Does issuing building permits reduce the cost of land? An estimation based on the demand for building land in France

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Abstract – While the aggregate value of constructed land rose from 45% to nearly 260% of gross domestic product in France between 1998 and 2006, stabilising after the crisis, regulatory constraints on construction are used to explain the rise in land prices, which are weighing on production costs for new housing units. Here we analyse to what extent the issuance of building permits reduces the price of land. We first propose a theoretical assignment model of heterogeneous households (in terms of preferences) to heterogeneous building plots (in terms of location) to study the effects of construction on the price of land. We then estimate the inverse demand for building land by instrumenting construction (quantity) by instrumental variables relating to the nature of the land, to its topography, to the agricultural opportunity cost and to the presence of industrial brownfields. A 1% increase in the number of permits issued resulted in a moderate decrease in land prices of 0.3%, on average. The effect, which differs according to the type of construction, increases with proximity to dense zones.

JEL Classification: R14, R31, R52
Keywords: land policy, land development, assignment model, instrumental variables

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Between 1998 and 2006, the aggregate value of built land rose from 45% to 257% of GDP and has stabilized at slightly lower levels since the crisis (222% in 2016)[1]. Developed land inflation therefore affects all advanced economies and has contributed to about 80% of real estate inflation at the macro-economic level since the Second World War (Knoll *et al.*, 2017). This inflation is a major economic and political issue, directly responsible for the increase in the weight of housing in household budgets and with strong implications for non-housing purchasing power and the distribution of wealth (Bonnet *et al.*, 2015).

The solutions proposed to mitigate this inflation mainly revolve around the growth of construction to increase the quantity of housing units and to bring down prices. Given the increasing weight of developed land, land appears to be the most severe limiting factor, and suffering the highest inflation, it is therefore the natural lever to increase housing supply. However, this lever is the subject of much controversy between its supporters (Repentin & Braye, 2005; Atelier parisien d'urbanisme, 2007; Trannoy & Wasmer, 2013; Fondation Abbé Pierre, 2016) and its opponents (Bisault, 2009; Société d'aménagement foncier et d'établissement rural, 2018; Courtoux & Claveirole, 2015; Fondation pour la nature et l'homme, 2016). This lack of consensus stems both from questioning the diagnosis of a supply deficit (Cornuel, 2017) and the need to take into account the induced effects of land development on agriculture, the environment and living conditions (Béchet *et al.*, 2017). We propose to address this controversy through the location of building plots and their suitability with regard to household preferences. The heterogeneity of land and its immobility being determining factors of its relative scarcity (Ay, 2011; Cavailhès *et al.*, 2011b), it is a question of studying to what extent construction must be adapted to demand for it to actually translate into a fall in the price of building land.

According to the literature, the relationship between construction and the price of building land is often approached from the point of view of supply (Gyourko & Molloy, 2015). Studies differ in the way supply is defined, either in terms of the number of housing units produced by the construction sector, or in terms of the areas authorised for construction by land-use policies. Early publications refer, more or less explicitly, to the concept of housing production function where land is an input in order to estimate the extent to which construction responds to the price of land (Epple *et al.*, 2010; Combes *et al.*, 2016b). Saiz (2010) provides an estimate of the price elasticity of housing supply in the United States based on exogenous changes in demand measured in demographic terms. It also appears that these elasticities depend on the distribution of land slopes within the cities. Caldera and Johansson (2013) set out to categorise OECD countries according to the responsiveness of construction to building land prices. North American countries appear the most sensitive (elasticity greater than 1), continental European countries the most rigid (elasticity less than 0.5), while the countries of Northern Europe are somewhere in the middle. For France, the estimated value is 0.36, a result recently confirmed by Chapelle (2017), who obtains the same order of magnitude. The other publications on land-use policies (for surveys of the literature, see Duranton & Puga, 2015; Glaeser & Gyourko, 2018) generally show that regulation of land use by restricting the supply of building land increases the price of land and reduces the volume of construction. The results of these studies, which focus on land use regulations, differ according to the policy studied (Grieson & White, 1981), the empirical strategy used (Quigley & Rosenthal, 2005) and the effects measured (Turner *et al.*, 2014). These publications are echoed in France and feed the academic literature (Lecat, 2006; Levasseur, 2013; Geniaux *et al.*, 2015) and professional literature (Benard, 2007; Charmes, 2007; Comby, 2015).

Here we analyse the effect of construction on the price of building land in terms of demand emanating from households looking for land on which to build a dwelling. The relevance of this angle of attack rests on two main points. On the one hand, in the French context, application for a building permit is a legally required prerequisite for construction, often done at the same time as purchasing the land. Building land transactions make it possible to observe the price of land, which corresponds to the cost of land for construction. On the other hand, the decision to look at land markets from a demand perspective allows for the implementation of an identification method based on exogenous variations in actual construction. While the usual

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[1] *Insee, 2016 financial statements base 2010, https://www.insee.fr/fr/statistiques/2832716?sommaire=2832834.*

approaches for estimating the demand for building land are based on hedonic methods, which marginally value land features and neglect construction (Kuminoff *et al.*, 2013), here we use the theoretical framework of an assignment model derived from an analysis of the labour market (Sattinger, 1993). This type of model has recently been applied to the housing market by Landvoigt *et al.* (2014); we apply it to the building land market, where the price of land arises from the balance between household demand for land and supply that we consider to be exogenous. Using a similar methodology, Hilber and Vermeulen (2016) use regional differences and a land regulation reform in England to estimate the impacts of local supply constraints on the relationship between local average incomes and the price of land.

Our empirical approach focuses on the market for land intended for the construction of individual houses. We use the *Sit@del2* databases (1974-2015) for building permits issued, and the *EPTB* survey (2006-2014) on land prices, together with data on soils, topography and agricultural opportunity costs (the value of agricultural production that is lost by assigning land to housing), as well as the presence of former industrial sites. We econometrically estimate an inverse demand equation for land, where constructed quantities are instrumented by exogenous supply variations. Permits and prices result both from supply effects and demand effects, that we aim to distinguish here. Economic theory considers the price elasticity of demand to be negative as, for a given demand function, increasing the quantity of land offered should lead to a decrease in its price. These are the expected effects of a supply shock in partial equilibrium. Conversely, for a given supply, a demand shock caused by increasing the demand for land should lead to price increases if the price elasticity of supply is positive. This simultaneity, due to the market equilibrium, manifests itself in a large number of constructions in desired and expensive locations, regardless of supply (Geniaux *et al.*, 2015). This correlation complicates the estimation of the causal effects associated with changes in supply. Furthermore, we propose an approach using instrumental variables in which constructed quantities are projected on exogenous variations in land availability, with exogeneity of supply being understood as independence from prices. For this purpose, we use variables present in the empirical literature (soil type, topography) and other more original variables (the opportunity cost of agriculture and industrial brownfields).

The theoretical model shows that the price of land decreases with the number of building permits issued and, that this elasticity of demand is even more negative when the location of the land corresponds to household preferences. The empirical analysis confirms the results of the theoretical model, with a negative elasticity of the order of - 0.3. This estimation (taken as an absolute value) is significantly higher in municipalities in the ninth density decile (above 387.1 inhab./km^2) compared to those in the first decile (less than 26.5 inhab./km^2).

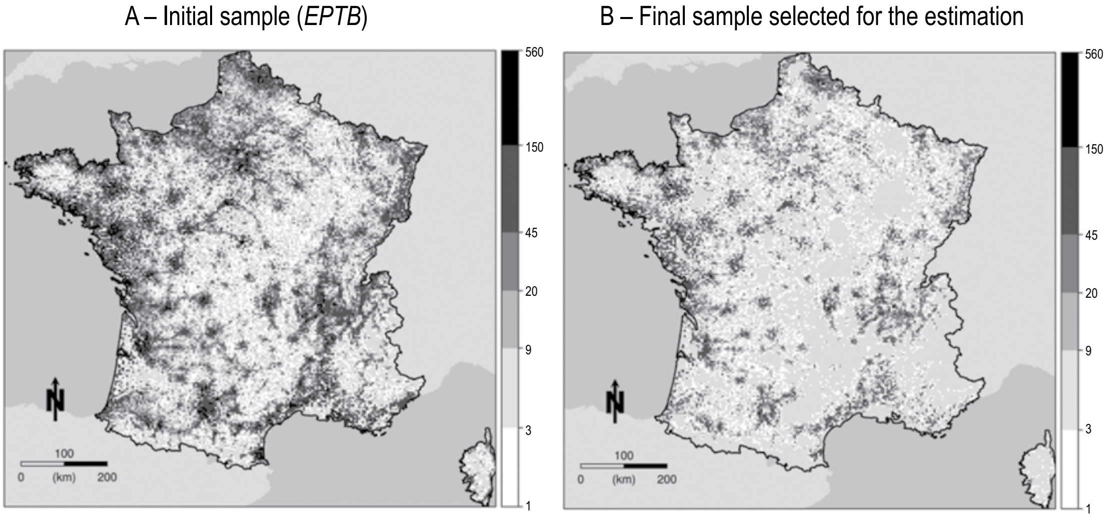
Data

The population of interest, i.e. the land plots for which the price is observed, corresponds to the population of the *EPTB* survey, namely plots of land belonging to individuals who have been granted building permits for individual houses in the detached housing sector (excluding sub-divisions, see Box 1). For the period 2006-2014, pooling of *EPTB* observations provided a sample of 873,823 observations. For 315,825 of them (36.1%), the applicant did not buy the land on which the deposit was placed or did not answer the question about the price of the land. Georeferencing nevertheless enables them to be mapped (Figure I-A). Research (not reported here) based on the Insee *Housing* survey of 2013 show that, for about 10% of the houses built, the owners obtained the land by inheritance or donation. This reason does not seem sufficient to explain the loss of more than 30% of the observations. An additional selection source is the inability to georeference the plot, resulting in a loss of 172,817 observations (19.8%). Observations were also lost due to the atypical values of some variables, mainly regarding prices and surface areas. For each of the variables reported in Table 1, we eliminate 105,966 observations (12.1%) whose values are extreme in terms of the interquartile ratio, meaning that the value is higher (lower) than the upper (lower) quartile plus (minus) 1.5 times interquartile range. We obtain a final sample of 279,215 observations (31.9% of the initial population), which size is comparable to that of various empirical studies using the *EPTB* without cadastral georeferencing (Vermont, 2016; Combes *et al.*, 2016b). The spatial distributions of the *EPTB* observations used in the analyses are presented in Figure I-B. Although limited to the diffuse housing sector, these land price observations are concentrated in urban areas with a spatial distribution very close to that of the issued building permits, as in the *Sit@del2* database.

Each observation in the final sample is matched to municipal construction measures from building permits filed between 1974 and 2015, derived from the raw data in *Sit@del2* (Box 1). This measure of construction includes all residential construction, not only pure individual houses resulting from single-unit construction projects, but also grouped individual houses resulting from multi-unit construction projects for individual houses or a single individual house with outbuildings, and collective housing defined by excluding the first two. Figure II shows the number of housing units, floor areas and land areas permitted for construction at the national level. It compares the evolution of construction in the detached housing sector relative to other sectors. The total number of units authorised annually between 1974 and 2016 varies by more than double between years, from 250,000 in the mid-1990s to almost 550,000 at the peak of 2006. Individual housing and collective housing intersect to form the largest source of new housing, while grouped individual housing represents about three times less units built than for each of the previous modalities. In terms of floor area, individual houses (single and grouped) represent almost half of total construction, due to significantly larger surfaces than collective housing. This gap has narrowed sharply in the recent years, due to the decreasing size of houses and the relative increase in the construction of collective buildings. In terms of land area, the gap is even wider between pure individual houses and collective housing, while the latter shows levels close to grouped individual houses: individual houses account for approximately 90% of the total surface area intended for construction.

Table 1 presents the statistics describing the variables in the database for econometric analysis. The average price of building land is 88 Euros per m² for an average surface area of just over 1,000 m². The average cost of building an individual house is 1,097 Euros per m² for an average floor area of 127 m². The characteristics of the houses in the sample are less variable than the characteristics of the land plots. Land represents, on average, 30% of the total building cost of an individual house, and the floor area covers on average 15% of the land area. We use five qualitative variables

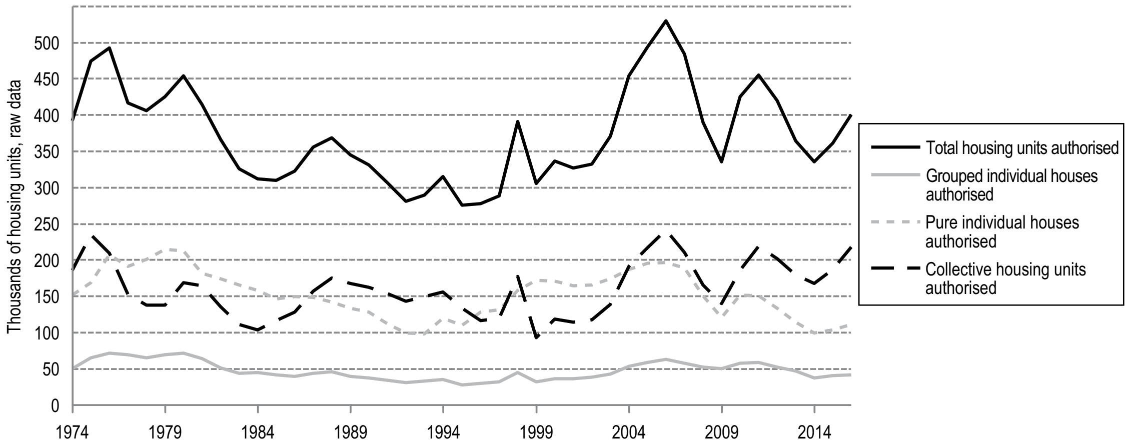
Figure I
Distribution and selection of the *EPTB* observation sample for econometric analysis


A – Initial sample (*EPTB*)
B – Final sample selected for the estimation

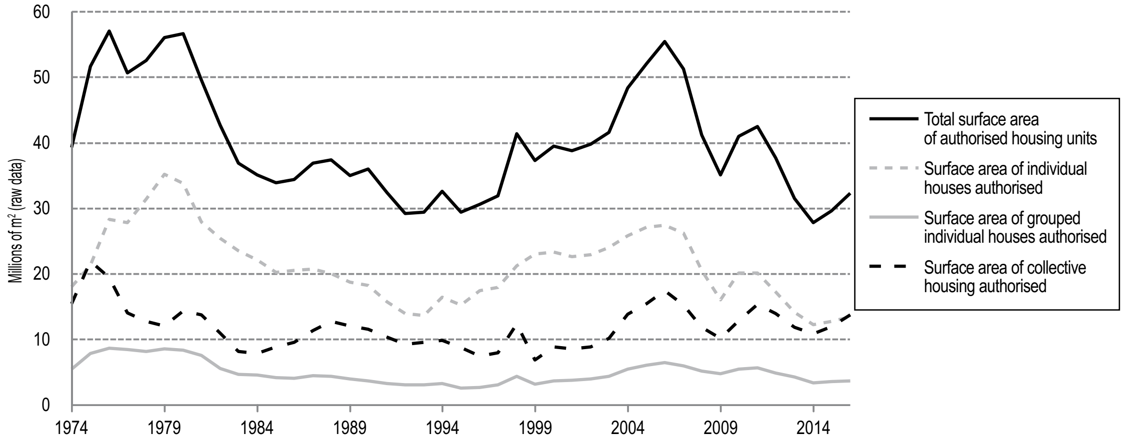
Note: The resolution of the raster for mapping the *EPTB* observations is 4 km. For each raster cell, map A shows the 701,006 georeferenced observations present in the initial sample (N = 873,823). Map B shows the observations used in the econometric analysis (N = 279,215). The reduction in the size of the sample is due to a variety of factors: land was not purchased by the applicant, or missing or atypical values for important variables.
Coverage: Metropolitan France.
Sources: *EPTB* (SDES), *Sit@del2* (SDES), Insee; authors' treatment.

Figure II
Evolution of construction from 1974 to 2016 according to building permits

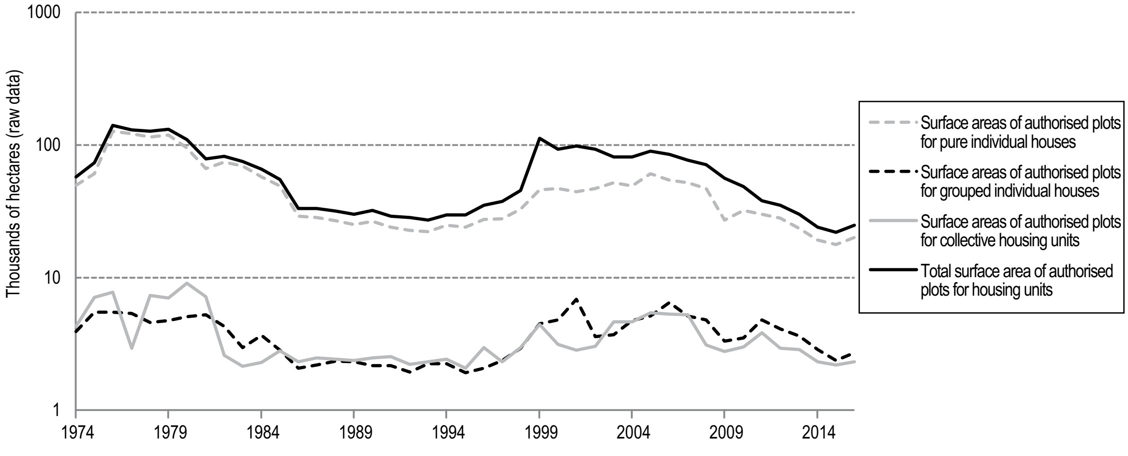
A – Annual number of units authorised by type, from 1974 to 2016



B – Annual surface area of units authorised by type, from 1974 to 2016



C – Annual surface areas of authorised plots for housing units by type from 1974 to 2016



Note: Total permissible housing includes the three categories presented, as well as residential housing, which are units built by a developer for occupation by a highly targeted public depending on the type of residence, along with the provision of specific services. The annual values are calculated from all the authorized building permits, referenced at the date of authorisation. The values for the number of housing units and the floor area have been disseminated by the SDES at the municipal level since 2005 (http://www.statistiques.developpement-durable.gouv.fr/donnees-ligne/r/sitdel2-donnees-detaillees-logements.html). Data on plot surface areas are not publicly available, so come from the same raw data for building permits. To an unknown extent, the latter overestimate the surface areas actually artificialised due to abandoned building permits and initially large cadastral plots which are not fully constructed. By way of comparison, Cerema's data from the DGFiP show annualised artificialised surface areas of around 32.2 thousand hectares per year between 2006 and 2015, which is not far from the values presented here. Conversely, Cerema data have less historical depth than the *Sit@del2* data and do not distinguish between residential and non-residential uses.
Coverage: Metropolitan France.
Sources: *Sit@del2* (SDES).

Table 1
Descriptive statistics for the variables in the database used in the regressions

	N. observations	Mean	Standard error	Min	Max
Price of land (current Euros/m^2 of land)	279,231	87.8	72.8	5.0	429.9
Cost of the house (current Euros/m^2 floor area)	279,231	1096.8	315.5	6.2	7,254.9
Surface area of the plot (m^2)	279,231	1027.2	673.0	100.0	4653.0
Floor area (m^2)	279,231	126.9	34.1	50.0	289.0
Ratio of land price to total price (%)	279,231	30.9	12.4	0.5	99.4
Ratio of floor area to total area (%)	278,577	16.3	8.7	2.0	99.4
Altitude of the plot (m)	279,231	149.3	141.8	0.0	823.5
Slope of the plot (%)	279,231	3.9	3.6	0.0	21.3
Population density in 1990 (inhab./km^2)*	279,231	171.3	260.8	1.6	3766.3
Housing units authorised 1974-2014 (log (num))*	279,231	6.1	1.2	1.1	9.0
Floor area authorised 1974-2014 (log (m^2))*	279,231	10.9	1.2	5.6	13.5
Land area authorised 1974-2014 (log (m^2) *	279,231	13.5	1.0	7.5	15.9
Land area artificialised 2006--2015 (log(m^2))*	279,215	11.8	1.2	3.0	14.2
Portion of surface area subject to shrinkage or swelling of clays (%)*	279,231	22.9	29.4	0.0	100.0
Standard gross agricultural income 2014 (Euros/ha)*	279,231	9553.1	11477.0	6.0	142343.0
Share of inhabitants on slopes between 10 and 15% (%)*	279,231	5.2	9.3	0.0	100.0
Share of inhabitants on slopes above 15% (%)*	279,231	3.0	8.7	0.0	100.0
Number of old industrial sites (num)*	279,231	0.2	0.6	0.0	9.0

Notes: The first six variables were taken from the *EPTB* survey (SDES). Topographic variables are obtained by georeferencing and merging with BD ALTI (IGN). The population density in 1990 (Insee) is a municipal variable merged through the code of the municipality. The first three variables for building permits come from *Sit@del2* (SDES), the fourth variable on artificialised surface areas comes from Cerema (from the DGFiP), they are also merged with the code of the municipality. The last five variables are used as instrumental variables, also merged at the municipal level (see Box 3). They come respectively from the BRGM (re-swell of clay soils), from the SSP (agricultural census for 1988 and agricultural accounting information network 1989-2014), from cross-referencing of the grid population data (Insee) and BD ALTI from the IGN, and finally from *Basias* (BRGM).
* Variables measured at the municipal level.
Coverage: Metropolitan France.
Sources: *EPTB* (SDES), *Sit@del2* (SDES), Insee, BD ALTI (IGN), Cerema, *Basias* (BRGM), SSP; authors' treatments.

present in the *EPTB*: the date of purchase of the land, servicing of the land, the presence of an intermediary at the time of purchase, the socio-professional category of the buyer and their age at the time of applying for the building permit. The statistics for these variables are presented in Table A-1 in the Appendix.

Georeferencing of the *EPTB* observations allows the merging with a digital elevation model at a resolution of 75 metres (BD ALTI) to estimate the altitude and slope of the plots. These land characteristics are used as control variables in the price equations. In our empirical strategy, they nevertheless prove to be decisive in distinguishing price variations due to plot characteristics from those due to construction in the municipality. We use municipal population densities of 1990 (Insee) as the main measure of both the position of the plot on the urban-rural gradient and the induced accessibility to jobs and services. Density is preferred to positioning criteria in terms of the centre of the urban area (and its size) because this variable has the advantage of not depending on division of the land, which is somewhat arbitrary. The 1990 density value is used to reduce random correlations with prices over the 2007-2015 period. Construction variables are summed for each municipality for the last 40 years. Construction is measured both in terms of the number of authorised housing units, authorised floor areas and authorised areas of land, and includes individual and grouped individual houses and collective housing, as households arbitrate between these different housing offers. The area artificialised over the 2006-2015 period is calculated from the changes in the purpose of land plots: natural, agricultural or forested areas and built-up areas in the cadastral sense. The last five variables in Table 1

Box 1 – **Databases: *EPTB* and *Sit@del2***

The units surveyed in the Building Land Price Survey (*Enquête sur le prix des terrains à bâtir, EPTB*) are individuals who have been authorized to build individual houses. Collection was done by post. The first *EPTB* survey covering the entire French territory dates from 1985, it was stopped at national level in 1996. It was relaunched in 2006 and has been exhaustive since 2010. We use the raw unadjusted *EPTB* data for 2006-2014 referenced on the date the land was purchased. The data allows the price of land to be traced back to the 1990s, although in almost 75% of cases, the land is purchased in the year the permit is filed. Georeferencing data comes from *Sit@del2*, the information and automated processing system for basic data on housing and premises, provided by the Department of Statistical Data and Studies (SDES). The 2007-2015 permits are geocoded to the plot identifier using the cadastral information (*Majic II* from the DGFiP).

The *Sit@del2* information system contains all building permits processed by the planning centres. We only use residential permits. Information on construction work and completion of works is provided at the initiative of the petitioners, it is less reliable and is therefore not used here. The data refer to the actual date: they record the authorisations at the actual date of the event and not at the time of forwarding to the SDES. These data are net of cancellations. This source is administrative with its own limitations, such as breaks in collection, mis-entered variables and permits which did not result in construction. Nevertheless, it appears to be the most reliable source for measuring construction at the municipal level over a long period.

are instrumental variables used to control the endogeneity of construction in econometric models (presented later in the Empirical Strategy).

Theoretical model

We consider a set of households seeking to acquire land to build a housing unit within an urban area. Potentially buildable land plots differ by their location, which households value differently. We note $\theta \geq 0$ this location, which is a one-dimensional measure of what we describe as the quality of the land. Household preferences regarding this quality constitute a second dimension of heterogeneity. These two dimensions of the building land market are matched using a stylized assignment model, along the lines of Landvoigt *et al.* (2014). We also apply the principle of assignment to construction, which is new in this literature mainly focused on the existing housing stock.

Each household is looking for a single land plot of a given size and maximizes its utility under a budgetary constraint. Utility depends on the consumption of a quantity c of a composite good at a price standardized to 1, and of the synthetic measure θ of the quality of the land purchased. The utility function, $U(c,\theta)$, is increasing and concave in each of its arguments. By noting $p(\theta)$ the price of land of quality θ and R being the disposable income of the household, we substitute the saturated budget constraint for the variable c in the utility function to obtain program (1) and the optimality condition (2) (we note U'_x the partial derivative of U with respect to x):

$$\max_{\theta}\left\{U\left(R-p(\theta),\theta\right)\right\}, \tag{1}$$

$$p'(\theta)=U'_{\theta}/U'_{c}\equiv\chi\geq 0. \tag{2}$$

A rational choice is therefore to equalize the marginal value of the quality of the plot $p'(\theta)$ and the marginal rate of substitution (MRS) between quality and the composite good. This presentation of demand for quality is standard in hedonic approaches applied to housing and building land (Kuminoff *et al.*, 2013). According to Landvoigt *et al.* (2014), we note χ the MRS corresponding to a given household at equilibrium. Unlike the usual analyses, which consider a representative household, this MRS is heterogeneous for the population of potential land buyers. It corresponds to the quality consumed at equilibrium and is distributed in the population according to a distribution function $f(\chi)$ of mass 1.

Given this demand for building land and certain quality criteria, one necessary condition for construction is to obtain a permit. We assume that permits are obtained simultaneously with the purchase of the land for a proportion $\rho \in [0,1]$ of households. At equilibrium, the equalization of supply and demand gives the distribution of construction between the various locations through the $G(\theta) = \rho F(\chi)$ function, which corresponds to the quantity of land actually built on with a quality lower than θ. The function F is the cumulative function corresponding to the distribution of household preferences. This equilibrium condition describes the assignment of households to land plots such that each land quality value corresponds to a type of household. We also note that the function $g(\theta)$, derived from $G(\theta)$, does not integrate to the unit because not all plots are built on in equilibrium. Given the empirical strategy employed, this distribution is assumed to be exogenous.

The price structure is then directly derived from this assignment, consistent with the rationality of individual choice. Rather than expressing the quality of a building land plot as a function of the corresponding household type, it is customary to consider the type of household as a function of the type of land, which makes it possible to write the assignment function (3) as follows:

$$\chi(\theta) = F^{-1}\left[G(\theta)/\rho\right]. \qquad (3)$$

This function assigns MRS $\chi(\theta)$ of the household occupying it at equilibrium, to each land quality θ. It represents the relationship between the two distributions in the form of a Quantile-Quantile diagram (*Q-Q plot*), which are frequently used in statistics to compare two distributions. A representation of the assignment function for specified distributions is shown in Box 2. Combining (3) with the optimality condition (2), we see that the assignment function gives the marginal willingness-to-pay for quality. We also note that, if the two distributions are identical, $F = G$ and all households receive a building permit, the marginal willingness-to-pay is proportional to quality $p'(\theta) = \theta$. Conversely, still for $\rho = 1$, if the cumulative distribution of supply is thicker than demand, $G(\theta) > F(\chi(\theta))$, marginal willingness-to-pay for quality is less than proportional to quality, and therefore smaller than in the case with identical distributions. This result is due to the fact that the relative abundance of land of quality inferior to θ leads households to accept lower quality levels. Box 2 presents, in more detail, the role of land distribution where the same total quantity is constructed, but with a different distribution along the land quality distribution. It therefore appears that, for a given quantity of construction, the effect on the price becomes stronger as the characteristics of these plots come into line with the preferences of households (Landvoigt *et al.*, 2014).

By setting the price of the lowest quality land $p(0) = 0$ to 0, the price of land of quality θ is obtained by integrating the marginal willingness-to-pay:

$$p(\theta) = \int_0^\theta F^{-1}\left[G(\tilde{\theta})/\rho\right] d\tilde{\theta}, \qquad (4)$$

which enables us to deduce some results at equilibrium. It therefore appears that the price of the land increases with quality, that increasing the proportion of permits issued decreases the price of the land, and that this reduction increases in absolute value with quality:

$$\begin{cases} \dfrac{\partial p(\theta)}{\partial \theta} = \chi & \geq \ 0 \\ \dfrac{\partial p(\theta)}{\partial \rho} = -1/\rho^2 \displaystyle\int_0^\theta 1/f(\tilde{\theta})\, d\tilde{\theta} & \leq \ 0 \\ \dfrac{\partial^2 p(\theta)}{\partial \rho \partial \theta} = -1/\left(\rho^2 \times f(\theta)\right) & \leq \ 0 \end{cases} \qquad (5)$$

A direct consequence of this model is that construction produces heterogeneous effects along the land quality gradient. Depending on the distribution of marginal willingness-to-pay for quality at equilibrium, the same construction distribution may have differentiated effects on the price of land. Symmetrically, for the same distribution of preferences, the distribution of construction along the quality gradient may have differentiated effects on the price of land. Two major lessons for the empirical section of our work can be drawn from this modelling process. On the one hand, demand for building land does not have constant elasticity as in the case of demand from homogeneous households, indifferent at any point in space (Duranton & Puga, 2015). The inverse demand equation therefore presents interactions between the quantity and the quality of construction. On the other, the theoretical model assumes construction to be exogenous (see also Box 2). However, this is not the case in reality and the inverse demand function cannot be directly estimated using contextual data (joint evolution of quantities and prices). The evolution of the quantity of available housing depends on supply-side strategies (municipal building policies, etc.), which are themselves influenced by local demand. In order to remedy the problem of simultaneity inherent in any analysis of market equilibrium based on contextual data, variables which influence construction levels without having a direct impact on the equilibrium price of land are used as instrumental variables. They are presented in more detail in the next section, and in Box 3 in particular.

Empirical strategy

In line with the previous theoretical insights, we estimate the effect of construction on the price of building land through the demand of households in terms of location. The prices are assumed to be determined according to a reverse demand function which makes the unit price of land plots dependant of construction supply in the following way:

$$p_{it} = \beta_1 \cdot \theta_{c(i)} + \beta_2 \cdot \hat{q}_{c(i)} + \beta_3 \cdot \theta_{c(i)} \times \hat{q}_{c(i)} + W_{it}\lambda + \alpha_{u(i)} + \eta_t + \varepsilon_{it}. \quad (6)$$

Variables relating to the price per square meter p_{it} of plot i on date t, as well as to location $\theta_{c(i)}$ and to construction $\hat{q}_{c(i)}$, are specified logarithmically so that the β coefficients can be interpreted as elasticities. These elasticities are defined conditionally to a land characteristics vector called W_{it}, by annual indicators that control the cyclical macroeconomic effects η_t (GDP growth, interest rate or inflation rate) and spatial fixed effects $\alpha_{u(i)}$ that control for unobserved spatial heterogeneity not observed at the scale of urban areas or employment zones according to specifications[2]. Construction at equilibrium and the quality gradient are measured at the municipal level and merged with the location $c(i)$ of the price observations. The municipal scale is used as this is the scale at which building permits are issued. Despite the presence of spatial fixed effects, the locations chosen could be otherwise spatially segmented (neighbourhoods of municipalities, buffer zones, etc.). In the absence of *a priori* theoretical assumptions, construction is measured in terms of the number of housing units constructed, constructed floor areas and areas of developed land plots. These municipal values do not have a temporal dimension and are duplicated for all observations in the same municipality, which produces a correlation between them but, using the usual assumptions, does not bias the estimated coefficients, and the errors between observations for different municipalities remain non-correlated (Angrist & Pischke, 2008). Standard errors are corrected by clustering the estimated residuals at scale $c(i)$ of the municipalities. The quality of a location is measured by the population density in 1990 (as a proxy for accessibility to jobs and services)[3].

The interaction between land quality $\theta_{c(i)}$ and construction measures $\hat{q}_{c(i)}$ in the inverse demand equation allows one to test the properties of the theoretical model described by the equations (5) in a simple manner. As such, the decrease in the inverse elasticity of demand with land quality corresponds to the restriction $\beta_3 < 0$. The increase of prices with quality corresponds to the restriction $-\beta_1 / \beta_3 > \hat{q}_{c(i)}$. Negativity of the price elasticity of demand corresponds to the restriction $-\beta_2 / \beta_3 < \theta_{c(i)}$, still for $\beta_3 < 0$. Equation (6) uses the projected values for construction $\hat{q}_{c(i)}$ rather than the actual values observed due to the simultaneity of the latter. The equation is estimated using a two-stage least squares procedure with instrumental variables derived from the soil and topographic characteristics, an exogenous measure of the opportunity cost of agriculture and the presence of former industrial sites (these variables are presented in detail in Box 3). The validity of these instruments derives from the fact that they influence construction without being determined by the price of the land. The intuition behind this strategy is to bring the empirical model closer to the theoretical model in which construction is exogenous, whereas this is typically not the case in reality. Table 2 assesses the relevance of the instruments for projecting construction. Note that these regressions are estimated at the municipal level which is the same as for construction observations and that they include the control variables for which the results are not reported. Fisher's

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[2] *An urban area is a group of municipalities, contiguous and without division, constituted by an urban cluster (urban unit) and by rural communes or urban units of which at least 40% of the employed resident population works in the area or in the municipalities surrounding it (https://www.insee.fr/fr/metadonnees/definition/c2070). The term, urban unit is used to refer to a municipality or group of municipalities with a continuous constructed zone (no break of more than 200 metres between two buildings), and home to at least 2,000 inhabitants (https://www.insee.fr/fr/metadonnees/definition/c1501). An employment zone is a geographical area within which most of the active population resides and works, and in which establishments may find most of the manpower necessary for the jobs on offer (https://www.insee.fr/fr/metadonnees/definition/c1361).*

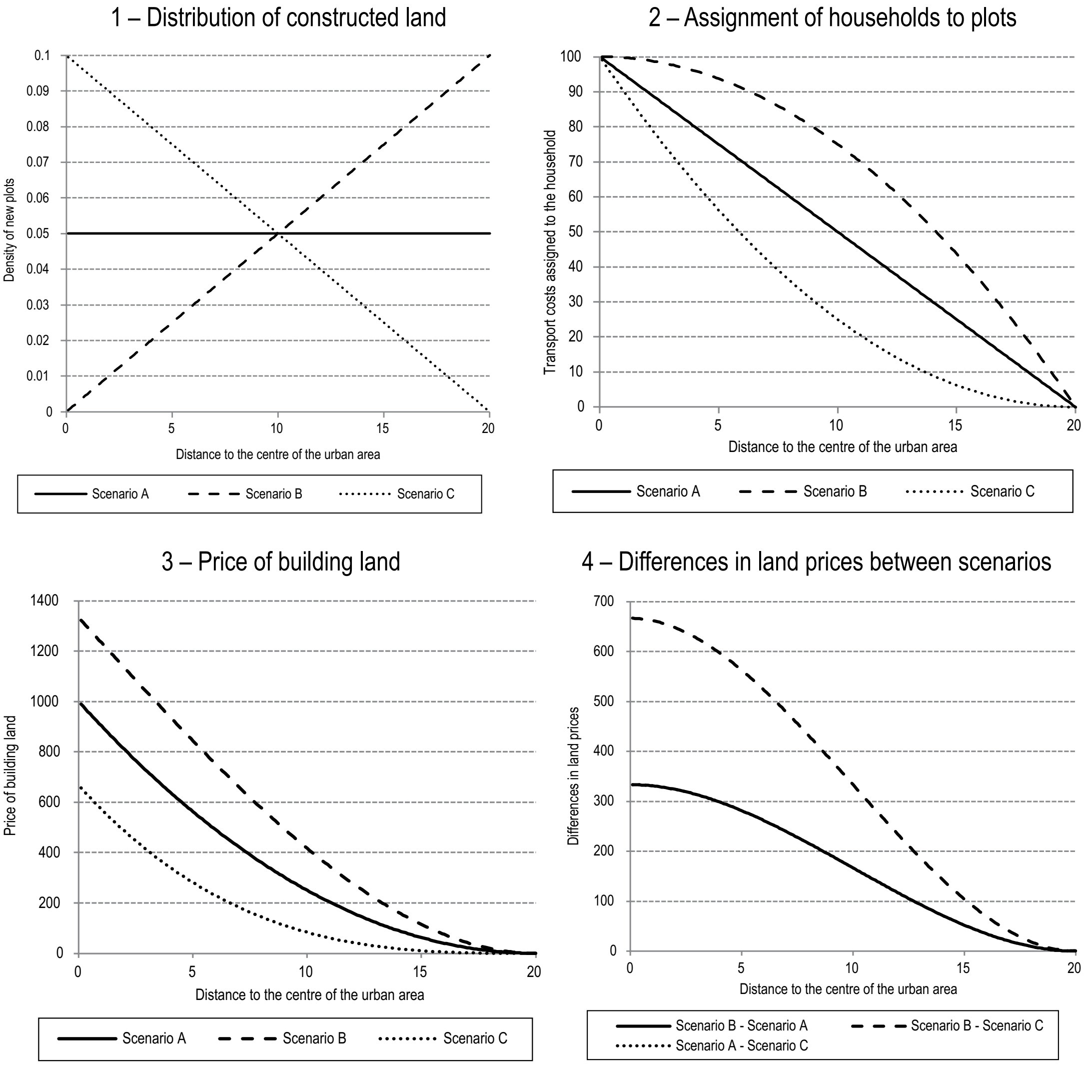
[3] *Robustness tests have been carried out using distances/times as a measure of location without the results changing, these estimates are available on request.*

Box 2 – Simulation of a parametrized assignment model

In line with the Alonso-Mills-Muth seminal model in urban economics, we assume that the quality θ of land is the distance d to the city centre in an urban area of radius $\bar{x}$. For analytical reasons (growth of the assignment function) we measure the location of land based on the distance to the boundary of the urban area. The city centre is therefore located at $x = \bar{x}$ and the periphery at $x = 0$. To promote understanding, the graphs in Figure A allow the distance to the city centre $x - \bar{x}$ on the x-axis to show the usual negative price gradients in the urban economy.

The distribution of existing land is considered to be exogenous here because alternative construction scenarios are compared. Similarly, as we are reasoning at identical total construction, the share of building permits issued ρ is fixed at 1 (its effect on prices is studied in the text). The purpose of this box is to specify the roles of various

Figure A
Distribution of built land, household assignment and land prices according to three location scenarios A, B and C



1 – Distribution of constructed land

2 – Assignment of households to plots

3 – Price of building land

4 – Differences in land prices between scenarios

Note: The three construction scenarios A, B and C differ according to the location of building plots, while the distribution of households is identical (uniform law). The total amount of building land is normalized to 1 in all three scenarios. To simulate equilibriums, the radius of the urban area is calibrated to 20, the maximum marginal cost of travel to 100 and the price of land is assumed to be zero at the boundary of the urban area. Note that, in part 4 of the Figure, the two upper curves overlap as the distributions are symmetrical.
Reading note: In scenario A, the spatial distribution of the plots is uniform, as are household preferences. The curves of scenario A serve as the reference. In scenario B, the distribution of constructed plots increases with distance (Figure A-1). This over-representation of construction around the periphery, compared to scenario A, leads households to be located further away: in Figure A-2, households with transport costs of 60 are further away (12.6 km). The relative scarcity of land near the centre (Figure A-1) leads to higher prices (Figure A-3). This price differential is more pronounced as one gets closer to the centre (Figure A-4).

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Box 2 – (contd.)

distributions of heterogeneity. We will consider three equilibrium distributions of construction h_M corresponding to three scenarios *M* = *A*, *B* and *C*. They all make the same amount of land constructible, but with different spatial distributions:

- Scenario A is a uniform distribution: $h_A(x) = 1/\bar{x}$

- Scenario B favours the periphery:

$$h_B(x) = 2(\bar{x} - x)/\bar{x}^2$$

- Scenario C favours the centre: $h_C(x) = 2x/\bar{x}^2$

Figure A-1 represents the distribution of construction in these three scenarios as a function of the distance to the centre of the urban area. Households are assumed to have logarithmic utility, exclusively drawn from the consumption of the composite good *c* whose price is normalized to 1. As in the more general model of the text, they consume a fixed amount of land. The heterogeneity of preferences is modelled using unit costs τ to travel to the city centre. The distribution of τ is assumed to be uniform of mass 1 in $[0, \bar{\tau}]$, and so $f(\tau) = 1/\bar{\tau}$. This heterogeneity in terms of travel costs results from different opportunity costs of the time spent in transport. Households will maximize the utility gained from non-land and non-travel consumption within the budget constraint $R \geq p(x) + \tau(\bar{x} - x) + c$, where *R* is the earned income and *p*(*x*) is the price of land. The constraint is saturated then substituted into utility to obtain the programme:

$$\max_x \left\{ U(x) \equiv \log\left(R - p(x) - \tau(\bar{x} - x)\right) \right\}.$$

Each household is assumed to choose the optimal location under the condition of optimality $p'(x) = \tau$. This condition means that the marginal willingness-to-pay to build closer to the city centre is equal to the marginal cost of the trips avoided in this way. As explained in the text, the assignment function for a given scenario maps one type of household to each plot location based on the equilibrium conditions of the market. As such, noting $H_M(x)$ the cumulative functions associated with distributions of new building plots in scenarios *M* = *A, B, C,* we get:

$$\begin{cases} \tau_A(x) = & (\bar{\tau}/\bar{x}) \times x \\ \tau_B(x) = & (\bar{\tau}/\bar{x}) \times (2x - x^2/\bar{x}) \\ \tau_C(x) = & (\bar{\tau}/\bar{x}) \times (x^2/\bar{x}) \end{cases}$$

These assignment functions are all decreasing with distance to the city centre, as is shown in Figure A-2. For scenario *A*, we get the result mentioned in the text, namely that when distributions of heterogeneity are identical, the gradient of the assignment function is constant. As such, scenario *B*, which offers relatively more land at the periphery, has an assignment function which is less decreasing. This scenario implies a greater distance of the centre for households with the same unit travel costs. Conversely, scenario *C* produces a more decreasing assignment function than scenario *A*. Another way of interpreting the assignment functions is to draw a vertical line in Figure A-2, showing that households at a given distance have higher unit transport costs in scenario B then in scenario A, and lastly in scenario C.

The optimality condition for household choices $p'(x) = \tau$ implies that the derivative of the equilibrium price with respect to distance is given by the assignment function. The relationship between price and distance is therefore found by integrating the assignment function at a given distance x:

$$\begin{cases} p_A(x) = & k_A + (\bar{\tau}/\bar{x}) \times (x^2/2) \\ p_B(x) = & k_B + (\bar{\tau}/\bar{x}) \times (x^2 - x^3/3\bar{x}) \\ p_C(x) = & k_C + (\bar{\tau}/\bar{x}) \times (x^3/3\bar{x}) \end{cases}$$

These price functions are both decreasing and convex (cf. Figure A-3, with $k_A = k_B = k_C = 0$). The assignment model also makes it possible to find the convexity of prices as a function of the distance to the city centre on the basis of linear transport costs, a standard result of the urban economy literature which has strong empirical validity. Because living close to the city centre is desirable, the relative scarcity of construction close to the city centre in scenario *B* leads to higher prices. Conversely, the three construction scenarios have identical effects at the boundary of the urban area due to fixing the building permits issued ρ to 1 and normalization of the integration constants at 0. Figure A-4 shows the price differences between the scenarios for all distances to the centre. The symmetrical nature of the distributions implies that the price differences between scenarios *A* and *B* are strictly equal to the price differences between scenarios *C* and *A*. The curves are therefore superimposed.

statistics indicate that the instruments are strong compared to the thresholds typically used (approximately $F = 10$, according to Angrist & Pischke, 2008). Furthermore, the sign of Student's *t* statistics, having the same sign as the estimated coefficients, show that the effects of the instruments are consistent with the assumptions presented in Box 3.

Results

Estimations of inverse demand functions – land prices as a function of construction, respectively measured in terms of the number of housing units authorised, floor areas authorised and artificialised areas according to

Table 2
Fisher and Student's statistics for the instrumental variables

	Dependent variables			
	Number of housing units	Floor areas	Artificialised areas	Land areas
No spatial fixed effects	F=154.1***	F=291.2***	F=130.5***	F=265.0***
SSC	-3.819***	-4.68***	-1.055	-10.447***
AGRI	-13.751***	-13.976***	-12.304***	-18.988***
INDUS	9.595***	13.782***	8.032***	7.841***
SLOPE	-3.146***	-12.7***	-6.277***	-0.529***
Fixed effects for urban areas	F=230.7***	F=354.4***	F=143.8***	F=287.6***
SSC	-0.349	-1.43	-0.24	-5.483***
AGRI	-14.591***	-15.034***	-8.799***	-18.637***
INDUS	14.027***	20.07***	11.969***	13.318***
SLOPE	-6.207***	-7.49***	-7.694***	-3.862***
Fixed effects in employment zones	F=129.8***	F=249.2***	F=105.3***	F=167.2***
SSC	-2.327***	-3.278***	-2.043***	-3.06***
AGRI	-13.885***	-14.643***	-10.062***	-17.896***
INDUS	13.679***	19.729***	11.504***	12.878***
SLOPE	-5.676***	-7.046***	-7.648***	-3.571***

Note: The table shows Fisher's F's and Student's t's for 12 regressions, corresponding to 4 construction measures, each modelled with no fixed spatial effects, with fixed effects by urban area or with fixed effects by employment zone. The sample includes all municipalities that contain at least one observation in the *EPTB*. In each of the regressions, the average plot size, the population density, the mean elevation, the mean slope, and the mean year of *EPTB* observations are included in the control. Fisher's F's correspond to joint nullity tests of the coefficients associated with the instruments and Student t's to individual significance tests. The agricultural opportunity cost variable (AGRI) is positive for all municipalities, the shrinkage or swelling of clay hazard (SSC), the number of former industrial sites (INDUS) and the portion of the population living on slopes steeper than 10% (SLOPE) respectively comprise 8111 (34.8%), 21,779 (93.44%) and 9655 (41.4%) null values, which are nevertheless distributed homogeneously. Less than 3,000 municipalities have zero values for the three variables at the same time.
Reading note: Fisher's statistics reject the joint nullity of instrument coefficients in all cases. Student's statistics show that, apart from the SSC variable in urban area fixed-effect models, the instruments have a significant impact on construction measures (*** means significant at the 1% threshold), a negative impact for SSC, AGRI and SLOPE and a positive impact for INDUS.
Coverage: Metropolitan France.
Sources: *EPTB* (SDES), *Sit@del2* (SDES), Insee, BD ALTI (IGN), INRA, Cerema, *Basias* (BRGM), SSP; authors' treatments.

Cerema – are shown in Tables 3, 4, and 5. The results for areas authorised for construction are shown in Table A2 in the Appendix. The tables present the coefficients associated with equation (6), with and without spatial fixed effects for specifications with and without interaction with the location of the land. For all models without spatial fixed effects (columns (1) and (2) in the tables) the instruments used are the SSC hazard and the agricultural opportunity cost AGRI. These instruments are strong for all specifications, they are valid in the sense of the Sargan test when construction is measured by the number of housing units without interaction (model (1) in Table 3). For models that use *Sit@del2* construction measures with spatial fixed effects (shown as (3) to (6) in the tables), the instruments used are the SSC hazard and the percentage of the population located on a slope SLOPE greater than 10%,. The inclusion of fixed effects significantly decreases the power of the instruments, but the Sargan tests do not allow their validity to be rejected for all of the specifications (except for the model with the authorised surface areas presented in the Appendix, Table A2). For models that use Cerema's artificialised areas with spatial fixed effects (Table 5), the instruments used are the inhabitants residing on slopes, SLOPE and the number of former industrial sites INDUS. These instruments are strong in the sense of the conditional Fisher test for all specifications, and their validity cannot be rejected (except for model (5) where validity is rejected at 5% but not at 10%). The tables also show Moran's I statistics, which test the null hypothesis of no spatial autocorrelation of the estimated residuals. They are calculated at the scale of *EPTB* observations with a spatial weight matrix based on the contiguity derived from the Delaunay triangulation. They indicate the presence of significant spatial autocorrelation which decreases with the inclusion of spatial fixed effects and interactions. The spatial autocorrelation of residuals does not call into question the validity of the instruments nor, therefore, the absence of bias in the estimators. Its effects on statistical inference are controlled by the use of a robust cluster inference. However, spatial autocorrelation indicates the presence of spatial effects not taken into account here, but which could be analysed in future research.

The effects of control variables are relatively stable across the specifications. The price elasticity of land area is about -0.9 for models without spatial fixed effects and about -0.7 for others. Elasticities as a function of density are more heterogeneous between the specifications but are, in all cases, positive (some of this heterogeneity is only apparent as it is linked to interactions with construction). This variable captures the quality effects of the location through proximity to jobs and services. A 1% increase in population density increases the unit price of land by about 0.7% in fixed-effect models for urban areas and about 0.35% in fixed-effect models for employment zones. The coefficients associated with elevation and slope are significantly modified following the inclusion of fixed effects. Elevation has a negative effect on price and the slope no longer has a significant negative effect (values not reported). Serviced land is on average 18% more expensive, the presence of an intermediary at the time of the sale significantly increases the price, with significant variations depending on the type of intermediary (reference method is non-response). Using an estate intermediary to purchase land leads to a price increase of 23%, this effect is halved with the inclusion of spatial fixed effects. Similar results are obtained when the intermediary is a constructor whereas the absence of an intermediary decreases the price, this is not always significant however.

The sign of the estimated elasticities is robust to the construction measure, the inclusion of spatial fixed effects and the instruments used. The elasticities estimated in the models without interactions ((1), (3) and (5) in each of the tables) are all significant and negative, which confirms the theoretical results: all other things equal, increasing construction decreases the price of building land. The estimated elasticities, however, show strong heterogeneity between the specifications, from -0.191 for the effect of the estimated number of authorized housing units with fixed effects by employment zone (model (5) of Table 3)

Box 3 – **Instrumental variables for construction**

Four instrumental variables are assumed to influence construction without being related to land prices. The number of instruments is therefore greater than the endogenous explanatory variables to be instrumented: the models are over-identified, which makes it possible to use Sargan tests for their validity. The validity of the instruments is conditionally defined by the endogenous explanatory variable used to measure construction and the controls included in the regressions. The same instrument may be valid for some construction measures but not for others. Likewise, a valid instrument for a model without fixed effects may be invalid after the inclusion of fixed effects. This is especially the case with agricultural opportunity cost, which is exogenous at the national level but correlates to the residuals of the price equation within urban areas and employment zones. Descriptive statistics for the instruments are shown at the bottom of Table 1.

Shrinkage/swelling of clay hazard (SSC)

The SSC hazard is a characteristic of soils which affects construction due to ground stability effects. It increases construction costs and is the second largest natural disaster compensation item affecting individual houses. It therefore causes additional insurance costs, while the fact that it is natural in origin makes it non-sensitive to land prices. This is a construction datum that cannot be modified in areas where land prices are high. SSC hazard maps are produced by the BRGM and available online (http://www.georisques.gouv.fr/dossiers/alea-retrait-gonflement-des-argiles). Higher hazard levels affect 2% of metropolitan France (10,600 km²), medium hazard levels affect 15% (83,800 km²), and low levels affect 44% (241,300 km²). Areas that are *a priori* non-clayey, cover 39% of metropolitan France (212,800 km²). We use the portion of the municipal area with medium or high SSC hazards to instrument construction. To our knowledge, this instrument is original in the literature. Given its impact on construction and insurance costs, negative effects in the first stage of instrumentation are expected.

Share of the population living on steep slopes (SLOPE)

As with the SSC hazard, the slope of a plot hinders construction due to its impact on costs, while its

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Box 3 – (contd.)

natural origin makes it a potential instrument. The distribution of slopes at the national scale is calculated using the BD ALTI model, available at a resolution of 75 meters on the IGN website (http://professionnels.ign.fr/bdalti). The distribution of the slopes was combined with the 200 metre gridded population data from Insee (https://www.insee.fr/fr/statistiques/2520034) to calculate, at the municipal level, the portion of the population living on slopes between 10 and 15%, and the portion of the population living on slopes greater than 15%. A similar procedure to strengthen the power of topography for identification is being implemented by Saiz (2010). The idea of using the slope to explain construction is also present in Burchfield *et al.* (2006) and Hilber and Vermeulen (2016), where it is measured as the difference between the maximum altitude and the minimum altitude of the spatial unit, unless better data is available. A negative effect of this variable is expected in the first stage.

Standard gross agricultural income (AGRI)

Housing and agriculture compete for the scarce land resources. It follows that the agricultural production that would have occurred in the absence of construction constitutes an opportunity cost of said construction. However, this effect is difficult to measure because housing construction influences agricultural activity, and therefore the measure of opportunity cost (Cavailhès *et al.*, 2011a). The instrumental variable AGRI must therefore represent the agricultural value of the land regardless of the effects of land prices over the period the prices are studied (1995-2014). To do this, we consider an earlier measure (1988) of the agricultural specialization of each region, the farms being classified according to their main technical-economic orientation, OTEX[(a)]. It is then possible to calculate local agricultural growth rates, which are exogenous to the local evolution of land prices, by multiplying the 1988 specialization by the national growth rates of the same OTEX over the period 1989-2014. By noting I_{js}^{88} the portion of OTEX *s* in region *j* in 1988 and g_s the 1989-2014 national growth rate for OTEX *s*, the instrument is written as:

$$\widehat{AGRI}_j = \sum_s I_{js}^{88} \cdot g_s \qquad (1)$$

The literature attributes the origin of the use of such instruments to Bartik (1991) (characterized as *shift and share* by Baum-Snow & Ferreira, 2015). The source of identification comes from initial agricultural specializations that impact the resistance of agriculture to construction. The validity of this instrument is based on the *a priori* assumption that agricultural specializations in 1988 do not depend on recent land dynamics (or any other variable that could be correlated with these dynamics). This type of instrument has been extensively used in the literature (see in particular Saiz, 2010; Hilber & Vermeulen, 2016; Combes *et al.*, 2016a) for local labour markets (demand variations), but not for land markets (variations in the offer). A negative effect of this instrument is expected in the first stage of instrumentation.

Number of old industrial sites (INDUS)

Like agriculture, industry is facing national and international shocks that affect its profitability regardless of the local context, in particular the land market. Industries are facing technological shocks that lead to cessation of business, so freeing up construction land (gas plants, printing plants, etc.). Former industrial activities and service activities have been systematically inventoried since 1994. The data collected for these inventories are archived in a national database, *Basias* (*Base des Anciens Sites Industriels et Activités de Service*)[(b)]. We can use the number of old industrial sites as an instrument at the municipal level. Due to effects of externality and the local labour market, the presence of a former industrial site can have a negative effect on construction and housing prices. We can, however, evaluate the net effect in the first stage as, on the one hand, release of the land should have a positive effect on construction and, on the other, externalities should have a negative effect. The estimation of a positive effect in the first stage indicates that the effects of externalities are relatively less important.

(a) OTEX classification of farms is done by the SSP (Service de la Statistique et de la Prospective, Ministère de l'Agriculture et de l'Alimentation) using standard gross production (SGP). The classification distinguishes 11 activities (field crops, market gardening and horticulture, viticulture, fruits, milk, cattle breeding and meat, milk, combined cattle breeding and meat, other herbivores, granivores, polyculture-polyseeding, other). SGP is calculated by valuing the cultivated areas and herds belonging to each farm according to coefficients which do not constitute observed financial results. They must be considered as orders of magnitude defining the potential production of the farm per hectare or head of livestock present, excluding all types of assistance.

(b) Available online http://www.georisques.gouv.fr/dossiers/inventaire-historique-des-sites-industriels-et-activites-en-service-basias#/

to -0.743 for the effect of floor areas authorised for construction with fixed effects by large urban area (model (3) in Table 4). Most of the estimated elasticities, however, do not significantly differ from -0.3. It appears that, among the construction measures from *Sit@del2*, the floor area construction produces the most significant effects on prices. The construction of floor areas (cf. Table 4) has larger effects (in levels) on the price of land relative to the number of housing units (Table 3) and the surface area of the land authorized for construction (Appendix, Table A-2). They therefore appear to be more relevant levers for public policies that seek to create supply shocks. Cerema's artificialised

Table 3
Inverse demand equations in number of authorised housing units

	Dependent variable: Log of price per ha of land, two-stage least squares estimate					
	(1)	(2)	(3)	(4)	(5)	(6)
Population density (log) [β_1]	0.434*** (0.040)	0.703*** (0.038)	0.621*** (0.087)	0.638*** (0.045)	0.337*** (0.071)	0.364*** (0.052)
Constructed housing units (log) [β_2]	-0.302*** (0.056)	-0.101** (0.045)	-0.552*** (0.108)	-0.363*** (0.055)	-0.191** (0.088)	-0.006 (0.062)
Housing units x density (log) [β_3]		-0.043*** (0.004)		-0.043*** (0.003)		-0.045*** (0.003)
Surface area of the plot (log)	-0.932*** (0.015)	-0.926*** (0.011)	-0.753*** (0.017)	-0.752*** (0.009)	-0.694*** (0.015)	-0.695*** (0.011)
Serviced land (0-1)	0.187*** (0.009)	0.182*** (0.007)	0.203*** (0.007)	0.201*** (0.004)	0.188*** (0.005)	0.186*** (0.004)
Agency (0-1)	0.236*** (0.012)	0.233*** (0.010)	0.113*** (0.010)	0.114*** (0.007)	0.095*** (0.008)	0.095*** (0.007)
Constructor (0-1)	0.027*** (0.010)	0.026*** (0.009)	0.013 (0.009)	0.011* (0.006)	0.021*** (0.007)	0.019*** (0.006)
Other intermediary (0-1)	-0.00004 (0.010)	-0.003 (0.008)	0.029*** (0.008)	0.027*** (0.006)	0.031*** (0.007)	0.028*** (0.006)
No intermediary (0-1)	-0.050*** (0.009)	-0.051*** (0.008)	-0.018** (0.009)	-0.019*** (0.006)	-0.007 (0.007)	-0.008 (0.006)
COND. F	109.379***	109.379***	29.245***	29.245***	29.064***	29.064***
SARGAN	0.137	0***	0.245	0.97	0.058*	0.74
SSC F	30.782***	30.782***	16.809***	16.809***	22.98***	22.98***
AGRI F	103.325***	103.325***				
SLOPE F			47.946***	47.946***	19.135***	19.135***
Moran's I	0.556***	0.514***	0.413***	0.260***	0.315***	0.252***
Fixed effects			UA	UA	EZ	EZ
Observations	279,215	279,215	279,215	279,215	279,215	279,215
Residual standard deviation	0.685	0.578	0.607	0.418	0.46	0.411

Notes: All models include indicator variables for the year of purchase of the land, and elevation and slope deciles for the plots. Included fixed effects are for large urban areas (UA, N = 230) and employment zones (EZ, N = 320). Box 3 presents the instruments, SSC for shrinkage/swelling of clay, AGRI for the exogenous agricultural opportunity cost and SLOPE for housing units located on slopes greater than 15%. Fisher's tests are identical side by side because the first steps of instrumentation are identical. The additional online complement table shows the ordinary least squares estimates and coefficients estimated in the first step of instrumentation. The strength of the instruments is measured by Ficher's statistics (COND. F, Sanderson & Windmeijer, 2016). The table shows the critical value (p-value) of the SARGAN associated with the null hypothesis of validity of the instruments. The Moran *I's* are calculated using the estimated residuals and test their spatial autocorrelation on the basis of contiguity matrices. statistical inference is obtained using 1,000 permutations. For the variables relating to the presence of an intermediary, the reference method is non-response. Standard deviations are clustered at the common level. *p<0.1; **p<0.05; ***p<0.01.
Coverage: Metropolitan France.
Sources: *EPTB* (SDES), *Sit@del2* (SDES), Insee, BD ALTI (IGN), Cerema, *Basias* (BRGM), SSP; authors' treatments.

areas show the most stable effects between the specifications, between -0.288 and -0.348. The values of these elasticities are close to the elasticities obtained for the construction of floor areas, apart from model (3) in Table 4, the high value of which can be explained by the low explanatory power of the instruments. The conditional Fisher test is, however, significant.

The estimated elasticity of -0.3 confirms that the construction of new housing can reduce the price of building land; however, this value is relatively small in absolute value, indicating that this lever is only moderately effective. Online complement tables C-1, C-2, C-3 and C-4 show the elasticities estimated by models that do not take into account the endogeneity of construction. These models are estimated using OLS and show that the coefficients of the construction effect on the building land prices are positive (regardless of the construction measure or the presence of spatial fixed effects). This result is related to the location of construction, preferably in the places requested and therefore valued (Geniaux *et al.*, 2015). Our instrumental variable identification strategy corrects the endogeneity bias and estimates the negative effects of construction demand on the price of building land. This change in sign of the elasticities illustrates the importance of controlling the coefficients obtained by OLS of the endogeneity of construction resulting from the simultaneity of the observed equilibria. The tables in the Online complement also present the first steps of instrumentation. For a given construction variable and fixed effect type, models both with and without interactions are based on these same first steps.

In each of Tables 3, 4, 5, and A2, columns (2), (4) and (6) show the interaction coefficients between construction and a location measure based on population density. The coefficients associated with interaction show high stability between the specifications for a given construction measure and, to a lesser extent, between the construction measures

Table 4
Inverse demand equations for authorised floor areas

	Dependent variable: Log of price per ha of land, two-stage least squares estimate					
	(1)	(2)	(3)	(4)	(5)	(6)
Population density (log) [β_1]	0.426*** (0.038)	0.908*** (0.054)	0.746*** (0.132)	0.763*** (0.057)	0.356*** (0.082)	0.388*** (0.057)
Authorised floor areas (log) [β_2]	-0.300*** (0.054)	-0.093** (0.046)	-0.743*** (0.173)	-0.546*** (0.073)	-0.225** (0.106)	-0.038 (0.071)
Authorised surface areas x Density (log) [β_3]		-0.044*** (0.004)		-0.044*** (0.003)		-0.046*** (0.003)
Surface area of the plot (log)	-0.928*** (0.014)	-0.921*** (0.011)	-0.765*** (0.022)	-0.764*** (0.010)	-0.695*** (0.015)	-0.696*** (0.011)
Serviced land (0-1)	0.188*** (0.009)	0.183*** (0.007)	0.217*** (0.011)	0.215*** (0.005)	0.191*** (0.007)	0.189*** (0.005)
Agency (0-1)	0.233*** (0.012)	0.231*** (0.010)	0.122*** (0.012)	0.123*** (0.007)	0.097*** (0.008)	0.098*** (0.007)
Constructor (0-1)	0.026** (0.010)	0.025*** (0.009)	0.010 (0.011)	0.008 (0.006)	0.021*** (0.007)	0.018*** (0.006)
Other intermediary (0-1)	0.005 (0.010)	0.002 (0.008)	0.036*** (0.010)	0.034*** (0.006)	0.033*** (0.007)	0.031*** (0.006)
No intermediary (0-1)	-0.047*** (0.009)	-0.047*** (0.008)	-0.019* (0.010)	-0.020*** (0.006)	-0.006 (0.007)	-0.008 (0.006)
COND. F	120.393***	120.393***	17.05***	17.05***	22.721***	22.721***
SARGAN	0.016**	0***	0.18	0.927	0.292	0.784
SSC F	28.986***	28.986***	9.827**	9.827**	16.792***	16.792***
AGRI F	119.481***	119.481***				
SLOPE F			28.985***	28.985***	21.48***	21.48***
Moran's I	0.551***	0.514***	0.445***	0.260***	0.328***	0.252***
Fixed effects			UA	UA	EZ	EZ
Observations	279,215	279,215	279,215	279,215	279,215	279,215
Residual standard deviation	0.682	0.578	0.702	0.418	0.473	0.411

Notes: cf. Table 3.
Coverage: Metropolitan France.
Sources: *EPTB* (SDES), *Sit@del2* (SDES), Insee, BD ALTI (IGN), Cerema, *Basias* (BRGM), SSP; authors' treatments.

themselves. The interaction effects are all negative and significant, which confirms the results of the theoretical model. As accessibility of jobs and services (approximated by population density) is a desirable feature of the land plots, increasing construction has stronger price effects in absolute terms in more densely populated areas. For construction measured in number of housing units and authorized floor areas, the cross effects of density amount to -0.045, whereas for construction measured in land area (according to Cerema and *Sit@del2*) they are in the order of -0.075. This indicates that a 10% increase in construction decreases the price of building plots by 0.45% and 0.75% respectively in the top 10% most dense areas. Table 6 reports the different elasticities of construction for different density values, they come from models with effects fixed to employment zones (i.e. column (6) of the results tables). The median values are close to the elasticities obtained in the models without interactions (i.e. β_2 in columns (1) of the results tables). The values of these elasticities remain low, apart from the floor areas which always have a stronger effect on prices. It appears, for all construction measures, that the elasticity is higher in municipalities in the ninth density decile (387 inhab./km^2) compared to those of the first decile (26 inhab./km^2), about 0.1 in absolute value.

Table 5
Inverse demand equations for artificialised areas

	Dependent variable: Log of price per ha of land, two-stage least squares estimate					
	(1)	(2)	(3)	(4)	(5)	(6)
Population density (log) [β_1]	0.318*** (0.018)	1.204*** (0.087)	0.331*** (0.020)	0.297*** (0.013)	0.317*** (0.022)	0.278*** (0.014)
Artificialised areas (log) [β_2]	-0.288*** (0.052)	0.053 (0.052)	-0.348*** (0.047)	0.080* (0.041)	-0.319*** (0.050)	0.131*** (0.045)
Surface areas x Density (log) [β_3]		-0.074*** (0.007)		-0.068*** (0.005)		-0.071*** (0.005)
Surface area of the plot (log)	-0.874*** (0.008)	-0.870*** (0.006)	-0.694*** (0.006)	-0.683*** (0.005)	-0.690*** (0.007)	-0.676*** (0.005)
Serviced land (0-1)	0.216*** (0.014)	0.211*** (0.010)	0.221*** (0.008)	0.202*** (0.005)	0.221*** (0.008)	0.201*** (0.005)
Agency (0-1)	0.205*** (0.010)	0.203*** (0.009)	0.084*** (0.008)	0.086*** (0.006)	0.083*** (0.008)	0.083*** (0.006)
Constructor (0-1)	0.037*** (0.010)	0.036*** (0.009)	0.030*** (0.008)	0.026*** (0.006)	0.031*** (0.008)	0.027*** (0.006)
Other intermediary (0-1)	0.003 (0.009)	0.002 (0.008)	0.027*** (0.008)	0.025*** (0.006)	0.032*** (0.008)	0.029*** (0.006)
No intermediary (0-1)	-0.059*** (0.010)	-0.059*** (0.008)	-0.026*** (0.008)	-0.019*** (0.006)	-0.019** (0.008)	-0.013** (0.006)
COND. F	74.724***	74.724***	73.864***	73.864***	69.139***	69.139***
SARGAN	0.003**	0***	0.587	0.616	0.008**	0.616
SSC F	18.301***	18.301***				
AGRI F	80.942***	80.942***				
INDUS F			70.67***	70.67***	68.617***	68.617***
SLOPE F			66.463***	66.463***	56.178***	56.178***
Moran's I	0.551***	0.513***	0.462***	0.260***	0.358***	0.252***
Fixed effects			UA	UA	EZ	EZ
Observations	279,215	279,215	279,215	279,215	279,215	279,215
Residual standard deviation	0.67	0.578	0.544	0.418	0.527	0.41

Notes: cf. Table 3.
Coverage: Metropolitan France.
Sources: *EPTB* (SDES), *Sit@del2* (SDES), Insee, BD ALTI (IGN), Cerema, *Basias* (BRGM), SSP; authors' treatments.

Table 6

Summary table for the elasticities of inverse demand for building land

	Municipal population density in 1990 (inhab./km^2)				
	D1 26.5	Q1 44.3	Median 85.2	Q3 178.2	D9 387.1
Number of housing units authorised	-0.241 [-0.28; -0.20]	-0.263 [-0.31; -0.22]	-0.291 [-0.33; -0.25]	-0.323 [-0.37; -0.28]	-0.356 [-0.40; -0.31]
Authorised floor areas	-0.503 [-0.55; -0.46]	-0.525 [-0.57; -0.48]	-0.553 [-0.60; -0.51]	-0.585 [-0.63; -0.54]	-0.618 [-0.67; -0.57]
Developed areas	-0.152 [-0.23; -0.08]	-0.175 [-0.25; -0.10]	-0.204 [-0.28; -0.13]	-0.237 [-0.31; -0.16]	-0.272 [-0.35; -0.2]
Land areas	-0.237 [-0.28; -0.19]	-0.260 [-0.30; -0.22]	-0.288 [-0.33; -0.24]	-0.32 [-0.36; -0.28]	-0.354 [-0.4; -0.31]

Note: The models used to calculate the elasticities include fixed effects for the employment zones, these are the (6) columns of Tables 3, 4, 5, and A2. The confidence intervals of the elasticities are at the 95% threshold and calculated using the asymptotic delta method with a clustered variance/covariance matrix at the municipal scale. D1 and D9 represent the thresholds of the first and last deciles of municipal population density, Q1 and Q3 are the thresholds of the first and last quartiles.

Reading note: a 10% increase in the number of dwellings decreases the price of land by 2.41 % in a municipality in the lower population density decile and by 3.56 % in a municipality in the upper decile.

Coverage: Metropolitan France.

Sources: *EPTB* (SDES), *Sit@del2* (SDES), Insee, BD ALTI (IGN), Cerema, *Basias* (BRGM), SSP; authors' treatments.

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In a context of significant increases in the price of built land and the costs of new housing construction, this article shows that the issuance of building permits does have significant negative effects on the price of land. This means that household demand is price elastic. However, the measured effect on prices is relatively small, the elasticity of inverse demand is, on average, less than 0.5 (in absolute value). These small estimated values vary with two important determinants, the construction measure and the location of the land. Firstly, the price response is larger (in absolute terms) for a relative change in floor areas authorised for construction than for the same relative change in the number of housing units authorised, or the artificialised area. Secondly, whatever the measure of construction, the denser the area of location, the more the variations will have an impact on prices. These results are to be put in perspective with households' preferences. An increase in available floor area appears to be a construction quality which is highly valued by households; this therefore has a more important role to play in lowering land prices. This interpretation is also valid for the location of the construction, where, more than the total quantity, the proximity of the housing units to jobs and services is a decisive element to consider in order to implement an effective supply shock.

This article highlights two important determinants for reducing the weight of land in new housing construction costs. Others should also be studied, such as zoning and infrastructure land policies, as well as strategies used by owners of building land. The issuance of building permits is not the only regulatory tool available to policy-makers. The effects of planning documents – which constrain the use of land – on land prices, and the establishment of density limits for construction, should also be subject to economic assessments. However, our results provide additional explanations for the weak correlations observed between construction and the prices of land and housing – low elasticity of inverse demand – whereas the academic and specialized literature usually invokes supply restrictions as stemming from regulatory constraints on construction (zoning in particular). Furthermore, the link between the price of land and density also depends on the types of housing built on it, which would also merit a special study.

Finally, it should be borne in mind that lower land prices due to construction do not necessarily improve households' well-being. The virtuous effects on the price of building land are of a low order of magnitude and must be compared to the hidden costs and the externalities (positive and negative) of construction. As proximity to jobs and services is valued by households, and existing housing units are generally better located than available land plots, our results on the effects of construction on prices must be compared with those for reconstruction, demolition, renovation and mobilization of vacant housing. These aspects are only partially taken into account in this analysis which only covers those relating to reconstruction which requires a building permit. Regarding trade-offs between the construction of new housing and existing housing stocks, amenities such as gardens and open spaces are also relevant. While household preferences for the latter were strong enough to reduce their demand for the existing, with smaller housing stocks, reconstruction and renovation would have little or no effect on prices. Lastly, construction in desirable locations may face physical, regulatory or strategic land availability issues that prevent construction and limit the virtuous effect of this price lever. Follow-ups of this study may seek to measure the impact of construction on the value of existing housing stocks or, more specifically, to analyse constraints related to land availability. ☐

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Table A1
Descriptive statistics for discrete variables in the final sample

	Frequency	Percentage (%)	Cumulative percentage (%)
Year land was purchased			
1995	521	0.2	0.2
1996	69	0.0	0.2
1997	85	0.0	0.2
1998	106	0.0	0.3
1999	171	0.1	0.3
2000	277	0.1	0.4
2001	292	0.1	0.5
2002	362	0.1	0.7
2003	553	0.2	0.9
2004	829	0.3	1.2
2005	1520	0.5	1.7
2006	5060	1.8	3.5
2007	31287	11.2	14.7
2008	29,742	10.7	25.4
2009	22,360	8.0	33.4
2010	32,178	11.5	44.9
2011	40,852	14.6	59.5
2012	45,738	16.4	75.9
2013	37,576	13.5	89.4
2014	27,172	9.7	99.1
2015	2481	0.9	100
Serviced land			
No	105,239	37.7	37.7
Yes	173,992	62.3	100
Intermediary for the purchase			
Not known	6439	2.3	2.3
Agency	66,264	23.7	26
Constructor	46,294	16.6	42.6
Other	49,608	17.8	60.4
None	110,626	39.6	100
Socio-Professional Category			
Farmer	2481	0.9	0.9
Artisan	18,111	6.5	7.4
Manager	52,224	18.7	26.1
Intermediary	27,430	9.8	35.9
Office worker	124,106	44.5	80.4
Blue-collar worker	36,291	13	93.4
Retiree	18,588	6.7	100
Age on filing of the building permit			
<30	75,542	27.1	27.1
30-39	107,629	38.5	65.6
40-49	49,352	17.7	83.3
50-59	27,610	9.9	93.2
>60	19,098	6.8	100

Coverage: Metropolitan France.
Sources: *EPTB* (SDES).

Table A2
Inverse demand equations for buildable areas

	Dependent variable: Log of price per ha of land, two-stage least squares estimate					
	(1)	(2)	(3)	(4)	(5)	(6)
Population density (log) [β_1]	0.307***	1.378***	0.573***	0.604***	0.334***	0.388***
	(0.016)	(0.111)	(0.111)	(0.043)	(0.069)	(0.045)
Constructible areas (log) [β_2]	-0.245***	0.115**	-0.933***	-0.614***	-0.357**	-0.075
		(0.053)	(0.270)	(0.107)	(0.161)	(0.102)
Surface areas x Density (log) [β_3]		-0.079***		-0.080***		-0.084***
		(0.008)		(0.006)		(0.006)
Surface area of the plot (log)	-0.857***	-0.854***	-0.701***	-0.701***	-0.680***	-0.683***
	(0.007)	(0.006)	(0.012)	(0.005)	(0.009)	(0.006)
Serviced land (0-1)	0.177***	0.173***	0.204***	0.203***	0.188***	0.188***
	(0.008)	(0.006)	(0.012)	(0.005)	(0.006)	(0.004)
Agency (0-1)	0.226***	0.225***	0.131***	0.133***	0.102***	0.107***
	(0.011)	(0.009)	(0.017)	(0.008)	(0.010)	(0.008)
Constructor (0-1)	0.032***	0.031***	0.009	0.006	0.020**	0.016***
	(0.010)	(0.009)	(0.013)	(0.006)	(0.008)	(0.006)
Other intermediary (0-1)	-0.001	-0.003	0.029***	0.027***	0.031***	0.028***
	(0.009)	(0.008)	(0.011)	(0.006)	(0.007)	(0.006)
No intermediary (0-1)	-0.046***	-0.046***	-0.020*	-0.021***	-0.008	-0.011*
	(0.009)	(0.008)	(0.012)	(0.006)	(0.008)	(0.006)
COND. F	99.741***	99.741***	4.656***	4.656***	6.68***	6.68***
SARGAN	0***	0***	0***	0.074*	0***	0.832
SSC F	1.153	1.153	0	0	2.214	2.214
AGRI F	128.142***	128.142***				
SLOPE F			16.421***	16.421***	22.262***	22.262***
Moran's I	0.532***	0.513***	0.356***	0.258***	0.353***	0.250***
Fixed effects			UA	UA	EZ	EZ
Observations	279,215	279,215	279,215	279,215	279,215	279,215
Residual standard deviation	0.65	0.579	0.807	0.418	0.512	0.411

Notes: cf. Table 3.
Coverage: Metropolitan France.
Sources: *EPTB* (SDES), *Sit@del2* (SDES), Insee, BD ALTI (IGN), Cerema, *Basias* (BRGM), SSP; authors' computations.