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C O N T E N T S

INTRODUCTION (1)

The two main aims of this study are: *a)* to measure the quality improvements from which cars have benefited in Spain, and *b)* to estimate the quality bias of the car price index released by INE (the Spanish National Statistics Office). In order to measure quality improvements in a good such as the car, a broad set of information on its characteristics or quality "indicators" is needed. As is well known in the literature on hedonic regressions (2), these indicators tend to be highly correlated. Top-range cars are generally very sophisticated while cars at the other end of the range have basic accessories. Consequently, the value of each of the indicators can hardly be identified through the estimation of hedonic regressions, since discrete estimates of these values are generally biased and very unstable. Thus, traditional hedonic regressions do not provide an accurate measurement of the value of a good's quality. The literature therefore prefers to estimate quality improvements residually. More significantly, it prefers to use a limited number of indicators, which may lead to an inaccurate assessment of quality improvements (owing to the omission of important variables), if not to an underestimation.

Drawing on Arévalo (2001) and the unpublished ideas of Javier Ruiz-Castillo, this paper proposes an alternative methodology for estimating hedonic regressions. The proposal by Arévalo and Ruiz-Castillo consists of grouping the indicators in a quality index, its first main component, which replaces the indicators in the hedonic regression. This methodology eliminates the previously mentioned problems of collinearity, and allows an accurate estimation of the value of the quality. However, the in-

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(2) An summary of this literature can be found in Bover and Izquierdo (2001). The reference applications for cars are Court (1939), Griliches (1971) and Gordon (1990). An interesting theoretical discussion can be found in Diewert (2001).

dex thus obtained may, generally, be difficult to interpret, especially when a large number of indicators is available. The methodology proposed in this study involves classifying the “indicators” in “sub-indices” that reflect different aspects of quality, subsequently grouping the sub-indices in an overall quality index. Statistical analysis of the data helps determine the organisation of the indicators into sub-indices, and it is then possible to estimate the weight of each indicator in the corresponding sub-index and the weight of each sub-index in the overall quality index. Finally, quality value is estimated by an hedonic regression, in which the overall index is used as a regressor. This methodology enables us to work with a high number of indicators, which may be reduced to a single more readily interpretable quality index, thereby resolving the collinearity problems present in traditional hedonic regressions. Consequently, car quality can be measured by a readily interpretable index; and car prices, and how these move over time, can be estimated with statistical accuracy. This all helps quantify the value of quality improvements in a readily interpretable fashion.

The rest of the study is organised in five chapters. In the first one, an index of car prices in Spain is constructed adhering, as far as possible, to INE methodology in the construction of the CPI for cars. The second one considers the estimation of the traditional hedonic regression and proposes an alternative estimation based on the use of an overall car quality index. The third one sets out the construction of this quality index. The fourth one presents the empirical results obtained in the various hedonic regressions and, finally, the fifth one draws the main conclusions.

I

PRICE INDICES

To conduct this analysis we have a monthly database on cars sold in Spain between January 1997 and December 2000. The data were compiled by IEA, and contain information on 48 car makes and around 300 car and four-wheel-drive models, disaggregated into some 5000 versions. On average, there are six models per make and 17 versions per model. In the original records, information for each version is available on the catalogue price and 26 characteristics. New car registrations, however, are available by model, which is why the basic information unit of the study is the "model" (1).

One of the advantages of our database over the data used by INE is that we have prices and quantities (new car registrations) for all models sold in the Spanish market during the period under study. In statistical terms, we have information on the "population" of cars and four-wheel-drive vehicles (although this information is obviously measured with error). It is thus possible to construct a car price index, the result of aggregating the prices of all versions sold in Spain during the period under study. INE, by contrast, constructs its price index from a sample extracted from this population. Given that we seek to estimate quality bias in the INE price index, our first task is to replicate, with our data, a car price series similar to that published by INE.

The INE methodology for constructing the new car price index adheres to the following criteria (2):

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(1) In grouping the versions by model, we have opted to distinguish between models on the basis of the type of engine (petrol or diesel). For instance, there are two models for the Renault Megane: one petrol, the other diesel.

(2) The car price series published by INE also contains a second-hand car price series. Unfortunately, INE does not publish either the weight of second-hand cars in the index or the price series relating to new and second-hand cars.

1. The taking of prices is centralised at national level, and information is obtained from specialist journals or from inquiries to companies in the industry. The prices are, as in our database, “catalogue” prices.

2. A series of segments is defined in terms of the price of the car (small utility, medium-sized, saloon, etc.), and in each segment the prices of the best-selling models are tracked. These models account for around 80 % of total sales.

3. For each model, a single version (normally the best-selling one) is tracked, without distinguishing between petrol- or diesel-engine cars.

4. The car price index is an average of the price changes of models, weighted by the units sold annually. These weights are revised each year.

5. Quality adjustments. Along with the price, information is available on a set of car characteristics (according to specialist magazines). When there is a change in any characteristic or in the vehicle sale price, the manufacturer is consulted to assess the change, and this assessment is then used to adjust the price. If a characteristic which was offered as an option is then offered as a standard feature, the price of the option may be used to assess the change. In some cases, the change in the average price of the versions of the model is used.

On the basis of the IEA data, we have constructed a price series that aggregates price changes in all versions of cars sold between January 1997 and December 2000. This index was compiled as follows:

1. For each model, we have constructed a simple average of price changes, in relation to the previous month, for all those versions that are simultaneously in both periods. This index represents the monthly inflation of the model.

2. The changes in the price index for the various models are aggregated into a car inflation index, using the following weights: for each month, the sales of a model as a proportion of total units sold during the previous year. Given that we do not have information for 1996, we have used 1997 sales to weight the months for that year.

The criterion followed for the construction of the car price index is similar to that known as the matching-model (3) criterion. When a version

(3) See, for example, the discussion in Aizcorbe et al. (2000).

ceases to be marketed, it is removed from the sample and affects the index, for the last time, in the month prior to that of its exit. A new version, meanwhile, affects the index for the first time in the month following that of its entry (since there is no price available for the preceding month). When quality improvements are introduced only via new versions, and the value of these improvements is incorporated into their prices, then a matching model-type index adjusts for the quality improvements. To illustrate, let us assume that a make of car has been marketing a single version of a model, at the same price, over the past months, and that it decides to replace it with a new, higher-quality, higher-price version, whose price will be held constant over the coming months. Further, both versions are jointly marketed for some months. Given that neither of the two versions sees its price rise, the change in the price of the model is zero, calculated in accordance with point 1 above. Therefore, any quality improvement introduced via a new version is not reflected in a matching model-type index.

However, this price index measurement criterion does not adjust for all potential quality improvements. For example, if the new version were sold at the same price as the previous one, the quality-adjusted price of the model would have to fall. Yet a matching model-type index would say that the price had held constant. In this respect, this type of index is not capable of fully correcting quality bias in prices. Moreover, many quality improvements are introduced changing the characteristics of existing versions, in which case the index we propose is incapable of correcting them. In our database, 25 % of the versions undergo at least one change in their characteristics during the sample period, although less than half of these changes are accompanied by an increase in price.

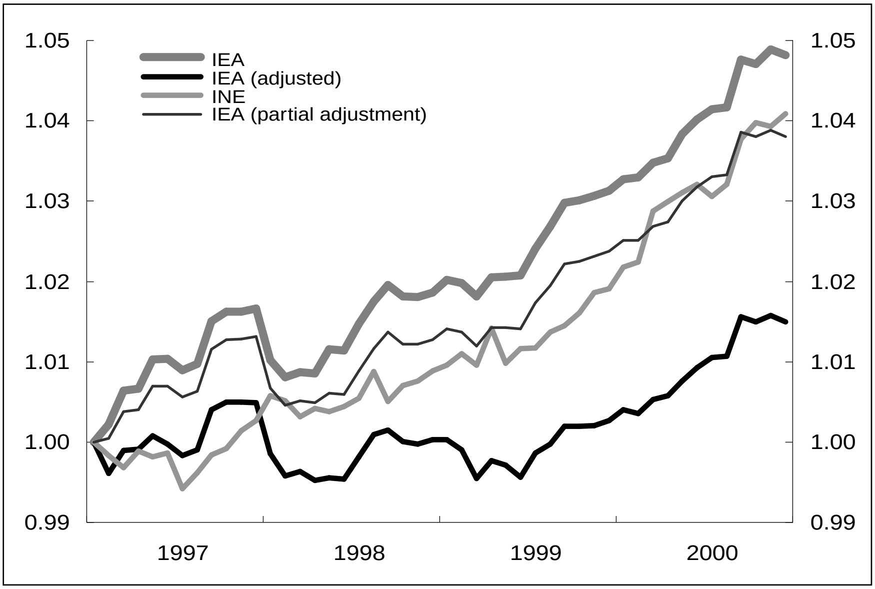
To adjust for quality changes occurring at the level of the version, we use two alternative car price indices that seek to reproduce the criteria followed by INE (4). In the two cases, the correction proposed only modifies the way of calculating the changes in the price of the version described in point 1 above. The criteria used are as follows:

1. Adjusted price series. For those versions in which a characteristic comes to be included as "standard", and for which the price of the "option" is available (this is the case of the air-bag, air-conditioning, ABS, electric windows, centralised locking, type of height-adjustable steering wheel, metallic paint finish, leather up-

(4) One alternative, for the construction of a matching model-type index, would be as follows: to consider any change in the characteristics of a version as the introduction of a new version. In this case, it would not be necessary to introduce any correction of the price of the versions since, under the alternative version definition, a version never changes its characteristics. This alternative has not been considered in this paper.

CHART I.1

CAR PRICE INDICES
(January 1997 = 1)



holstery, reclining seats and on-board computer), the price of the option is added to the vehicle price corresponding to the previous month. The change in the price of the version is calculated on the basis of this adjusted price.

2. Partially adjusted price series. For those versions in which there is a price increase of at least 4 % from one month to the next, it is tested whether any characteristic comes to be included as "standard". Only if this is the case is the procedure the same as for the foregoing point.

Chart I.1 compares the series obtained from the IEA data with the car price series published by INE. Firstly, it should be pointed out that our (unadjusted) price series has a very similar profile to the INE series, with the exception of the year 1997, for which we do not have equivalent weights to those used by INE (5). Our (unadjusted) price index grew at 1.21 % per year between January 1997 and December 2000, while the INE index grew at 1.03 %. This therefore infers that INE made relatively

(5) In 1997 we used the sales for the year as weights, while INE uses 1996 sales. For the other three years, we follow the same criteria as INE, i.e. we weight each version by the sales of the previous year.

insignificant quality adjustments (for less than 0.2 % per year). Secondly, when we adjust for all the quality changes for which we have a price (in accordance with point 1 above), we see that the car price has increased by scarcely 0.38 % per year. Finally, when these adjustments are applied only to those versions whose price has increased by at least 4 % from one month to the next, adjusted car inflation is very similar to that calculated by INE. As a result of the foregoing comments, and in order to measure quality bias in the INE car price index, we shall take as a reference price series the partially adjusted price series (point 2 above).

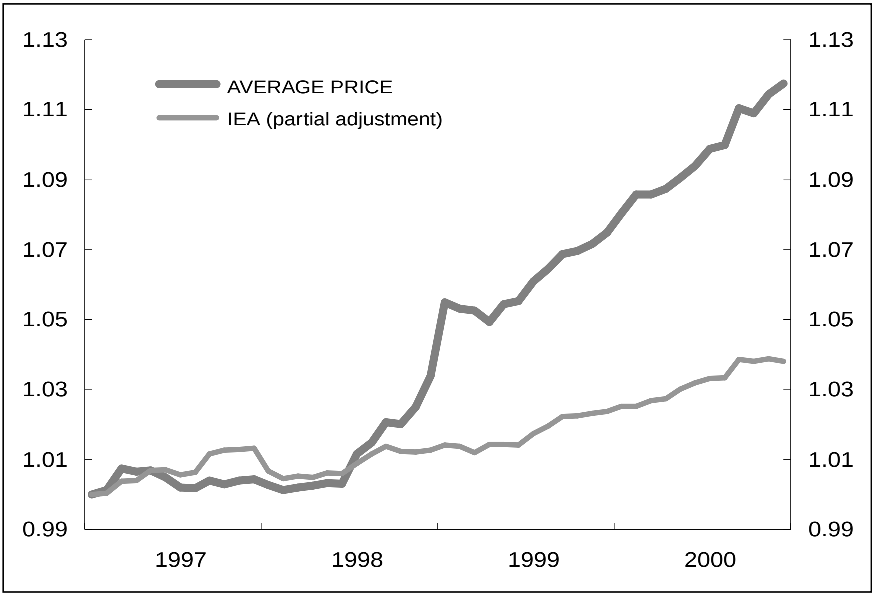
Regarding the corrections proposed, two final comments are in order. First, our database does not have prices for all changes in characteristics. As a result, the corrections we attribute to the quality changes observed are partial. Second, it is to be expected that the price of the "option" overestimates the value of the characteristic when this becomes "standard". When a characteristic is included as "standard", it is bought by all the individuals who acquire the vehicle, many of whom would probably have decided not to include it if its price were that of the "option". Hence, when a characteristic becomes widespread, its price falls, since said price is given by the valuation attributed to it by the marginal consumer. However, we should not confuse this overvaluation of the option price with the reduction in costs from which the producer may benefit, whether due to the accumulation of experience in the production of a certain characteristic (learning effect), or because, on offering the characteristic as standard, the scale of production increases (scale effect). This reduction in costs is what makes quality improvement possible, through the generalisation of a certain characteristic. Yet the value of the improvement is given by the utility individuals obtain therefrom, and not by a reduction in the production cost.

Finally, the relationship between quality improvements and price indices may be further clarified. As can be seen in Chart I.2, the average price of cars sold in Spain has grown more than our car price index (6). Why is this? All price indices compare changes in the prices of a basket of goods at given weights (quantities sold), since what an index seeks to measure is changes in the cost of this basket. An average price, however, is not a price index. And it changes not only when prices change, but also when the composition of the consumption basket changes. In this case, an increase in the average price reflects an improvement in the average quality of the vehicles sold, owing to a shift in demand. In this respect, the difference observed in Chart I.2 between the average price and

(6) The average price has been calculated as the weighted average of prices of all models, using units sold during the previous year as weights. In 1997 we use the weights for the year.

CHART I.2

AVERAGE PRICE AND PRICE INDEX
(January 1997 = 1)



our reference price index measures an increase in average quality due to a shift in demand towards higher-range cars. Consequently, we may say that the shift in the demand for cars towards higher-range vehicles has raised the average quality of cars sold in Spain by 1.9 % per year from January 1997 to December 2000. By the very definition of a price index, this quality component has been corrected by INE.

II

HEDONIC REGRESSIONS AND QUALITY INDICES

In this chapter we present the specification of the hedonic regressions and the quality indices estimated in this paper. We have information on I indicators of car quality and we use the index i to refer to any one of these indicators. The letter j denotes one of the J models of cars that we observed. The models are grouped by make, and we use the letter m to refer to one of the M < J makes. For each model j we have x_t^{ij} data on the indicator i in the period t. The variable p_t^j represents the (logarithm of) the catalogue price of model j.

A traditional hedonic regression arises from estimating the parameters of the following specification (1):

$$p_t^j = p_t + \underbrace{p^d D^{dj}}_{\text{diesel value}} + \underbrace{p^m D^{mj}}_{\text{make value}} + \underbrace{p^n n_t^j}_{\text{variety value}} + \underbrace{\sum \pi^i x_t^{ij}}_{\text{quality value}} + \varepsilon_t^j \qquad [1]$$

where the coefficients represent the prices of the characteristics (2). The dummy variable D^{dj} takes the value one if the model uses a diesel engine and the parameter p^d measures the value of having this type of engine. D^{mj} is a dummy variable that takes the value one for the make to which the model belongs, while the coefficient p^m represents the price of the make. The variable n_t^j represents the number of versions offered of the

(1) We have opted for a semi-logarithmic specification of the hedonic regression. Estimations of some logarithmic specifications (in which we replace the continuous variables by their logarithm) have given similar results to those presented in chapter V as regards the estimation of the quality-adjusted price index.

(2) For the sake of simplicity it is not made explicit here that these prices may vary over time. Later we will see how, in an initial regression for the entire period, it is assumed that prices do not vary over time, subsequently relaxing this assumption so that first, they vary for each pair of periods, and further, that they show monthly variation in estimations made for each period.

model j in t, and its value is given by the coefficient p^n (3). ε_t^j is a random shock that is assumed to be iid, both between models and longitudinally. p_t is the coefficient associated with the time dummy variable t (which is one if the observation is for the period t and zero otherwise) and represents the average price of the car in t, after having deducted the value that consumers assign to the type of engine (petrol or diesel), to the make, to the variety of versions offered and to the quality of the model. Finally, π^i represents the price of the quality indicator i. Since there is generally high collinearity between the indicators, this type of specification poses serious estimation problems. In particular, estimates of the prices of the indicators are biased and are usually rather insignificant and highly volatile.

In this paper we propose an alternative methodology. As its basis it groups the indicators into quality sub-indices and the latter into an overall quality index, which we then use in the hedonic regression. To do this we assume that car quality can be broken down into H < I sub-indices, and we use the letter h to refer to one of these sub-indices. The quality sub-index h is defined as

$$Q_t^{hj} = \sum_{i \in I^h} \beta^i x_t^{ij} \qquad [2]$$

where I^h is the sub-set of indicators belonging to the sub-index h and β_i represents the weight of the indicator i in the sub-index. In turn, the overall quality index is defined as

$$Q_t^j = \sum_{h \in H} \gamma^h Q_t^{hj} \qquad [3]$$

where γ^h represents the weight of the sub-index h in the overall quality index.

Finally, the price of each model can be written as

$$p_t^j = p_t + \underbrace{p^d D^{dj}}_{\substack{\text{diesel}\\ \text{value}}} + \underbrace{p^m D^{mj}}_{\substack{\text{make}\\ \text{value}}} + \underbrace{p^n n_t^j}_{\substack{\text{variety}\\ \text{value}}} + \underbrace{p^q Q_t^j}_{\substack{\text{quality}\\ \text{value}}} + \eta_t^j \qquad [4]$$

(3) By grouping the data by model, we lose information on consumer capacity to choose between different versions of a same model. For this reason, we have created a variable called "number of versions" of a model, which is an indicator of the diversification possibilities a make offers to buyers.

where p^q is the quality index price. η_t^j is a random shock that is assumed to be iid, both between models and longitudinally.

Note that $p^q \beta^i \gamma^h$ could be considered as a measure of the price of the indicator i, or of the contribution of this indicator to the price of the car. However, as there may be high correlation between the indicators and, ultimately, between the sub-indices, the estimated weights do not necessarily reflect the direct (economic) contribution of the indicator to quality. If correlation is very high, an indicator may be capturing the contribution of other indicators to quality, even the contribution of certain omitted indicators, with which it is highly correlated. Consequently, though it is possible to obtain a measure of the contribution of each indicator to quality, its interpretation requires great caution.

III

QUALITY INDICES

In compiling quality sub-indices [2] and a quality index [3] for cars, various strategic decisions must be made:

1. A set of quality indicators on which to compile the index must be selected from the set of characteristics in the database.

2. A base period (one month, in our case) must be selected in which to estimate the coefficients of the quality indices, those which are assumed to remain unchanged throughout the sample period.

3. The number of quality sub-indices must be selected.

4. A dimensionality reduction criterion must be adopted. In this paper we have opted to create quality indices as linear combinations, with maximum variability, of the indicators (principal components).

Based on the 26 characteristics observed, 35 indicators were constructed, of which 18 were finally retained to construct the quality indices. As detailed in Table III.1, the remaining 17 indicators were ruled out for one or more of the following reasons:

1. They do not show an improvement over time. In this case, although the indicator could be a valid indicator of a quality index, it is not necessary to include it as an indicator of a quality improvements index, which is the main aim of this study (1).

2. They have too many “missing” data. For certain models, and also for certain makes, there is no information in the database about some indicators. When the inclusion of an indicator entails the

(1) Of the indicators excluded for this reason, only the maximum speed of the car shows declining behaviour during the study period. The behaviour of the remaining excluded indicators is relatively stable.

TABLE III.1

INDICATORS NOT INCLUDED IN THE ANALYSIS

Indicator	*Label*	*Motive*
cilin	cc	1
veloc	maximum speed	1
malet	boot capacity	1
pma	maximum authorised weight	1, 2
vacio	empty weight	2
cierre	centralised locking	1
vola	manually adjustable steering wheel	4
volae	electrically adjustable steering wheel	3
airbag	passenger airbag	2
alarmn	normal alarm	1, 3
alarmp	perim./volum. alarm	1, 3
alarmpm	perimetric alarm	1, 3
alarmr	remote alarm	1 (diesel), 3
alarmv	volumetric alarm	3
tipop	metal paint finish	1, 3
cuero	leather upholstery	3
asiab	reclining setas	1
turbo	turbo	1 (petrol)

elimination of a make or of a model with a high volume of sales, this indicator is excluded from the analysis (2).

3. They correspond to a very infrequent characteristic. Some indicators reflect a characteristic which, while a good indicator of increases in quality, appears solely in a very low proportion of the total number of cars sold (essentially in those models in the highest range). In this case, the indicator is not representative of the car market under consideration; it is only representative of a market segment.

4. They have no empirical relationship with the other indicators. In this case, if a sole quality index is obtained, the indicator in question will have a zero weight in the index. Conversely, if several sub-indices are used, it will be necessary to include a sub-index solely for this indicator.

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(2) In some cases no information is available on an indicator for one or several months, but is so for prior or subsequent months. In such cases we have used different imputation methods.

TABLE III.2

SELECTED QUALITY INDICATORS

Indicator	*Label*	*Indicator*	*Label*
volumen	volume of model	elevt	electric windows (back)
cv	horsepower	airba	driver's airbag
consu	consumption in litre/100km	airba2	twin airbags
acele	acceleration	abs	ABS
	(seconds 0-100 km/h)	cierrer	remote centralised locking
direc	power steering	orden	computer
aire	air conditioning	llandal	alloy rims
elevd	electric windows (front)	airec	climate control

Table III.2 includes the indicators that have been retained to construct the quality indices. The "volume" indicator is the product of the "height", "width" and "length" indicators, hence Table III.2 only contains 15 indicators. The first four indicators are continuous variables and, for each model, they correspond to the simple average of the versions of this model. The other 11 indicators are frequencies, and each one measures, for each model, the proportion of versions that offer this "standard" characteristic.

The base period selected is January 1997, the starting point of the series. In order to build the quality indices, the models present on the market in the base period were used, weighted according to sales that month. The analysis was repeated using annual sales as a weight, and very similar results were obtained. All the results presented in this section refer to the monthly weight. Given that substantial differences were observed in the averages, variations and correlations between these indicators for petrol and diesel cars, all the analyses were conducted separately, which is why we have different indices for cars according to the type of engine (petrol or diesel).

To select the number of quality sub-indices that might summarise these 15 indicators, unrestricted factor analysis was used. To make the results more readily interpretable, factor analysis was performed using correlations. Given that the size of the sample is very big, and that we have population data, statistical significance tests were not used to evaluate the goodness of fit of the various models; this was evaluated using the residuals. In particular, the rule was adopted whereby a model reproduces the data satisfactorily if no residual correlation is greater, in absolute terms, than 0.10. Using this criterion, it was found that five dimen-

TABLE III.3

PROPOSED QUALITY SUB-INDICES AND THEIR INDICATORS

Quality index	*Index indicators*	*Weights: petrol*	*Weights: diesel*
performance	acceleration	-0.995	-0.998
	consumption	0.555	-0.264
power	volume	1.000	1.000
	horsepower	0.833	0.810
comfort	power steering	0.890	0.471
	air conditioning	0.579	0.855
	electric windows (front)	0.864	0.744
	electric windows (back)	0.715	0.678
safety	airbag	0.856	0.896
	twin airbags	0.800	0.669
	ABS	0.879	0.717
	remote locking	0.271	0.312
luxury	computer	0.689	0.319
	alloy rims	0.866	0.629
	climate control	0.849	0.958

sions (sub-indices) were necessary to satisfactorily reproduce the correlation matrices (3).

We then proceeded to analyse separately the continuous indicators (“acceleration”, “fuel consumption”, “volume”, “horsepower”) and the binary indicators (the rest) so as to identify groups of indicators whose correlations might be reproduced by a single dimension. After testing numerous combinations, it was found that indicators could be grouped as they are presented in Table III.3. As can be seen, the 15 car quality indicators have been grouped into 5 quality sub-indices, namely “performance”, “power”, “comfort”, “safety” and “luxury”. These results need to be qualified. If “climate control” were added to the set of “comfort” variables, then several non-negligible residuals associated with “climate control” would appear. The same would occur if “remote locking” were added to “comfort”. Moreover, it is not possible to reduce the number of sub-in-

(3) Unfortunately, if it is specified that the indices are orthogonal to one another, or that they are allowed to be correlated, the sub-indices resulting from factor analysis are not interpretable. However, and although factor analysis was of no use in determining how to obtain quality sub-indices on the basis of these indicators, it did allow us to ascertain that, to satisfactorily reproduce the correlations observed, 5 sub-indices were needed.

TABLE III.4

PERCENTAGE OF VARIANCE RE-SCALED BY THE FIRST COMPONENT IN EACH OF THE GROUPINGS OF VARIABLES

	Variance explained		*Weights*	
	petrol %	*diesel %*	*petrol*	*diesel*
performance	65	53	0.805	0.081
power	85	83	1.000	1.000
comfort	59	49	0.818	0.706
safety	55	47	0.839	0.683
luxury	65	47	0.736	0.611
quality	71	47		

dices without obtaining non-negligible residuals. For instance, the "performance" and "power" indices cannot be drawn together in a single index.

The conclusion was thus reached that the groupings of indicators shown in Table III.3 are homogenous blocks of variables, as regards their correlations, in both petrol and diesel cars. The linear coefficients of the quality sub-indices were estimated as the first main re-scaled component of each group of indicators, using the covariance matrix. The analysis of principal components is not invariant to scale changes, so it must be decided whether the covariance matrix or the correlation matrix should be used. Since the quality indices are to be used longitudinally, and as the use of standardised variables at each point in time is questionable, it was decided to use the covariance matrix. However, given that the indicators show an uneven variability within each block (the continuous variables in particular), it was decided to re-scale the coefficients of the principal components, using the variances of the indicators to do so. Table III.4 offers the percentages of variance explained by the first main component, for each block of indicators (4).

The weight of the indicators in the sub-indices is given in Table III.3. As expected the weights of all the indicators relating to the sub-indices "power", "comfort", "safety" and "luxury" have a positive sign. As to the

(4) The use of principal components, instead of factor analysis, to calculate the weights of the indicators in the five sub-indices is due to two reasons. First, under principal components the indices are obtained as a linear combination of the indicators, as specified in equations [2] and [3], while under factor analysis it is assumed that the indicators are a linear combination of the indices plus an error. Second, the factor analysis model is not identified (it cannot be estimated) when there are only two indicators (as in the case of "performance" and "power").

TABLE III.5

MATRIX OF CORRELATIONS BETWEEN QUALITY INDICES FOR PETROL-RUN CARS

	performance	*power*	*comfort*	*safety*	*luxury*
performance	1.00	0.80	0.79	0.63	0.53
power	0.80	1.00	0.82	0.84	0.74
comfort	0.79	0.82	1.00	0.71	0.49
safety	0.63	0.84	0.71	1.00	0.66
luxury	0.53	0.74	0.49	0.66	1.00

sub-index “performance”, the following remarks should be made. First, the negative weight of “acceleration” is due to the fact that the less the acceleration time needed to reach a certain speed, the better the performance of the vehicle. The variable “fuel consumption” has a positive weight in petrol-engine cars, since better performance is associated with greater consumption. The negative weight in diesel cars must be associated with the significant improvements in turbo engines.

Given the high correlations observed (Tables III.5 and III.6) between these indices, an overall quality index can be constructed. This index is the first component extracted from the covariance matrix among the 5 quality sub-indices, re-scaling the coefficients on the basis of the variance of the components. The weights of the sub-indices in the overall index are presented in Table III.4, along with the percentage of the variance explained by the first main component. They all have the expected sign and, moreover, the overall index accounts for 70 % and 47 %, in petrol and diesel cars, respectively, of the total re-scaled variance of the quality sub-indices. As can be seen in Chart III.1, both the overall quality indices for petrol and diesel cars and the average

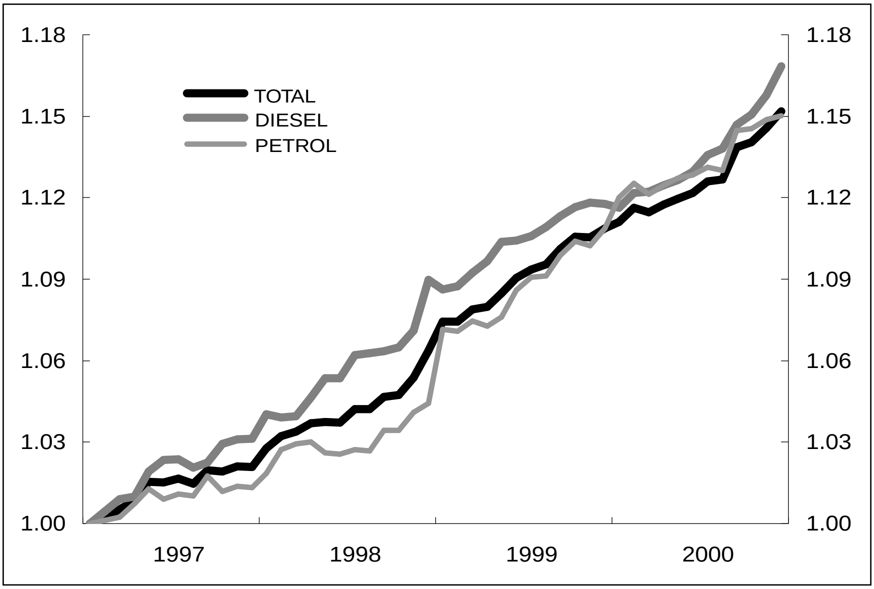
TABLE III.6

MATRIX OF CORRELATIONS BETWEEN QUALITY INDICES FOR DIESEL CARS

	performance	*power*	*comfort*	*safety*	*luxury*
performance	1.00	0.08	0.05	0.22	0.19
power	0.08	1.00	0.71	0.68	0.61
comfort	0.05	0.71	1.00	0.59	0.27
safety	0.22	0.68	0.59	1.00	0.58
luxury	0.19	0.61	0.27	0.58	1.00

CHART III.1

QUALITY INDICES
(January 1997 = 1)



overall index for all cars grow sustainedly during the entire sample period (5).

In sum, an overall quality index of cars sold in Spain has been constructed, which it is possible to break down into five sub-indices: performance, power, comfort, safety and luxury. These indices have been obtained from 15 selected quality indicators and have been estimated separately for petrol and diesel cars. The quality of each car can be summarised in a single number, which is readily interpretable in terms of the indicators comprising it. Finally, the quality index constructed grows throughout the sample period, both for petrol and diesel cars, thereby clearly indicating the existence of quality improvements in the car.

(5) These indices are the annual sales-weighted average of the quality indices constructed for each model.

IV

HEDONIC REGRESSIONS

IV.1. Estimation strategies

In the estimation of hedonic regressions, three different strategies can be followed:

1. Data pool. Equation [1], or [4], is estimated simultaneously for the whole sample period. In this case, the coefficients p^d, p^n, p^m, p^q and π^j are assumed to be time-invariant. In particular, the price of quality is assumed to be constant.

2. Adjacent periods. Equation [1], or [4], is estimated for adjacent periods, i.e. for pairs of periods $t - 1$ and t, where t runs from February 1997 to December 2000. In this case, the coefficients of the regression are assumed to be constant for each pair of periods, but variable from one pair of periods to the next.

3. Period by period. Equation [1], or [4], is estimated for each period separately. In this case, the coefficients of the regression are assumed to vary from one period to another.

To analyse the consequences of these three estimation strategies, let us define a price index, e.g. for hedonic equation [4], under the assumption that there are no dummy variables of makes or of engines, and that there is no number of versions. Since we are seeking to calculate the price index, we should consider the quantities consumed as given. In our case, the quantities are summarised in the overall quality index on which we must take a reference value, for instance Q_0^j, the quality of model j in the base period. Under these assumptions, the price of a model can change from one period to the next for two reasons: a change in the constant p_t, or a change in the price of quality p_t^q.

Consequently, the estimation of the inflation of model j, at a given quality Q_0^j, is

$$(p_t - p_{t-1}) + (p_t^q - p_{t-1}^q)\, Q_0^j \qquad [5]$$

When the hedonic regression is estimated as a data pool, it is assumed that the price of quality is constant over time, i.e. that $p_t^q = p_{t-1}^q$ for all t. Accordingly, the adjusted inflation is the same for all models and the adjusted car price index is given exclusively by the coefficients p_t of the time dummy variables. When the hedonic regression is estimated using adjacent periods, it is assumed that $p_t^q = p_{t-1}^q$ for each pair of periods. Consequently, as in the previous case, all models undergo the same quality-adjusted inflation, and p_t measures the adjusted inflation of the car in period t (since, in this case, $p_{t-1} = 1$). Under these two methods quality-adjusted inflation is residually estimated as temporary changes in prices not explained by car quality changes. Finally, when period by period estimation is used, the adjusted price of each model varies for two reasons, not only due to changes in the time dummy coefficient but also because the price of quality is varying. The inflation of each model is constructed following equation [5]. The index of quality-adjusted prices is the result of aggregating the adjusted indices of the models using their sales of the previous year as weights.

IV.2. Results

This section presents several estimations of hedonic regressions for the period running from January 1997 to December 2000. First, we present data pool estimations, which we then compare with adjacent-period and period by period estimations. Our reference estimation, of the quality-adjusted price, corresponds to the estimation of the traditional hedonic regression [1], in which we include all the indicators available (Tables III.1 and III.2]. Second, we have estimated the traditional hedonic regression for the 15 indicators retained (Table III.2). Finally, we have estimated hedonic regression [4] using the overall quality index estimated in chapter III (1).

In the construction of car quality indices, a distinction has had to be drawn between the type of fuel used: petrol or diesel. For this reason, although we have grouped the 15 indicators retained into the same five sub-indices, irrespective of the type of fuel used, the estimation of the weight of the indicators in each sub-index is different, as is the estimation

(1) Hedonic regressions have also been estimated using the five quality sub-indices. The results, both in terms of the explanatory power of the regression and of the performance of the quality-adjusted price index, are similar to those presented here.

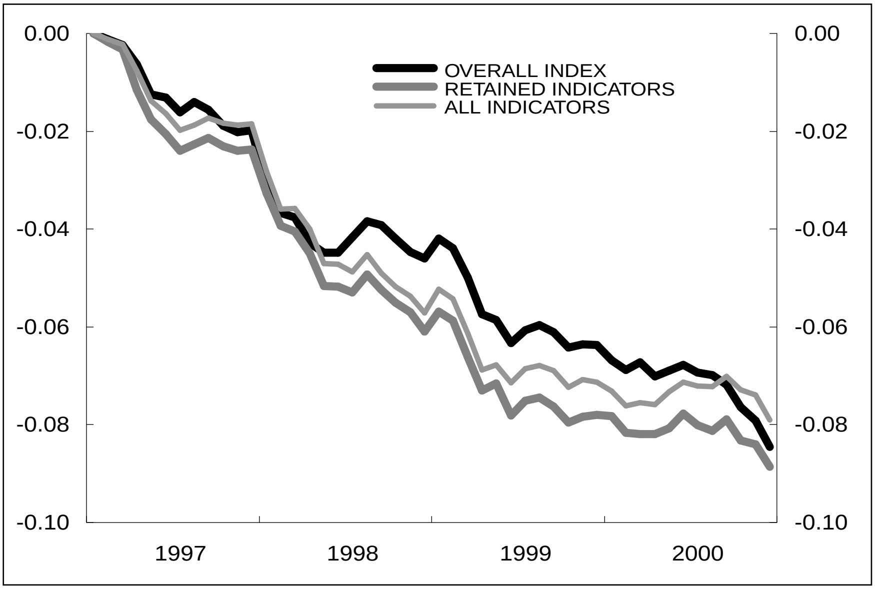
ESTIMATION OF THE VALUE OF QUALITY INDICATORS (a)

	petrol	*diesel*	*common*
acele	-0.006121	0.000080	-0.003876
	(-12.76)	(0.22)	(-11.43)
consu	0.010849	0.005423	0.008218
	(12.41)	(6.27)	(11.71)
volumen	0.037165	0.055242	0.060863
	(32.95)	(60.47)	(83.82)
cv	0.007138	0.007537	0.006124
	(101.98)	(70.50)	(103.23)
direc	0.100005	-0.000676	0.025851
	(17.05)	(-0.09)	(5.37)
aire	0.021890	0.105824	0.083652
	(5.54)	(28.82)	(27.69)
elevd	0.034215	0.011939	0.044433
	(6.28)	(2.33)	(10.71)
elevt	0.039135	0.054415	0.042682
	(9.71)	(12.14)	(12.72)
airbag	0.010529	0.048557	0.034462
	(3.03)	(14.62)	(12.53)
airbag2	-0.008291	0.003369	-0.008799
	(-2.69)	(1.16)	(-3.54)
abs	-0.025089	0.040881	0.012956
	(-6.24)	(12.37)	(4.40)
cierre	0.008249	0.009168	0.002852
	(2.47)	(2.77)	(0.97)
orden	0.003892	-0.010163	-0.001456
	(0.94)	(-2.33)	(-0.42)
llandal	0.067859	0.026865	0.056297
	(17.01)	(5.78)	(16.71)
airec	0.037521	0.102576	0.101608
	(7.15)	(24.54)	(28.34)
Adjusted R^2		0.971	0.966
Overall index	0.010769	0.016452	0.011677
	(303.38)	(255.18)	(278.88)
Adjusted R^2		0.956	0.933

Note:
(a) t-statistics in brackets

CHART IV.1

ADJUSTED PRICE INDICES
(Cumulative change since January 1997)

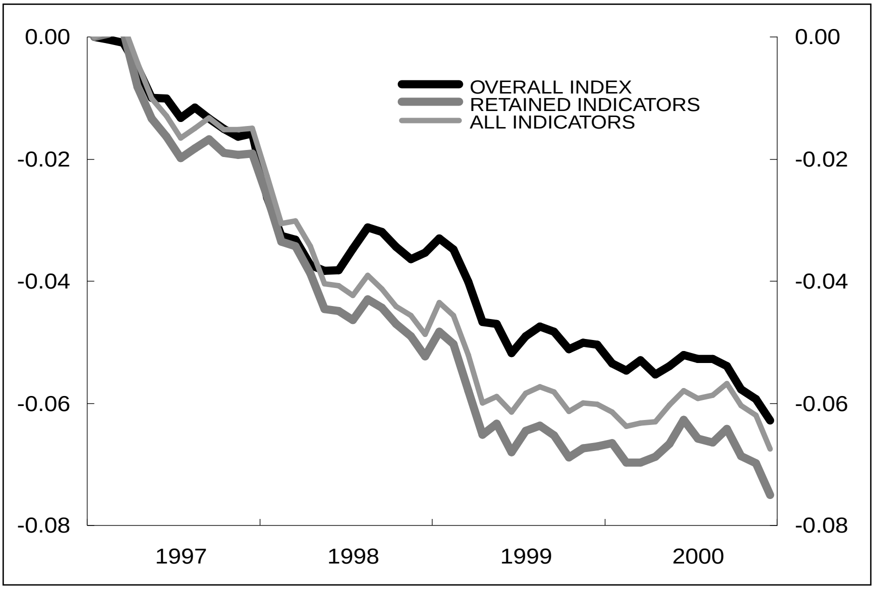


of the weight of each sub-index in the overall index. Consequently, the market's assessment of the overall quality index may differ depending on whether the model has a diesel or petrol engine. Therefore, in the estimation of equations [1] and [4], we have estimated different π^i and p^q coefficients according to the type of fuel used.

The estimations of [1] and [4] were made via weighted least squares, where the weights correspond to the weights of the model in the prior year's new registrations. For the months in 1997, we have used 1997 new registrations.

Table IV.1 gives the estimated coefficients of the traditional hedonic regression [1] for the 15 quality indicators retained. Notably, the adjusted R^2 of this regression (0.971) is scarcely lower than that of the regression with the 35 indicators (0.975). The first two columns correspond to the estimation in which it is assumed that the value of each indicator differs for petrol and diesel cars. The third column corresponds to the estimation that imposes a common value on each indicator for the two types of engine. The coefficient in brackets is the t-statistic. The time dummy variables relating to these regressions have been depicted in Charts IV.1 and IV.2, which will be discussed below. As was to be expected, not all the estimated coefficients had the expected sign (which should be positive, with

ADJUSTED PRICE INDICES
(Cumulative variation since January 1997)



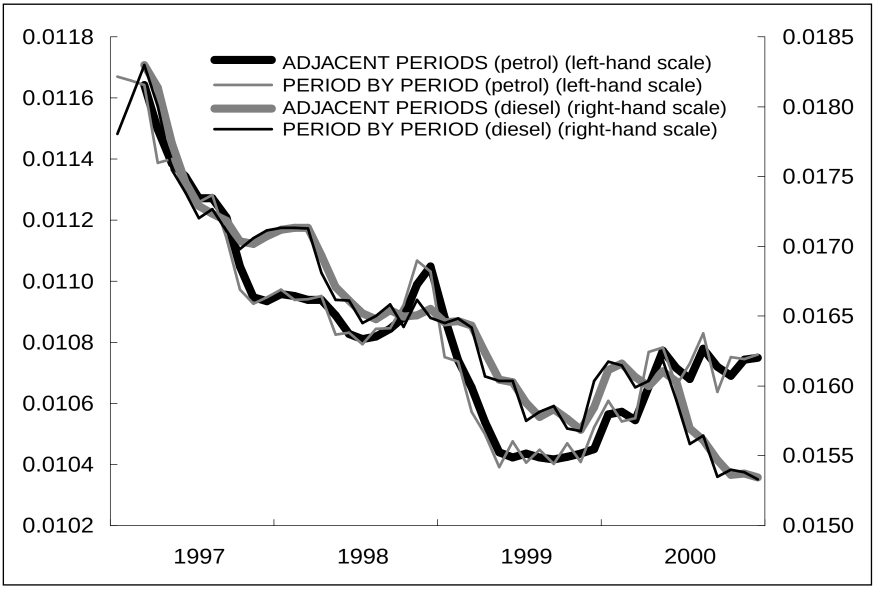
the exception of the "acceleration" indicator). The assumption of equality of the parameters between the two types of engines scarcely reduces the explanatory power of the model (the adjusted R^2 moves from 0.971 to 0.966), despite the fact that several of the coefficients are significantly different, owing probably to the aforementioned collinearity problems.

Table IV.1 also offers the estimations of hedonic regression [4]. The time dummy variables corresponding to this regression are also depicted in Charts IV.1 and IV.2. The overall index depicts very well the set of indicators used in the traditional hedonic regressions: the loss of explanatory power is very limited, especially when we estimate different prices for the quality index of each type of engine.

Chart IV.1 tracks the time dummy variables, parameters p_t in [1] or [4], estimated for the three aforementioned hedonic regressions. In all three cases, the coefficients associated with the petrol- or diesel-engine models were estimated separately. It should be recalled that p_t is a car price index adjusted for the quality improvements specified in [1] or [4]. The (quality-adjusted) price of the car is on a clearly falling trend. We may conclude from the comparison of the different estimations that the sub-set of indicators retained (Table III.2) captures relatively well the behaviour of prices insofar as their estimation is not very different from that resulting from in-

CHART IV.3

PRICE OF QUALITY
(Coefficient of the quality index in the hedonic regression)

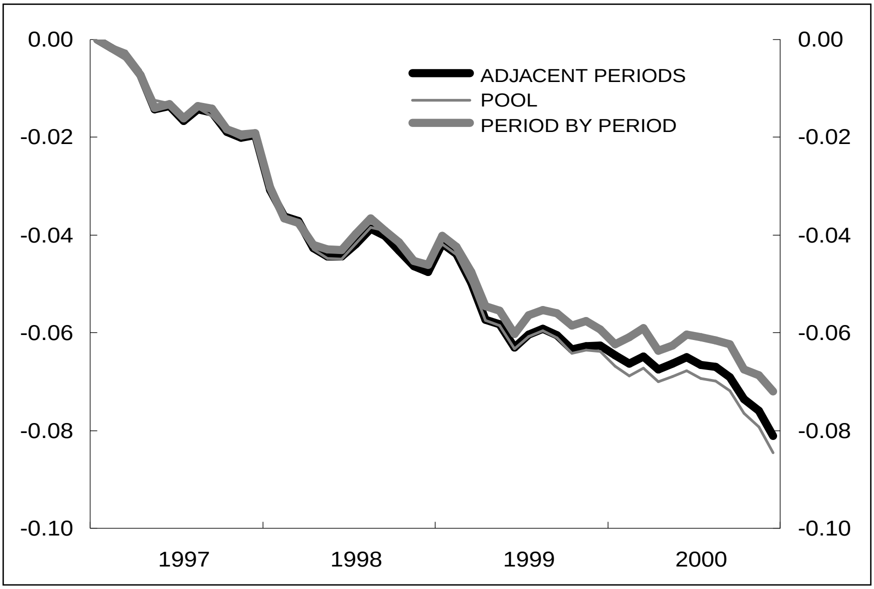


cluding all the indicators. More significant still, the overall index also provides a very good approximation, in respect of the reference estimation, of the course of the adjusted car price. On the basis of these three estimations, we may conclude that the quality-adjusted price of the car declined during the four years under study at a cumulative annual average rate of 2.2 % (2). The results are similar when we impose the same quality value (both for the indicators and for the overall index) for petrol and diesel cars. The quality-adjusted price is plotted in Chart IV.2. Its course is very similar to that in Chart IV.1, although the annual average rate of decline of prices is somewhat less at between 1.8 % and 2 %.

Second, we have estimated the adjacent period hedonic regression [4], to control for the possible change over time in the price of quality, and its effects on the price-adjusted index. For the period as a whole, the price of quality is on a declining line for both petrol- and diesel-engine cars (Chart IV.3). However, this reduction in the price of quality does not have a significant effect on the adjusted car price, estimated – as be-

(2) This is the average rate of decline using the overall quality index. However, the average rates of the other two estimations are very similar. When we consider the regression with the 15 indicators retained, this rate is estimated at 2.3 %, and at 2.1 % using the 35 original indicators.

ADJUSTED PRICE INDEX
(Cumulative change since January 1997)



fore – by the course of the time dummy variables depicted in Chart IV.4. The annual average rate of decline of prices stands at 2.1 %.

Finally, hedonic regression [4] has been estimated period by period. The price of quality, as can be seen in Chart IV.3, does not differ substantially from that estimated by adjacent periods. The advantage of having a quality index, the price of which has been appropriately estimated, lies in the fact that we can readily construct a car price index at a constant quality level (3). Chart IV.4 depicts the quality-adjusted index constructed on the basis of these estimations. In this case, unlike the two previous methods, regard is had for the calculation of the quality-adjusted price index to the changes in the price of quality throughout the period. The price index thus calculated shows the monthly course of the price of quality for a level of quality set in the base year. Its trend can be seen to be very similar to that of the adjusted price indices estimated by the other two methods, with an annual average rate of decline of 1.9 %. This

(3) It is possible to construct a constant-characteristic price index based on a traditional hedonic regression such as that considered in [1]. However, the instability and inaccuracy problems discussed in the estimation of the prices of each of the characteristics may make it unfeasible. In any event, having a single accurately estimated quality price facilitates calculation of these price indices enormously.

TABLE IV.2

CONTRIBUTION OF QUALITY PRICE CHANGES TO ADJUSTED CAR INFLATION

	Contribution
dummy variables	1.9
quality (petrol)	-1.1
quality (diesel)	-2.1
variety	-0.6
adjusted inflation	-1.9

method also allows calculation of the contribution of the changes in prices of the different variables included in the hedonic regression to the total change in prices. Table IV.2 shows this breakdown, highlighting the contribution of the decline in the price of quality, of the price of variety and of the dummy variables. If the coefficients of the dummy variables (time, make and engine) had remained constant, the car price would have fallen by 3.8 % per year. It is reasonable to think that, as time passes, new characteristics will appear and some of the existing characteristics (generally those most valued) will gain in significance compared with others. The quality gains derived from omitted or underestimated characteristics have not been appropriately adjusted, and they are part of the 1.9 % increase in prices attributed to the dummy variables. A portion of this increase could be adjusted if we had a quality index that accepted changes in weights and, essentially, the entry of new quality indicators.

In sum, the different methods used in this study to estimate changes in the hedonic price of cars in Spain in the period from January 1997 to December 2000 offer very similar results. Our estimation of the decline in car prices once quality improvements are stripped out stands at 2.1 % per year (4). This estimation does not vary significantly if, instead of using the estimated index of car quality, all the quality indicators available or a smaller set of indicators in the traditional hedonic regression are used. In turn, when the assumption that the coefficients of the hedonic progression hold constant during the study period is relaxed, the results are once again very similar, both when their variation between adjacent periods is allowed and when the monthly change in the price of quality is estimated. In this latter case, having an overall quality index whose price can be accurately estimated monthly makes it easier to calculate a given-characteristic (given-quality) car price index and to measure the contribution to the total change in the price index of each of the variables included in the hedonic regression.

(4) The average of the results obtained with the overall quality index with the three methods used.

V

CONCLUSIONS

The first aim of this study is to estimate the quality improvements from which cars have benefited in the period running from January 1997 to December 2000. To do this, we have measured the growth rate of the average car price and its rate of change adjusted for observed quality improvements. The difference between both rates measures, in real monetary units, the value of the car quality improvements. In our database, which encompasses the population of cars and 4-wheel drive vehicles, the average price increased at a rate of 2.9 % per year, while our best estimation of the decline in the quality-adjusted price is 2.1 % per year. Consequently, car quality has increased by around 5 % per year over the past four years.

Our second aim is to measure quality bias in car inflation as estimated by INE. In this connection, we have constructed a reference price index, whose behaviour is similar to the index released by INE. Specifically, both series evidence the same annual average growth rate between January 1997 and December 2000. It should be borne in mind that all price indices adjust for quality improvements from a shift in demand towards higher-range versions or models. Further, our reference price index makes a 0.2 % annual adjustment for observed quality improvements (corrections which, we estimate, INE also makes). Since our reference price index has increased in this period by 1 % per year, this infers that the implicit quality bias during the study period, between January 1997 and December 2000, is 3.1 % per year. Consequently, INE only makes a 1.9 % annual adjustment for quality improvements, attributable in the main to a shift in demand towards higher-range versions or models.

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