Table 4.1. 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)

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 4.1. 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 converge 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 (see the questionnaires at the beginning of appendix B). 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. In the following question, people were 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. They were told 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 whether 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 [6].

After the basic trade-off had been presented, the elicitation questions were introduced. Two different formats were applied. 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 asked.

4.3 Estimation and results

Contingent ranking format The contingent ranking was introduced by Beggs, Cardell and Hausman (1981) and first applied to the valuation of environmental goods by Rae (1983). (Rowe and Chestnut, 1983) It constitutes a particular case of conjoint analysis or stated preference methods in which prices –bids– and quantities –deviations from a baseline– 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 a scenario under which overall density would be either higher or lower.

Respondents faced five alternatives, $J = 5$, that combined different changes in green areas per person and price (see table 4.2). Alternatives 1a and 1b refer to urban growth paths implying two different levels of density reductions. Likewise, type 2 alternatives

[6] More complete descriptive statistics relating the questions preceding the elicitation questions can be found in appendix B.

depict changes towards more dense urban paths. 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 4.2. Alternatives in the contingent ranking exercise

Alternatives	*Percentage of variation in green areas per capita*	*Associated payment*
1a	+10%	60
1b	+ 5%	30
0	0%	0
2b	-5%	-30
2a	-10%	-60

In euros, transformed from 1998 pesetas

In the questionnaire, the alternatives implying density reductions involved an extra annual payment –positive bid. The justification in the questionnaire is that growing outwards is more expensive because it requires new urbanization and infrastructure, and an increase in taxes would be needed to finance it. This positive sign of the bid is consistent with the assumptions made in subsection 3.1 when generally describing Scenario 1. Those in favor of greater outer growth would show positive preferences towards a change implying less density. This is equivalent to saying that $C_{k_1} > E_{r_1}$, or similarly, that $C_1 > 0$.

As for the alternatives implying density increases, they were linked to an annual reduction of taxes –negative bids. Similarly, the justification used was that more dense development allows for a reduction of the taxes per person needed to finance new urbanization and infrastructure. The negative sign of the bid would equally be in accordance to the assumptions made in subsection 3.2.

The responses 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 alternatives. 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,

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

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 $m_{ij} = 1, \dots, M$ 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

$$\begin{aligned} Pr\{m_{ij} = 1\} = Pr\{&v_{1a}(k_{1a}, r_{1a}, y - A_{1a}, \epsilon_{1a}) \geq v_{1b}(k_{1b}, r_{1b}, y - A_{1b}, \epsilon_{1b}) \geq \dots \\ &\geq v_{2a}(k_{2a}, r_{2a}, y - A_{2a}, \epsilon_{2a})\}. \end{aligned}$$

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

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

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. Assuming that the cdf is a standard logistic, and following for instance Greene (1998), the probability of any of the single choices that intervene in the product above is [7]

$$Pr\{y_i = j\} = \frac{e^{v_j(k_j,r_j,y-A_j)}}{\sum_{1a}^{J} e^{v_j(k_j,r_j,y-A_j)}}$$

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

$$\Pr\{m_{ij}\} = \prod_{j=1a}^{J-1} \frac{e^{v_j(k_j,r_j,y-A_j)}}{\sum_{l=j}^{J} e^{v_l}(k_l, r_l, y - A_l)}.$$

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

$$lnL = \sum_{i=1}^{N} \sum_{j=1a}^{J} d_{m_{ij}} Pr\{m_{ij}\}, \tag{4.2}$$

where $d_{m_{ij}}$ represents a dummy variable that takes value 1 whenever ranking ordering m_{ij} has been chosen, and zero otherwise. The maximization of the function above provides an estimation of the parameters α and β in expression 4.1. Software packages such as Limdep permit a relatively easy estimation of these parameters.

Results with the Contingent Ranking 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 mean value of the WTP for a 1 per cent decrease in density levels resulted in about 4,8 euros per person and year. Assuming linearity, a 10 per cent density decrease would be valued in 48,6 euros per person and year (see table 4.3 below[8]). The estimated parameters did not result statistically significant, though. This fact makes it difficult to obtain any conclusive results. However, some of the qualitative information obtained from respondents facing the ranking format will be useful in corroborating the results that are presented in the subsection that follows.

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

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

[8]The output of the estimation procedure appears in section 3 in appendix B

Table 4.3. Valuation results for the Contingent Ranking Format

	Parameter estimates
Bid coefficient	$-.705 \times 10^{-4}$ (-1.06)
Quantity coefficient	0.569×10^{-1} (1.501)
Mean	4,8

Number of observations=252; t-statistics in brackets
Mean value in euros, transformed from 1998 pesetas

Double-bounded format Under the double-bounded format, respondents are asked two consecutives closed-ended questions. With respect to the fist bid, a higher value follows a yes answer to the first question, while a lower bid follows a no answer to the first question. In this way, a bound for the WTP of each respondents is obtained. 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.

When the double-bounded format is applied, the responses to the screening question conditioned the specific elicitation question that followed. Depending on their answers, each respondent was assigned her presumably desired urban growth model, which was more compact development for those more worried about losing outer landscapes, and less dense development for those especially concerned for increased population densities. Those who declared equally worried about the two aspects or urban growth were assumed to be indifferent between the two alternative urban growth models[9]. In the questionnaire, and as it happened with the ranking format, the variation of green areas per person offered was expressed in percentual terms. In particular, variations of a 10 per cent were considered. Pro-outer growth were offered a reduction in density levels

[9]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 payment and compensation amounts were explicit.

in exchange for an extra payment –Scenario 1. Those considered to be in favor of more compact growth were offered an scenario where density would be increased by a 10 per cent, and they would be compensated with a tax reduction, as justified above. For those indifferent, we interpret that their willingness to pay is zero for any changes in density and how undeveloped landscapes are occupied.

To integrate the responses of all those who are in favor, against or indifferent towards outer urban growth, consider that the change being valued consists in moving to a 10 per cent less dense [10]. Let us focus now in those respondents we have considered to be 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 would constitute a benefit, and thus $C_{k_1} > 0$. Second, the welfare decrease associated to the growth of the city up to r_1, which requires a compensation, and so $E_{r_1} < 0$. For this type of respondents who feel more concerned about the loss of landscapes it is assumed that $E_{r_1} > C_{k_1}$ and as a result $C_1 < 0$. Thus, they would show negative preferences towards a change implying less dense urban growth.

However, pro-containment respondents were in the questionnaire asked for a change towards a more compact urban development, and answered accordingly. When using their responses to value the cost of moving towards a less dense context, 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 the change valued involves a density reduction. On the other hand, we could be underestimating the cost component associated to the variation from r_0 to r_1, which represents a larger loss of outer landscapes than the one actually contemplated in the elicitation question. For the sake of aggregation, it is here assumed that these two opposite deviations counterbalance themselves, and so the information is used as if they had directly been

[10] We could likewise focus on the 10 per cent more dense scenario, and the assumptions and results should be the inverse with respect to the ones presented here.

offered a less dense scenario.

The estimation model chosen in this instance followed the spike model, first applied to the valuation of environmental goods by Kriström (1997). Since a significant proportion of the sample declared indifferent, it was considered that this type of model is 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, it allows for the possibility that the provision of a certain good can be perceived as undesirable by a number of respondents. If still, 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 distinction comes from the use of the double-bounded format, fact that modifies the specification of the log-likelihood function.

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. Probabilities 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. The estimated proportion of zeroes is given by the difference $(p^+ - p^-)$. The two underlying distributions of willingness to pay for the change as well the p^+ and p^- values will be estimated from the available data by means of maximum likelihood methods.

The following is the expression of 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:

$$
\begin{aligned}
\ell = \sum_{i}^{N} & p_i(1 - z_i)yy_i log\left[1 - F_{C_1}(A_u)\right] \\
& + p_i(1 - z_i)nn_i log\left[F_{C_1}(A_d) - F_{C_1}(0)\right] \\
& + p_i(1 - z_i)yn_i log\left[F_{C_1}(A_u) - F_{C_1}(A)\right] \\
& + p_i(1 - z_i)ny_i log\left[F_{C_1}(A) - F_{C_1}(A_d)\right] \\
& + (1 - p_i)(1 - z_i) log\left[F_{C_1}(0^+) - H_{C_1}(0^-)\right] \\
& + (1 - p_i)z_i yy_i log\left[H_{C_1}(0^-) - H_{C_1}(A_d)\right] \\
& + (1 - p_i)z_i nn_i log\left[H_{C_1}(A_u)\right] \\
& + (1 - p_i)z_i yn_i log\left[H_{C_1}(A_d) - H_{C_1}(A)\right] \\
& + (1 - p_i)z_i ny_i log\left[H_{C_1}(A) - H_{C_1}(A_u)\right].
\end{aligned}
\tag{4.3}
$$

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 to the first question is "yes" 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.

Results with the Spike Model 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[11]. The results appear in table 4.4.

Table 4.4. Valuation results for a 10 per cent density decrease, using the Weighted Extended Spike Model.

	α_1	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	10.3	9
Double-bounded	-0.51 (-4.22)	3.88 (16.30)	-1.28 (-9.00)	1.34 (5.50)	0.37	0.21	7.9	4.2

t-statistics in brackets; Number of observations=337
Mean and median values in euros, transformed from 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 landscapes around cities resulted in a median value of 10.3 euros for the single-bounded format and a more conservative of 7.9 euros per person and year, for the double-bounded. Mean measures, however, differed more from the single to the double-bounded format. Figure 4.3 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.

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

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

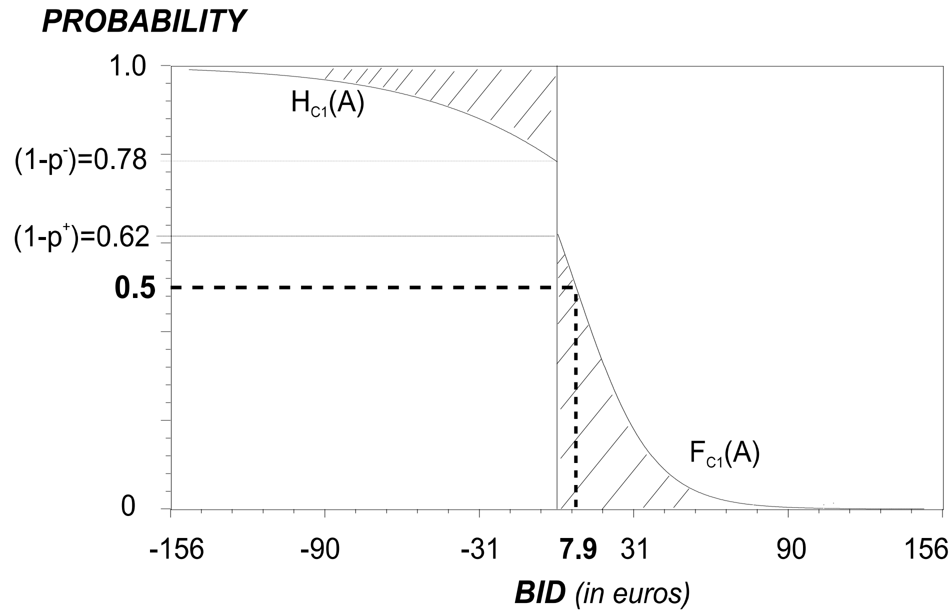


Figure 4.2. Estimation of the WTP distribution for the Weighted Extended Spike Model –double-bounded–.

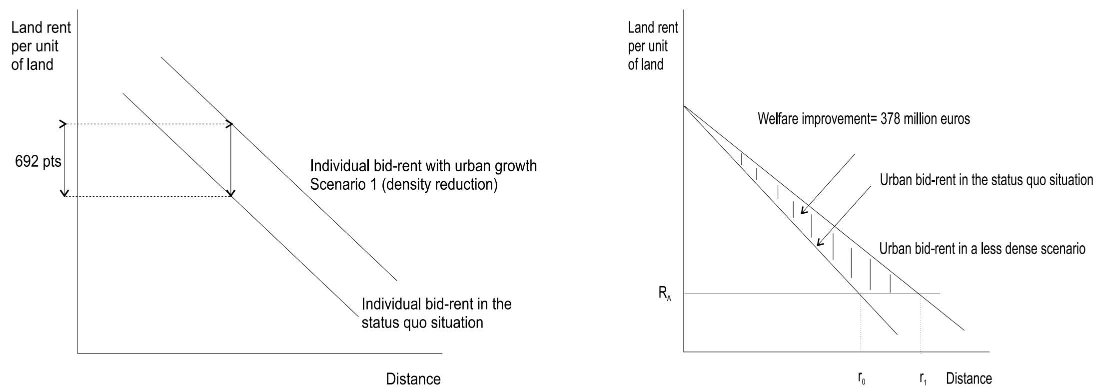
The results suggest that an scenario in which growth would lead to a 10 per cent lower density at the expense of outer landscapes would increase an individual's representative welfare in 4.2 euros per year, in aggregate terms and using the most conservative –low– value (see table 4.5). Based on the assumption 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

Table 4.5. Valuation results for a 10 per cent density decrease –Contingent Ranking and Double-bounded formats–. Values in euros.

CV elicitation format	Aggregate WTP for a 10% density reduction	Welfare increase
Ranking	48.6	$4,370.4 \times 10^6$
Double-bounded format	4.2	374.4×10^6

Population=3.6 million people; discount rate=4 per cent

graphically. Part (a) in figure 4.3 illustrates how, for the representative household, a decrease in density levels increases the maximum rent for land the individual 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 around 374 million euros, 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) of figure 4.3. The two



(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 4.3. Value of a density reduction in the bid-rent framework

different valuation methods 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 socially desirable. The contingent ranking resulted in a significantly higher value estimate of the mean WTP than the double-bounded format, though.

5. Conclusions

In this chapter an alternative approach to deal with the urban sustainability issue has been provided. 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. The analysis yields that the mean value an individual would be willing to pay in order to achieve a less dense environment is a positive amount of money, even when 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 would be over-correcting the environmental externalities caused by outward urban growth. 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.

Although the analysis shown throughout the chapter is based on some simplifying assumptions, we think it could help in the understanding of the different costs of urban development. There are several possibilities for further research. First, the 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. Although we have shown that growing outwards is socially desirable, a figure on *how much* sprawl would be needed was not derived. In further research this estimation ought to be empirically plausible in the context of the approach here utilized.