Optimal Urban Growth with Environmental Effects. A Valuation Exercise *

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Abstract

This study provides an alternative empirical approach to identify optimal urban growth when accounting for its associated environmental effects. Rather than focusing on the energy and pollution consequences of urban form often discussed in the literature, this paper analyses the problem of the so-called sustainable city from the perspective of the environmental amenities perceived by residents. Departing from the existing trade-off between the environmental benefits derived from living at lower densities and the environmental costs of transforming rural landscapes to urban uses, the exercise analyzes the welfare effects of current urban growth trends in the Metropolitan Region of Barcelona. Thus, it is analyzed whether more compact or more disperse urban growth would be welfare-improving in this particular setting. The results are obtained from a market simulation exercise that uses both contingent ranking and contingent valuation data. Both types of discrete response format yield positive willingness to pay estimators for a diminishment of density levels within cities in this area, even if this implies cities to grow at the cost of losing some of their surrounding landscapes. According to these results, a more compact city scenario would be welfare-decreasing from the perspective of the estimated demand of urban environmental goods. These results suggest that a planning systems that lead to rather high density levels and higher land prices in the area would not be justified on environmental grounds, because they would overcorrect the externalities caused by the loss of undeveloped landscapes.

1 Introduction

Urban sprawl is a controversial issue in many countries, since the size and characteristics of cities and the distribution of land uses may have consequences on the environment. The concept of *urban sustainability* is frequently used to refer to this link between the characteristics of cities and their effects on the environment. Urban growth is sometimes said to be the cause of negative effects such as traffic congestion, pollution, or the loss of outer open spaces for current and future generation. One of the main criticism to sprawl is that, since it apparently increases commuting lengths, it leads to larger levels of fuel and land consumption. In the proposed alternative scenario cities would be more compact. The underlying idea is that higher densities are more environmentally friendly in the sense that they shorten trip lengths, they permit a wider use of public transit systems and preserve more undeveloped landscapes.

One of the pioneering studies supporting the compact city proposal view in the USA was Kenworthy and Newman (1989), but several aspects of the study and of the compact city proposal it followed were criticized in Gordon, Kumar and Richardson (1990) and Giuliano and Small (1993). In Europe, the *Green Book in Urban Environment* (EEC, 1990) also defended compact urban structures, and its conclusions were questioned by several authors, as Breheny (1992a), Owens (1992) or Banister (1992). Taking into account available studies, and despite the straightforward intuition behind it, there seems to be no conclusive evidence clearly supporting that compact cities better accomplish certain environmental goals. In a more recent paper, Crane (1999) provides a survey and classification of the studies available on the relationship between urban form and travel, the conclusion of which being that apparently contradictory results can be explained by differences in methodology, and that little can be said about the impacts of urban form on travel. Gordon and Richardson (1997), Ewing (1997) and Breheny (1997) are recent examples of the state of the debate on urban sprawl and the compact city proposal.

In this chapter a different empirical approach is taken to investigate about the environmental goodness of alternative forms of urban growth. The most common approach in the literature tries to statistically test the relationship between certain indicators of urban form and some chosen environmental variables, like the ones mentioned above. Instead, we base our work on how urban residents perceive the environmental effects of urban growth. The study focuses on the changes in welfare caused by variations in available open spaces and rural land around cities, and by different urban densities, always from the perspective of urban residents. We readily assume that compact urban forms preserve more rural landscapes, what would constitute a benefit for resident households. In a way, we have chosen rural landscape preservation as the representative of the possible environmental benefits associated to compact urban structures. This allows us to focus on the existing trade-off between outer land preservation and environmental quality within cities, understood as lesser density or more green space per person *inside* cities. Smaller densities and better environmental amenities can be obtained at the expense of growing further and extending the cities at lower densities, but more dispersed cities *consume* more outer landscapes. Taking into account these two environmental consequences of alternative patterns of urban growth, it is intended to establish whether future urban growth should be developed at higher or lower densities in relation with recent trends.

To test which type of urban development would be welfare-improving in a particular case, an exercise that uses the contingent valuation method (CVM) was undertaken for the Metropolitan Region of Barcelona. By definition, negative externalities are not considered by market forces. Despite the fact that market trends show how people prefer outer and less dense locations, in the market simulation exercise we allow for the possibility that current growth trends are inefficient in the sense that they ignore some external costs of urban growth, in particular the loss of open spaces around cities. The exercise attempted the simulation of a market where respondents could trade-off density and preservation of landscapes. The results show that a majority of people favored maintaining outward growth, and the same outcome is obtained from the aggregate WTP measure.

The paper organizes as follows. In section 2, the underlying theoretical setting is briefly outlined. Section 3 applies the foundations of CVM to the present context of the environmental consequences of urban growth. Section 4 firstly offers some data on the characteristics and growth trends in the territory where the analysis applies, and then shows how the CVM exercise was here designed. The main results arising from the exercise are interpreted to identify optimal urban growth patterns. Finally, section 5 highlights the main conclusions and discusses some urban policy implications.

2 The underlying theoretical framework: the bid-rent model

This section briefly summarizes some aspects of the bid-rent model, a theoretical tool widely applied to deal with urban problems from a theoretical perspective. The bid-rent approach was first developed by Alonso (1964). A comprehensive description of the bid-rent model and some of its extensions in a static framework can be found in Fujita (1989).

The residential location problem is considered to be a particular case of the microeconomic utility maximization problem of the household. The same problem can be analyzed through bid-rent curves. Consumers can spend income Y between z, a composite good –chosen to be the *numéraire* and s, that represents the amount of land. They obtain utility from the consumption of these two goods. Besides they must face the transportation costs $T(r)$ of commuting to the Central Business District, where all employment is located by assumption. Distance is denoted by r. If $\Phi(r)$ represents the bid-rent function, or the maximum payment per unit of land an individual would be willing to make for living at a certain distance r from the city centre while enjoying a certain fixed utility level, u, then

$$\Phi(r, u) = \max_{s} \frac{Y - T(r) - z(u, s)}{s}.$$

Bid-rent curves can then be understood as indifference curves at the locational space. For the utility level to remain at a constant level, land rents must diminish with distance to counterbalance the transportation costs savings from more central locations.

So far we have referred to the maximum willingness to pay of an individual in order to live at a certain location. The urban bid-rent function that represents the overall population in a city can be determined too. To obtain the equilibrium land pattern in the city, two conditions are needed. Firstly, land market must clear everywhere in such a way that all individuals are accommodated within the city. Since landowners seek to maximize land rents, for them to be willing to dedicate their land to urban uses it is necessary that at the city boundary land rent reaches at least the opportunity cost of land, commonly assumed to be the agricultural rent R_A. As a result, at the city boundary urban rent equals the opportunity cost of land. The second equilibrium condition implies that households have no incentive to relocate within the city. Assuming that all individuals are identical, this implies that the urban land rent must coincide with one particular bid-rent of any representative individual so that everyone achieves the same utility level. In a simple context in which transport costs are linear and all households consume an exogenously fixed land plot $\overline{s}$, urban land rents in the city are as follows:

$$R(r) = \begin{cases} \frac{Y-T(r)-z(\overline{s},u)}{\overline{s}} & \text{if } r \leq \overline{r} \\ R_A & \text{if } r > \overline{r}, \end{cases}$$

where $s(r,u) = \overline{s}$ is the individual demand for land, and $\overline{r}$ represents the city boundary. Notice that with linear transportation costs and a constant $\overline{s}$, the urban bid-rent is linear. In a given context where population N is exogenously determined, city size is directly related to plot size and inversely related to density, measured as the inverse of pre-fixed plot size:

$$\overline{r} = N\overline{s}.$$

That is, if we consider $\overline{s_1} < \overline{s_2}$, then $\frac{1}{\overline{s_1}} > \frac{1}{\overline{s_2}}$, and for a given population it must be the case that $\overline{r_1} < \overline{r_2}$. As expected, in a closed-city context higher densities imply more landscape preservation, while lower densities result in larger urban growth.

2.1 The bid-rent model with environmental amenities

Households' utility may also depend on other variables such as local environmental amenities, denoted by E. If this is the case, then the bid-rent of an individual will also be affected by the environmental characteristics of a particular site

$$R(r,u) = \max_{s} \frac{Y - T(r) - z(u,s,E)}{s(r,u)}.$$

When environmental conditions improve at a certain site, $E_1 > E_0$, locating there becomes more valued, and this translates into higher land rents. Consequently, at any location, the bid-rent increases in a better environment.

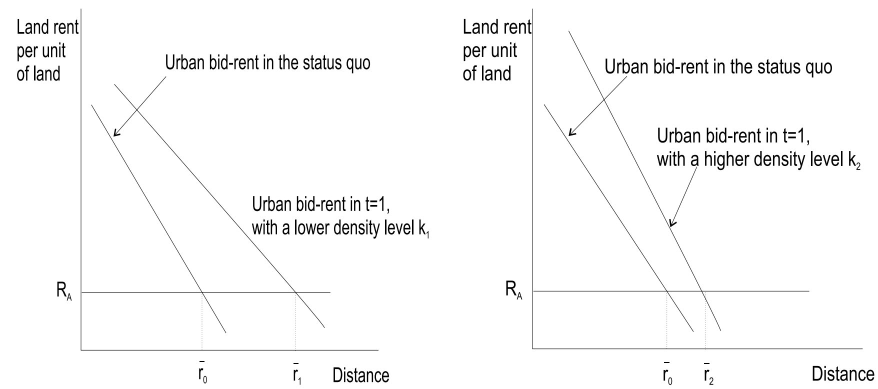
Most cities are not purely market determined; rather, they are planned. The correction of externalities and the provision of public goods are probably the most important economic role of urban planning. In a planned city, local planners can fix density levels directly or through the regulation of lot sizes and city boundaries. As shown in equation 2 above, by fixing lot sizes two key environmental variables are being affected: density levels and consumption of open spaces around cities. To evaluate the effects on welfare of alternative urban growth scenarios in practice, an exercise based on stated preferences has been carried out in the Metropolitan Region of Barcelona(MRB), Spain. To our knowledge, the approach presented here constitutes a novelty. As it will be seen later, it permits to establish whether outer urban growth is or is not welfare-improving when accounting for externalities.

3 The CVM and optimal urban growth

The approach taken in this paper is to use a non-market based valuation technique to search for the efficiency of current urban growth trends in the MRB, to appropriately account for private and external effects or urban growth. For this purpose an empirical application based on the Contingent Valuation Method (CVM) was developed, in the terms described below. The objective of the CVM exercise was the identification of whether a decrease in density levels and the consequent further growth of the city would increase or decrease the overall welfare. If welfare were to increase, then the optimal city in the terms described above should be somehow less compact and less dense; on the contrary, if welfare were to decrease, then a more compact growth scenario would be advisable.

CVM has extensively been applied in the valuation of environmental goods, when no ordinary markets exist. CVM has also the potential of measuring the non-use component of value, which may be present when valuing undeveloped landscapes (Mitchell and Carson, 1989). The method consists on simulating a hypothetical market in order to elicit the value that individuals attribute to certain non-market goods. By appropriately surveying individuals about their willingness to pay or to willingness to accept for a certain change from the status quo situation, the variations in welfare can be obtained. In recent years closed-ended questions and other types of discrete response formats have become very popular in CVM exercises, since they are believed to better fit the behaviour of consumers in actual markets (Hanemann and Kanninen (1999); Hanemann and Kriström (1995)). The welfare measure can then be obtained through the use of a statistic discrete choice model by which the welfare measure is estimated.

The exercise simulated a change in urban densities. Lower density levels imply environmental benefits derived from better quality conditions within cities. The value of this improvement could have been estimated through other existing markets, for example by means of the hedonic price method. However, a decrease in density implies environmental costs as well, due to the loss of open landscapes around cities, and this cost is not as clearly reflected in other markets. Our purpose is then to estimate the value of a change in urban growth patterns that would change density levels as well as the rate of occupation of outer landscapes. It is assumed that households regard both higher preservation of landscapes and a reduction of density levels as improvements, but since they relate inversely, they must trade-off one for another if growth is to be accommodated.



(a) A reduction in density levels (b) An increase in density levels

Figure 1: Density levels and urban size in two alternative urban growth scenarios

Let k_0 be the current density level, and $\overline{r_0}$ the initial city size. This scenario represents the status quo situation. Two growth patterns that would change density levels and would alter the rate of occupation of open spaces around cities are used to compare the consequences of the two alternative scenarios. In the first one, density diminishes but occupation of outer landscapes takes place at a faster rate; in the second, density increases but more landscape preservation is accomplished.

3.1 An urban growth scenario with less density

Consider first the case where the alternative situation implies a growth path that would lead to a lower density level but to a relatively high city size and loss of outer landscapes. Lower density is denoted by k_1, and $\overline{r_1}$ represents the new city size. This scenario, which will be referred to as *Scenario 1*, is represented in part (a) of figure 1[1]. The figure illustrates an urban growth scenario, caused for instance by an increase in population, where density is smaller and the city size extends until $\overline{r_1}$. Shifting from k_0 to k_1 is considered to be an improvement, so individuals may be be willing to pay up to a certain sum of money in order to obtain the change. That amount would be the *compensating variation* associated to the density decrease, C_{k_1}. Assume that an individual is offered the density variation in exchange for a certain amount of money A_{k1}. Then,

$$Pr\{yes\} = Pr\{v(k_0, y, \epsilon) < v(k_1, y - A_{k1}, \varepsilon)\},$$

where v denotes the indirect utility function, which depends on individual income y, on density levels k_i and on ϵ, a random variable that embodies any other information that may be relevant but that the researcher does not observe. Other variables such as prices of private goods in the economy or socioeconomic characteristics could be likewise included, but they are omitted here for simplicity. The economic foundations underlying CVM and other discrete choice techniques is thus the *random utility maximization* theory, that incorporates the stochastic component ϵ. For a more formal treatment, see for instance Hanemann and Kanninen (1999). Expressed in terms of the compensating variation measure, which is a random variable itself, the probability that the respondent favors the change is:

$$Pr\{yes\} = Pr\{C_{k_1}(k_0, k_1, y, \epsilon) \geq A_{k1}\}.$$

Linked to the density reduction phenomenon is the relatively high increase in city size. Moving from $\overline{r_0}$ to $\overline{r_1}$, is considered to be welfare-worsening. In this theoretical section, we assume that all individuals are negatively affected by the loss of undeveloped landscapes, although some agents, such as housing developers, could certainly favor it. Individuals would only be in favor of

[1]We represent changes in density departing from a purely market situation, to simplify the analysis. In practice, both the status quo situation and the alternative scenario correspond to an intervened market.

such a change if they were compensated at least in an amount that would leave them indifferent. This would be the compensating variation measure, denoted by $E_{\overline{r_1}}$, which again would be a random variable. If households are offered to sacrifice some outer landscapes, that is to go from $\overline{r_0}$ to $\overline{r_1}$, in exchange for a compensation $A_{\overline{r_1}}$, then the probability of favoring the change is:

$$Pr\{yes\} = Pr\{\upsilon(\overline{r_0}, y, \epsilon) < \upsilon(\overline{r_1}, y + A_{\overline{r1}}, \epsilon)\},$$

or in terms of the compensating variation measure $E_{\overline{r_1}}$:

$$Pr\{yes\} = Pr\{E_{\overline{r_1}}(\overline{r_0}, \overline{r_1}, y, \epsilon) < A_{\overline{r1}}\}.$$

Combining the variations of the two environmental goods involved when urban growth takes place less densely, the probability that an individual would vote for the change would be:

$$Pr\{yes\} = Pr\{\upsilon(k_0, \overline{r_0}, y, \epsilon) < \upsilon(k_1, \overline{r_1}, y - A_{k_1} + A_{\overline{r1}}, \epsilon)\}.$$

Again, in terms of the compensating variation measures, we have:

$$Pr\{yes\} = Pr\{(C_{k_1} - E_{\overline{r_1}}) \geq (A_{k1} - A_{\overline{r1}})\}.$$

To express the previous probability in statistical terms, let C_1 be the gap $C_1 = C_{k_1} - E_{\overline{r}}$, and let denote with A_1 the difference $A_1 = A_{k1} - A_{\overline{r1}}$. Then, the previous probability can be expressed as

$$Pr\{yes\} = 1 - G_{C1}(A_1),$$

and

$$Pr\{no\} = G_{C1}(A_1),$$

where G_{C1} denotes the cumulative distribution function (cdf) of the random variable C_1. Using for example the standard logistic[2] cdf it is found:

$$Pr\{yes\} = \frac{1}{1 + e^{\alpha_1 + \beta_1 A_1}}$$

and

$$Pr\{no\} = \frac{e^{\alpha_1 + \beta_1 A_1}}{1 + e^{\alpha_1 + \beta_1 A_1}}.$$

[2]A single-bounded format is here assumed.

3.2 An urban growth scenario with more landscape preservation

Consider now a second case, referred to as *Scenario 2*, illustrated in part (b) of figure 1. The change from the status quo situation consists in moving towards a denser urban growth path. Thus, this alternative implies a higher density level k_2 but a relatively lower city size $\overline{r_2}$. With respect to the first variable, an increase in density is contemplated as a loss of welfare, and therefore it would only be accepted if compensated. An individual would only be for an increase of density if she was offered an amount of money A_{k_2} that would at least offset the loss. Thus,

$$Pr\{yes\} = Pr\{\upsilon(k_0, y, \epsilon) < \upsilon(k_2, y + A_{k2}, \epsilon)\},$$

or

$$Pr\{yes\} = Pr\{E_{k_2}(k_0, k_2, y, \epsilon) < A_{k2}\},$$

where E_{k_2} is a random variable that represents the compensating variation that would leave the individual indifferent after the increase in density.

Let us focus on the other environmental variable implied, related to city size. In a more restricted growth scenario, and although more landscapes are preserved compared to Scenario 1, the increase from $\overline{r_0}$ to $\overline{r_2}$ would lead to a decrease of individuals' utility, too. Respondents would be willing to sacrifice the amount of undeveloped landscapes $(\overline{r_2} - \overline{r_0})$ if appropriately compensated. That is,

$$Pr\{yes\} = Pr\{\upsilon(\overline{r_0}, y, \epsilon) < \upsilon(\overline{r_2}, y + A_{\overline{r2}}, \epsilon)\},$$

or

$$Pr\{yes\} = Pr\{E_{\overline{r2}}(\overline{r_0}, \overline{r_2}, y, \epsilon) < A_{\overline{r2}}\}$$

Combining the two environmental effects involved in Scenario 2 when more compact urban growth is considered, an individual would be willing to accept the change if utility was higher in the alternative situation after combining the two effects. Then,

$$Pr\{yes\} = Pr\{\upsilon(k_0, \overline{r_0}, y, \epsilon) < \upsilon(k_2, \overline{r_2}, y + A_{k_2} + A_{\overline{r_2}}, \epsilon)\},$$

or alternatively,

$$Pr\{yes\} = Pr\{(E_{\overline{r_2}} + E_{k_2}) < (A_{\overline{r2}} + A_{k2})\}.$$

Both $E_{\overline{r2}}$ and E_{k_2} and their sum, would be random variables themselves. Let E_2 denote the sum $E_2 = E_{\overline{r2}} + E_{k_2}$ and A_2 the sum $A_2 = A_{\overline{r2}} + A_{k2}$. Notice that $E_{\overline{r2}}$ and E_{k_2} refer to compensations, as E_2 does. Assuming again that the cdf would be the standard logistic, and bearing in mind that we consider negative payments, the probabilities of being in favor or against the change would respectively be:

$$Pr\{yes\} = G_{E_2}(A_2) = \frac{e^{\alpha_2+\beta_2 A_2}}{1+e^{\alpha_2+\beta_2 A_2}}$$

and

$$Pr\{no\} = 1 - G_{E_2}(A_2) = \frac{1}{1+e^{\alpha_2+\beta_2 A_2}}.$$

4 Application of the CV exercise

In this section we first provide some data on the recent urban evolution from the geographical area where the empirical exercise was applied, the Metropolitan region of Barcelona. A brief description of the sample and the questionnaire follows. Finally, some details on the estimation techniques and the results are discussed.

4.1 The Metropolitan Region of Barcelona: some data

This subsection summarizes some key data on the geographical characteristics of the area object of analysis. The results of the analysis apply to what we refer as the Metropolitan Region of Barcelona (MRB hereafter), integrated by 163 different municipalities[3]. It covers a territory of 3,235 squared kilometres (km^2) with a population of more than 4,225,000 in 1996[4]. The municipality of Barcelona itself represents a 3 per cent of this territory but more than 35 per cent of the population. Together with its first ring the area

[3]The MRB corresponds to the widest defined metropolitan context, known as *Regió Metropolitana de Barcelona*. It includes the following counties (*comarques*): Alt Penedès, Baix Llobregat, Barcelonès, Garraf, Maresme, Vallès Occidental i Vallès Oriental.

[4]The data here used has been obtained from the Institut d'Estadística de Catalunya (IEC), and from the information already collected in Otero and Serra (1998) and ERMB (1996).

covered is the 18 per cent and the percentage of population in the MRB rises to nearly 70 per cent[5].

The urban territory in the MRB has grown during last years. While overall population has stabilized, the trend is that both population and economic activity move outside the central city and locate in smaller cities around, especially in municipalities in its second ring. Land consumption and the incipient problems related to the progressive abandonment of the central city have started to become an issue for urban planners. The evolution of urbanized land in the metropolitan area is one of the variables often cited. Land occupied for urban uses has shifted from about 22,000 hectares in 1972 to more than 46,000 hectares in 1992 (*Pla Territorial Metropolità de Barcelona, PTMB*, 1997). This means that figures on land conversion from rural to urban use more than doubled in 20 years. However, data are not that impressive in relative terms. According to the same source, urbanized land represented less than 14 per cent of total land in the MRB in 1992, even though it is a highly populated geographical area. Table 1 shows information on ratios of urban to total land corresponding to year 1997.

Table 1: Population, urban land and density in the MRB

	Barcelona	MRB
Population (1996)	1,508,805	4,228,048
Squared kilometres	97'6	3,234'5
Percentage urban/total land(1997)	76'7	15'8
Density (people/km^2)	15,459	1,307
Density (people/urban km^2)	21,158	8,288

Font: Padró Municipal d'Habitants 1996 (Institut d'Estadística de Catalunya, IEC) and Otero and Serra (1998)

Municipalities in the second ring offer have become relatively more attractive for individuals and firms. They offer several advantages for households. The rate of urban to total land in the municipality of Barcelona is above 76 per cent, and it goes down to about 33 per cent for Barcelona plus its first ring. When considering the whole MRB, this rate falls to approximately 16

[5] The *first ring* roughly corresponds to the set of municipalities in the *Metropolitan Area of Barcelona* (MAB), delimited here by the 30 cities belonging to the Environmental Entity (*Entitat del Medi Ambient* or *EMA*). When we refer to this first ring alone, Barcelona city is excluded.

per cent. Availability of land for residential and other purposes is becoming rather scarce in Barcelona city, and people often find cheaper and larger housing away from the city. Most new housing is currently being built in the first and second rings. Another distinct feature comes from differentials in population densities, shown in table 1. In Barcelona, density goes up to 15,459 inhabitants per km^2. To compare this figure to other world cities, consider for instance the 9,151 people/km^2 in New York or almost 6,000 people/km^2 in San Francisco, as reported by the US Census Bureau for the year 1990. We find it useful, however, to calculate *effective densities*, comparing population to urban land only, especially since urban to total land rates greatly vary throughout the MRB. In doing so, Barcelona shows a density of above 21,000 people/urban km^2, while the average for the MRB is above 8,000 people urban km^2. With the continuing of decentralization of population towards less crowded areas, densities among the MRB have started to homogenize little by little, although great differences still exist.

4.2 The sample and description of the questionnaire

The sample was randomly chosen from the population of six municipalities of the MRB, representative of the different urban sizes in the area. In 1998, personal interviews were conducted on 600 individuals who were surveyed about some aspects of the environmental consequences of urban growth. The average length of interviews was reported to be around 25 minutes.

First, basic information on the environmental consequences of urban growth was given to respondents so that they would become familiar with the valuation scenario. The existing trade-off between restricting growth and enjoying smaller density levels was emphasized. The questionnaire included some points dedicated to obtain the respondents' opinion on some related aspects of their cities, including the availability of open spaces, the livelihood of central cities and other factors affecting their location choices. The first questions related to their perception of the characteristics of urban growth in the MRB. When asked about the environmental quality of new residential areas, 63 per cent of respondents thought that they comparatively provided more green open spaces, 19 per cent that the environmental quality was about the same, and an 18 per cent found they had less public areas than older neighborhoods.

Next, the environmental effects of urban growth were highlighted, basically with reference to the loss of landscapes and the relative abandonment of central cities, and the changes in density levels. About 58 per cent of the respondents declared never having considered those referred environmental consequences of urban growth before, while the remaining 42 per cent asserted to be aware of them before being told. People were then asked about possible abandonment problems in central cities. While almost 80 per cent considered that relocations went to more suburban areas, a more reduced 22 per cent thought this phenomenon was causing abandonment problems in central areas.

Once informed about the main environmental implications of extending and compacting cities, and preceding the elicitation questions, individuals were given the chance of choosing the future urban scenario path better suiting their preferences. The status quo situation corresponded to the situation at the time of the interviews, characterized in terms of the density level and city size. It was assumed that more compact growth allows for a relatively greater preservation of open spaces around cities, but that it negatively affects environmental quality inside urban areas, the latter understood in terms of increased density or reduced availability of public spaces per capita. Alternatively, less intensive urban development would allow to enjoy lower densities, but it would mean a faster loss of outer landscapes as well. An screening question was used by means of which individuals could express what worried them the most: the possibility of having to live with higher densities; having to sacrifice more landscapes; or they felt equally concerned about the two effects. The results for this question show that roughly half the sample declared to be more worried about increased densities, 25 per cent felt that losing outer landscapes was more important and the remaining 25 per cent was equally worried about the two events.

After the basic trade-off had been presented, the elicitation questions were introduced. Two different formats were used. A contingent ranking format was used for about the 40 per cent of the sample, while for the remaining 60 per cent a double-bounded referendum question was used.

4.3 Estimation and results

4.3.1 Contingent ranking format

The contingent ranking constitutes a particular case of conjoint analysis methods in which prices –bids– and quantities –deviations from the status quo– are allowed to vary. Thus, the varying scenarios implying changes in density and the urban size were summarized in changes in green areas per person, from the status quo level to an scenario under which overall density would be either higher or lower. For those willing to live more densely, they were offered to lose a percentage of green areas per person –then losing less outer landscapes– and to benefit from a certain reduction in the annual payment of local taxes. Similarly, with those in favor of less dense urban growth, they were offered an increased amount of green areas per person in return of an extra yearly payment justified in order to finance new infrastructure and urbanization.

Respondents faced five alternatives, $J = 5$, that combined different changes in green areas per person and price (see table 2). Type 1 scenarios refer to urban growth patterns implying density reductions, following the notation used in section 3. Likewise, type 2 scenarios depict changes towards more dense urban paths; and finally, alternative 0 denotes the status quo situation, which was included. The bids used had previously been chosen when validating the questionnaire with a pre-test, and are comparable to those used for the double-bounded referendum format shown in the next subsection.

Table 2: Alternatives in the contingent ranking exercise

Alternatives	*Percentage of variation in green areas per capita*	*Associated payment*[a]
1a	+10%	10000
1b	+ 5%	5000
0	0%	0
2b	-5%	-5000
2a	-10%	-10000

[a]In 1998 pesetas

The responses of respondents to ranking formats consist in providing an ordering of the alternatives from most to least preferred. Different rankings respond to differences in the utilities associated to the alteranatives. Thus, utility is supposed to depend upon the attributes that vary with the alternatives, that is, the percentage of change in green areas per person, ZV_j, the bid, A_j, and other non-observed factors. Then,

$$\upsilon_j = \alpha ZV_j + \beta A_j + \epsilon_j, \tag{4.1}$$

where ZV_j captures both changes in density and in the city size. With 5 different alternatives, there are $M = 5! = 120$ possible orderings. Let

$m_{ij} = 1, \ldots, M$ denote each of the possible orderings that individual i can choose. As an example, and following the order in the table above, consider that $m_{ij} = 1$ corresponds to a ranking such that alternative 1a is ranked first by the i respondent, alternative 1b is ranked second, etcetera. Then, the probability that this particular ranking is chosen would be

$$Pr\{m_{ij} = 1\} = Pr\{\upsilon_{1a}(k_{1a}, \overline{r}_{1a}, y - A_{1a}, \epsilon_{1a}) \geq \upsilon_{1b}(k_{1b}, \overline{r}_{1b}, y - A_{1b}, \epsilon_{1b}) \geq \ldots \geq \upsilon_{2a}(k_{2a}, \overline{r}_{2a}, y - A_{2a}, \epsilon_{2a})\}.$$

The ranking output can also be interpreted as a sequence of choices from the available alternatives. Then, if the choices verify the independence of irrelevant alternatives property (IIA), the probability in the example above can be expressed as the product of the successive conditional probabilities, that is

$$\begin{aligned} &Pr\{m_{ij} = 1\} \\ &= Pr\{1a|1a, 1b, 0, 2b, 2a\}Pr\{1b|1b, 0, 2b, 2a\}Pr\{0|0, 2b, 2a\}Pr\{2b|2b, 2a\}, \end{aligned}$$

where $Pr\{1a|1a, 1b, 0, 2b, 2a\}$ is the probability of choosing $1a$ among the set of alternatives $\{1a, 1b, 0, 2b, 2a\}$; $Pr\{1b|1b, 0, 2b, 2a\}$ is the probability of choosing $1b$ when the set of alternatives is constituted by the remaining $\{1b, 0, 2b, 2a\}$; and so on. Let $y_i = j$ denote the event by which alternative j is chosen. Then, assuming that the cdf is a standard logistic, the probability of any of the single choices[6] that intervene in the product above is[7]

$$Pr\{y_i = j\} = \frac{e^{\upsilon_j(k_j, \overline{r}_j, y - A_j)}}{\sum_{1a}^{J} e^{\upsilon_j(k_j, \overline{r}_j, y - A_j)}}$$

Thus, the probability of a specific ranking can be expressed as

$$\Pr\{m_{ij}\} = \prod_{j=1a}^{J-1} \frac{e^{\upsilon_j(k_j, \overline{r}_j, y - A_j)}}{\sum_{l=j}^{J} e^{\upsilon_l}(k_l, \overline{r}_l, y - A_l)}.$$

[6]See for instance Greene (1998)

[7]Notice that in correspondence to the analysis in section 3

$$A_j \begin{cases} > 0 & \text{if } j = 1a, 1b \\ = 0 & \text{if } j = 0 \\ < 0 & \text{if } j = 2b, 2a \end{cases}$$

For every possible ranking outcome the associated probability could be calculated, and the associated log-likelihood function could be expressed as

$$lnL = \sum_{i=1}^{N} \sum_{j=1a}^{J} m_{ij} Prob\{m_{ij}\}. \tag{4.2}$$

The maximization of the function above would provide an estimation of the parameters α and β in expression 4.1. Software packages such as Limdep permit an easier estimation of the parameters that saves having to work with the log-likelihood function in 4.2.

The ranking format in the elicitation question was offered to the 43 per cent of the sample. The choice ranked first corresponded in about a 54 per cent of the cases to the status quo scenario, followed by the options implying smaller density levels. The estimated median value of the WTP for a 1 per cent decrease in density levels resulted in about $5 per person and year (808 pesetas), although the estimated parameters did not result statistically significant. Assuming linearity, a 10 per cent density decrease would be valued in 8080 pesetas per person and year (see table 4 below).

The fact that parameters did not result statistically significant makes it difficult to rely on any of the figures above, although some of the qualitative information obtained from respondents will be useful in corroborating the results that are presented in the subsection that follows.

4.3.2 Double-bounded format

When the double-bounded format is applied, the responses to the screening question conditioned the specific elicitation question that followed. The estimation model chosen in this instance followed the spike model, first applied to the valuation of environmental goods by Kriström (1997). With respect to the single-bounded, the double-bounded version has the advantage of providing more information to the researcher, and it generally yields more accurate –and more conservative– estimators of welfare measures. We did not obtain protest answers or surprise reactions to the second question, one of the risks sometimes encountered with the use of this format.

A double-bounded closed-ended CVM question was presented to the remaining 57 per cent of the sample. This second subsample was divided again. Depending on the responses obtained from the screening question, each respondent was *assigned* her presumably desired urban growth model. Those more worried about losing outer landscapes were assumed to be in favor of more compact development, while those more worried for increased density levels inside cities were assumed to agree with less dense development. There still exists a third category, those equally worried about the two phenomena. For this latter group it has been assumed that current growth patterns are preferred, thus maintaining density levels and the rate of conversion of landscapes. [8] In the questionnaire, those in favor of less dense development were offered a 10 per cent reduction in density levels in exchange for an extra payment, while those in favor of more compact growth were offered an scenario where density would be increased, the city would grow more slowly and they would be compensated with a tax reduction.

Again, for those who declare themselves equally affected by density variations and changes in the loss of landscapes, we interpret that their willingness to pay is zero for any changes in density implying accelerated or slower occupation of undeveloped landscapes. Since this is the case for a significant proportion of the sample, it was considered that the spike model was satisfactory in the sense that it allows for the consideration of a spike at a certain value, zero in this case.

In particular, it was used the extended version of the spike model introduced in Kriström (1995). This extended version permits the consideration of negative preferences in the valuation of a certain environmental good, thus incorporating the possibility that the provision of a certain good –or a combination of goods– can be perceived as undesirable by a number of respondents. In this case, if the good were to be provided, those individuals would feel they should be compensated for the associated decrease in their welfare levels.

The model used here incorporates two main differences with respect to the features in Kriström (1995). First of all, and since there is information available both for those with positive and negative preferences, symmetry with respect to the zero value is not assumed. An additional slight distinction comes from the use of the double-bounded format, fact that modifies the specification of the log-likelihood function.

The environmental change being valued consists in a variation in the

[8] Concerning this distribution of respondents, it can be argued that, in fact, respondents had not been given all the information before choosing their most preferred urban growth model. In particular, in the screening question they were not explicitly questioned about their willingness to pay or to accept. Notice that this problem does not apply with the ranking format, where payments and compensations were explicit.

urban growth scenario towards a less dense path, described in general terms in subsection 3.1 above. For our purpose, the good to be provided consists in a urban growth path implying a 10 per cent decrease in density and a 10 per cent more rapid occupation of landscapes. This is a particular case of Scenario 1, and so we make use of the same notation utilized there. Those in favor of greater outer growth would show positive preferences towards the change. This implies that $C_{k_1} > E_{\overline{r_1}}$, or similarly, that $C_1 > 0$. If we think in terms of the individual bid-rent curves, the meaning of this assumption is that when accounting for the two environmental changes, in net terms the individual would be willing to pay a certain positive amount in order to live in what she regards as a better environment.

Let us focus now in those in favor of a greater containment. For them, an urban growth path that takes place a 10 per cent less densely implies two things. First, the reduction of density levels, which constitutes a benefit, and thus $C_{k_1} > 0$. Second, the welfare decrease associated to the growth of the city up to $\overline{r_1}$, which requires a compensation, and so $E_{\overline{r_1}} < 0$. For this type of respondents who feel more concerned about the loss of landscapes it is assumed that $E_{\overline{r_1}} > C_{k_1}$ and as a result $C_1 < 0$. Thus, they would show negative preferences towards a change implying less dense urban growth. In terms of the bid-rent curves, the *worsening* of the environmental conditions would make them willing to pay smaller land rents at every possible location. Thus, from the responses of those people more concerned about the loss of landscapes we obtain the necessary information about respondents with negative preferences towards more rapid urban growth.

Since we found it more natural to offer a compensation when growth takes place more densely, pro-containment respondents were in fact asked about a change towards a more compact urban development, such as that considered in Scenario 2, and answered accordingly. Afterwards, we use their responses to value the cost of moving towards an less dense context, what requires an assumption. On the one hand, we could be over-estimating the intensity of the negative preferences, because actual responses incorporated a cost component associated to the increase in density, while Scenario 1 involves a density reduction. On the other hand, we could be underestimating the cost component associated to the variation from $\overline{r_0}$ to $\overline{r_1}$, which represents a larger loss of outer landscapes than the one considered actual contemplated in the elicitation question. For simplicity, we assume that these two opposite deviations counterbalance themselves, and so we use the information as if we had directly offered them a less dense scenario.

Finally, those indifferent would simply be *out of the market*, and would be willing to pay zero for the change in the rate of urban growth. The distribution of the willingness to pay in the extended spike model can then be expressed as:

$$
\begin{aligned}
G_{C_1}(A_1) &= H_{C_1}(A) \text{ if } A \leq 0 \\
&= p^- \text{ if } A \to 0^- \\
&= p^+ \text{ if } A \to 0^+ \\
&= F_{C_1}(A) \text{ if } A \geq 0.
\end{aligned}
$$

Basically, H_{C_1} describes those with a negative WTP while F_{C_1} describes those with a positive WTP. p^+ and p^- represent the estimated probabilities that a respondent would reject a positive change at a zero price or would accept a negative one at a zero compensation, respectively. Both distributions will be estimated from the available data. The estimated proportion of zeroes is given by the difference $(p^+ - p^-)$. The two underlying distributions of willingness to pay for the change can be estimated by maximum likelihood methods.

The following is the expression for the log-likelihood function for the extended spike when using the double-bounded format, and allowing for asymmetry with respect to the spike at zero:

$$
\begin{aligned}
\ell = \sum_{i}^{N} & p_i(1 - z_i) yy_i log[1 - F_{C_1}(A_u)] \\
&+ p_i(1 - z_i) nn_i log[F_{C_1}(A_d) - F_{C_1}(0)] \\
&+ p_i(1 - z_i) yn_i log[F_{C_1}(A_u) - F_{C_1}(A)] \\
&+ p_i(1 - z_i) ny_i log[F_{C_1}(A) - F_{C_1}(A_d)] \\
&+ (1 - p_i)(1 - z_i) log[F_{C_1}(0^+) - H_{C_1}(0^-)] \\
&+ (1 - p_i) z_i yy_i log[H_{C_1}(0^-) - H_{C_1}(A_d)] \\
&+ (1 - p_i) z_i nn_i log[H_{C_1}(A_u)] \\
&+ (1 - p_i) z_i yn_i log[H_{C_1}(A_d) - H_{C_1}(A)] \\
&+ (1 - p_i) z_i ny_i log[H_{C_1}(A) - H_{C_1}(A_u)].
\end{aligned}
$$

where p_i is a dummy variable that equals 1 if the respondent has positive preferences, and 0 otherwise; z_i takes the value of 1 when the respondent has negative preferences, and 0 otherwise. Variables yy_i, nn_i, yn_i and ny_i are dummy variables used to capture the combination of the yes/no responses arising from the double-bounded format elicitation question. For instance, yn_i would equal 1 if the answer was "yes" to the first question and "no" to the second, and it would equal 0 in any other case. Likewise, nn_i takes value 1 if the answer is "no" to both the first and second elicitation questions, and 0 otherwise; and so on. As for the bids, A refers to the initial bid, $A_d < A$ would follow a "no" answer, and $A_u > A$ would follow a "yes" answer.

Each observation was given a certain weight to appropriately take into account the proportion of individuals in favor of outer growth, more dense growth or the status quo situation. Assuming the standard logistic function for the distributions of H_{C_1} and F_{C_1} in equation 4.3, the coefficients for the two distributions were estimated, only including the bid as explanatory variable of the yes/no answers. The calculus were made for the single-bounded format, too[9]. The results appear in table 3.

Table 3: Valuation results for a 10 per cent density decrease, using the Weighted Extended Spike Model.

	α_1[a b]	β_1	γ_1	δ_1	p^+	p^-	Median	Mean
Single-bounded	-0.66 (-5.56)	3.83 (10.58)	-1.40 (-9.94)	1.68 (4.18)	0.34	0.19	1718	1493
Double-bounded	-0.51 (-4.22)	3.88 (16.30)	-1.28 (-9.00)	1.34 (5.50)	0.37	0.21	1309	692

[a]t-statistics in brackets

[b]Values in 1998 pesetas

The welfare measures were calculated. The value of the WTP for a 10 per cent increase in available open areas and an associated greater occupation of

[9]In this instance, the log-likelihood function is as follows:

$$\ell = \sum_{i}^{N} p_i(1-z_i)y_i log[1 - F_{C_1}(A)] + p_i(1-z_i)(1-y_i) log[F_{C_1}(A) - F_{C_1}(0)]$$

$$+(1-p_i)(1-z_i) log[F_{C_1}(0) - H_{C_1}(0)] + (1-p_i)z_i y_i log[H_{C_1}(0) - H_{C_1}(A)]$$

$$+(1-p_i)z_i(1-y_i) log[H_{C_1}(A)]$$

landscapes around cities resulted in a median value of 1,718 pesetas for the single-bounded format and a more conservative of 1,309 pesetas per person and year, for the double-bounded. Mean measures, however, differed more from the single to the double-bounded format. Figure 4.3.2 plots the estimated WTP distributions for the double-bounded format. The median value is highlighted, as well as the shaded areas needed to calculate the mean.

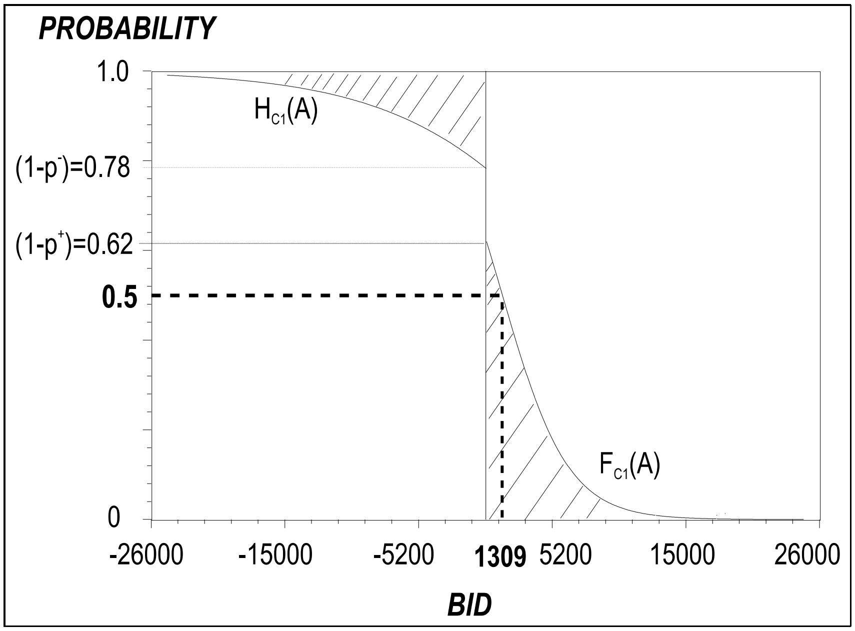


Figure 2: Estimation of the WTP distribution for the Weighted Extended Spike Model –double-bounded–.

The results suggest that an scenario in which growth would lead to a 10 per cent lower density at the expense of outer landscapes would increase an individual's representative welfare in 692 pesetas per year, in aggregate terms and using the most conservative –low– value (see table 4). Based on the assumption that the utility function is linear, it can be inferred that this is the amount by which individual welfare would decrease under an alternative scenario leading to a 10 per cent density increase and to a slower conversion of outer landscapes, that is the one considered Scenario 2. The interpretation of the results in terms of the bid-rent model can be better shown graphically. Part (a) in figure 3 illustrates how, for the representative household, a decrease in density levels increases the maximum rent for land the individual

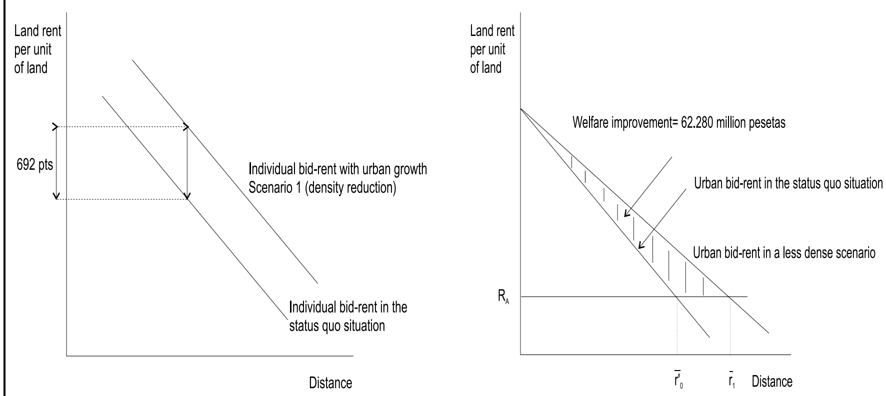
Table 4: Valuation results for a 10 per cent density decrease –Contingent Ranking and Double-bounded formats–.

CV elicitation format	Aggregate WTP for a 10% density reduction[a]	Welfare increase [bc]
Ranking	8080	727.000
Double-bounded format	692	62.280

[a]Median values, in 1998 pesetas
[b]In million pesetas
[c]Population=3.6 million people; discount rate=4 per cent

would be willing to pay at any location. The parallel shift in the individual bid-rent assumes that the environmental benefit would equally affect all locations in the city. This implies that the average individual feels indifferent between enjoying a *better* environment –characterized by a less dense urban residential area and some less landscapes– while satisfying a higher payment for land, and living in a *worse* environment and paying less per unit of land. This value is also the meaning of the *aggregate* WTP measure obtained from the CVM exercise. If all individuals in the city could be represented with the net mean WTP estimator obtained, then land rents in the city would be higher at each possible distance. A more realistic assumption would be that some individuals lose and some win with the change, and as a result land rents would be smaller in certain locations and higher in others. However, the net effect can be calculated in 62,280 million pesetas, using the representative mean value and a population of 3,6 million people over 18 years old for the MRB. This figure represents the net increase in overall welfare associated to the 10 per cent reduction in density and the increase of the city boundary. This result is represented in part (b) in figure 3.

The two different CV formats employed, the ranking and the double-bounded, resulted in positive willingness to pay for decreases in density levels implying more rapid urban growth and the loss of more open landscapes in the geographical area of reference. This result suggests that at that moment, population considered outward urban growth to be welfare-improving. The contingent ranking resulted in a significantly higher value estimate of the mean WTP than the double-bounded format, though. Despite the fact that the upper bounds of the bids utilized were comparable, the variability in the bids used was much lower in the ranking format.



(a) Shift in individual bid-rent after a 10 per cent density reduction

(b) Shift in urban land rent after a 10 per cent density reduction

Figure 3: Value of a density reduction in the bid-rent framework

5 Conclusions

In this paper it has been provided an alternative approach to deal with the urban sustainability issue. The environmental costs of urban sprawl have been summarized in terms of the loss of landscapes derived from extending cities. Thus, it is assumed that growing with more dispersion implies more environmental costs. However, less dense development also allows for the achievement of better environmental conditions inside cities, in the form of less density or more green open spaces per capita. The important point is that there exists a trade-off between these two variables that can be associated to urban growth.

In a particular analysis that applies to the Metropolitan Region of Barcelona, we find that in net terms, the population perceives as welfare-improving a change implying less density and more green areas per person, even if this is achievable at the expense of losing more undeveloped landscapes around their cities. Both the results from the contingent ranking and the double-bounded exercises lead to this conclusion. This is shown by the fact that the mean individual would be willing to pay a positive amount of money in order to achieve a less dense environment, even using the most conservative of the outcomes. This suggests that urban restrictions on urban development, frequently vindicated for environmental reasons, should be somehow relaxed in this area. Actual growth restrictions in this area would be over-correcting the environmental externalities caused by outward urban growth, here represented by the loss of open landscapes. For the geographical context where the analysis took place, less dense growth trends are recommended in order to attain lower density levels. As a result, we argue that the convenience of compact urban forms should constitute a local recommendation rather than a universal proposal independent of the urbanization characteristics.

However, it is true that a significant proportion of the population has shown concern for the costs that urban growth imposes in terms of the loss of open spaces around cities, and this proportion will probably increase as environmental quality conditions inside cities improve and as landscapes disappearance becomes a more serious problem. In this sense, the CVM format is probably superior to the ranking format, because it provides more information about the preferences of different groups of population.

Although the analysis shown throughout the paper is based on some simplifying assumptions, we think it helps in the understanding of the different costs of urban development. There are several possibilities for further research. First, our results could be tested against market-based techniques, that in principle could be used to account for the density component. This could be useful in assuring that the estimated welfare measures correctly incorporate changes not only in density but also in outer landscapes. A different line would consist on designing the exercise in a way that it was possible to translate the obtained welfare measures into physical figures representing optimal urban growth. That is, although we have shown that growing outwards is socially desirable, we failed to provide a figure on *how much* growth would be needed. We think this estimation is empirically plausible in the context of the approach here utilized.

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