses (quadratic form), sanitation facilities (bathrooms and toilets), main room size (quadratic form), heating type, garage, parking space, cellar, veranda, fireplace(s), date of construction of the structure (quadratic form), and the date the household moved in.

Spatial variables were also introduced into the equations (see Appendix 2).[3] Lastly, variables characterizing the climate were introduced into each of these equations.

3. Climatic data

Climatic variables come from Météo-France (monthly data for the period 1970–2000). They are (cf. Appendix 2): mean annual temperature, temperatures for January and July, number of days

[2] We thank Alain Jacquot and Anne Laferrère for authorizing this operation when they were heads of the Housing Division.

[3] Urban areas comprise an urban center (urban units with 5000 jobs or more) and a periurban belt (communes where 40% of active residents commute to work outside the commune but within the urban area). The delimitation method is similar to that for *Statistical Metropolitan Areas* in the US but the thresholds are lower.

with temperatures of less than –5 °C in January and more than 30 °C in July, mean monthly rainfall, rainfall in January and July, number of days' precipitation in January and July.
These data are recorded by a network of scattered weather stations. Interpolation is used to reconstruct a spatial continuum based on this information (Joly et al., 2008). First we use regressions between temperature/rainfall and explanatory variables suggested by climatology,[4] and then kriging of residuals from the regressions. As the models and parameters estimated are not identical over an area of the size of France, interpolation is done for small polygons including the 30 closest stations. The predicted values are computed for each French commune, and then merged with the housing survey data.

IV. RESULTS

We do not comment here on the results of the non-climatic characteristics as they are not the relevant variables in this paper (see complete results in Appendix 3). Table 1 shows the results of climatic variables.
For the housing equations, we tested whether the living space was endogenous (because of a simultaneous choice between the size of the housing and its price). The results show that it is endogenous in three out of four equations (it is exogenous for owner-occupied of single-detached houses); in this case its projection is used in the main equations, estimated by 2SLS or by PLS. The *condition number* diagnostic shows that multicollinearity occurs between climatic variables anyway; it is average-sized despite the high Pearson's correlation coefficients. Therefore, the PLS estimation was made in any case. In most of the equations, the results are similar to those of the OLS/2SLS, confirming that multicollinearity does not affect the estimates too much (probably because of the high number of observations).
From the equation and the estimation method, the R^2 varies between 0.54 and 0.61.

1. Hedonic price of temperature and rainfall

The first finding shown by Table 1 is the lack of significance of the estimates in the wage equation (the number of January days with rainfall is an exception, with an unexpected negative sign). In France, climatic amenities are not capitalized in wages. This is probably because wages are often independent of location (and so insensitive to climatic amenities), due to labor-market regulations at the national level. Afterwards, we focus on the real-estate findings.
The mean annual temperature has a positive significant effect on the housing price for owner-occupiers: a rise of 1 °C entails an increase in housing prices of 5.9–6.2% (according to the equation and estimation method). The sign is also positive for tenants, with values between 2.5 and 3.9%, which are roughly half as much as for owner-occupiers.
The effect of warmer summers (mean July temperature minus mean annual temperature) is compounded with the preceding one for single-detached houses: an extra 1 °C entails a price increase of 3.7 to 8.4% (depending on the model). This effect is insignificant for apartments. Hot summer days (more than 30 °C) have a significant effect for owner-occupiers of single-detached houses and renters of apartments. At the median point, an extra day of heat lowers the value of

[4] A GIS was made up of climatic data, geographical coordinates of the weather stations and a set of explanatory variables used in regression, made up from two information sources: a land-use image from the Corine Land Cover (CLC) European database and a digital elevation model (DEM) produced by France's *Institut géographique national* (IGN). Eleven explanatory variables are produced: latitude and longitude, a vegetation index, the distance to the nearest forest, to the nearest sea or ocean, slope angle, slope orientation, topographic ruggedness, prominence index, and aggregate theoretical radiation for the summer solstice. Temperature and rainfall are explained by the best covariates.

housing by 4.3% (owner-occupiers) or by 1% (tenants). This effect is quadratic, probably due to seaside sites where hot summers are appreciated. French households are insensitive to cold winters, either the January temperature minus the mean annual temperature or the number of coldest days (less than – 5 °C). These influences may be unimportant because it is easy to protect oneself both by heating and by winter clothes.

	owner-occupiers							
	single detached houses				**apartments**			
	OLS		**PLS**		**2SLS**		**PLS**	
	estimate	**Pr > |t|**	**estimate**	**p value**	**estimate**	**Pr > |t|**	**estimate**	**p value**
Mean annual temperature (°C)	0.0599	<.0001	0.05726	<.0001	0.057262	0.0074	0.05812	0.009
Difference (July-mean annual temperature) (°C)	0.08037	0.0004	0.06848	0.001	0.063547	0.2275	0.04482	0.135
Difference (January-mean annual temperature) (°C)	0.02591	0.1814	0.01459	0.37	0.046843	0.2858	0.01777	0.359
July warm days (> 30° C)	-0.04199	<.0001	-0.0405	<.0001	-0.01963	0.2092	-0.02498	0.109
(July warm days)² (> 30° C)	0.00149	<.0001	0.001424	<.0001	0.001413	0.0481	0.001596	0.031
January cold days (< - 5° C)	0.00669	0.4935	0.0009078	0.476	-0.01368	0.5215	-0.01974	0.229
(January cold days)² (< - 5° C)	0.0014	0.0504	0.001858	0.011	0.00268	0.1034	0.002955	0.054
July days with rainfall	0.00948	0.0723	0.007804	0.088	0.042811	0.0001	0.03886	<.0001
January days with rainfall	-0.02237	<.0001	-0.02203	<.0001	-0.01444	0.076	-0.01427	0.057
	Tenants							
	single detached houses				**apartments**			
	2SLS		**PLS**		**2SLS**		**PLS**	
	estimate	**Pr > |t|**	**estimate**	**p value**	**estimate**	**Pr > |t|**	**estimate**	**p value**
Mean annual temperature (°C)	0.037957	0.0162	0.03737	0.005	0.027625	0.0005	0.02504	0.004
Difference (July-mean annual temperature) (°C)	0.062578	0.0678	0.03617	0.022	-0.00171	0.9285	-0.002226	0.453
Difference (January-mean annual temperature) (°C)	0.033658	0.2703	0.005734	0.411	-0.0109	0.5144	-0.015	0.081
July warm days (> 30° C)	-0.00714	0.4654	-0.01138	0.115	-0.02554	<.0001	-0.02361	0.001
(July warm days)² (> 30° C)	0.000237	0.4755	0.0002927	0.184	0.001056	<.0001	0.0009637	0.001
January cold days (< - 5° C)	-0.02078	0.1754	-0.02962	0.045	-0.00454	0.6019	-0.008856	0.218
(January cold days)² (< - 5° C)	0.003287	0.006	0.004102	0.001	0.000299	0.6781	0.0005114	0.308
July days with rainfall	0.008452	0.3083	-0.001103	0.443	0.013582	0.0011	0.01394	0.002
January days with rainfall	-0.01335	0.0205	-0.01225	0.022	-0.02014	<.0001	-0.01987	<.0001
	wages							
	OLS		**PLS**					
	estimate	**Pr > |t|**	**estimate**	**p value**				
Mean annual temperature (°C)	0.00245	0.7347	0.001933	0.395				
Difference (July-mean annual temperature) (°C)	-0.01279	0.5443	-0.002569	0.461				
Difference (January-mean annual temperature) (°C)	-0.02325	0.2086	-0.01892	0.136				
July warm days (> 30° C)	-0.00185	0.4407	-0.002552	0.176				
(July warm days)² (> 30° C)								
January cold days (< - 5° C)	0.0005306	0.8947	-0.00178	0.349				
(January cold days)² (< - 5° C)								
July days with rainfall	0.00531	0.2469	0.005169	0.127				
January days with rainfall	-0.00819	0.0112	-0.007652	0.011				

Table1: Results: climatic variables

Source: Authors' results

The number of days' rain in January and July has a significant effect on real-estate values. The January sign is the expected: prices or rents fall by almost 1.2–2.3% for an extra day's rain. The number of days of rainfall in July also exerts a positive effect on the price of apartments (but not on the price of single-detached houses), indicating that households pay more for their housing (1.4 to 4.4%) for an extra summer day's rain.

2. Does France benefit from warming?

It would be beyond the scope of this paper to propose a scenario of climate change and to assess its effects on French GDP. We propose something less ambitious here: to show that direct consumption of climate and its capitalization in rents and/or wages have a significant macroeconomic effect.

Let us set out some simplifying assumptions: (i) in France, the capitalization of the price of climate into wages can be ignored; (ii) the land and structure combination in the housing production function is assumed to be constant, which is an acceptable hypothesis, since the housing stock in France is renewed slowly; (iii) land consumption by firms is ignored; (iv) housing and workers are internationally immobile. It follows that warming does not impact on production; the price of warming is capitalized only in the land rent. French consumers' utility increases, owing to the greater quantity of temperature, entailing a real increase in wealth. GDP therefore rises in real terms. We also assume there is neither redistribution nor are there indirect effects, and we ignore the regional effects within France (migrations, etc.).

By way of illustration, we study the effects of a rise of the mean temperature by 1 °C from 11.8 °C to 12.8 °C. We assume the rise in temperature is uniform nationwide. July temperatures, and July days of more than 30 °C (if significant) are changed when mean annual temperature rises, in accordance with the elasticity between these variables. We ignore the effects of warming on rainfall, and the effects on temperature for months other than July. Table 2 shows the results.

	single detached houses		**apartments**	
	OLS	**PLS**	**2SLS**	**PLS**
	owner-occupiers			
Mean annual temperature (°C) (€)	1008.8	963.0	920.3	934.5
Difference (July-mean annual temperature) (°C) (€)	1367.6	1158.3	NS	NS
July warm days (> 30° C) (€)	-763.0	-738.9	NS	NS
TOTAL (€)	1613.3	1382.4	920.3	934.5
TOTAL (%)	9.9%	8.5%	5.9%	6.0%
	tenants			
Mean annual temperature (°C) (€)	2.67	2.63	1.79	1.62
Difference (July-mean annual temperature) (°C) (€)	4.47	2.55	NS	NS
July warm days (> 30° C) (€)	NS	NS	-1.85	-1.71
TOTAL (€)	7.14	5.18	-0.07	-0.09
TOTAL (%)	10.3%	7.5%	-0.1	-0.14

NS: unsignificant

global effect on GDP	**1,0%**	**0,8%**

Table2: Effect of a 1 °C mean annual temperature rise on housing prices and GDP
Source: Authors' results

The effects on housing prices are sizeable for single-detached houses (9% or so), weaker for owner-occupiers of apartments (6%) and negligible for tenants of apartments (-0.1%). Housing represents 16% of GDP in France. Under our assumptions, GDP is affected only by the variation in the price of housing that appears in the Household Account. The effect on GDP of 1 °C warming is therefore equal to one-sixth of housing prices or rents, weighted by the proportion of the two occupier-statuses (56% for owners and 44% for tenants). By the OLS/2SLS method, GDP increases by 1.0%, and by the PSL it increases by 0.8% when temperature rises by 1 °C. This effect is substantial, contrary to the result obtained by Rehdanz and Maddison (2008), who concluded that, in Germany, the selected emissions scenario has a negligible effect because, as the authors concede, climatic variables are not measured with sufficient precision.

3. Who benefits from warming in France?

We first look at owner-occupiers of single detached housing, who are the most sensitive to climate characteristics. Table 3 takes the same variables as Table 1 and adds interaction variables with significant parameters from among those tested.

	owner-occupiers of single detached houses OLS	
	estimate	**Pr > |t|**
Mean annual temperature (°C)	0.06182	<.0001
Difference (July-mean annual temperature) (°C)	0.08312	0.0003
Difference (January-mean annual temperature) (°C)	0.03924	0.0444
July warm days (> 30° C)	-0.06131	<.0001
(July warm days)² (> 30° C)	0.00157	<.0001
July days with rainfall	0.00778	0.1432
January days with rainfall	-0.01974	<.0001
Mean annual temperature (°C) and rural space	0.02603	<.0001
Difference (July-mean annual temperature) (°C) and cities	0.02847	0.0007
January days with rainfall and poor heating	-0.01029	0.0187
July warm days (> 30° C) and garden	0.01566	<.0001
January cold days (<- 5°C) and date of construction of the structure:		
Before 1914	-0.00668	0.3676
1914-1948	0.00413	0.5602
1949-1961	-0.00181	0.8128
1962-1967	0.01734	0.0525
1968-1974	0.01522	0.0284
after 1974	0.02842	<.0001
January cold days (<- 5°C) and montain region	0.00557	0.0407

Table3: Owner-occupiers of single-detached houses: results with interaction variables
Source: Authors' results

An extra one degree of mean annual temperature has an effect + 2.8% more than the mean effect in rural areas, or an overall effect of + 9.2% per degree Celsius. In owner-occupied detached housing in cities, an interaction variable with July temperatures has a positive parameter, showing that high July temperatures in cities are enjoyed more in detached housing than in apartments. Heatwave days have a negative mean effect, but that is reduced (by 1.6%) for houses with gardens. The effects of severe January weather are less expected than the previous ones for, while older buildings have smaller parameters, it seems that very cold January days are appreciated in recent detached housing (built after the first oil crisis in 1974). It may be that this unexpected result derives from inadequate control for the benefits procured by new or recent housing, which may be correlated with harsh winters (heat insulation is better in houses in cold regions, etc.).

Climate also has different effects depending on household heterogeneity. We do not estimate demand elasticity of climate here, as this would require data from different markets (Brown and Rosen, 1982) to ensure sufficient price variability. Moreover, the second stage of Rosen's method involves serious econometric difficulties (Sheppard, 1999), meaning that few workers risk using it in practice.

We analyse climate consumption for owner-occupiers of single detached houses and tenants of apartments. Climate consumption is calculated by dividing households according to quartiles of income, age of the head of the household, and number of units of consumption. We do not reproduce the results for income and household size here, as the variations are very small from one quartile to another. Table 4 shows the results for the age of the head of the household.

Owner-occupiers of single detached houses

quartiles of age	Q1: < 32	Q2: 32-37	Q3: 37-45	Q4: > 45
Mean annual temperature (°C)	11.34	11.46	11.63	11.83
Difference (July-mean annual temperature) (°C)	7.81	7.92	7.97	7.92
Difference (January-mean annual temperature) (°C)	-7.10	-7.22	-7.24	-7.16
July warm days (> 30° C)	5.04	5.49	5.94	6.36
July days with rainfall	7.39	7.23	7.00	6.73
January days with rainfall	11.31	10.98	10.75	10.64

Tenants of apartments

quartiles of age	Q1: < 24	Q2: 24-29	Q3: 29-37	Q4: > 37
Mean annual temperature (°C)	11.94	11.91	12.04	12.17
Difference (July-mean annual temperature) (°C)	8.04	8.08	8.17	8.16
Difference (January-mean annual temperature) (°C)	-7.37	-7.42	-7.49	-7.38
July warm days (> 30° C)	5.97	5.88	6.25	6.44
July days with rainfall	6.92	7.06	6.87	6.57
January days with rainfall	10.46	10.34	10.10	9.96

Table4: of climate according to the age of the household's head

Source: Authors from INSEE housing surveys

Consumption of mean annual temperature rises regularly with the age of the head of the household for owner occupiers of individual houses: those in the last quartile consume about 0.5 °C more than those in the first quartile (+ 4%). The variation between these two extreme groups is 1.3 for the number of very hot July days (+ 26%) and – 0.7 for the number of rainy days in January (– 6%). For apartment tenants, the variation between the two extreme groups is of the same sign but is less marked: + 2% for mean annual temperature, + 8% for very hot July days and – 5% for the number of wet winter days.

V. CONCLUSIONS

Climate is a directly-consumed, non-market good that is therefore a direct component of welfare. Analyses of the consequences of warming by cost-benefit methods do not allow for this direct effect, leading to inaccurate evaluations. In this paper, we estimate the hedonic price of climatic attributes (temperature, rainfall) from individual data on housing and wages in France. Climatic variables are obtained by local interpolation (by regression and kriging) from weather stations. Econometric estimates are obtained by two methods (OLS/2SLS and PLS) for 12,298 owner-occupied houses (9,640 single-detached houses and 2,658 apartments) and 12,062 rented dwellings (3,447 single-detached houses and 8,615 apartments) and on the wage-earners occupying the housing (19,063 people).

The results show that climate is not capitalized in wages (as in France wages are often independent of location because of national labor regulations) and that capitalization is quite high in the value of housing, especially for owner-occupiers. So, housing is worth almost 6% more when the mean annual temperature increases by 1 °C. At the median point, an extra day of excessive July heat lowers housing values by 4.3% (owners) or by 1% (tenants). The effects on housing prices and rents of mean January temperatures and of the number of days of extreme cold in winter are insignificant. Rainfall affects housing prices or rents less than temperature. whenever there is an effect on production. Macroeconomic models are required to extend this analysis, but they lie outside the scope of this paper.

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Appendix 1.
Pearson correlation coefficients between climatic variables
(Example of owner-occupier single-detached houses)

	Mean annual tempera-ture (°C)	Difference (July-mean annual temperature) (°C)	Difference (January-mean annual temperature) (°C)	July warm days (> 30° C)	Janua-ry cold days (< - 5° C)	July days with rainfall
Mean annual temperature (°C)	1.000					
Difference (July-mean annual temperature) (°C)	0.115	1.000				
Difference (January-mean annual temperature) (°C)	0.026	-0.951	1.000			
July warm days (> 30° C)	0.746	0.632	-0.470	1.000		
January cold days (< - 5° C)	-0.650	0.512	-0.606	-0.128	1.000	
July days with rainfall	-0.847	-0.242	0.030	-0.794	0.464	1.000
January days with rainfall	-0.605	-0.652	0.499	-0.802	0.064	0.735

Source: authors computations by interpolation of Météo-France climatic data.

Appendix 2: descriptive statistics
Climatic variables

	mean	std	min	max
Mean annual temperature (°C)	11.6585	1.4248	7	15.8
Difference (July-mean annual temperature) (°C)	7.9623	0.8668	5	9.8
Difference (January-mean annual temperature) (°C)	-7.2442	0.8909	-10	-4.3
July warm days (> 30° C)	5.7722	4.0067	0	23.4
January cold days (< - 5° C)	2.9790	1.9270	0	14.3
mean monthly rainfall (mm)	66.3353	15.3687	33.9917	178.025
Difference (July-mean monthly rainfall) (mm)	-12.2074	15.7812	-116.925	24.7083
Difference (January-mean monthly rainfall) (mm)	3.1912	12.0487	-38.1917	55.0833
July days with rainfall	7.0474	2.0660	1	12.1
January days with rainfall	10.7308	2.2790	4.8	17.1

Source: authors computations by interpolation of Météo-France climatic data.

Appendix 2: descriptive statistics (continued)

Wage equation

	mean	std
senior managerial	0.1357801	0.3425640
intermediate managerial	0.2136579	0.4098990
office worker	0.0538539	0.2257353
personal service providers	0.0791030	0.2699066
skilled industrial worker	0.0925265	0.2897755
skilled self-employed worker	0.0797422	0.2709009
skilled workers (other)	0.0614180	0.2401018
industrial unskilled worker	0.0820860	0.2745030
unskilled self-employed worker	0.0286582	0.1668483
farmworker	0.0143291	0.1188466
full time employment	94.4587972	15.6109294
apprentice	0.0158739	0.1249909
interim worker	0.0294572	0.1690887
limited-tenure employment	0.0798487	0.2710661
age: <19 years	0.0192297	0.1373352
age: 20–24	0.0910350	0.2876665
age: 25–29	0.1381239	0.3450392
age:30–34	0.1565546	0.3633900
age: 40–44	0.1401481	0.3471499
age: 45–49	0.1252863	0.3310521
age:50–54	0.1115432	0.3148120
age:55–81	0.0620039	0.2411691
male	0.5760933	0.4941890
4 years higher education	0.1507484	0.3578130
2 years higher education	0.1002504	0.3003415
capbepc	0.4090449	0.4916707
no educational qualification	0.1881958	0.3908789
French by naturalisation	0.0346775	0.1829664
European nationality	0.0279124	0.1647263
African nationality	0.0218399	0.1461644
other nationality	0.0044745	0.0667437
born in Europe	0.0112395	0.1054221
born in Africa	0.0132637	0.1144050
born in other region	0.9430032	0.2318426
rural commune	0.1522399	0.3592629
disadvantaged region	0.0770255	0.2666390
market size	31.3590847	54.4587101
poor commune 1000-1500K	0.0698343	0.2548744
poor commune Paris	0.0581154	0.2339677
poor commune 500-1000Kinhabitants	0.0238108	0.1524634
unemployment rate	0.1204421	0.0492953

Sources: Housing surveys (1988 to 2002) by INSEE (Institut national des statistiques et études économiques).

Appendix 2: descriptive statistics (continued)

Housing equation

	owners		renters	
	mean	std	mean	std
detached house	0.7838673	0.4116226	0.2857735	0.4518008
housing in an apartment block	0.2161327	0.4116226	0.7142265	0.4518008
1988 survey (detached house)	0.2316637	0.4219124	0.0569557	0.2317676
1992 survey (detached house)	0.1774272	0.3820454	0.0789256	0.2696337
1996 survey (detached house)	0.136445	0.3432744	0.062842	0.2426886
2002 survey (detached house)	0.2383314	0.4260802	0.0870502	0.2819204
1988 survey (housing in an apartment block)	0.060335	0.2381162	0.1217045	0.3269578
1992 survey (housing in an apartment block)	0.0500081	0.2179706	0.1967335	0.3975457
1996 survey (housing in an apartment block)	0.0410636	0.1984454	0.1886918	0.3912798
2002 survey (housing in an apartment block)	0.064726	0.2460517	0.2070967	0.4052422
living space (detached house)	112.3328838	36.2140997	90.7719756	29.9605117
living space (housing in an apartment block)	74.7599699	24.0453159	54.9673825	23.5503152
garden size (detached house)	958.4891079	1146.53	470.3263708	762.0989275
number of bathrooms (detached house)	2.5316909	0.8900301	2.2489121	0.7332841
number of bathrooms (housing in an apartment block)	2.1403311	0.5805972	1.8904817	0.4514918
poor heating	0.1026183	0.303472	0.1370419	0.3439059
room size (detached house)	23.2651831	6.1306681	22.2538758	5.7007738
size of the roons (housing in an apartment block)	22.5275005	4.8642808	23.8414523	6.3841104
garage (detached house)	0.8655602	0.341142	0.7229475	0.4476076
garage (housing in an apartment block)	0.5921746	0.4915229	0.3890888	0.4875718
cellar (detached house)	0.4221992	0.4939356	0.3785901	0.4851061
cellar (housing in an apartment block)	0.7633559	0.4251019	0.5216483	0.4995601
veranda	0.0352903	0.1845201	0.0155861	0.1238728
date of arrival in the housing	2.448203	3.8836823	1.0501575	1.0973906
before 1948 (detached house)	0.1927386	0.39447	0.4078909	0.491514
1949–1974 (detached house)	0.1207469	0.3258498	0.2164201	0.4118636
1975–1984 (detached house)	0.1060166	0.3078748	0.1430229	0.350147
after 1985 (detached house)	0.5804979	0.4935031	0.2326661	0.4225925
before 1948 (housing in an apartment block)	0.1997743	0.3999058	0.3461405	0.3461405
1949-1974 (housing in an apartment block)	0.3720843	0.4834517	0.3012188	0.3012188
1975-1984 (housing in an apartment block)	0.1617758	0.3683143	0.10296	0.10296
after 1985 (housing in an apartment block)	0.2663657	0.4421409	0.2496808	0.2496808
fireplace (detached house)	0.4068465	0.4912713	0.2251233	0.4177241
fireplace (housing in an apartment block)	0.027088	0.1623705	0.0123041	0.1102458
number of storeys of the building	1.0822085	2.8006593	2.9461118	3.3325853
ground floor	0.0307367	0.1726105	0.1316531	0.3381273
urban area, center < 30 000 inhabitants	0.0727761	0.2597791	0.0737854	0.2614322
urban area, center 30 000 – 50 000 inhabitants	0.0535859	0.2252079	0.0423645	0.2014276
urban area, center 50 000 – 100 000 inhabitants	0.0909904	0.2876072	0.0882109	0.2836131
urban area, center 100 000 – 200 000 inhabitants	0.0952187	0.2935288	0.0997347	0.2996584
urban area, center 200 000 – 500 000 inhabitants	0.126606	0.3325445	0.1713646	0.3768429
urban area, center 500 000 – 1 million inhabitants	0.0799317	0.2711985	0.1060355	0.3078958
urban area, center 1 – 3 million inhabitants	0.0822085	0.2746933	0.092522	0.2897734
urban area, center Paris	0.2027972	0.402099	0.1994694	0.3996181
rural commune	0.1386404	0.345585	0.0984911	0.2979899
peri-urban commune	0.2803708	0.4491986	0.120461	0.3255133
urban commune	0.5809888	0.4934173	0.7810479	0.4135532
population of the commune < 500 inhabitants	0.0803383	0.2718272	0.0280219	0.1650422
population of the commune 500 – 2 500 inhabitants	0.2503659	0.4332414	0.1190516	0.3238626
population of the commune 2 500 – 10 000 inhabitants	0.2454871	0.4303931	0.16581	0.3719254
population of the commune 20 000 – 50 000 inhabitants	0.1429501	0.3500362	0.1769193	0.3816162
population of the commune 50 000 – 200 000 inhabitants	0.106928	0.3090342	0.2273255	0.4191219
population of the commune 200 000 – 500 000 inhabitants	0.0387868	0.1930943	0.1169789	0.3214085
Paris	0.0202472	0.1408505	0.0669043	0.2498666
richness of the commune (log) (detached house)	3.1395885	0.2465024	3.1136964	0.2197903
block)	3.2023353	0.2443167	3.1802341	0.2627972
density	1718.28	2324.55	3058.21	2677.59
unemployment rate	0.1172443	0.0481474	0.1357735	0.0477133
evolution of the population (1990-1999)	6.0803383	10.7442968	3.8191013	8.2522482
coastal commune	0.0950561	0.2933043	0.1096833	0.3125076
commune less than 15 min from the coast	0.033664	0.1803701	0.0232963	0.1508492
harbor	0.0826964	0.2754339	0.0808324	0.2725888

Sources: Housing surveys (1988 to 2002) by INSEE (Institut national des statistiques et études économiques).

Appendix 3. Results

	owner-occupiers							
	single detached houses				apartments			
	OLS		PLS		2SLS		PLS	
	estimate	Pr > |t|	estimate	p value	estimate	Pr > |t|	estimate	p value
Intercept	9,87409	<,0001	/	/	8,892751	<,0001	/	/
1988 survey	-0,15075	<,0001	-0,04824	0,005	-0,3255	<,0001	-0,2287	<,0001
1992 survey	-0,13403	<,0001	-0,02829	0,031	-0,06711	0,0008	0,0282	0,06
1996 survey	-0,13182	<,0001	-0,02306	0,02	-0,05121	0,0156	0,04881	0,012
2002 survey	/	/	0,1059	0,001			0,09578	0,004
living space	0,00413	<,0001	0,004121	<,0001	0,007962	<,0001	0,008599	<,0001
garden size (detached house)	8,105E-05	<,0001	8,006E-05	<,0001	/	/	/	/
garden size (detached house) (square term)	-7,7E-06	<,0001	-7,58E-06	<,0001	/	/	/	/
number of bathrooms	0,08094	<,0001	0,08175	<,0001	0,085326	<,0001	0,07643	0,01
poor heating	-0,14581	<,0001	-0,1461	<,0001	-0,03264	0,2677	-0,01739	0,238
room size	-0,00339	0,1125	-0,001467	0,499	0,015499	0,0151	0,01751	0,052
(room size)²	-4,13E-05	0,2298	-7,57E-05	0,195	-0,00025	0,0242	-0,000302	0,125
garage	0,10454	<,0001	0,1072	<,0001	0,069522	0,0002	0,05512	0,006
cellar	0,06036	<,0001	0,06233	<,0001	0,073781	<,0001	0,06694	0,001
date of arrival in the housing	-0,03579	<,0001	-0,03622	<,0001	-0,02649	<,0001	-0,0269	<,0001
age of the structure	-0,00771	<,0001	-0,007371	<,0001	-0,01575	<,0001	-0,01583	<,0001
(age of the structure)²	3,896E-05	<,0001	3,626E-05	<,0001	0,00011	<,0001	0,0001106	<,0001
fireplace	0,05736	<,0001	0,05688	<,0001	0,179896	<,0001	0,1222	0,034
urban area, center < 30,000 inhabitants	-0,07608	<,0001	-0,09164	<,0001	-0,05553	0,6089	-0,02833	0,075
urban area, center 30,000 à 50,000 inhabitants	-0,05497	0,0075	-0,06209	<,0001	-0,08103	0,4575	-0,02036	0,188
urban area, center 50,000 à 100,000 inhabitants	-0,03133	0,0853	-0,04651	0,003	-0,03667	0,7292	-0,02596	0,045
urban area, center 100,000 à 200,000 inhabitants	0,02523	0,1655	0,002651	0,382	-0,06716	0,5151	-0,05251	0,01
urban area, center 200,000 à 500,000 inhabitants	0,02068	0,2464	0,006955	0,217	-0,07155	0,4852	-0,04912	0,037
urban area, center 500,000 à 1 million inhabitants	0,00512	0,8114	-0,0132	0,167	-0,04401	0,6789	-0,001648	0,465
urban area, center 1 à 3 millions inhabitants	0,0727	0,0004	0,05852	<,0001	-0,00629	0,9516	0,00802	0,382
urban area, center Paris	0,30677	<,0001	0,2921	<,0001	0,199977	0,0523	0,2212	<,0001
rural commune	-0,05166	0,0014	-0,06905	<,0001	0,007775	0,9473	-0,0147	0,295
city and suburbs commune	0,09756	<,0001	0,101	<,0001	0,113623	0,0143	0,1049	0,015
population of the commune < 500 inhabitants	-0,14947	<,0001	-0,1313	<,0001	0,144308	0,6913	/	/
population of the commune 500 à 2,500 inhabitants	-0,10587	<,0001	-0,08941	<,0001	-0,1079	0,0895	-0,04958	0,339
population of the commune 2,500 à 10,000 inhabitants	-0,04746	0,0006	-0,03367	0,065	-0,02443	0,4655	-0,01924	0,494
population of the commune 20,000 à 50,000 inhabitants	0,02858	0,0787	0,03163	0,065	0,052164	0,0401	0,03206	0,158
population of the commune 50,000 à 200,000 inhabitants	0,07578	0,0001	0,07727	0,016	0,127807	<,0001	0,104	0,026
population of the commune 200,000 à 500,000 inhabitants	0,24651	<,0001	0,2484	<,0001	0,134574	0,0005	0,09113	0,091
Paris	0,21586	0,2788	/	/	0,523102	<,0001	0,4753	<,0001
richness of the commune (log)	0,13775	<,0001	0,1513	<,0001	0,266095	<,0001	0,305	<,0001
density	1,647E-05	<,0001	0,0000175	<,0001	0,000029	<,0001	3,084E-05	<,0001
unemployment rate	-1,51771	<,0001	-1,404	<,0001	-2,47922	<,0001	-2,253	<,0001
evolution of the population (1990-1999)	0,00116	0,0012	0,001096	0,002	0,00022	0,8596	-6,47E-05	0,46
coastal commune	0,09357	<,0001	0,0897	<,0001	0,114716	0,0028	0,09776	0,031
commune less than 15 mn from the coast	0,07437	0,0002	0,0687	0,03	0,04371	0,5505	-0,009506	0,361
harbor	0,05125	0,0001	0,04428	0,001	0,057143	0,0898	0,02094	0,428
Mean annual temperature (°C)	0,0599	<,0001	0,05726	<,0001	0,057262	0,0074	0,05812	0,009
Difference (July-mean annual temperature) (°C)	0,08037	0,0004	0,06848	0,001	0,063547	0,2275	0,04482	0,135
Difference (January-mean annual temperature) (°C)	0,02591	0,1814	0,01459	0,37	0,046843	0,2858	0,01777	0,359
July warm days (> 30° C)	-0,04199	<,0001	-0,0405	<,0001	-0,01963	0,2092	-0,02498	0,109
(July warm days)² (> 30° C)	0,00149	<,0001	0,001424	<,0001	0,001413	0,0481	0,001596	0,031
January cold days (< - 5° C)	0,00669	0,4935	0,0009078	0,476	-0,01368	0,5215	-0,01974	0,229
(January cold days)² (< - 5° C)	0,0014	0,0504	0,001858	0,011	0,00268	0,1034	0,002955	0,054
July days with rainfall	0,00948	0,0723	0,007804	0,088	0,042811	0,0001	0,03886	<,0001
January days with rainfall	-0,02237	<,0001	-0,02203	<,0001	-0,01444	0,076	-0,01427	0,057

Regression results. Explained variable: log(price of the dwelling). Each line of the Table is a covariate. Method: OLS (exogenous covariates) or 2SLS (instrumental variable method when living space is endogenous) and Partial least squares (PLS). Sources: Insee Housing surveys and climatic variables interpolated from Météo-France data.

Appendix 3. Results (continued)

	Tenants							
	single detached houses				apartments			
	2SLS		PLS		2SLS		PLS	
	estimate	Pr > |t|	estimate	p value	estimate	Pr > |t|	estimate	p value
Intercept	5,366151	<,0001	/	/	5,025905	<,0001	/	/
1988 survey	-0,29258	<,0001	-0,1681	<,0001	-0,23613	<,0001	-0,1402	0,009
1992 survey	-0,16786	<,0001	-0,05179	0,001	-0,09425	<,0001	-7,4E-05	0,421
1996 survey	-0,06137	0,0001	0,06076	<,0001	-0,04786	<,0001	0,04649	0,033
2002 survey	/	/	0,1143	<,0001	/	/	0,09258	0,009
living space	0,010031	<,0001	0,009231	<,0001	0,009911	<,0001	0,009648	<,0001
garden size (detached house)	0,000028	0,1141	3,36E-05	0,026	/	/	/	/
garden size (detached house) (square term)	-5,11E-06	0,123	-6,2E-06	0,007	/	/	/	/
number of bathrooms	-0,00744	0,5762	0,008011	0,318	0,010825	0,1886	0,0174	0,267
poor heating	-0,15368	<,0001	-0,1681	<,0001	-0,04298	<,0001	-0,04495	<,0001
room size	-0,0382	<,0001	-0,03459	<,0001	-0,00207	0,141	0,000691	0,441
(room size)²	0,000397	<,0001	0,000356	<,0001	-0,00004	0,0543	-9,3E-05	0,037
garage	0,024669	0,0869	0,03182	0,019	0,018138	0,0077	0,02286	<,0001
cellar	-0,01766	0,1876	-0,0085	0,242	0,001938	0,7562	0,007144	0,303
date of arrival in the housing	-0,04987	<,0001	-0,04963	<,0001	-0,03738	<,0001	-0,03736	<,0001
age of the structure	-0,00539	<,0001	-0,00525	<,0001	-0,0057	<,0001	-0,00564	<,0001
(age of the structure)²	0,000028	<,0001	2,66E-05	<,0001	0,000038	<,0001	3,79E-05	<,0001
fireplace	0,008148	0,5774	0,01821	0,168	0,026604	0,2931	0,01049	0,082
urban area, center < 30,000 inhabitants	-0,02982	0,3325	-0,08122	0,001	-0,04999	0,0999	-0,06958	0,001
urban area, center 30,000 à 50,000 inhabitants	0,004471	0,893	-0,03718	0,155	-0,00873	0,7845	-0,01339	0,022
urban area, center 50,000 à 100,000 inhabitants	0,049531	0,0949	-0,0059	0,563	-0,01514	0,6069	-0,03375	0,012
urban area, center 100,000 à 200,000 inhabitants	0,09808	0,001	0,02375	0,003	0,024884	0,3886	0,004085	0,393
urban area, center 200,000 à 500,000 inhabitants	0,085517	0,0033	0,006764	0,198	-0,01764	0,5334	-0,02987	0,02
urban area, center 500,000 à 1 million inhabitants	0,09625	0,0048	0,008058	0,186	0,041756	0,1656	0,03093	0,014
urban area, center 1 à 3 millions inhabitants	0,111507	0,0022	0,02096	0,104	0,026326	0,3676	0,008716	0,316
urban area, center Paris	0,410022	<,0001	0,3225	<,0001	0,31061	<,0001	0,293	<,0001
rural commune	-0,01755	0,4869	-0,08567	0,001	-0,09504	0,0006	-0,1041	<,0001
city and suburbs commune	0,067806	0,0006	0,08158	<,0001	-0,00359	0,8362	0,00696	0,383
population of the commune < 500 inhabitants	-0,1121	0,0006	-0,06681	<,0001	-0,27561	<,0001	-0,2754	0,001
population of the commune 500 à 2,500 inhabitants	-0,06823	0,0091	-0,0353	0,016	-0,13712	<,0001	-0,1315	<,0001
population of the commune 2,500 à 10,000 inhabitants	-0,00071	0,9749	0,03168	0,016	-0,04449	0,0007	-0,05039	0,009
population of the commune 20,000 à 50,000 inhabitants	0,015431	0,5593	0,02043	0,041	0,027943	0,0146	0,006517	0,481
population of the commune 50,000 à 200,000 inhabitants	0,034723	0,2597	0,01205	0,03	0,04156	0,0006	0,01647	0,382
population of the commune 200,000 à 500,000 inhabitants	0,046914	0,3967	0,001433	0,184	0,037881	0,0171	0,003411	0,475
Paris	/	/	/	/	0,245218	<,0001	0,2126	<,0001
richness of the commune (log)	0,045296	0,0979	0,07457	0,015	0,143893	<,0001	0,1523	<,0001
density	0,000021	0,0003	2,74E-05	<,0001	0,000018	<,0001	1,91E-05	<,0001
unemployment rate	-0,37285	0,018	-0,1117	<,0001	-0,8475	<,0001	-0,7219	<,0001
evolution of the population (1990-1999)	0,003154	<,0001	0,003377	<,0001	0,004107	<,0001	0,004039	<,0001
coastal commune	0,074546	0,0025	0,03784	0,01	0,051313	<,0001	0,05941	<,0001
commune less than 15 mn from the coast	0,074344	0,0116	0,01804	0,412	-0,0052	0,835	-0,01389	0,044
harbor	0,056488	0,0041	0,03074	0,076	0,019369	0,0891	0,003792	0,374
Mean annual temperature (°C)	0,037957	0,0162	0,03737	0,005	0,027625	0,0005	0,02504	0,004
Difference (July-mean annual temperature) (°C)	0,062578	0,0678	0,03617	0,022	-0,00171	0,9285	-0,00223	0,453
Difference (January-mean annual temperature) (°C)	0,033658	0,2703	0,005734	0,411	-0,0109	0,5144	-0,015	0,081
July warm days (> 30° C)	-0,00714	0,4654	-0,01138	0,115	-0,02554	<,0001	-0,02361	0,001
(July warm days)² (> 30° C)	0,000237	0,4755	0,000293	0,184	0,001056	<,0001	0,000964	0,001
January cold days (< - 5° C)	-0,02078	0,1754	-0,02962	0,045	-0,00454	0,6019	-0,00886	0,218
(January cold days)² (< - 5° C)	0,003287	0,006	0,004102	0,001	0,000299	0,6781	0,000511	0,308
July days with rainfall	0,008452	0,3083	-0,0011	0,443	0,013582	0,0011	0,01394	0,002
January days with rainfall	-0,01335	0,0205	-0,01225	0,022	-0,02014	<,0001	-0,01987	<,0001

Regression results. Explained variable: log(rent of the dwelling). Each line of the Table is a covariate. Method: 2SLS (instrumental variable method because living space is endogenous) and Partial least squares (PLS). Sources: Insee Housing surveys and climatic variables interpolated from Météo-France data.

Appendix 3. Results (continued)

	wages			
	OLS		PLS	
	estimate	Pr > |t|	estimate	p value
intercept	8,48484	<,0001	/	/
senior managerial	0,56473	<,0001	0,5804	<,0001
intermediate managerial	0,17879	<,0001	0,1908	<,0001
office worker	-0,13727	<,0001	-0,1255	<,0001
personal service providers	-0,31372	<,0001	-0,3122	<,0001
skilled industrial worker	0,05538	0,0001	0,0661	<,0001
skilled self-employed worker	-0,05691	0,0002	-0,03917	0,003
skilled workers (other)	-0,01387	0,4061	0,00008014	0,421
industrial unskilled worker	-0,07718	<,0001	-0,06173	0,001
unskilled self-employed worker	-0,1582	<,0001	-0,1618	<,0001
farmworker	-0,28111	<,0001	-0,2453	<,0001
full time employment	0,01155	<,0001	0,01154	<,0001
apprentice	-0,5666	<,0001	-0,5403	<,0001
interim worker	-0,34414	<,0001	-0,3455	<,0001
limited-tenure employment	-0,34379	<,0001	-0,3403	<,0001
age: <19	-0,57992	<,0001	-0,5797	<,0001
age: 20–24	-0,34235	<,0001	-0,3255	<,0001
age: 25–29	-0,17752	<,0001	-0,1621	<,0001
age:30–34	-0,06613	<,0001	-0,05018	0,001
age: 40–44	0,03424	0,0039	0,04886	<,0001
age: 45–49	0,0494	<,0001	0,0657	<,0001
age:50–54	0,1007	<,0001	0,1204	<,0001
age:55–81	0,09387	<,0001	0,1116	<,0001
male	0,18547	<,0001	0,1774	<,0001
4 years higher education	0,09197	<,0001	0,08953	<,0001
2 years higher education	0,03469	0,0092	0,03026	0,028
capbepc	-0,05641	<,0001	-0,05637	<,0001
no educational qualification	-0,17576	<,0001	-0,1787	<,0001
French by naturalisation	-0,07915	<,0001	-0,064	0,006
European nationality	-0,039	0,2221	0,02423	0,12
African nationality	-0,09393	<,0001	-0,08251	<,0001
other nationality	-0,15937	0,001	-0,1198	0,001
born in Europe	-0,00507	0,8872	0,01504	0,019
born in Africa	-0,1259	0,0017	-0,05516	<,0001
born in other region	-0,05125	0,0765	0,003248	0,433
rural commune	-0,05078	0,0012	-0,05159	0,002
disadvantaged region	-0,02996	0,0389	-0,03389	0,021
market size	-0,03693	0,0155	-0,03331	0,026
poor commune 1000-1500K inhabitants	-0,03359	0,0096	-0,02752	0,062
poor commune Paris	0,0009621	<,0001	0,0009854	<,0001
poor commune 500-1000Kinhabitants	-0,02547	0,0574	-0,03691	0,015
unemployment rate	-0,06509	<,0001	-0,08159	<,0001
poor commune 500-1000Kinhabitants	-0,04269	0,0509	-0,03148	0,053
unemployment rate	-0,4206	<,0001	-0,3544	<,0001
Mean annual temperature (°C)	0,00245	0,7347	0,001933	0,395
Difference (July-mean annual temperature) (°C)	-0,01279	0,5443	-0,002569	0,461
Difference (January-mean annual temperature) (°C)	-0,02325	0,2086	-0,01892	0,136
July warm days (> 30° C)	-0,00185	0,4407	-0,002552	0,176
January cold days (< - 5° C)	-0,000531	0,8947	-0,00178	0,349
July days with rainfall	0,00531	0,2469	0,005169	0,127
January days with rainfall	-0,00819	0,0112	-0,007652	0,011

Regression results. Explained variable: log(wage). Each line of the Table is a covariate. Method: OLS (exogenous covariates) and Partial least squares (PLS). Sources: Insee Housing surveys and climatic variables interpolated from Météo-France data.