Chapter 4

Optimal Urban Growth with Environmental Effects: A Contingent Valuation Exercise

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 generations. One of the main criticisms 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 US 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 on Urban Environment* (EEC, 1990) also defended compact urban structures, and its conclusions were questioned by several authors [(Breheny, 1992a); (Owens, 1992); (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. Dieleman, Dijst and Burghouwt (2002) focus on the importance of socio-demographic aspects in explaining travel choices. Gordon and Richardson (1997), Ewing (1997) and Breheny (1997) are other examples of the state of the terms of 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 [(Breffle, Morey and Lodder, 1998); (López, Shah and Attolbello, 1994)]. 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 socially preferred 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 chapter 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. Let $\Phi(r)$ represent 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

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

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 a certain city are as follows:

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

where $s(r, u) = \overline{s}$ is the individual demand for land, and r_i represents the city boundary corresponding to scenario i. 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:

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

That is, if we consider $\overline{s_1} < \overline{s_2}$, then $\frac{1}{s_1} > \frac{1}{s_2}$, and for a given population it must be the case that $r_1 < r_2$. 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

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

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 at least partially 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 above, by fixing lot sizes two key environmental variables are being affected: density levels and consumption of open spaces around cities. To assess the effects on welfare of alternative urban growth scenarios in practice, an exercise based on stated preferences has been undertaken in the Metropolitan Region of Barcelona (MRB, hereafter), Spain. To our knowledge, this approach constitutes a novelty in this context. As it will be seen later, it permits to establish whether outer urban growth is or is not socially preferred when accounting for externalities.

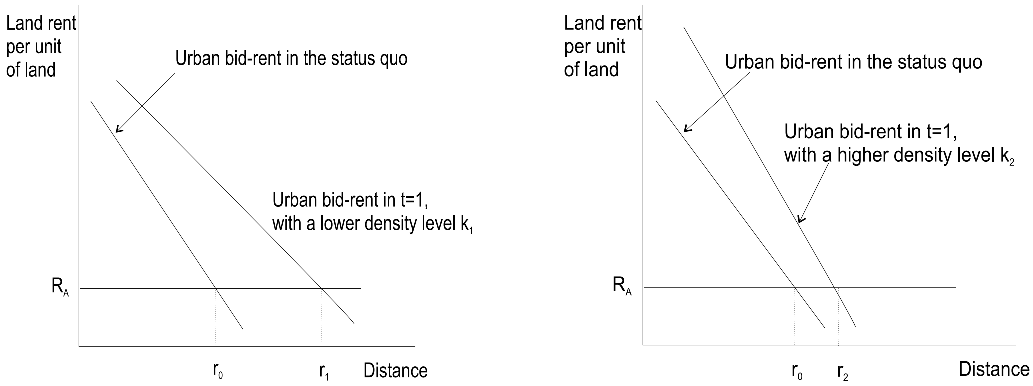
3. The CVM and optimal urban growth

The approach taken in this chapter 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 accept for a certain change, 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. 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.

Let k_0 be the current density level, and r_0 the initial city size. This scenario



(a) Scenario 1: A reduction in density levels

(b) Scenario 2: An increase in density levels

Figure 4.1. Density levels and urban size in two alternative urban growth scenarios

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 r_1 represents the new city size. This scenario, which will be referred to as *Scenario 1*, is represented in part (a) of figure 4.1[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 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

[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.

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 formal treatment, see 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 r_0 to 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 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_{r_1}, which again would be a random variable. If households are offered to sacrifice some outer landscapes, that is to go from r_0 to r_1, in exchange for a compensation amount A_{r_1}, then the probability of favoring the change is:

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

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

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

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:

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

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

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

To express the previous probability in statistical terms, let C_1 be the gap $C_1 = C_{k_1} - E_{r_1}$, and let denote with A_1 the difference $A_1 = A_{k1} - A_{r_1}$. 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 4.1. 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 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,

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

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 r_0 to r_2 would lead to a decrease of individuals' utility, too. Respondents would be willing to sacrifice the amount of undeveloped landscapes $(r_2 - r_0)$ if appropriately compensated. That is,

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

or

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

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,

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

or alternatively,

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

Both E_{r_2} and E_{k_2} and their sum, would be random variables themselves. Let E_2 denote the sum $E_2 = E_{r_2} + E_{k_2}$ and A_2 the sum $A_2 = A_{r_2} + A_{k2}$. Notice that E_{r_2} 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 of the geographical area where the empirical exercise was applied, the Metropolitan region of Barcelona. A brief description of the sample and the questionnaire follows, wth special attention devoted to the elicitation questions and how they relate to the theoretical framework presented in section 3. Finally, a brief description of the estimation techniques as well as the main 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 the MRB, integrated by

163 different municipalities[3]. It covers a territory of 3,235 squared kilometres (km^2) with a population of more than 4 million 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 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 the last years. While the 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 of the 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 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 converted from rural to urban use more than doubled in 20 years. In relative terms, this implies a ratio of urban to total land around a 15 per cent. Table 4.1 shows information on these ratios and other information corresponding to year 1997.

Municipalities in the second ring 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. When considering the whole MRB, this rate falls to approximately 16 per cent. Thus, availability of land for residential and other purposes is becoming rather scarce in Barcelona city, and people

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[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).

[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.