Quality bias in the measurement of prices: empirical evidence and macroeconomic implications for Spain

The authors of this article are Olympia Bover, Mario Izquierdo and María de los Llanos Matea of the Research Department.

1. INTRODUCTION

Technological progress, which goes hand in hand with economic development, gives rise to continuous and significant changes in the characteristics (and quality) of the goods and services produced by an economy, as well as to the appearance of new products. The statistical apparatus of each country needs to be able to detect these changes and incorporate them rapidly into the measurements of economic variables. However, notwithstanding the effort devoted, this incorporation is never complete, since the adaptation of statistics to new realities is a costly process requiring time and analysis. One of the problems generated by this insufficient adaptation is the biased measurement of price changes, since the statistical techniques applied are unable to distinguish between that part of the change in the price of a good that stems from a change in its characteristics and that part that represents a pure price change. This, in turn, has significant implications for the measurement of real magnitudes, because if the price indices used to deflate nominal magnitudes are biased, then the real magnitudes obtained will be too. In recent years, this type of measurement problem has particularly affected economic sectors in which technical progress has been most rapid, such as information technologies.

The traditional methods used by statistical offices to correct observed price changes for changes in the quality of products are often inadequate. As an alternative to these traditional methods, the literature and the experts of government statistical offices have, in some cases, been using the so-called hedonic method popularised by Zvi Griliches in the early sixties. The hedonic approach starts by assuming that the observed price of a good is a function of its characteristics. Accordingly, if the relationship between the price of the product and its characteristics (the hedonic function) is estimated, then an index can be constructed representing the path of prices for a constant level of quality (1). Countries that have adopted this methodology for productive sectors characterised by rapid technological progress, such as computers, have made significant corrections to the price indices for these products. Moreover, incorporation of these corrections into the deflators used to estimate macroeconomic magni-

(1) For further details of the hedonic methodology, see Bover and Izquierdo (2001).

tudes in real terms (such as investment and output) has entailed significant upward revisions to these variables.

Given the obvious importance to the economic authorities of having the most accurate possible measurement of growth and inflation, the Banco de España decided to undertake a research project with the aim of approximating the size of the biases that might be operating in the measurement of real magnitudes in Spain, as a consequence of the use of traditional techniques to compile price indices (2). This project had two basic elements. First, hedonic price equations were estimated for some of the products identified as having experienced particularly significant changes in quality: computers, cars and housing. Electrical household appliances and the products of the other ICT (information and communication technologies) industries also incorporate significant changes in quality, but the absence of suitable data has made it impossible to make the necessary estimates. Second, a macroeconomic exercise was carried out in an attempt to gauge the importance of the resulting bias in the estimation of the main macroeconomic aggregates. This exercise was, in turn, tackled in two phases. First (3), to obtain a point of reference, the price corrections that had been estimated in other economies pioneering the use of these techniques were applied to Spanish National Accounts data for the period 1986-1994, and second (the phase presented in this article), the price corrections deriving from the sectoral analysis for Spain were applied to the most recent National Accounts data (1995-1999).

The reasons for including computers among the three groups of products studied in this project are obvious, since the quality improvements in recent decades have been enormous. Processing power (associated with developments in the semiconductor industry) has doubled approximately every one and a half years and other computer components (hard disk, memory, monitor, graphics card, programmes, etc.) have also improved dramatically. As a result, today's computers are very different from those available a few years ago, even offering attributes that were not then available. Since a price index must compare the prices of identical products at two points in time, the adjustments made to take into account such blatant quality changes are particularly important in this sector and the hedonic methodology has been shown to be particularly suitable for this purpose. Thus, the hedonic price indices estimated for the computer sector in different countries show average annual price reductions of 20% to 40%, depending on the type of product and the period considered, while in those countries that use more traditional techniques the price falls recorded are very small and in some cases prices even increase. Eurostat (4) recommends the use of hedonic methodology to calculate computer price indices and the statistical offices of at least the United States, Canada, Denmark, France and Sweden are applying them.

In the case of cars, quality improvements have also been unquestionable, although less dramatic than in computers. The first studies of hedonic prices in this sector were carried out in 1939, when Court estimated that, over the period 1925-1935, the price of new cars had fallen by 55% in the United States, when official US Statistical Office figures showed an increase of 45%. In Spain, the adjustment of the prices of this sector for quality changes is important in macroeconomic terms, given its weight in the economy: in 1999, it accounted for more than 5% of Spanish GDP, 6.5% of total household consumption and more than 15% of exports.

As regards housing, it should be noted that the US Bureau of Economic Analysis adopted hedonic techniques for the first time in 1963, precisely for the National Accounts deflator of new housing, in order to take into account the slow but constant improvements in the quality of construction. In all countries, residential construction has a considerable weight in investment and real output. Indeed, in Spain, gross fixed capital formation in residential construction accounted for 5.2% of GDP in 1999 and 21.1% of total gross fixed capital formation. Moreover, there is a growing consensus that the European harmonised index of consumer prices (HICP) should reflect owner-occupied housing by including an index of prices for new housing duly corrected for quality changes (5). This question is particularly important for Spain, since it has one of the highest percentages of owner-occupied housing (approximately 85%) in Europe.

Finally, it should be noted that although the estimates of hedonic functions presented in this article for the prices of computers, cars and housing are all based on the hedonic method, they differ in important aspects, as they have had to be adapted to the particular characteristics of each product and the information available in each case.

The article is structured as follows. Section 1 summarises the study carried out on computer

(2) See Banco de España (2001).
(3) See Izquierdo and Matea (2001a and 2001b).
(4) See Eurostat (1999).
(5) See Eurostat (2000).

prices, while Sections 3 and 4 summarise those on the prices of cars and housing, respectively. Section 5 then uses the results obtained for the biases due to changes in quality in these sectors to assess their impact on the measurement of Spanish macroeconomic variables over the period 1995-1999. Lastly, Section 6 presents some brief conclusions.

2. HEDONIC PRICE INDICES FOR PERSONAL COMPUTERS (6)

2.1. Model and data used

Traditional hedonic methodology was applied in the study of personal computers. As already mentioned, this methodology assumes that the observed price of a product is a function of its characteristics. Once the relevant characteristics of a product have been determined, the relationship between them and the observed price is estimated. The basic hedonic function can generally be written as:

$$\log P_{it} = \alpha_0 + \delta_t + \sum_k \beta_k \log c_{ikt} + \varepsilon_{it} \qquad [1]$$

where P_{it} corresponds to the price of model i in period t, c_{ikt} is the level of the k characteristic in model i and ε_{it} is a shock term. To estimate δ_t dummy time variables are defined, such that $\delta_t = \sum_{t \neq 0} d_t D_t$, where D_t takes the value one in period t and zero in the rest of the periods. Note that d_t refers to the initial period and, therefore, provides the change between period t and the initial period in the estimated price net of changes in quality. Accordingly, on the basis of an estimation of these coefficients it is possible to construct an index of hedonic prices.

An important aspect of this methodology is the selection of the most relevant characteristics of each product, which requires intimate knowledge thereof. In the case of computers, the database used has been designed and provided by experts from the SEDISI (Spanish Association of Computer Sector Companies), and contains information for desktop and laptop computers between 1990 and 2000. In particular, data are available on computer price, manufacturer or distributor brand, processor speed, hard disk capacity, the amount of random access memory (RAM), CD-ROM availability (in the case of desktop computers). These are the variables that have been most frequently used in the literature. Although they are all fundamental, it would nonetheless have been desirable to have other characteristics, such as the type of screen, the type of processor and the various computer accessories available. These have undoubtedly improved substantially in recent years and should therefore be taken into account when the relevant estimates are made.

The sample was compiled with information provided by distributors. Consequently, it is representative of sales to households, since firms usually buy directly from manufacturers. The price is the average price at which the distributor sells a computer, including the monitor and any other incorporated accessory. Both the price and the characteristics correspond to the computers sold by distributors in the year in question. As new features are continually being incorporated in this sector, the time a particular model remains on the market is very short. This, together with the fact that the frequency of the sample is annual, means that only one observation is available for each model.

For desktop computers, 132 observations per year are available on average. The majority of the computers in the sample are so-called cloned computers, i.e. computers assembled by distributors and sold under their name. The upper panel of Chart 1 shows the rates of change of the characteristics and prices of desktop computers, the importance of the quality improvements that have taken place being readily appreciated. Processor speed has grown each year at an average rate of 41%, RAM at a rate of 49% and hard disk capacity at 65%. Moreover, while in 1990 no computer had CD-ROM, in 2000 they all did. However, despite these marked improvements in the characteristics of computers, their average selling price fell at an annual rate of 13%.

As for laptops, the sample is somewhat smaller, with 67 observations per year on average, more than half of these being for brand computers. As before, the average characteristics of the laptops sold during the study period show substantial quality increases (see the lower panel of Chart 1). The average processor speed increased each year at a rate of 43%, RAM at 49% and hard disk capacity at 72%. All this occurred while the average price fell at a modest annual rate of 3%.

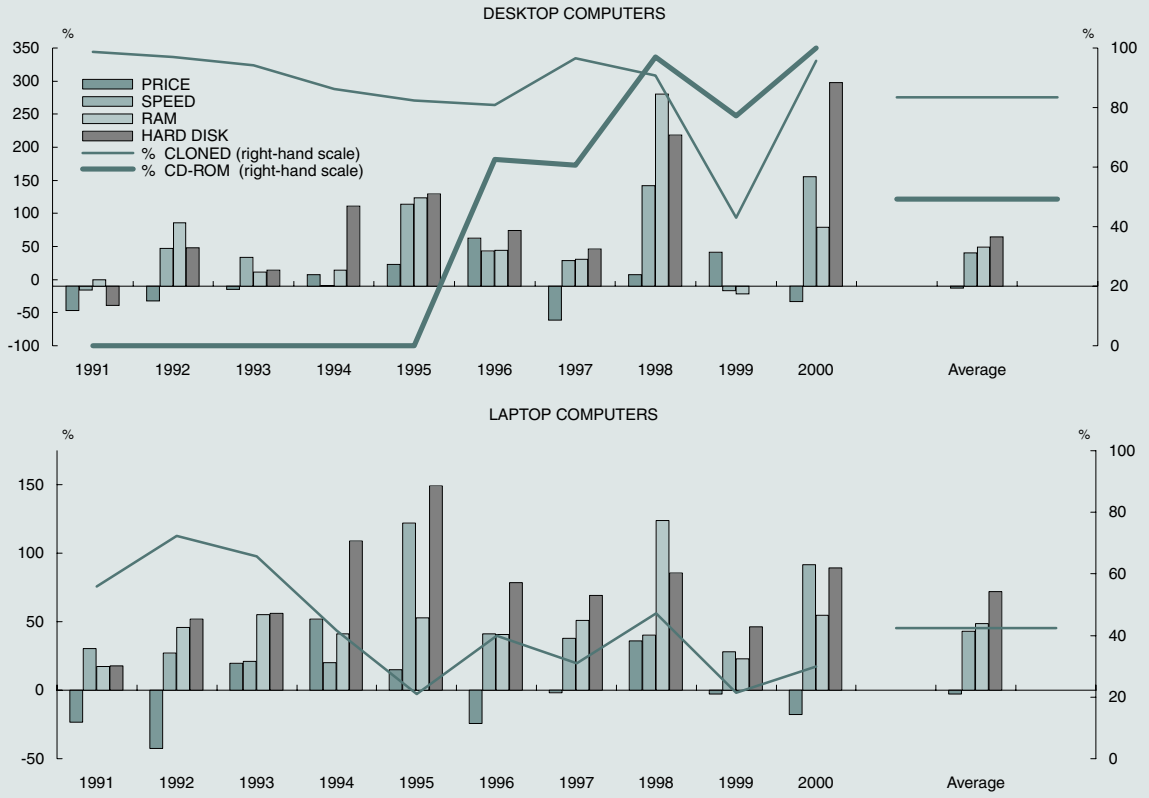
2.2. Estimation and results

Desktop and laptop computers have been analysed separately since, as they provide different services, they can be considered differ-

(6) This section summarises Izquierdo and Matea (2001c).

CHART 1

Changes in computer characteristics (a)



Source: Banco de España.
(a) Annual rates of change, except for CD-ROM and cloned computers, for which the percentage of computers with the characteristic concerned is depicted.

ent products. In this respect, Berndt and Rappaport (2001), with a set of characteristics like the one used here, but with data for the United States, conclude that the relationship between the prices of these two types of computer and their characteristics is not the same. In fact, in the literature independent regressions are usually constructed for each type of computer, as done, for example, by the Bureau of Labor Statistics (BLS) and the Institut National de la Statistique et des Études Économiques (INSEE).

The best approximation to the behaviour of the data is obtained, for both types of computer, when the logarithm of the prices is expressed as a function of the logarithm of the characteristics, i.e. with a regression of the equation [1] type. It has been revealed in diverse studies of the sector that the brand is usually also a significant characteristic, in that it reflects aspects such as prestige, guarantee, etc., that permit manufacturers to price computers with the same attributes differently. In this connection, dummy variables are included for each of the brands in the equation selected for laptops, while in the case of desktops it was better to use a single dummy variable that takes the value one if the computer is cloned and zero if it is not.

At the same time, if a single equation is estimated for each type of computer then the coefficients of the characteristics are being held constant over time. This is an over-restrictive assumption, given the significant changes that have taken place. One way of relaxing this assumption (the one chosen) is to divide the sample into sub-samples for two consecutive periods and to estimate a regression for each of them. In each regression, except the initial one, the first period considered is the last one of the previous regression. This strategy keeps the coefficients of the characteristics constant within each of the consecutive periods, but allows them to vary between regressions. In fact, it is concluded from the results obtained that it is not acceptable to assume that the coefficients of the characteristics are the same over the estimation period.

The hedonic price indices are calculated on the basis of the temporary dummy variables in-

cluded in the hedonic regressions. Chart 2 depicts the quality-adjusted price indices obtained for desktop and laptop computers, as well as their year-on-year rates of change. According to these estimates, the prices of desktop computers have fallen at an average annual rate of 40% over the period 1990-2000. As seen in the lower panel of the chart, the price falls fluctuated around roughly this value in every year of the sample period [with the sole exception of 1990, when prices actually rose (7)], although the rate of fall accelerated in the second half of the decade.

As regards the price index for laptops, the average annual rate of decline estimated for the period 1990-2000 was 36%. 1994 was the only year in which there was an increase in the price of these products, which is not explained by the trends in the characteristics considered (8). From 1995, the indices return to a downward path, with significant reductions. In fact, in this case too, an acceleration in the downward movement is discerned in the second half of the decade.

The hedonic price indices calculated separately for desktop and laptop computers have been aggregated to form a single index of hedonic prices for personal computers. As sales by type of computer are not available, the aggregation has been carried out by taking the simple mean. The result is an estimated average annual fall of 38% in the price of personal computers between 1990 and 2000.

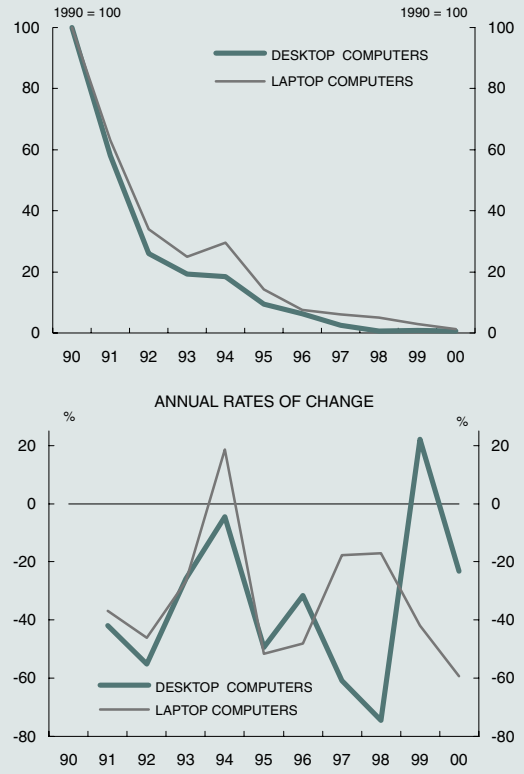
Comparison of the path of this index with that of the consumer price index for the subclass of personal computers, typewriters, etc. enables the bias present in the Spanish case owing to insufficient adjustment of prices for the extraordinary changes in computer quality to be quantified. This subclass of the CPI is available from 1992, so that the comparison is limited to the period 1992-2000. During this time, the average annual rate of change of this subclass was –9%, while the hedonic index fell at a rate of 35%. In other words, the estimate of the quality bias in the Spanish CPI for computers is estimated, with all due caveats, as 26% per annum.

(7) This increase in prices may have been related to the worldwide scarcity of RAM components in the wake of the September 1999 earthquakes in Taiwan. The increase in the demand for computers caused by the arrival of the year 2000 may also have had an effect.

(8) One explanation for this behaviour may be the notable increase in the demand for laptop computers around that year, given that the successive reductions in their weight meant that such computers, from being merely transportable, had become true laptops.

CHART 2

Hedonic price indices for computers



Source: Banco de España.

3. PRICE INDICES IN THE CAR SECTOR (9)

3.1. Methodology and data used

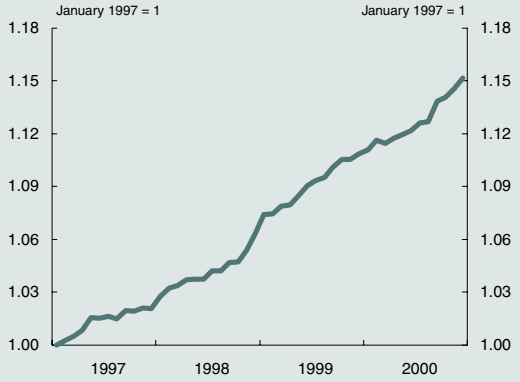
A monthly database supplied by the Automobile Studies Institute (IEA), with information on the prices and a wide range of characteristics of all the cars sold in Spain between January 1997 and December 2000, was used to measure quality improvements in the Spanish car industry and to calculate hedonic price indices. This database contains information on around 5,000 different versions of cars belonging to 200 models corresponding to 48 makes. The data on new registrations (the measure of sales of each car used), however, are available by model, which is why the basic unit of information of the study is the model [distinguishing by engine type (petrol or diesel)].

In principle, as already mentioned, the more the information available on car characteristics or quality indicators, the better the approximation of the quality changes. That said, these in-

(9) This section summarises Izquierdo, Licandro and Maydeu (2001).

CHART 3

Overall index of car quality



Source: Banco de España.

dicators 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, it is difficult to identify the value of each of the indicators by estimating traditional hedonic regressions, since the discrete estimates of these values may be biased and display instability problems. However, if a small number of indicators are used, the valuation of quality improvements may be inaccurate (owing to the omission of significant variables), if not an underestimation.

This paper proposes an alternative methodology consisting of classifying the available car quality indicators into sub-indices reflecting different aspects of quality, which are subsequently grouped into an overall quality index. Statistical analysis of the data enables the indicators to be organised into sub-indices, and it is then possible to estimate the weight of each indicator in the relevant sub-index and the weight of each sub-index in the overall quality index. This methodology enables us to work with a large number of indicators, which may be reduced to a single 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 the appropriate statistical accuracy.

The study departed from the information on 15 available indicators of car quality (10), which was summarised in a single overall quality index. The first step was to construct quality sub-indices, reflecting different aspects of the characteristics of cars. Using unrestricted factor analysis it was found that five such indices were necessary to satisfactorily reproduce the matrix of correlations between the original quality indicators. After testing numerous combinations, the 15 car quality indicators were grouped into the following five sub-indices: *a)* performance, based on acceleration and consumption indicators; *b)* power, based on volume and horsepower indicators; *c)* comfort, based on power steering, air-conditioning and front and back electric windows; *d)* safety, based on airbag, twin airbags, ABS and remote locking and *e)* luxury, based on computer, alloy rims and climate control. The second step was to construct an overall car quality index, as the first component extracted from the matrix of covariances between the five quality sub-indices, which enables the quality of each car to be summarised in a single number, readily interpretable in terms of the indicators that make it up. Chart 3 presents the average, weighted by sales, of the quality indices constructed for each model. This aggregate quality index can be seen to show substantial increases over the period of study (15% in four years).

3.2. Results

Having constructed the overall quality index for each car, an equation like [1], in which the set of characteristics in the regression has been replaced by the aforementioned index, can be readily estimated. Also included, are monthly dummy variables for the make and type of fuel, as explanatory factors, and the number of versions of each model, as an indicator of variety. The regressions were estimated – separately for diesel- and petrol-fuelled cars – by weighted least squares, with weights equal to the annual sales of the relevant model the previous year. Estimates were made for the complete data sample, for adjacent two-month periods and, finally, month by month. In the first two cases the temporary dummy variables give the path of car prices controlling for improvements in quality over the period, while in the third the monthly estimate of the price of quality is used to prepare the hedonic price index. Although the results obtained are very similar, the preferred estimation was that based on regressions for adjacent two-month periods. The hedonic car price index so constructed exhibits a clear downward trend, as can be seen in Chart 4. Specifically, it fell at an average annual rate of 2.1% between January 1997 and December 2000. The overall estimate for the complete data sample gives an average annual rate of 2.2%.

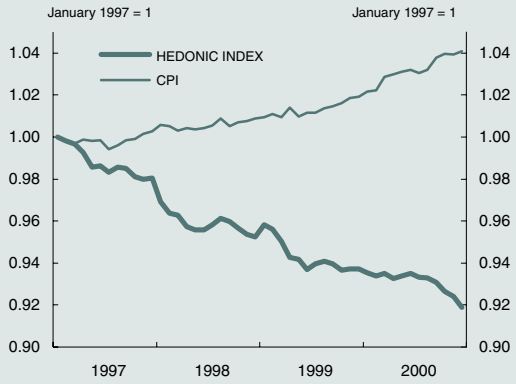
(10) The available database contains a wider set of characteristics, but various problems, basically associated with a high incidence of lost data, prevented them from being used.

One of the advantages of having a synthetic quality index is the ability to obtain stable month-by-month estimates of the price of quality. On the basis of this series of monthly quality prices an index of prices of characteristics of cars can be constructed for a constant quality level. The path of this price index is very similar to that of the corrected price indices estimated by the other two methods, with an average annual rate of fall of 1.9%. It is worth mentioning that in each estimation the results obtained indicate that the overall quality index constructed represents very closely the set of characteristics used in traditional hedonic regressions: the adjusted R^2 of the regression using only the overall quality index in the regressions is very high (it exceeds 90%) and, in comparison with the regressions in which all the available indicators are included, the loss of explanatory power is very small.

Finally, as in the previous case, comparing the CPI for cars (11) and the estimated hedonic price index enables the overestimation of prices in this sector, arising from insufficient consideration of quality improvements, to be quantified. Chart 4 shows the path of both indices over the study period, the effect of the quality corrections being clearly visible. In terms of average annual rates of change, the CPI for cars grew at an annual rate of 1%, while the hedonic index fell at an average annual rate of 2.1%. Accordingly, the implicit quality bias during the study period, from January 1997 to December 2000, is 3.1% per annum.

CHART 4

CPI and hedonic price index for cars



Source: Banco de España.

4. PRICE INDICES FOR NEW HOUSING (12)

4.1. Models and data used

In the study on the housing sector, inflation in the quality-adjusted prices of new housing is estimated in an alternative way to traditional hedonic methods. One particularly problematic aspect of conventional hedonic estimates for a product such as housing is that the omission of unobservable characteristics may seriously bias the results of the estimation. The exact location of housing, transport, traffic, proximity to services or construction quality are some of these characteristics, which are generally not observed but are relevant. In order to be able to bear these factors in mind and control very generally for the unobserved characteristics, we rely on the changes in prices of housing units belonging to the same housing development (or site). This ensures that price changes are not due to differences in house characteristics. That is the case insofar as houses on the same site share all the relevant characteristics (except size).

A property development takes the form of one or several blocks of apartments or various houses with similar quality standards built together on the same site. They may share certain facilities such as a garage area or garden. A site is usually on the market over an extended period of time, from 18 to 24 months on average. Therefore, the method proposed is based on the change in prices within sites over time to capture price increases net of changes in site characteristics.

To assess the extent of the quality adjustment in relation to identical data, the following equation is estimated as a benchmark:

$$\left(\log P_{it} - \log M_{it}\right) = \gamma_o + \delta_t + u_{it} \qquad [2]$$

where P_{it} is the price of dwelling i in year t and M is its floor area. The terms δ_t are coefficients of time dummy variables defined as changes in relation to the base-year value base γ_0. The δ_t estimated in [2] is the measure used here of non-quality-adjusted house price inflation, which is equivalent to the average house price statistics usually available, defined in terms of price per square metre. Specifically, the growth rate of average prices with respect to the base year is approximately given by $\exp(\delta_t) - 1$.

(11) This comparison may be affected by the fact that the series of car prices published by the INE contains a series of prices for second-hand cars. However, the weight of this latter series is certainly small. Moreover, an index of traditional prices was constructed, following the INE methodology as faithfully as possible, based on the data for new cars only, and this gave an average annual growth rate of 1%.

(12) This section is a summary of Bover and Velilla (2001).

The model with site-specific effects proposed to adjust for quality is:

$$\log P_{ijt} = \delta_t + \beta_j \log M_{ijt} + \zeta_j + v_{ijt} \qquad [3]$$

where j represents the site. Note that additive and multiplicative site-specific effects (ζ_j and β_j, respectively) are permitted, as some site facilities may conceivably influence the price-to-size elasticity. Indeed, this elasticity is expected to be less the more shared services are paid on top of the dwelling itself. In this model all the dwelling characteristics (except size) are included in the site-specific effects, both observable and unobservable characteristics alike. The site-specific effects can be estimated by means of repeated observations over time, and the availability of different types of dwellings (as defined by floor area) at each site.

The data used cover newly constructed housing in some of the main Spanish cities and on the outskirts of Madrid during part of the nineties. The database, provided by the Spanish Development Ministry, contains half-yearly information on new housing (apartments and houses) available. The amount of information in this database is most substantial. For each site there are details on the different types of dwellings available. The difference between them lies essentially in floor surface area. Moreover, apart from the price and floor area of the dwelling, there is information on a series of site characteristics: municipal district, total number of dwellings on the site, total number of dwellings on offer, number of bedrooms, number of bathrooms, availability of garage space, central heating, air conditioning, fitted wardrobes, kitchen fittings, utility space, lift, garden, swimming pool and sports facilities, among others. The wide range of the characteristics collected is one of the main advantages of this data set. It makes it possible to estimate conventional hedonic equations and compare them with alternative methods of obtaining quality-adjusted house price indices.

The sample period used starts in 1993 and ends in 1997. The cities analysed are Barcelona, Bilbao, Cádiz and its outskirts, Madrid, outskirts of Madrid, Málaga, Sevilla, Valencia, Valladolid and Zaragoza. On average, there are observations of 23,000 dwellings per half-year period for all the cities, relating to approximately 1,570 property developments.

4.2. Results

Firstly, the estimates for cities of the various price indices obtained are given. Specifically, for the different cities, Chart 5 shows the traditional average price per square metre index (the non-quality-adjusted reference indicator) and the hedonic index with site-specific effects proposed for housing quality adjustments. For most cities, the average per square metre index can be seen to outgrow, on average, the quality-adjusted index, although this is not so in all cases. This result has also been obtained in other countries over short periods [see Bureau of the Census (1997) and Fleming and Nellis (1985)] and has been attributed to short-term shifts towards lower-quality housing.

The estimated difference between the traditional average price per square metre index and the index proposed to adjust for quality is significant in most cities. This is evident in Chart 5, which depicts the confidence intervals of these two indices.

As earlier commented, standard hedonic equations have also been estimated and compared with the results obtained in the hedonic index with site-specific effects. Despite the fact that the database is fairly rich in observable characteristics, the course of quality-adjusted prices is very different, in both cases, for certain cities. Note that the models with site-specific effects, in addition to being robust to relevant but unobservable (and therefore omitted) characteristics, have a significant additional advantage. Indeed, unlike the traditional hedonic model (depicted in equation [1]), they require very few data on characteristics, namely: price, floor area and a single site identifier.

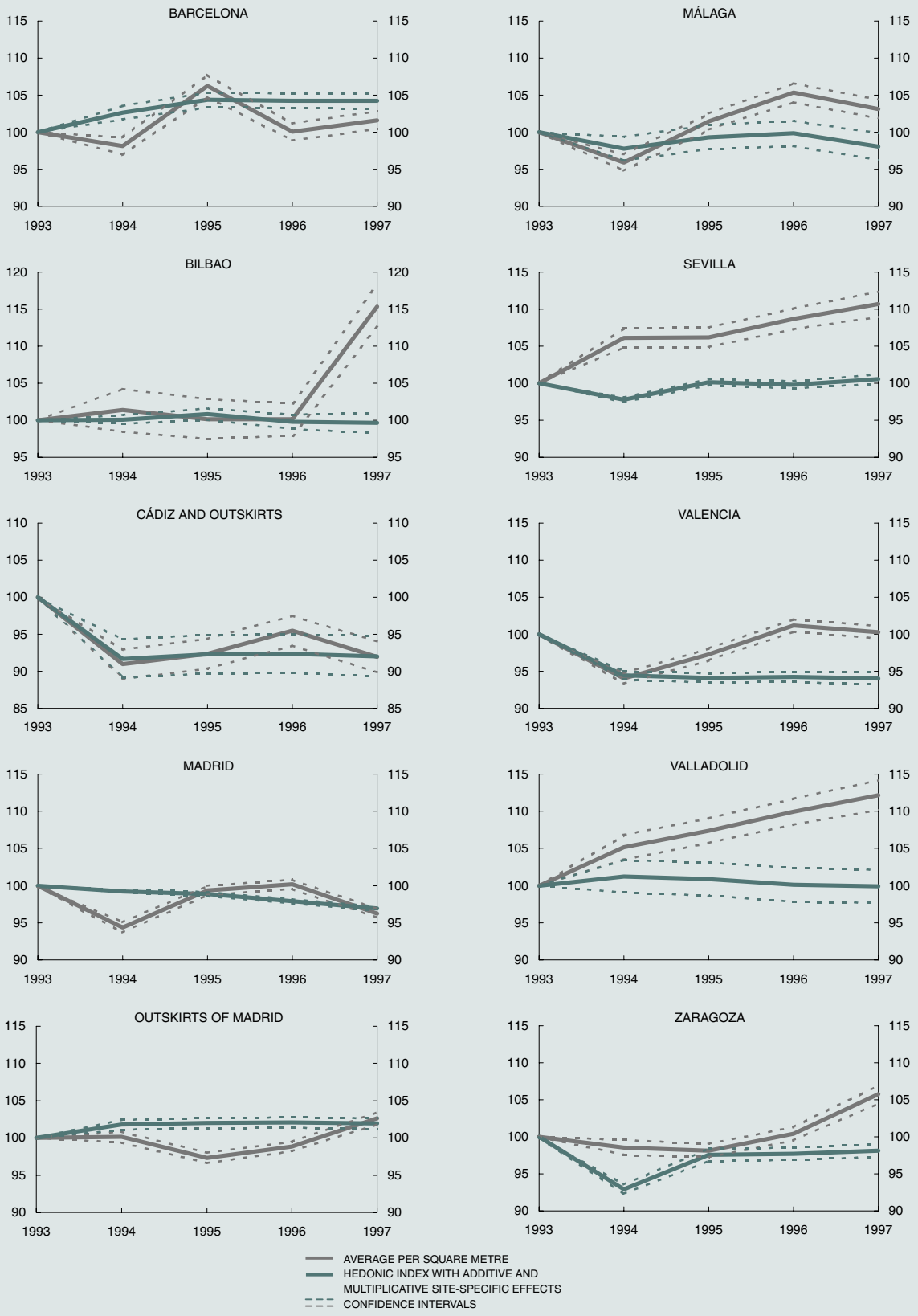
Thereafter, the previously obtained city indices have been used to prepare aggregate indices, which allows a more general assessment of the bias housing prices undergo when quality differences are not appropriately controlled for. The weights used are the city shares of dwellings in the sample. However, the results are robust to the use of different weights. The difference between the two aggregate indices, the average per square metre index and the hedonic index with site-specific effects is considerable. The upward bias due to increases in quality is estimated at between 0.75% and 1.2% per year throughout the period under analysis.

Finally, the quality-adjusted index is compared with the Spanish National Accounts residential construction deflator. The cumulative average growth of the official deflator was 3% for the period under study (13). By contrast, a cumulative annual decline of between 0.36% and

(13) A slight change was made to the definition of residential construction in 1995 and, therefore, there is a break in the index.

CHART 5

Estimated price indices for new housing and confidence intervals



Source: Banco de España.

0.56% is estimated for the quality-adjusted index. The upward bias of the residential construction deflator is therefore estimated at around 3.5% per annum for the period considered.

This is a sizeable discrepancy for a sector such as housing, and one that merits more detailed study. It is probably not only due to the fact that the Spanish National Accounts housing deflator is not adjusted for quality improvements in residential buildings, but also because it is affected by the very characteristics of the deflator, since what is largely involved here is an index based on the cost of construction industry factors. This problem of factor cost-based indices was earlier and originally highlighted in the Stigler report [see Price Statistics and Review Committee (1961)]. In fact, the difference in annual growth rates between the factor-based cost index and the non-quality-adjusted average price per square metre index is over 2 percentage points.

Lastly, the estimated indices are evidently based on a sample of cities that are not necessarily representative of the country as a whole. Nonetheless, for this to be responsible for the large discrepancy between the estimated index and the National Accounts deflator, housing inflation in the areas of Spain not studied here would have to be implausibly high. It may thus be concluded that, as in the case of the other two sectors analysed in this article, the results obtained are robust but should be treated with due caution.

5. MACROECONOMIC EFFECTS OF BIAS ARISING DUE TO CHANGES IN QUALITY

The empirical evidence provided in the foregoing sections confirms the presence of significant upward bias in the quantification methods habitually used to calculate the price indices of the three sectors analysed: computers, cars and housing. This is the result of an insufficient adjustment for quality changes in these products, changes which, in all the cases studied, are of great relevance. As these indices are used as indicators of the National Accounts deflators, the biases ultimately feed through to the macroeconomic variables in real terms. That not only biases the measurement of real GDP and its main components downwards, but also bears, for example, on the estimation of the economy's capital stock and on the measurement of total factor productivity.

Izquierdo and Matea (2001a and 2001b) furnished an initial estimation of the biases that may have been incurred in the measurement of Spanish macroeconomic magnitudes in the period 1986-1994 owing to an insufficient adjustment of prices to changes in the quality of products, applying to Spain the empirical evidence available for other countries. On the data provided at that time, the growth rate of real Spanish GDP during that period might have been understated by around two or three-tenths of a percentage point per year. It is now viable to use the results of those sectors where it was possible to make specific estimates for the Spanish case and arrive at a new, more accurate evaluation of the impact of biases arising from changes in quality on the measurement of real GDP and its main components, for the period 1995-1999. On this occasion the information used stems basically from the National Accounts, whereas a year earlier it was drawn from the Input-Output Tables. This is due to the fact that, on one hand, the sectoral breakdown in the new National Accounts involves a greater degree of detail and, on the other, because the Input-Output Tables are only available to 1996.

5.1. Simulation exercises

To quantify the effect of quality biases on the assessment of Spanish macroeconomic magnitudes in real terms, disaggregated information on nominal spending on each of the products considered is needed, along with their implicit deflators. These deflators, which are overstated owing to the presence of quality biases, are adjusted by the magnitude indicated by the specific sectoral studies, thereby obtaining deflators net of the quality changes. On deflating the nominal quantities of each of the products analysed by their corresponding adjusted deflator, a new figure for real-terms spending becomes available. The aggregation of these real quantities to GDP, and its components, allows – through comparison with the original quantities – for estimation of the macroeconomic effects of the quality-bias adjustments to the deflators.

The estimated final impact for the different components of aggregate demand will depend directly on the scale of the quality adjustments applied to the deflators and on the relative significance of the products affected. In the case of GDP, this impact will be lessened as a consequence of which portion of these products are imported, since their deflators are also subject to these biases and must be adjusted. The type of index used to aggregate the new real quantities is also a relevant factor in the calculation of quality bias. The Laspeyres-type quantities indices, which are those used by National Accounts, are constructed with fixed weights

based on initial-year prices. As a result, they tend to overstate the effects of quality adjustments. This is due to the fact that a fixed-weight structure does not enable the effect of changes in relative prices to be captured which, in the case of the products subject to quality changes, are usually fairly marked. Given this circumstance, a Fisher quantities index, which is the geometric mean of a Laspeyres index and a Paasche index (which uses weights based on final-year prices), proves more appropriate.

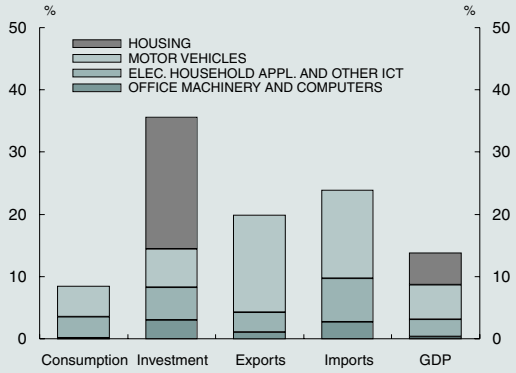
Chart 6 shows the relative significance of the four sectors considered most sensitive to changes in quality: housing, motor vehicles (hereafter, cars), office machinery and computers (hereafter, computers), and household electrical appliances and other ICT goods, which account for something over 8% of consumption, more than one-third of investment and around 20% of foreign trade, equivalent to 14% of Spanish GDP in 1999. That marks an appreciable increase in respect of the size of these sectors in the period 1986-1994, essentially reflecting their greater weight in private consumption.

Although the estimations made in the computer and car sectors refer exclusively to consumer products, their results have been extended to investment in these types of goods and to associated foreign trade flows, so as to complete the information needed to perform the exercise. This has made certain additional assumptions about the related deflators necessary. As, with regard to household electrical appliances and other ICT products (encompassing the manufacture of electronic equipment, precision instruments, and communications equipment and services), it has not been possible to estimate possible biases in the Spanish case, biases based on the empirical evidence found in other countries have been applied, as was done in the exercise performed in Izquierdo and Matea (2001a and 2001b).

The information used to make all these calculations is from the Spanish National Accounts product breakdown, although it has been necessary to resort to complementary data sources. In particular, the breakdown of investment by product available in the National Accounts has been expanded by resorting to the 1995 and 1996 Input-Output Tables, and deflators had to be constructed for investment on the basis of producer price indices and import unit value indices. Customs records have been used for the breakdown of the foreign sector items, while their deflators have been compiled using unit value indices. Lastly, the periods of the sectoral studies for cars (1997-2000) and housing (1993-1997) do not coincide, and this has also been taken into account.

CHART 6

Weight of products with quality-adjusted prices in relation to nominal GDP components in 1999



Source: Banco de España.

Given the degree of uncertainty prevailing about the exact amount of the adjustments for changes in quality, Table 1 proposes two alternative exercises. The first is the result of the direct application of the biases obtained in the sectoral studies conducted, with the odd minor adjustment. The second allows the uncertainty surrounding some of the assumptions made to be confined.

Specifically, in the first case, A, the downward adjustments in the deflators of the GDP components involved in this exercise were 26% for computers, 3% for cars and 3% for housing. In the case of the deflators of household electrical appliances and other ICT products, for which evidence relating to the Spanish economy is not available, an adjustment of 2% was opted for, in line with the data for other countries (as earlier mentioned).

In case B, regard has been had to the uncertainty about the adjustments made in the deflators of investment and foreign trade items of computers and cars, for which there is no direct evidence, and to which – as will be recalled – the same cuts that were estimated for the consumption of these products were applied. Thus, to avoid an overstatement through this channel, the 26% adjustment for the computers deflator has now been reduced to 20% in the investment and foreign trade items. Likewise, the 3% reduction applied to the car consumption deflator now stands at 2% for these same items. Further, the adjustment to the housing investment deflator has been considerably reduced from 3% to 1%. The reason for this change is that there is reasonable doubt about whether the difference between the housing deflator and the estimated hedonic index can be attributed in full to improvements in quality. Differences in Na-

TABLE 1

Aggregate effects on the real annual average growth rate, 1995-1999

	Consumption	Investment	Exports	Imports	GDP
Exercise A (a)					
Adjusted Laspeyres - original Laspeyres	0.38	3.34	3.16	2.79	1.19
Adjusted Fisher - original Fisher	0.27	2.33	1.93	1.87	0.75
Adjusted Fisher - original Laspeyres	0.25	2.29	1.78	1.89	0.70
Exercise B (b)					
Adjusted Laspeyres - original Laspeyres	0.38	1.94	1.89	1.80	0.77
Adjusted Fisher - original Fisher	0.27	1.36	1.20	1.28	0.49
Adjusted Fisher - original Laspeyres	0.25	1.32	1.05	1.30	0.45

Source: Banco de España.
(a) Adjustments applied: computers -26%, household electrical appliances and other ICT goods -2%, cars -3%, housing -3%.
(b) Adjustments applied: consumer computers -26%, computers for other uses -20%, electrical household appliances and other ICT goods -2%, consumer cars -3%, cars for other uses -2%, housing -1%.

tional Accounts coverage and the sample used or different methodological aspects of the quality adjustment in the calculation of the deflator could account for part of this difference. Therefore, in this second, more cautious scenario, it is opted to apply an adjustment of only 1%, which is the figure obtained if the respective courses of the average price per square metre of the sample and the hedonic index of housing prices are compared.

Although the results of these exercises should be interpreted with due caution, highly significant conclusions may be drawn. In both cases, the impact on real GDP and its components is very appreciable, particularly that relating to investment and the aggregates of the foreign sector. Moreover, it is clear that the type of index used in the aggregation is a fundamental element. As earlier indicated, estimates with Laspeyres quantities indices are overstated (these are those in the first line of each simulation), while those made with Fisher quantities indices (second line) provide a more appropriate measure of biases arising due to changes in quality that affect real variables. However, given that the National Accounts use Laspeyres-type quantities indices, it is also important to report the joint effect of introducing adjustments into the deflators owing to changes in quality and to change, at the same time, to Fisher-type quantities indices (third line).

As reflected in Table 1, in the first case considered (A) it is estimated that the real annual average growth of the Spanish economy for the period 1995-1999 could be understated by a figure fluctuating around 0.75 percentage points. In case B, where the risks of overstating the estimated effects have been limited, this figure diminishes to around half a percentage point. As earlier mentioned, the impact is particularly significant in the case of investment, where the upward adjustments are clearly in excess of two percentage points, in the first case, and somewhat lower than 1.5 percentage points in case B. Private consumption is the variable least affected, but the estimated biases are likewise significant, standing at approximately three-tenths of a percentage point of real growth per year. Finally, it is worth noting how the impact of the adjustments to imports and exports on GDP tends to cancel itself out in these years.

6. CONCLUSIONS

This article presents important empirical evidence on the differences between traditional price indices and price indices estimated using hedonic methodology, for three sectors of the Spanish economy, namely computers, cars and housing. The findings confirm the importance of correcting prices for quality biases to obtain an adequate view of their trends. In fact, when the deflators normally used in the National Accounts are corrected for the estimated biases, the real growth rates of the main macroeconomic aggregates are revised significantly upwards.

However, it should be pointed out that the extrapolation of empirical evidence on the magnitude of sectoral quality biases to Spanish National Accounts aggregates requires certain assumptions to be made that will affect the magnitudes eventually estimated. Moreover, the exercise does not take into account the changes in quality of other goods and services. In fact, in

some cases, there may have been losses of quality that would imply a bias in the opposite direction. Consequently, the estimates presented of the possible biases in the measurement of macroeconomic variables should be taken as indicative of the importance of taking the phenomenon of changes in the quality of products properly into consideration. It should also be noted that the adoption of hedonic methodology by statistics offices has its own problems. On one hand, it involves significant costs, so that it should only be adopted for certain key sectors, and on the other, the methodology itself has certain limitations which mean that some of its applications may be controversial.

A basic factor in studies like this is the availability of suitable databases, the characteristics of which sometimes influence the type of approximation methodology used. A special effort has been made in the studies presented here to obtain, analyse and edit the relevant information sources, notwithstanding which, the data used may have imposed certain biases on the results of the estimations. This should also be interpreted as an indication of the effort required to furnish the statistical agencies involved with adequate resources, if it is desired that they should continue with this line of research.

Analysis of the characteristics of the various goods studied shows that quality improvements have been significant in all cases. Those in the computer industry (speed, memory, capacity, etc.) particularly stand out, although improvements have also been notable in cars and housing. The particularities of the samples used have meant that approximations other than hedonic methodology have had to be used. For instance, in the case of cars, an overall quality index has been constructed for the industry to be introduced into the equation in place of the specific characteristics. In the case of housing, although information was available on a large number of characteristics, some of them are difficult to observe (such as location), and this may affect how good the estimates are. To resolve this problem residential property developments were taken as the unit of reference.

A measure of the bias arising from a partial or complete failure to correct the different rates of inflation for quality changes is obtained from the results of the estimates made. Specifically, the average annual growth of the price of computers is corrected downwards at an average annual rate of 26%; that of cars by 3% and that of housing also by 3%. The reference periods, with some variation, cover several years of the last decade. If these corrections are applied to the Spanish National Accounts deflators (for which purpose different information sources and certain specific assumptions are required) a certain approximation is obtained of the magnitude of the bias in the measurement of the real growth rates of the main macroeconomic aggregates in the Spanish economy. Also, to make this exercise as complete as possible and comparable with other studies carried out at the international and domestic levels, as done in Izquierdo and Matea (2001a y 2001b) for the period 1986-1994, the electrical household appliances industry and the rest of the ICT industries have also been included, although it has not been possible to make the relevant estimates for the Spanish economy.

In order to set a range for assessing the results and to clarify some of the assumptions made, two alternative scenarios have been prepared: the first one uses the values of the estimates made for the Spanish economy and the international empirical experience in the electrical household appliances industry and in the rest of the ICT industries; the second corrects some of the estimated biases downwards, thereby reducing the risk of exaggerating the estimated effects, as a consequence of excessive generalisation of the results obtained in the sectoral analyses. It should also be taken into account that the formula for aggregating the results is important. It is well known that Laspeyres indices introduce an upward bias into aggregate results, since their structure of fixed weights does not allow changes in relative prices to be taken into account. A Fisher index is more suitable for assessing the phenomenon in question.

Having made these clarifications, it is estimated that the average annual growth of the real GDP of the Spanish economy during the period analysed may be biased downwards by an amount ranging from half a percentage point to three-quarters of a percentage point. The bias is especially significant in investment, where the underestimation may lie between 1.4 and 2.3 percentage points. The impact on consumption is much smaller, given the lower relative importance of the sectors responsible for the corrections, and may be put at 0.3 percentage points. The impact on external trade flows is also notable, being estimated, in all cases, at well over one percentage point.

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REFERENCES

BANCO DE ESPAÑA (2001). "Los cambios en la calidad y la aparición de los nuevos productos: importancia de su valoración para la política económica", *Boletín económico,* January.

BERNDT, E. R. and RAPPAPORT, N. (2001). "Price and Quality of Desktop and Mobile Personal Computers: A Quarter Century of History", *The American Economic Review,* May, pp. 268-273.

BOVER, O. and IZQUIERDO, M. (2001). *Quality-adjusted prices: hedonic methods and implications for national accounts*, Estudio Económico No. 70, Servicio de Estudios, Banco de España.

BOVER, O. and VELILLA, P. (2001). *Hedonic house prices without characteristics: the case of new multiunit housing*, Estudio Económico No. 73, Servicio de Estudios, Banco de España.

BUREAU OF THE CENSUS (1997). "New One-Family Houses Sold", *Current Construction Reports*, May.

COURT, A. T. (1939). "Hedonic Price Indexes with Automobile Examples", in *The Dynamics of Automobile Demand*, pp. 99-117, General Motors, Detroit.

ECONOMIC COMMISSION FOR EUROPE (1993). "Annual Bulletin of Housing and Building Statistics for Europe and North America", United Nations, Geneva.

EUROSTAT (1999). "Report of the Task Force Volume Measures for Computers and Software", June, Luxembourg.

— (2000). "The Treatment of Owner Occupied Housing in the HICP", Final report of the Task Force XII.

FLEMING, M. C. and NELLIS, J. G. (1985). "The Application of Hedonic Indexing Methods: A Study of House Prices in the United Kingdom", *Statistical Journal of the United Nations*, pp. 249-270.

HOLDWAY, M. (2000). Quality-Adjusting Computer Prices in the Producer Price Index: An Overview, Bureau of Labor Statistics, November.

IZQUIERDO, M., LICANDRO, O. and MAYDEU, A. (2001). *Car quality improvements and price indices in Spain,* Estudio Económico No. 72, Servicio de Estudios, Banco de España.

IZQUIERDO, M. and MATEA, Mª LL. (2001a). *An approximation to biases in the measurement of Spanish macroeconomic variables derived from product quality changes,* Estudio Económico No. 71, Servicio de Estudios, Banco de España.

— (2001b). "Impacto de los cambios de calidad de los productos sobre la medición de las variables macroeconómicas: una aproximación a la economía española", *Boletín económico,* June.

— (2001c). *Hedonic prices for personal computers in Spain during the 90s*, Estudio Económico No. 74, Servicio de Estudios, Banco de España.

MOREAU, A. (1996). "Methodology of the Price Index for Microcomputers and Printers in France", in Industry Productivity: International Comparison and Measurement Issues, OECD Proceedings.

PRICE STATISTICS REVIEW COMMITTEE (1961). "The Price Statistics of the Federal Government", New York, NBER.