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C O N T E N T S

INTRODUCTION (1)

Price stability and a high rate of growth are two of the main objectives of economic policy. A correct measurement of these magnitudes is, therefore, essential for assessing a country's inflation and growth performance.

The rapid development of information technologies in recent years has brought measurement problems to light in many countries owing to changes in quality and the emergence of new products. Disregarding changes in quality leads to an underestimation of output growth and to an overstatement of price changes. Rapid ongoing technological progress in certain industries, such as computers, has highlighted the fact that the conventional methods used by public statistics offices to correct these biases are often inappropriate for capturing such quality changes. The alternative methodology most used and the one that has attracted most research is that based on hedonic methods.

Hedonic methods use information on the changes in product characteristics to break down price variations into those attributable to changes in characteristics and those that take place for given characteristics. In periods of intense innovation, the first component may be expected to increase, so that obtaining quality-adjusted price indices is particularly important.

The report by the Boskin commission in the United States [see Boskin *et al.* (1996)] showed to what extent the US consumer price index (CPI) might be affected by various measurement problems, particularly those relating to changes in quality. In the case of Spain, the size of potential CPI measurement biases has been addressed by Ruiz Castillo *et al.* (1999). However, as no papers have specifically assessed the scale of quality-related biases in Spain, the previous study used the results for the US (adjusting for Spain's different sectoral structure). The Spanish Na-

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(1) We thank L.J. Álvarez, M. Arellano, J.M. Bonilla, P. L'Hotellerie, Ll. Matea, F.Restoy, and J. Vallés for their comments and suggestions.

tional Statistics Office (INE) is currently setting up a new system of consumer price indices. This will come fully into force in 2002, and will foreseeably reduce the existing biases significantly. One area under study is the use of hedonic methods to correct the prices of certain goods.

Nonetheless, the problem of quality-related biases is not confined exclusively to the CPI. It is common to other price measures and has broader implications as it affects output and productivity growth estimates at the sectoral and aggregate levels alike. In this survey we focus on the use of hedonic methodology, and its implications, for measuring changes in quality in the deflators of significant National Accounts aggregates. Hedonic methods are used in the United States to deflate items accounting for around 18 % of US GDP, whereas only 5 % of the CPI items incorporate this methodology [see Landefeld and Grimm (2000)]. Furthermore, many of the hedonic studies conducted can be used for constructing deflators of National Accounts aggregates as well as for measuring changes in the prices of goods included in the CPI.

Traditionally, statistics offices have used various methods to adjust for changes in quality when they deem such changes to be sufficiently worth taking into account. One possibility is to use an overlapping method, i.e. when it is possible to observe two different models of a particular good in a common period, the ratio in the prices in the overlapping period can be used as a measure of the quality adjustment. Another possibility is to use only a sample of matched models, i.e. confining the sample to models whose characteristics do not change from one period to the next. These techniques are not feasible for goods involving rapid technical progress, as is the case with high technology products. For example, Berndt, Griliches, and Rappaport (1995) mention that in their sample of computers only 3 % of the models existing in 1991 survive up to 1992 if the matched-models restriction is used. Another widely used method is the valuation of the price of the change in the product, e.g. when a specific car model starts offering air-conditioning in its basic version. Estimating the cost of the air-conditioning is feasible either through information from the manufacturer or from published prices on the cost of adding this option. This is one of the most satisfactory traditional methods for taking quality changes into account (2). Often, however, information on the price of the change is not available. And above all, these methods assume that, to attain an increase in quality, an increase in production costs is necessary. This is not currently the case with high technology products.

(2) Table 3.2 in Gordon (1990) shows the percentage of quality-adjusted products considered by the Bureau of Labor Statistics in 1976 in its construction of certain producer price indices (PPI), along with the type of adjustment applied.

The hedonic method, popularised in the early seventies by Zvi Griliches, offers an alternative quality adjustment technique. It assumes that most models and varieties of a product (e.g. computers) can be understood in terms of a number of basic characteristics or attributes (speed, memory, etc). From this perspective, the scale of the problem of new models is substantially reduced, given that most of them can be seen as new combinations of existing characteristics. Estimation of the hedonic relationship provides the implicit prices of the characteristics (3). As we shall see, one of the specific uses of the hedonic methodology involves using the estimated prices of characteristics in the more traditional framework of valuing the price of the change.

The hedonic methodology has been adopted by the national statistics offices of several countries (Canada, the United States, France, and Sweden, among others) to construct various price indices, particularly consumer price indices and industrial production indices (4). Some of the reasons why it is not more widely used are the large amount of data required, the econometric problems involved and the fact that, in certain cases, the estimates obtained are not fully satisfactory (in particular, they are often unstable) (5). The OECD is currently sponsoring an international project to analyse the extent to which hedonic price functions are transferable from country to country. Its conclusions may be useful for the Eurostat project, which aims to create a centre where hedonic price functions are calculated for use across European countries.

The introduction of hedonic techniques for constructing price indices in production sectors characterised by rapid technological progress has led to sizable price declines being estimated in those countries that have adopted such techniques. The most notable case has been in the US computers and peripheral equipment industry. In 1985 the Bureau of Economic Analysis (BEA), the agency responsible for producing the US National Accounts, adopted the use of hedonic regressions. Since then, prices have experienced negative rates of change of between 10 % and 30 % (6). As a result, the estimated output of these industries in real terms has increased, since now nominal output figures are deflated by a lower price index. Higher real output estimates in these industries affect, inter alia, the study of sectoral contributions to growth, sectoral productivity developments, the figures for investment in this type of good and, con-

(3) Note, however, that this method also fails to capture shifts to totally new products, e.g. the shift from calculators to computers.

(4) Eurostat (1999) recommends the use of hedonic price indices for measuring prices in the IT industry.

(5) A defence of the robustness of the results of these techniques in the United States can be seen in Landefeld and Grimm (2000).

(6) Depending on the period and on the GDP component involved.

sequently, the measurement of capital stock. Finally, it also has a bearing on the economy's aggregate real growth figures.

The first part of this paper describes the hedonic methodology. In particular, we shall discuss the various aspects to be taken into account when estimating a hedonic function. Knowledge of these aspects is needed to assess the advantages and drawbacks of their use. Furthermore, we will describe the different types of indices that can be constructed on the basis of the estimation of an hedonic function.

The second part of the paper will survey various hedonic studies in the literature. The aim here is to evaluate the size of the biases potentially incurred through not using hedonic methods to adjust price indices for changes in product quality. Next, we shall describe the use made at present of the hedonic methodology by various national statistics offices in constructing National Accounts deflators. The focus will be on three products. First, computers and related equipment, which is where technical progress has been quickest and, therefore, where the largest quality-adjusted price changes have been recorded. Second, we shall review cars, this being a product that has undoubtedly undergone quality changes, though not to the same radical extent as computers. Moreover, cars may be particularly important in macroeconomic terms in Spain's case given the product's significant weight in production. The third and final product will be housing, given the crucial role of construction for properly measuring the real investment level. It is indeed in construction where a national statistics office (namely the US Bureau of Economic Analysis) first adopted an hedonic price index for housing and used it to deflate more than 50 % of the construction sector in the National Accounts. Types of housing differ from country to country and it is more difficult to adopt common quality-adjusted price changes than it is in an industry such as computers. On the other hand, improvements in housing tend to be slower.

In this paper we do not consider products such as videos, DVDs, etc. The Bureau of Labour Statistics (BLS) has recently adopted hedonic measures for their prices but these are items of relatively little significance in total expenditure according to the BLS (7). Nor do we review telephone equipment, which has seen significant improvements recently but for which there is not much empirical evidence. Finally, there are certain services (the financial sector, communications, transport, health) that have seen significant changes in quality; yet not only their characteristics but also, sometimes, their prices and output are very difficult to measure.

(7) Gordon (1990) provides seventeen hedonic indices for several household electrical goods, and for telephone and other communications equipment.

The third and final section will study the consequences at the sectoral and aggregate levels of the use of hedonic techniques in the measurement of prices of certain products. The adoption of these techniques by most countries is still some way off. Accordingly, international comparisons of developments in certain sectors, of investment and of economic growth should be performed bearing in mind the extent to which the behaviour in real terms of each of these magnitudes is affected by the use of hedonic price indices in some countries but not in others. Against this background, we will describe various recent studies that make macroeconomic comparisons using methodologies for measuring prices that are uniform from one country to another.

I

HEDONIC METHODS AND THEIR APPLICATION TO OBTAIN PRICE INDICES

The hedonic approach considers that the observed price of a product is a function of its characteristics. The estimation of this hedonic function provides the implicit prices of the characteristics. The so-called hedonic price indices are constructed on the basis of the estimated function. These indices show the change in the price of a good net of changes in its quality. There are several ways of constructing an hedonic index, given an estimation of the hedonic function. And in turn, there is more than one way of estimating an hedonic function. In this section we review first the various methods used to calculate hedonic price indices, given an estimated hedonic function. Secondly, we discuss certain aspects concerned with the estimation of hedonic functions.

I.1. Methods for calculating hedonic price indices (1)

I.1.1. Dummy variables

The technique used in this case to measure the price change of a specific product is to allow the constant term in the hedonic regression to vary over time. Assuming a linear specification we have

$$P_{it} = b_t + \sum_k a_k c_{ikt} + e_{it} \qquad [I.1]$$

(1) The main references for this section, among other sources, are: Gordon (1990), Griliches (1971), and Triplett (1986, 1989, 1990).

where P_{it} is the *i*-th observation of the product price in period t, c_{ikt} is the level of the *k*-th characteristic, a_k is the implicit price of characteristic *k,* and e_{it} is a disturbance term. The intercepts b_t are estimated as the coefficients of time dummy variables D_{st}, so that $b_t = \sum_s b_s D_{st}$, where $D_{st} = 1$ when s=t, and 0 otherwise. With this method, the estimated coefficients bt reflect the price changes from one period to another that are not due to changes in characteristics. For simplicity, in [I.1] we have assumed a linear relationship in the levels of the variables. However, the logarithmic transformation of the dependent variable and other non-linear transformations have been much used, as we shall discuss later.

In the literature the coefficients b_t have been estimated using a variable number of periods t. One possibility is to estimate [I.1] using the entire sample period with constant a_k coefficients. Another possibility is to estimate [I.1] using pairs of adjacent years (there is a potential problem here of a lack of sufficient observations), subsequently chaining the indices obtained. For example, to measure the change in price between periods 1 and 2 in this way, we would use the change in the constants and in the following equations:

$$P_{i1} = b_1 + \sum_k a_{12k}\, c_{ik1} + e_{i1}$$

$$P_{i2} = b_2 + \sum_k a_{12k}\, c_{ik2} + e_{i2}$$

The shadow prices of the characteristics, a_{12k}, are held constant in the two periods, although they may change between pairs of periods. In this way the prices of the characteristics a_k can change over time. Foreseeably, the implicit prices of the characteristics will change over time, especially for certain products (see, for example, Table 6 in Cole *et al.* (1986), where the fall in the prices of processing capacity and speed is clear). These price variations are related to changes in the underlying supply/demand relationships of the characteristics. A further problem with estimating a single equation using data from several periods is that, for products prone to rapid obsolescence and frequent technological innovations (as is the case with computers), the relevant characteristics for consideration change rapidly. Both the change over time in the estimated prices of the characteristics and the change in the overall set of relevant characteristics point to the use of alternative indices using the prices of the characteristics estimated period by period. We will describe these below. In practice, the number of periods used in estimating [I.1] will depend on the number of observations available and on the expected changes in the prices of the characteristics.

The dummy variable method was initially the one most used [Court (1939) and Griliches in his early work]. An advantage of this method is that the price index is given directly and straightforwardly. Moreover, it avoids the problem of using the estimated coefficients of the characteristics (as in the methods we shall see below) in the event of multicollinearity. Indeed, in that case (which is not unusual in hedonic function estimates), the estimated coefficients may be very unstable. However, a problem with this method may arise if we have characteristics of the models that are relevant but have not been considered. If the composition of the samples in different years is not comparable (in terms of the characteristics not included), changes in the characteristics not included in the analysis will be correlated with D_{st} and, therefore, b_t will not be capturing a quality-adjusted price change effect. There have been some proposals to refine the method [e.g. Berndt and Griliches (1993), and Gordon (1990)].

I.1.2. Characteristics price indices

As we have seen, hedonic functions provide estimates of the prices of the characteristics. It is natural to think of an index based on these prices, using the amounts of characteristics as weights. The difference from the dummy variable method lies in the fact that the shadow prices of the characteristics are allowed to change in each period. Such indices were first considered by Griliches (1964), who calculated Laspeyres and Paasche indices of characteristics for cars. In this way we can calculate, for example, the price in the current period of the amounts of characteristics contained in a base period good. This is the type of index that the US *Bureau of Economic Analysis* uses to construct its index of new house prices.

Specifically, if we estimate, for each period t, the following regression

$$P_{it} = b_t + \sum_k a_{kt}\, c_{ikt} + e_{it} \qquad [I.2]$$

a Laspeyres-type quality-adjusted price index would be

$$I_{Lt} = \frac{\hat{b}_t + \sum_k \hat{a}_{kt}\, Q_{kt_0}}{\hat{b}_{t_0} + \sum_k \hat{a}_{kt_0}\, Q_{kt_0}} \qquad [I.3]$$

where Q_{kt0} are the averages of the quantitative characteristics (or the proportions of the qualitative variables) existing in the base period. $\hat{b}_{t_0}$ y $\hat{a}_{kt_0}$ are the coefficients obtained from estimating [I.2] for the base period t_0 , and $\hat{b}_t$ $\hat{a}_{kt}$ are those obtained estimating [I.2] for each period *t* considered.

If [I.2] (or [I.1]) is non-linear, which is often the case in practice in hedonic estimates, the price of the characteristics will depend, in turn, on the amount of the characteristics and on the level of product prices [see, for example, Triplett (1989)]. These amounts and prices may, among other possibilities, be the averages. In turn, these averages may be calculated for different periods. For example, if both the dependent variable and the characteristics are in logarithms, the implicit price of the *k*th characteristic will be given by: $\hat{a}_{kt} \frac{P_{it}}{c_{ikt}}$.

I.1.3. Imputing price

Let us assume that the new and old models of the product we wish to compare differ only in the amount of one characteristic (e.g. the amount of memory a computer has). Let us further assume that the manufacturer cannot place a value on the variation in production cost directly attributable to this change in memory capacity. Having estimated the price of the characteristic hedonically (here again, in the non-linear case, there is not a single price for this characteristic), a value can be given to the difference in the amount of the characteristic, adding (subtracting) this amount to (from) to the observed price of the old (or new) model. For example, in an hedonic regression for personal computers in the United States for June 1999 [see Holdway (2000)], the estimated coefficient relating to the system memory variable is 1.686. Let us assume that the price of the equivalent personal computer were to hold at \$1500 but that the amount of memory were to increase from 32 to 64 MB. Under this imputation method the change in price, adjusted for quality, would be:

$$P_I = \{[(1500 - (32 \times 1.686)) / 1500] - 1\} \times 100 = -3.6\ \%$$

With this adjustment, the price can be used to calculate a traditional product index, together with the prices taken for the models that have undergone no changes in quality. This is the method used by the United States in constructing hedonic prices for computers. One advantage with these indices is that they allow observed prices to be used to the maximum, thus minimising the potential specification errors of hedonic functions.

More generally, if we have some products that are comparable from one period to another, while others are only observed in one of the two periods, hedonic regressions can be used to estimate missing prices. Specifically:

$$P_{lit} = \widehat{b}_t + \sum_k \widehat{a}_{kt}\, c_{ikt}$$

In the literature on changes in quality and hedonic prices, there is little discussion of the advantages and drawbacks of the various indices described above. In general they provide similar price evolutions. However, this is not always the case.

The different ways of constructing hedonic indices can be seen as alternative ways of specifying price changes of a certain product. In fact, according to [I.2], price changes arise via changes in the prices of the characteristics a_{kt}. Accordingly, it is the prices of the characteristics in different periods which come into play in the calculation of the index in [I.3]. On the other hand, according to [I.1], the change in prices b_t is considered as the residual variation in prices not attributable to any specific factor.

I.2. Relevant considerations for estimating hedonic functions

The previous sub-section described different forms of obtaining hedonic price indices once an hedonic function had been estimated. We shall now discuss certain issues concerning the estimation of hedonic functions.

I.2.1. Theoretical framework

The theoretical relation between the hedonic function and utility and production functions was established by Rosen (1974) [see also Epple (1987) and Bartik (1987)]. This analysis assumes that the true arguments in the utility functions (and the true inputs in the production functions) are the characteristics of the goods and not the goods themselves (2). Agents behave according to a set of supply and demand functions of characteristics. In equilibrium, the hedonic price function reflects the distribution of the marginal rate of substitution of consumers and the distribution of marginal rates of transformation of firms. However, except in very particular cases, the hedonic price functions do not allow identification of the demand or the supply of characteristics and, therefore, neither

(2) Note that this approach assumes divisibility in production.

the consumer preference structure nor the production technology that generates them can be recovered. Among other things, hedonic price functions provide information on the budget constraint facing consumers in terms of characteristics. Namely, on the amount of the j-th characteristic that consumers must forgo to obtain a greater amount of the k-th characteristic, holding constant the product price. This constraint will often be non-linear, since for many functional forms of the hedonic equation the implicit prices of characteristics will depend on the level of such characteristics.

I.2.2. Representativeness and quality of the sample

Early studies used data on prices and specifications of the various models without taking into account the sales of each model. The data would be drawn, for example, from specialist publications. However, it is not desirable that the poorly selling models should overly influence the results of hedonic analyses. Therefore, although this is often difficult to achieve, representative samples of the models sold or the proportion of sales of each model should be used. For example, let us assume that the data available to us are not a random sample of computers sold, but that we have a list of the various models available on the market (along with their prices and characteristics). If we can obtain from some other source the proportion of sales of each model, we could use weighted least squares to adjust for the share in sales of each model [see, for example, the discussion in Berndt (1991) for the case where the use of aggregate data causes heteroskedasticity of the errors].

In hedonic studies, data quality is specially important. Owing to the frequent presence of multicollinearity in empirical hedonic functions, the estimated coefficients are often rather sensitive to errors in the data. Therefore, in-depth filtering of the data (for instance, checking them off against other sources of information) is often crucial for obtaining credible and stable hedonic functions.

I.2.3. List prices versus transaction prices

The most suitable data for an hedonic analysis are actual transaction prices. However, in most hedonic regression studies, the variable used is the manufacturer's listed price, owing to the difficulty in obtaining the transaction price. For articles (or periods) with frequent and sizable discounts (in the case of cars, for example), manufacturers' listed prices are not very good proxies for actual prices.

I.2.4. *Choice of variables*

As we have seen, hedonic analysis assumes that the production and consumption of goods (and services) can be analysed breaking these products down into their characteristics which are, ultimately, the object of the transaction. As discussed, the hedonic price function will most generally reflect, in equilibrium, consumers' (or buyers') preferences and manufacturers' (or sellers') production technology. Therefore, the characteristics that should be considered in an hedonic analysis are homogeneous economic variables from which the heterogeneous goods are constructed [see, for example, Triplett (1986)]. If characteristics-based price indices are to have any economic meaning and not be a mere statistical artefact, the variables selected as characteristics should represent what the buyer values when purchasing a product and what absorbs resources in production. Appropriate choice of the characteristics of a product requires, in many cases, technical knowledge of the production and the use of the product.

For example, in the early hedonic studies on cars, one of the variables used was the weight of the car. But weight is not a technical characteristic that is valued by consumers. It was included on the grounds that weight is a good proxy for the characteristics which are not observable, for instance, the comfort of the car. Sometimes, too, weight has been included because of its correlation with other characteristics (for instance, engine power, size) and the impossibility of obtaining separate implicit price coefficients for these characteristics owing to multicollinearity between them. However, the danger of using proxies should be highlighted because changes in the relationship between the proxy and the real technical variables may inadvertently occur. For example, thanks to technical progress, cars are produced that are lighter but which retain the level of comfort previously achieved only with greater weights.

Capital goods are also often valued in terms of their capacity to produce a certain output rather than because of their physical specifications. Gordon (1990) offers as an example a locomotive that is valued more for the weight it can pull at a certain speed than for its engine's horsepower. If technical progress increases the efficiency of the mechanism transmitting the engine's power to the wheels, but it is the engine's horsepower which appears in the hedonic regression, biases arise in the price estimates. Nonetheless, most hedonic studies have used data on physical characteristics rather than on performance, owing to their readier availability [for an exception, see Ohta and Griliches (1976)].

Finally, the importance of the characteristics selection process should not be understated, stressing the fact that if a characteristic which is a significant factor in price formation is omitted, the price indices derived from the hedonic regression may be biased.

I.2.5. Functional form

In some particular cases, economic theory offers precise indications as to the form of the hedonic price function. One of the examples mentioned by Triplett (1989) is the case in which all producers have the same production technology. In this case, the hedonic function will be «bowed-in», like the production isoquants. The double logarithmic function has this property and has been used in several hedonic studies on computers [another example can be found in Arguea and Hsiao (1993)]. Feenstra (1995) discusses how, in non-competitive situations in which prices are above marginal costs, a log-linear form may provide downward-biased estimates of the hedonic price index. In such cases, a linear relationship may be preferable.

However, except in special cases, the choice of functional form is an empirical matter. The linear, semi-logarithmic, double logarithmic and translog functional forms are those most used. In some studies, in order to compare statistically alternative functional forms, the Box-Cox transformation is used

$$\gamma = (\gamma^{\lambda} - 1)/\lambda \qquad \text{for } \lambda \neq 0$$

$$\log \gamma \qquad \text{for } \lambda \rightarrow 0$$

and the transformation providing a smaller mean squared error is chosen.

Cassel and Mendelsohn (1985), for example, warn of certain problems in the use of this transformation. In particular, if the variable we are interested in predicting is the non-transformed price of the good, having to go through the prediction of the transformed variable adds a bias (which will depend on the variance of the estimated residuals and on the functional form), for which an adjustment must be made. Moreover, as mentioned earlier, in non-linear cases the implicit prices of the characteristics will depend not only on the estimated coefficient, but also on the variables.

II

HEDONIC PRICES: EMPIRICAL EVIDENCE AND ITS USE IN STATISTICS OFFICES

In this section we shall review the empirical studies in which hedonic prices are obtained for the three types of products mentioned in the introduction: computers, cars and housing. In particular, we shall gather the estimates available on the magnitude of the differences in price changes, depending on whether hedonic or traditional methods are used. We shall then mention the National Statistics Offices which have adopted hedonic methods in constructing some of the deflators used in National Accounts items. Lastly, we shall detail in each case the particular use made of hedonic methods, as far as we can tell from the available information.

II.1. Computers

II.1.1. Available estimates of potential biases

In general, the studies of hedonic prices for the computer industry analyse separately the different components of computers, namely processors, peripheral equipment (disk drives, printers, screens), due both to the different characteristics to be taken into account in each case and to the different price evolution. For a discussion on the aggregation of the indices of the various computer components, see Triplett (1989) and Gordon (1990).

Early studies focused on hedonic price estimates for mainframes. Chow (1967) estimated an average annual rate of decline of -20.8 % for the period 1960-65. For a more extensive period from 1951-84, Gordon (1989) found that these prices had fallen on average by 20 % per year, but that there were differences across periods (1). Triplett (1989) provided annual estimates from 1953 to 1984. According to these estimates, prices fell on average by 27 % per year from 1953 to 1972, and in 1984 the quality-adjusted price of mainframes was one-tenth of its value in 1972 (2). On the other hand, the official US non-hedonic price index of computers remained constant from 1953 to 1985.

Gordon (1990) was the first to provide estimates of changes in personal computer prices based on a pilot study. More extensive papers in this connection are those of Berndt and Griliches (1993), Berndt, Griliches, and Rappaport (1995) and Nelson, Tangay, and Patterson (1994). All these papers show price falls that are greater than for mainframes, namely with declines of around –28 % per year in the period 1982-92. Berndt, Griliches, and Rappaport (1995) and Berndt, Dulberger, and Rappaport (2000) stress the need to model laptop and desk-top PCs separately and to take into account changes in the estimated coefficients over time. With estimates spanning the period from 1976 to 1999, the findings in Berndt, Dulberger, and Rappaport (2000) indicate that the fall in PC prices has been greater in the nineties than in the seventies and eighties, and greater in the late than in the early nineties.

Conversely, in the case of most peripheral equipment, the studies find a smaller decline in quality-adjusted prices, although these changes are very substantial [see, for example, Triplett (1989) and Table II.1 with the results in Cole *et al.* (1986)].

Finally, there are problems with studying software price changes hedonically, given the difficulty of defining the relevant characteristics. Eurostat (1999) mentions that the declines in software price indices adjusting for quality are not comparable with those that have taken place in the case of hardware.

A recurrent theme in studies of hedonic prices for computers is the treatment of the so-called technological disequilibrium. Indeed, in the case of products undergoing substantial and constant technological innovations, in the same period new models coexist alongside previous models that do not disappear immediately with the introduction of new, better models. The new models may be better than the previous ones in terms of characteristics, and they may also be cheaper. To avoid the disequilibrium problem, some authors focus only on new models. This may be a valid approach when studying price changes with an interest in technological progress. But

(1) All the studies referred to are for the United States.

(2) Triplett (1989) offers a survey of the work conducted until then and also provides two tables summarising the characteristics and functional forms used in the various studies.

TABLE II.1

PRICE INDICES FOR COMPUTER EQUIPMENT: HEDONIC AND MATCHED-MODEL ESTIMATES

	Processors		*Disk-drives*		*Printers*		*Terminals and Screens*		*Desk-top PCs*			*Laptop PCs*		
	Matched models	*Hedonic methods*	*Matched models*	*Hedonic methods*	*Matched models*	*Hedonic methods*	*Matched models*	*Hedonic methods*	*Arithmetic mean*	*Matched models*	*Hedonic methods*	*Arithmetic mean*	*Matched models*	*Hedonic methods*
Annual rate of change (average)														
Cole *et al.* (1986), Dulberger (1989)														
(1982 = 100)														
1972-77	–3.0	–8.5; –12.8	–7.9	–13.4; –18.9	–2.6	–4.4; –6	–0.4	–3.1; –4.0						
1977-84	–12.2	–22.3; –25.1	–6.2	–10.9; –15.5	–4.1	–14.4; –22.3	–2.0	–9.5; –10.8						
1972-84	–8.5	–17.3; –19.5	–6.9	–12.6; –16.9	–3.5	–10.4; –15.5	–1.3	–7.3; –7.8						
Berndt, Griliches, and Rappaport (1995)														
(1989 = 100)														
1989-92									–9.7	–19.3	–31.1; –36.6	–10.6	(a)	–17; –26.5

(a) Not available. For the period 1990-92 they provide: arithmetic mean, –12.5 %, and matched models, –24.7 %.

it is not satisfactory when a deflator of the production value of computers is sought. Papers that cover all the models existing in each period and provide alternative treatment to this problem are, for example, those by Cole *et al.* (1986), or Berndt, Griliches, and Rappaport (1995).

In addition to these studies, there are many papers that calculate computer prices with hedonic methods [see Table II.2 for a summary of findings, and the references in Triplett (1989), Schreyer (1998), or Landefeld and Grimm (2000)]. It is more difficult to find papers providing comparable estimates of price variations taking into account quality changes in a non-hedonic and hedonic way. In Table II.1 we reproduce results obtained in Cole *et al.* (1986), Dulberger (1989), and Berndt, Griliches, and Rappaport (1995). These compare hedonic indices and matched models indices. From this table we can conclude that a difference of –10 % per year on average between computer price changes measured using traditional methods to take into account quality changes, and those measured hedonically is, in general, reasonable. This is the estimate of the bias adopted in Schreyer (1998) in a simulation of the implications for the measurement of National Accounts magnitudes.

We should mention here a variation of the traditional method of comparing samples of products that do not change from one period to another (matched models). This method appears to lead, for certain types of goods, such as computers, to similar results to those obtained with hedonic methods. The idea is to collect, for each period, prices and quantities for a representative sample. The models in a representative sample at t are compared with homogeneous models at t+1, and an index is constructed between t and t+1. Then, based on a representative sample of t+1 (different from the one used in the comparison t/t+1), the index between t+1 and t+2 is calculated. Finally, the indices thus obtained are chained. The difference from the traditional method of comparing similar samples is that the same sample is not tracked for several periods, just for two. For this method to be valid for quality-change adjustments, the information should be collected frequently (monthly or quarterly) and at each point in time the proportion of models sold corresponding to recently introduced models (or models about to be discarded) should be small. Aizcorbe, Corrado, and Doms (2000) describe and justify this method in detail. Moreover, they calculate price indices for PCs and microprocessors under this method and compare the results with those obtained under hedonic methods. They find that between 1994 and 1998 the two types of indices show similar trends (–29.1 % and –29.8 % in annual average terms), but from one year to the next the discrepancies are sometimes considerable. These authors argue that this method of (frequent) overlapping adjacent-period comparisons is more reliable than the hedonic method. Significantly, Austria is experimenting with this method to de-

TABLE II.2

HEDONIC ESTIMATES OF PRICE INDICES FOR COMPUTERS

Reference and country	*Type of computer*	*Period*	*Annual average rate of change*
Chow (1967), USA.	Mainframes	1960-65	–21
Gordon (1989), USA	Mainframes	1951-84	–20
Triplett (1989), USA.	Mainframes	1953-72	–21
....	PCs	1972-84	–15
Cartwright (1986), USA.	Mainframes	1972-84	–14
Cole *et al* (1986), USA	Mainframes	1972-84	–19
Gordon (1990), USA	PCs	1951-84	–20
....	PCs	1981-87	–30
Berndt and Griliches (1993) , USA	PCs	1982-89	–20; –33
Berndt, Griliches, and Rappaport (1995), USA	Desk-top	1989-92	–31; –36
....	Laptop	1989-92	–17; –26
Nelson, Tanguay, and Patterson (1994), USA	PCs	1984-91	–27
Berndt, Dulberger, and Rappaport (2000), USA	PCs	1983-89	–18
....	PCs	1989-94	–32
....	PCs	1994-99	–39
Aizcorbe, Corrado, and Doms (2000), USA	PCs	1994-98	–30
....	Desk-top	1994-98	–31
....	Laptop	1994-98	–26
IBEA price index, USA	PCs	1994-98	–32
Shiratsuka (1999), Japan	PCs	1991-94	–24.4
US BEA price index before the introduction of hedonic methods.	Computers	1953-85	0

flate the software and computers component in its National Accounts [see Eurostat (1999)].

II.1.2. Hedonic indices for computer equipment prices in National Statistics Offices

a) United States

The BEA, the US National Accounts agency, has been using computer price indices based on hedonic methods to deflate several components of output since December 1985 (3). Until then, it had assumed that the computer price index had held constant since 1953.

The index originally used [see Cartwright (1986)] was a combination of indices for certain computer components (processors, disk drives, printers, terminals and screens). These indices were developed jointly with IBM. The data used (annual, from 1972 to 1984) on prices and characteristics were drawn from sales manuals, for IBM, and from trade and press information for the other three companies considered. Detailed information on characteristics and the hedonic specifications used for each computer component can be found in Cole *et al.* (1986). These indices had two substantial limitations. First, the sample of processors was confined to models sold by IBM and the other three companies with totally compatible products; moreover, personal computers were not included among the products sampled. Second, full information was not available on amounts dispatched, which act as the appropriate weights in the construction of the index.

In parallel, the BLS, the agency responsible for constructing the producer price index, began publishing an index of computer prices in 1991 that included hedonic quality adjustments, having experimented with such an index since 1987 [see Bureau of Labour Statistics (1997)]. The way the BLS obtains the sample is a significant improvement on other studies. First, the companies in the industry are selected in proportion to their employment (about thirty at present). Next, within each company, the products and the models are selected in proportion to sales. In addition to this type of basic information, the BLS also uses information which varies according to the product. Until 1996, this information was drawn from specialist publications, and from 1997 onwards from producers' sites on the Internet. Holdway (2000) offers details on the sample, specification and estimated coefficients for the case of personal computers. The specification is linear and among the characteristics included are memory, hard disk capacity, monitor size, video and sound cards, fax-modem, and operating system. The use the BLS makes of the estimated hedonic equations should be highlighted. Indeed, these estimates, made period by period, are used to adjust production prices when technical changes arise, i.e. to obtain the implicit prices for changes in the technical characteristics of computers included in the industrial production index (see the example in section I.1).

Currently, the BEA uses the detailed price indices for computers, peripheral equipment, etc. of the BLS [see Landefeld and Grimm (2000) or

(3) It also provides estimates for earlier periods, initially from 1969 and later from 1959.

Bureau of Economic Analysis (2000)]. To measure prices and real GDP, the BEA has been aggregating these indices since 1995, using chained indices with weights of adjacent periods.

As regards software prices, the BEA only used hedonic indices during the period 1985-93, and only for word processors and spreadsheets.

b) Other countries

INSEE, in France, publishes hedonic method-based prices for PCs and printers among its producer price indices. It began to publish these indices for PCs in 1991 (with retrospective figures from 1988), and for printers in 1992 (figures from 1990).

The nine major brands in the French market collaborate in the construction of the sample. Given the impossibility of distinguishing between computers (or parts thereof) produced outside or inside the country, the aim of this producer price index is to monitor the changes in prices paid by the first purchasers in French territory, in this case the distributors. To obtain the aggregate index, annual sales figures, broken down by manufacturer, type of processor, portability, etc., are used as weights.

The type of hedonic index used differs for PCs, on one hand, and for laptops and printers, on the other. In the case of PCs, an estimate is made, for several periods (4), of a relationship with quarterly data of the type

$$\ln P_{it} = b_{jlt_n} + \sum_k a_k c_{ikt} + e_{it}$$

where the coefficients b vary according to the brand (j) and the type of processor (l), and according to whether it is the first period in which it is on the market (t_n) (5).

In the case of laptops and printers, the observations available at INSEE are too few to enable use of the previous method where the dummy variables vary with both the brand, the type of processor and the newness of the model. In these cases INSEE estimates a relationship of the type

$$\ln P_{it} = b_{jt} + \sum_k a_{kt} c_{ikt} + e_{it}$$

(4) Initially, an hedonic equation was estimated for each company using pairs of adjacent years. This level of detail was abandoned because it was too costly.

(5) For details on the characteristics included in the INSEE models, see Moreau (1996). For comments on the difference in France in obtaining computer price indices for the consumer price producer price indices, see Bascher and Lacroix (1999).

for each quarter t, where the coefficients vary only according to the brand. The results of this estimate (specifically, the estimated coefficients $\hat{a}_{kt}$) are used to impute the price of the characteristics in the way of the example in section I.1 (price imputation).

In Canada (6), in 1986, the index used to deflate imports was changed in order to use the new hedonic indices of the BEA (7). These indices were also used as production deflators until 1992. That year (and with figures from 1990) hedonic production indices for PCs and printers based on information supplied by Canadian distributors began to be constructed. At present, work is underway on replacing these samples with data provided by manufacturers. The type of index used combines hedonic methods with more conventional quality-adjustment methods, and is similar to that used in the United States.

In constructing its official wholesale domestic price index, the Bank of Japan adopted the use of hedonic methods in its 1990 revision. The types of computers considered include PCs (laptops and desk-top alike) and mainframes (8).

Although we do not have precise information, Scarpetta *et al.* (2000) mention that hedonic methods are also being used in the construction of producer price indices for computers in Sweden and that Denmark uses the US hedonic index, adjusted for the exchange rate. According to Eurostat (1999), a type of hedonic adjustment is also used in Sweden in the import price index for PCs.

II.2. Cars

The early hedonic price studies were made for cars [Court (1939), Fisher, Griliches, and Kaysen (1962), Griliches (1964), Triplett (1969), Griliches (1971), Ohta and Griliches (1976)]. Along with computers, cars are the product on which most studies relating to prices and quality changes have focused (see a summary of findings in Table II.3). Court (1939) found that, according to his hedonic price index, there had been a

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(6) Information based on Lowe (1996, 1999) and Baldwin *et al.* (1997).

(7) Revised figures as from 1971 were published.

(8) For more information on the functional form and the characteristics chosen, see Baldwin *et al.* (1997).

55 % fall in new car prices in the period 1925-35. Conversely, the official BLS figures showed an increase of 45 %.

Nonetheless, no statistics office uses hedonic methods in constructing car prices. In the United States, the BLS publishes a breakdown of quality adjustments (both for passenger vehicles and for light trucks) divided into three categories: safety improvements, emission-control equipment and other changes. The adjustments are made on the basis of the production costs reported by manufacturers (9). Despite acknowledging that this is not a very satisfactory means of adjusting for quality changes [Triplett (1990)], the same author [in Triplett (1997)] sets out certain problems in using hedonic equations for cars, with the data available (10).

In particular, Triplett argues that the complexity of modern cars probably excludes the use of hedonic methods in constructing price indices for vehicles both for the consumer price index (CPI) and for producer price indices (PPI). He stresses that the characteristics that must be included in an hedonic function are variables which generate utility and that the variables normally included are very rough approximations to what consumers want from a vehicle. Moreover, it would also be theoretically correct to include variables interpretable as arguments in manufacturers' cost functions. Yet nor do the variables included square very well with this concept.

Even if the variables included are thought to be functions of the true arguments of consumer utility functions and of manufacturers' costs functions, it would be necessary to ensure that these functions remain stable over time (see the example of the weight of cars in section I.2).

Another limitation mentioned by several authors [for example, Gordon (1990), Triplett (1969)] is that cross-section hedonic regressions cannot capture improvements that are incorporated simultaneously into all vehicles. This is the case with certain new security fittings and emission-control mechanisms to reduce pollution which were introduced by law.

Consequently, Triplett (1997) argues that, in practice, hedonic price indices for cars will not adequately reflect quality changes, at least not until data on characteristics are gathered which are better suited to the requirements of hedonic functions theory.

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(9) For more information on the BLS method, see Gordon (1990), Chapter 8.

(10) J. Triplett is chief economist at the BEA.

TABLE II.3

HEDONIC ESTIMATES OF PRICE INDICES FOR CARS (a)

Reference	*Type of car*	*Period*	*Annual average rate of change. Hedonic index*	*Annual average rate of change. Traditional index* (b)
Court (1939)	New	1925-35	–7.7	3.8
Griliches (1964)	New	1947-61	0.5; 1.8	3.3
Triplett (1969)	New	1960-66	1.5	–0.9
Griliches (1971)	New	1937-60	1.2; 2.9	4.3
Ohta and Griliches (1976)	New	1955-71	1.0	0.9
....	Second-hand	1961-71	2.3	3.1
Gordon (1990)	New	1947-83	3.9	2.9
....	Second-hand	1953-83	3.4	4.4

(a) All the studies are for the United States.
(b) CPI for cars adjusted for quality changes through production costs reported by manufacturers.

Certain findings from comparisons made for the United States between official and hedonic indices appear to point along these lines. For instance, Gordon (1990) provides a table (Table 8.8) in which the similarity of changes in the official and hedonic indices of Ohta and Griliches (1976) for the period 1947-71 is patently clear. In this paper Gordon also offers more recent comparisons. In the case of new cars, he shows how the larger increase in the hedonic index during the period 1974-80 is due entirely to adjustments for safety and anti-pollution improvements in the BLS indices, which were not envisaged in the hedonic estimates. Bearing this in mind, no significant difference between the two indices can be seen. Nor in the case of second-hand vehicles, for the period 1965-80, were differences found between the official indices and the related hedonic index. These results are indicative of the difficulties hedonic specifications face in capturing vehicle quality changes accurately.

Finally, we will mention the fact that the Boskin report points out that a significant improvement in the quality of vehicles which has not been taken into account in the related studies, and which is difficult to measure in an hedonic context, is the increase that has taken place in the useful life of cars.

II.3. Construction (11)

II.3.1. Estimates available on potential biases

Contrary to the computer or car industries, few papers calculating hedonic price indices have been written for construction (see Table II.4). However, as we shall see, the use of hedonic price indices for construction by public statistics offices is as widespread as in the case of computers.

In 1974, the US BEA published tables with the changes in the new deflators, which use hedonic methods, and the previous ones, for different construction items. For residential construction, the hedonic index grew annually during the period 1947-1973 by 2.9 % on average, while the previously used index did so by 3.5 %. The overestimation of the change in housing prices when hedonic methods are not used is repeated for most of the sub-periods (e.g. 1950-53,1960-65, among others). Nonetheless, for certain periods it is the hedonic index which grows more quickly than the old index. For instance, between 1969 and 1973, it grew by 6.4 % per year compared with 6 % in the case of the traditional index. In more recent estimates, the Bureau of the Census has calculated that from 1992 to 1993, its hedonic index for new house prices increased by around 4.4 %, while an index based on a simple average of house prices rose by 2.5 %. This difference is due to the shift during this period towards the construction of smaller homes, with fewer fittings, and in more affordable areas, i.e. towards lower quality houses. Therefore, an index which takes into account the lower quality of the houses being built will outgrow an index that does not. It therefore seems that, in the short run, housing hedonic indices may be expected to grow above or below those calculated with methods that do not adjust for quality. However, in the long run, when more distant periods are compared, there are generally increases in the quality of the houses built and, therefore, the hedonic housing price indices will grow below non-hedonic ones (12).

Fleming and Nellis (1985a) estimate that between January 1983 and October 1984 the UK hedonic index grew by 16.6 % for housing in general and by 12.8 % for new houses, while with a simple average, house prices grew by 8.3 % for total housing and by 1.02 % for new hous-

(11) This section is based on the following information: Bureau of Economic Analysis (1974), Bureau of the Census (1997), OECD (1997), Pieper (1989), Pieper (1990) and the websites of the various national statistics offices.

(12) Arévalo (1998) estimates that there has been an increase in housing quality in Spain between 1980-81 and 1990-91. However, she does not calculate prices adjusted for this increase in quality.

TABLE II.4

HEDONIC ESTIMATES OF PRICE INDICES FOR CONSTRUCTION

Reference and country	*Type of construction*	*Period*	*Annual average rate of change. Hedonic index*	*Annual average rate of change. Traditional index*
BEA (1974), USA	New houses	1947-73	2.9	3.5 (a)
		1947-50	4.1	4.7 (a)
		1950-53	3.5	3.7 (a)
		1953-57	1.5	2.1 (a)
		1957-60	0.2	1.5 (a)
		1960-65	0.4	1.8 (a)
		1965-69	5.0	4.8 (a)
		1969-73	6.4	6.0 (a)
Bureau of the Census (1997), USA	New houses	1992-93	4.4	2.5 (b)
Fleming and Nellis (1985a), United Kingdom	New and second-hand houses	Jan. 1983-Oct. 1984	9.17	4.66 (b)
	New houses	Jan. 1983-Oct.1984	7.13	0.58 (b)
	Second-hand houses	Jan. 1983-Oct. 1984	9.27	5.19 (b)

(a) Index based on production factor costs.
(b) Index calculated as an average of house prices.

ing (13). Here the effect of an increase in construction of lower-quality housing is also clearly seen.

II.3.2. Hedonic indices for construction prices in Official Statistics Offices

a) United States

It was in the construction industry where a national statistics office, the US Bureau of Economic Analysis, first adopted an hedonic price in-

(13) The hedonic index constructed by Fleming and Nellis (1985) for the *Halifax Building Society* (United Kingdom) uses the following housing characteristics: type of dwelling, number of rooms, garage spaces, bathrooms, toilets, central heating, garden, age of the house, size of plot, location, type of lease.

dex. It is this index which is used to deflate more than 50 % of the construction sector in US National Accounts.

In 1961, a committee chaired by Stigler reached very critical conclusions after studying the indices used in the United States in the construction industry. In its report [see *Price Statistics Review Committee* (1961)], the committee argued that the indices used measured factor rather than production costs. Those indices assume that productivity is constant in construction and, therefore, that price changes in the industry may be overstated when productivity increases. Following the report, the Census Bureau began to collect data on new house sales in 1963. After experimenting with the hedonic method, it published its one-family-house price index (known as the «Census index») in 1968 with figures as from 1963.

The data used to construct the index are drawn from the *Bureau's Housing Sales Survey.* The survey provides information on the physical characteristics and price of new houses sold during the period. The information is collected monthly through interviews with builders or owners. The size of the sample is approximately 13,000 observations per year.

The physical characteristics of housing included in the regression have been changing. For example, in 1974 ten as opposed to eight characteristics were included, and size came to be considered as a continuous as opposed to a discrete variable. Initially, the *Bureau* adjusted the index by deducting the value of the land, but this adjustment is no longer made nowadays.

The first significant modification was made in 1992. Until then, the estimated model was the same for the entire territory, and regional differences were only allowed in the constant of the regression, by including twelve regional dummy variables. As from 1992, five different models have been estimated: one for detached dwellings, for each of the four major geographical areas and one solely for semi-detached dwellings, for the United States as a whole. In order to calculate the aggregate index, each index is weighted according to the weight of each type of dwelling in respect of total dwellings sold in 1992 (these weights remain effective at present).

Seven characteristics are common to all the models (surface area, geographical division within the area, metropolitan area, number of chimneys, number of bathrooms, garage, type of foundations), and others are specific to each model [see *Bureau of Census* (1997)]. The dependent variable of the hedonic regression is the logarithm of sale prices, and the characteristics are defined in terms of the dichotomic variables, except for the logarithm of the surface area, which is defined as continuous.

Indices constructed on the basis of the hedonic estimates were, until 1996, Laspeyres-type indices of characteristics. In this case, given the functional form, the index for a specific estimated model m was calculated as (14):

$$L_{mtt_0} = \frac{\text{antilog}\left\{\hat{b}_t + \sum_k \hat{a}_{kt}\, Q_{kt_0}\right\}}{\text{antilog}\left\{\hat{b}_{t_0} + \sum_k \hat{a}_{kt_0}\, Q_{kt_0}\right\}} \times 100 \qquad \text{[II.1]}$$

Note how in this formula the *Bureau* does not include the adjustment in terms of the variance of the regression error (15). Typically, this adjustment is not quantitatively significant, but it is a matter which should be checked in each application [see Berndt (1991)].

In the case of non-linear functional forms, as with the logarithmic model used by the Census Bureau, calculating an index of prices of characteristics of the type set out in [I.3] would be equivalent to a linearisation of [II.1] around average values of prices and characteristics.

In 1997 there was a further substantial modification to the index when the Bureau adopted Fisher's chained indices. The adoption of Fisher indices (note that the Fisher index is the geometric mean of the Laspeyres and Paasche indices (16)) responds to the need to accommodate satisfactorily the substitution that takes place when relative prices change. Until 1997, the *Bureau* would measure quality in constant terms in the house price index, fixing house characteristics over a specific number of periods. However, the same quality can be attained with different combinations of characteristics. Moreover, according to theory, an index that accurately reflects the price of a house of similar quality should not maintain the amount of characteristics fixed, given that buyers' preferences change [see Triplett (1992) for a detailed explanation].

Consequently, chained indices are now calculated. These indices are constructed by calculating the Fisher index for two adjacent years and multiplying the annual indices to form the new index. For example,

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(14) The formulas used in this section have been taken from the *Bureau of the Census* (1997) reference.

(15) See the section on *Functional form* at the end of section I.

(16) In the previous notation, the Paasche index is defined as:

$$P_{mtt_0} = \frac{\text{antilog}\left\{\hat{b}_t + \sum_k \hat{a}_{kt}\, Q_{kt}\right\}}{\text{antilog}\left\{\hat{b}_{t_0} + \sum_k \hat{a}_{kt_0}\, Q_{kt}\right\}} \times 100$$

the chained annual index based in an initial year 0 is obtained as follows:

$$CI_{t0} = F_{t,\,t-1}\; F_{t-1,\,t-2} \;\dots\; F_{2,\,1}\; F_{1,\,0} \qquad \text{where} \qquad F_{t,\,s} = \sqrt{L_{ts}\; P_{ts}}$$

This housing index is used by the *Census Bureau* not only to deflate residential construction (which includes, in addition to the type of dwellings covered by the index, multiunit residential buildings, and residential additions and alterations) but also the construction of small non-residential buildings. In this respect, the extension of the hedonic method to other construction components has proved difficult in the United States.

b) Other countries

Since 1995 the statistics office of the Netherlands (CBS) has been constructing a monthly hedonic price index, whose reference population are low-rent houses [OECD (1997)]. This index is used to deflate the residential property construction item in the National Accounts. The characteristics used for the buildings are: amount contracted, size in cubic metres, number of floors, depth of foundations, etc.

The Swedish statistics office (SCB) also uses hedonic methodology to calculate new residential construction price indices with which to deflate the National Accounts. It publishes a quarterly index for multi-dwelling buildings and another index for buildings with one or two dwellings. The information is obtained through investors and applications to the authorities for assistance for new construction. The depended variable is expressed in terms of price per square metre of useful surface area. The characteristics considered include weighted averages of various forms of equipment, geographical location, type of building, etc. The index calculated on the basis of the hedonic estimation is a chained Paasche index.

Norway has, since 1989, also been using hedonic chained Paasche indices in its National Accounts (17). The information comes from a census based on a questionnaire circulated to all owners of new detached houses (approximately 1,500-2,000 houses per quarter in 1995). The price used excludes the value of the land. The dependent variable is the

(17) Two years are used for the estimation of the hedonic regressions so as to obtain more stable estimates.

price per square metre, and the characteristics include the logarithm of the surface area, location, etc.

Finally, it is worth describing a method that is not properly hedonic but related. It is a method used by the *Department of the Environment, Transport and the Regions* (United Kingdom) to address the problem of non-comparability of house prices over time. For a sample of the houses sold each quarter, a series of characteristics other than price are taken, such as: type of dwelling, age (new or second-hand), number of bedrooms, and region (18). With these data a 156-cell matrix is constructed, defined by the previous characteristics. For each cell, the average price in each period is calculated. Finally, a weighted average whose weights are the number of transactions in each cell is calculated. This mix-adjustment procedure can be seen as a non-parametric method that is more general than an hedonic regression that were based on these same characteristics. Nonetheless, a significant limitation of this procedure, in practice, is the need for a sufficient number of observations in each cell of the matrix. For the period 1969-81, new house price increases in the United Kingdom, thus adjusted for composition, were much lower than using a simple average of prices. The opposite is the case for second-hand housing [see Fleming and Nellis (1985b) and *Department of the Environment* (1982)].

(18) Approximate sample size of 5,000 houses per quarter.

III

MACROECONOMIC IMPLICATIONS FOR NATIONAL ACCOUNTS

Since hedonic techniques are still far from being adopted by a majority of countries, international comparisons of variables such as productivity, investment and growth should be made bearing in mind to what extent the behaviour in real terms of each such variable is affected by the use, in certain countries but not in others, of hedonic price indices. A number of papers have studied the impact of the use of different techniques by different countries to measure changes in the prices of high technology products when international comparisons are made (both at the sectoral and aggregate levels).

At the sectoral level, Triplett (1996) and Schreyer (1996) showed that to calculate the impact on the value added of a sector, or on its productivity, it is not only necessary to consider the adjustments made to real production figures, but also to real input figures. This may offset to some extent the effects on sectoral value added. The upward adjustment of the sector's real output means that industries using inputs from this sector will see their value added reduced and, consequently, the aggregate effects on national GDP will be partly offset.

To study the overall impact on an economy's real growth figures of the various methodologies applied to capture changes in product quality, a series of essential aspects indicated by Schreyer (2000b) should be taken into account. The upward correction of the real output figures of high-technology sectors will have an impact on the aggregate growth figures of the economy the greater i) the relative importance of the sector in the country's economy; ii) the proportion of the sector's total output in final demand, compared with that intended for inputs; and iii) the portion of the sector's output produced domestically, compared with that imported, since any adjustment to the real output figures of the sectors analysed should also be made to imports, with the subsequent reduction in real GDP. Lastly, it should be borne in mind that a Laspeyres-type quantities index, such as those used traditionally in National Accounts, will bias growth figures upwards, owing to the substitution bias incurred by not taking changes in relative prices into account. When calculating the aggregate effect of adjustments to price indices in sectors where there are marked movements in relative prices, the use of an index with fixed weights in the base year will overestimate the aggregate effects of these adjustments. The superlative Fisher-type indices are, therefore, even more recommended in this context and their use will partly reduce the upward estimation of aggregate growth figures.

Various studies have performed simulations on the aggregate effects of this type of adjustment to price indices. These include most notably Schreyer (1996) and Schreyer (1998) for five OECD countries; Lilico (2001) in a comparison between the United States, the United Kingdom and Germany; and Eurostat (1999) for Germany, France and the Netherlands. As we shall see, the estimated quantitative impact varies from country to country and according to the study considered, although the conclusions may be summarised saying that the effects of these adjustments to price indices on the growth rate of real GDP are not of an amount sufficient to alone explain the growth and productivity differentials between the various countries.

In this section we shall first review the papers available which address the impact of the use of hedonic adjustments in price series on sectoral variables. Secondly, we shall present the available evidence on aggregate-level effects.

III.1. Sectoral effects of quality adjustments

Labour productivity in the computer and office equipment sector shows widely differing trends when international comparisons are made. While the United States exhibits annual growth rates close to 25 %, during the eighties countries such as Italy, Germany or France show rates lower than 5 % per year (1). Wyckoff (1995) takes such notable divergences as the starting point to analyse the impact the use of hedonic price indices may have had on productivity measurements. To do this he performs a simple exercise, involving the application of the same deflator - namely the US deflator calculated with hedonic techniques - to each

(1) France even had a negative productivity growth rate during this decade.

country's nominal office equipment and computer output figures (2). The results indicate that, with the common deflator, the differences between countries diminish notably. Although the United States remains among the countries with the biggest productivity growth in this sector, the impact of the use of the US deflator is so significant in Germany or France as to entail productivity growth of more than 15 % per year (3).

These results lead Wyckoff (1995) to conclude that most of the divergences in the computer sector between the productivity growth rates observed in OECD countries during the eighties are due to differences in the methodologies applied to calculate deflators in this sector. Nonetheless, these effects become progressively less significant as industries are aggregated; thus, for the manufacturing sector as a whole, the differences are scarcely noticeable. Specifically, the impact on the measurement of productivity in the manufacturing sector amounts to a few tenths of a point upwards in most countries. Only in France does it rise to half a percentage point per year.

On the basis of the evidence shown in Wyckoff (1995), Triplett (1996) and Schreyer (1996) emphasise the need to make the appropriate adjustments to the inputs of the sectors analysed, while in turn adjusting the final products. Triplett (1996) argues that the strikingly large falls in the prices reflected in hedonic indices are not confined solely to the computer sector but affect all high-technology sectors. And given that the computer sector uses high-technology products as inputs, if the appropriate adjustments are not made in the real measurement of such products, mistakes will be made in the measurement of value-added in the computer sector, even though appropriate adjustment has been made for final output.

After discounting the fall in semiconductor prices, which is one of the main inputs in the computer sector and whose prices have fallen by more than those of computers, productivity gains in the US computer sector remain high, albeit lower by a significant amount. The average price falls in the period 1978-94, of 14 % per year, drops to around 10 % once the effect of the decline in semiconductor prices is discounted (4). These pro-

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(2) By applying the same deflator to all countries without taking into account the characteristics particular to each country that may affect price changes in the computer industry, biases are undoubtedly being incurred in the measurement of productivity. However, this exercise seeks to illustrate the extent to which differences in deflators between countries affect this measurement and, moreover, given the degree of internationalisation of this sector, most of these differences may be expected to be caused by methodological differences from one country to another.

(3) For the nineties, and applying a broader definition than that used by Wyckoff (1995), Van Ark (2000) replicates this exercise and obtains very similar results in those European countries that continue not to use hedonic price indices.

(4) Triplett (1996) calculates several scenarios for price variations depending on the weight accorded to semiconductors in computer industry inputs. With the highest weight among those considered, price falls in the computer sector decline up to 5% per year.

ductivity gains are still high and greater than those in other manufacturing sectors. But this exercise is illustrative of the fact that sectoral studies on productivity performance and the effects of hedonic prices should be made introducing the appropriate adjustments into the price of inputs, not only of final output.

Schreyer (1996) performs a similar exercise, calculating the effects on sectoral value added and on aggregate GDP of introducing adjustments into both final output and inputs. The consequences on the measurement of value added in the sectors affected by adjustments to price indices are significant. He highlights how value added in other manufacturing sectors, which make intensive use of high-technology products as inputs, is reduced to around 1 % per year owing to the effect of the price index adjustments in the technology sectors. Therefore, part of the effect on the measurement of real variables arising from making this type of adjustment to price indices is a redistribution of growth across industries. Industries producing goods with rapid quality changes will see their growth revised upwards, but those using these goods in their productive process as inputs will see it revised downwards.

On assessing the impact of price index adjustments on the measurement of technological progress, a final factor should be considered. Namely, although the measurement of labour productivity is considerably affected in those sectors producing these types of goods, the impact will necessarily be less on a broader measure of technological process, such as total factor productivity, which also takes capital into account as a factor of production. Insofar as the investment series, in real terms, are adjusted upwards to reflect the positive effect on the figures for capital investment in the technological sector, the build-up of this greater investment will give rise to a greater capital stock in the economy, which will reduce the estimate made of the trend of total factor productivity (5). Specifically, the adjustments to price series will also affect the interpretation of economic growth by altering the breakdown of total growth into the growth of inputs, in this case of the capital stock, and the growth of total factor productivity.

(5) As Schreyer (2000a) indicates, the total effect may even be negative if the technology sector's goods are mostly imported. There is thus scarcely any increase in GDP following the adjustments, but the economy's capital stock does increase.

III.2. Aggregate effects of quality adjustments

III.2.1. General considerations

The aggregate effects of the adjustments to technology-sector price indices, so as to take quality increases into account properly, may be accounted for in the calculation of GDP from the standpoint of demand or supply. On the demand side, the effects on the GDP components (Consumption, Investment, Exports and Imports) are calculated, which avoids making the necessary adjustments to inputs. This approach further allows for the analysis of which GDP components are most affected by this type of adjustment. The aggregation of the value added of the different industries in order to calculate GDP from the supply side has the added complication of having to apply correctly double deflation, of both final output and inputs. But this is worthwhile insofar as it permits a study of the way sectoral contributions to economic growth or sectoral productivity measures are affected.

Discussion on these effects should also take a series of factors into consideration. First, the amount of the adjustments made and the relative importance of the sectors affected by these adjustments in the economy determine the scale of the aggregate effects. However, these effects will be qualified by the degree to which those products are intended for final demand or are intermediate goods, by the share in the national output of these sectors compared with imports and by the type of index used to aggregate the final demand components or the sectoral outputs.

At one extreme, when the output of a sector is used entirely as intermediate goods, any adjustment made to its real output will affect the sectoral measures of output, productivity or contributions to growth, but national GDP will be completely unchanged by this adjustment. At the other extreme, when the sector's entire output is intended for final demand, any upward revision of its real growth figures will pass through to GDP in direct proportion to the relative importance of the sector in the economy. Moreover, when adjustments are made to the output of various sectors, it should be borne in mind that any upward adjustment of output figures will also take place in the figures for imports of these products, whereby they will have a negative effect on GDP growth.

Lastly, the type of index used to aggregate the real figures and calculate GDP is very important. A Laspeyres-type quantities index with fixed weights in the base year will suffer from substitution bias (as mentioned earlier), since the substitutions arising as a result of relative price changes are not properly captured. Moreover, it is precisely when hedonic methods are used that changes in relative prices are most acute. A

Laspeyres quantities index aggregates the real amounts of output of each good in year t,q^i_t, with weights equal to the prices in the initial base year, p^i_0, with t = 0 being the initial period, t=T the final period, and 0 ≤ t ≤ T:

$$I^Q_{Laspeyres} = \frac{\sum_i p^i_0 q^i_t}{\sum_i p^i_0 q^i_0}$$

As the goods whose quantities tend to grow most are those whose relative prices exhibit less growth, weighting by base-year prices overestimates the aggregate growth of real total output. When the real output of technological goods grows more owing to the adjustments to their price indices to take quality changes into account, it is all the more necessary to correct the substitution bias incurred by weighting using base-year prices, which do not reflect changes in relative prices. The Laspeyres quantities index overestimates the aggregate impact of adjustments to this type of good, as it aggregates the different real quantities with the base-year prices, which do not reflect the change in relative prices prompted by these very adjustments.

A Fisher quantities index is preferable in these circumstances. The Fisher index is no more than the geometric mean of a Laspeyres index and a Paasche index, where the Paasche index is calculated using the prices for the final year, p^i_T, as weights (6). By using a Fisher quantities index, the relative price evolution brought about by the adjustments to certain sectors is taken into account, and this offsets part of the increase in real output.

In sum, the effects on a country's real growth of making this type of adjustment to the price indices of a set of industries are, ultimately, an empirical issue. This is related to the quantity of these adjustments, the country's productive structure, its sectoral specialisation and the distribution of its imports, and the degree of substitution caused by changes in relative prices.

(6)

$$I^Q_{Paasche} = \frac{\sum_i p^i_T q^i_t}{\sum_i p^i_T q^i_0};$$

$$I^Q_{Fisher} = (I^Q_{Laspeyres} \times I^Q_{Paasche})^{1/2}$$

III.2.2. Empirical studies available

A Eurostat task force [see Eurostat (1999)], set up to study the problems of measuring prices in the computer manufacturing sector, performed some simple calculations on the impact of adjusting price indices in this sector on aggregate growth figures. The exercise was conducted solely with the 1991 GDP growth rate in Germany, France and the Netherlands. It concluded that a 10 % adjustment to the computer industry price index meant, on average, one-tenth of a percentage point of extra growth per year. This simple exercise, which does not take into account the substitution effects induced by changes in relative prices and covers only one year, may be indicative of the degree of magnitude of the figures under discussion.

Schreyer (1998) made a detailed analysis of the impact of these types of adjustments on five OECD countries (United States, Japan, France, Canada and the Netherlands), bearing in mind the above-mentioned aspects. First, a set of products was chosen on which there was empirical evidence that their prices were greatly affected when changes in their quality were taken into account with hedonic methods. The sectors and the magnitude of the adjustments made were as follows: computers, –10 %; semiconductors, –10 %; TVs, radios and other electronic goods, –2 %; scientific and precision instruments, –2 %; and computer and communications services, –2 %. These adjustments mean that the difference between a price index without an hedonic adjustment and an hedonic index is of the magnitude indicated for each sector. The financial or health-care sectors are not included, although they use these new technologies intensively and it is quite likely that the phenomena associated with the incorrect measurement of quality are also present.

The magnitude of these adjustments adopted by the author may be considered to be cautious. As we saw in section II, there is a fairly wide range of estimated biases when deciding on the magnitude of the adjustment to apply. In the computer industry, for example, there is a wealth of empirical evidence available which, depending on the period considered, places the decline in the hedonic price indices in this sector at between 15 % and 30 % (7). The assumption by Schreyer is that the difference between an hedonic method (8) and a traditional one is 10 %, and there is less empirical evidence on this difference. As we saw in the previous sec-

(7) See Table II.2 in this survey and Box 1 in Schreyer (1998).

(8) As we saw in the introduction, this method involves calculating the increase in prices between two periods as the change in the prices of those products which remain on the market both periods.

tion, Cole *et al* (1986), Dulberger (1989) and Berndt, Griliches, and Rappaport (1995) obtain differences of around 10 %-15 % between a matched model method and the hedonic method. Although the traditional methods used by different statistical offices are not always matched model methods, this difference may indicate the order of magnitude of the differences between a traditional and an hedonic price index. Moreover, we should take into account that in a national accounts analysis, the output of the computer sector usually includes other outputs such as office machinery which, undoubtedly, reduces the average biases to be taken into account at this level of aggregation.

That said, given that the traditional methods used by each country are varied and produce price indices with widely differing evolutions, applying a difference common to all the countries between their traditional method and the hedonic method may be a substantial source of error. A traditional method may be a simple arithmetic mean of prices (which does not take into account any change in quality), or different imputations from the assessment of changes in quality (based on expert opinions, consultations with manufacturers or an estimation through the cost of options method), or the use of the matched model method. These methods capture the changes in product quality to widely differing degrees, and, therefore, to calculate the effects of using hedonic methods, the methodology previously used in the country must be taken into account. For example, during the period 1986-92, the deflator for the office machinery and computer industry evolved rather differently across the European countries that were applying various traditional methods. The differences with the US deflator for the same sector range from a figure of over 17 % for Spain, and of between 11 % and 12 % for Finland, Italy, the Netherlands or France, to one of 8 % for Germany or of 5 % for Sweden (9).

In that paper, Schreyer calculates the aggregate effects on the basis of the calculation of GDP from the demand side, so as to avoid making the adjustments to inputs. This approach also allows the analysis of the GDP components most affected by these adjustments. Aggregation is carried out, first, by a traditional Laspeyres quantities index in order to compare the results subsequently with the aggregation resulting from a Fisher quantities index. Table A.1 in the Appendix shows the results.

(9) The data for the United States and for the European countries are from Wyckoff (1995), and the Spanish figures have been calculated using official National Accounts data from INE. These differences may also be due to actual differences between countries. Nonetheless, given the high degree of internationalisation of this industry, the methodological differences in the construction of the deflators probably account for most of these differences.

In terms of GDP components, the results indicate that consumption (both government and private) is the least affected by the adjustments to high technology products. Investment, exports and imports increase at annual rates of between 0.4 % and 1 % more, if the changes in quality are properly discounted. The effect on investment is particularly significant since, as we have already mentioned, the incorrect measurement of investment has consequences for the measurement of the economy's capital stock and for the evolution of total factor productivity.

The aggregate effects are not, however, very substantial. With the exception of Japan, which would grow at an average rate of almost half a percentage point above the current rate following the adjustments, the other countries would not grow significantly above what the present figures indicate (see Table A.1 in the Appendix). Japan's greater specialisation in high technology products along with the significance of these products in Japanese exports explain why it is virtually the only country whose growth figures rise after the adjustments. In the other countries, although the effects on investment or exports are considerable, the aggregate effect on GDP is reduced by imports of this type of product.

Both these aggregate effects and the above-mentioned effects in terms of GDP components refer to the calculations comparing an initial situation -in which a country does not make hedonic adjustments to its price indices and uses a Laspeyres quantities index in the aggregation- with a final situation where, in addition to quality adjustments, the aggregation methodology has changed to a Fisher quantities index. This change precludes an overestimation of real output, due to the substitution bias incurred by a Laspeyres index, and partly offsets the positive effects of the quality adjustments on the aggregate growth rate. Simply comparing the growth rates of the two Laspeyres indices, before and after adjusting for quality, the aggregate effects would translate into a rise in growth rates for France, the United States and the Netherlands of between two and three-tenths of a percentage point per year, and of over seven-tenths of a point in Japan. Only in Canada would the effect be virtually zero (10).

Although the effects on GDP obtained in this paper are limited, they hinge crucially on the assumptions about the size of the adjustments made to price indices. These phenomena have probably become more

(10) These calculations indicate the significance of the substitution biases caused by the changes in relative prices. However, the substitution bias incurred by a Laspeyres index is not specific to the presence of these quality adjustments and the change to a Fisher index eliminates this bias in any situation. It is only the considerable changes in relative prices observed after quality adjustments in certain sectors that recommends the use of a Fisher index.

acute in the second half of the nineties (11). And nor can it be ruled out that they have spread to other sectors of the economy not considered in this study. Schreyer (1996) himself argues that both the financial sector and the communications services sector have invested heavily in new technology products that have enabled them to enhance the quality of the services provided. Such improvements are difficult to measure with the habitual National Accounts methodologies for the services sector.

The 1996 paper by Schreyer, unlike the same author's 1998 study, is conducted from the supply side, from sectoral value added up to GDP, once both final output and inputs have been suitably deflated. The aggregate growth rate is calculated by aggregating the sectoral growth rates using nominal rather than real weights, which partly offsets the aggregate effects of the sectoral value added adjustments. Using real weights to aggregate the real output of the technological sectors after the adjustments to their deflators means giving them excessive weight, since the fall in their relative prices would not be taken into account in this aggregation. Following an adjustment of 10 % to the IT sector price index, of 2 % in the manufacture of radios, TVs and other electronic goods sector, of 2 % in communications services and of 1 % in financial services, Schreyer concludes that aggregate real growth figures are between two and three-tenths of a percentage point per year higher in countries such as Germany, Canada, the United States or the United Kingdom. The result for Japan is once again a rise of up to half a percentage point.

Lastly, mention should be made of the work by Lilico (2001). The author calculates the overall impact on US growth of deflating computer production using the British deflator, which is not calculated by means of hedonic techniques (12). The results indicate that the average growth of 4.1 % between 1995 and 1999 would have fallen to 3.5 % in the United States had the UK deflator for computers been used. This aggregate impact, equal to six-tenths of a point of growth per year, is fairly high if we bear in mind that, unlike the study by Schreyer (1998), Lilico makes adjustments only in the computers sector, without extending them to the

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(11) At least it would seem so on the evidence available for the United States. Berndt, Dulberger, and Rappaport (2000) obtain an annual average fall in personal computer prices of 18% from 1980 to 1989, of 32% from 1989 to 1994 and of 39% from 1994 to 1999. However, the potentially significant bias is the difference between these declines and the movements reflected in the officially used figures.

(12) Quality adjustments in the United Kingdom computer sector are made following the same method as for other goods. When changes arise in product quality, manufacturers are asked for an estimate of the cost of having introduced the quality improvement and half of this cost is imputed as a change in quality. The computer deflator thus calculated decreases much more slowly than the US deflator calculated using hedonic techniques. See Lilico (2001) for greater detail.

other technology sectors. Likewise, the effect on British and German growth of having used the US hedonic deflator to deflate output in the IT sector is calculated. The effects in both countries are considerable, raising the annual average growth rate by four-tenths of a point in the UK and by three-tenths of a point in Germany. Unfortunately, the author does not give an exhaustive breakdown of how the various calculations have been made to arrive at these effects. Thus, although the effects on imports are borne in mind, it is not known whether the necessary adjustments are made to inputs and whether the aggregation is still by means of a Laspeyres quantities index.

IV

CONCLUSIONS

Rapid technical progress in recent years has exacerbated the problems of measuring price changes and, consequently, economic variables at constant prices which arise when there are changes in product quality. One natural way of addressing these measurement problems is to use hedonic prices. Hedonic methods break down a product into its characteristics and measure the «pure» change in prices as that which would take place for certain given characteristics.

In this survey we have briefly described the hedonic methodology, considering different aspects that are relevant when it comes to estimating an hedonic function. Specifically, we have considered the following issues: theoretical framework, representativeness and quality of the sample, list prices versus transaction prices, choice of variables, and functional form. Knowledge of these issues enables the advantages and drawbacks of the use of hedonic equations to be assessed.

The survey also explains how, on the basis of a specific hedonic equation, hedonic price indices can be constructed in different ways. The different indices can be seen as alternative ways of specifying a given product's price evolution. Moreover, they vary as regards the extent to which the results of the estimated hedonic equation are used.

Hedonic methodology has already been adopted by some public statistics offices. In the survey we have reviewed the differences estimated in the literature between hedonic and traditional indices, and the adoption of hedonic indices by statistics offices. We have focused on the use of hedonic methods in three industries: computer equipment, cars, and construction.

A significant barrier to the adoption of hedonic methodology to construct price indices is the data collection involved, as information is needed not only on product prices but also on their related characteristics. Moreover, the econometric estimations are not always stable. Lastly, it should be stressed that, although the distinction between changes in quality and the emergence of a new product is not always clear, the hedonic methodology is not capable of covering totally new products. The hedonic methodology is suitable provided that the setting is stable in terms of characteristics. This marks an advantage over traditional methods, which require a stable setting in terms of goods. However, nor does the hedonic function capture improvements attributable to technical progress enabling something which it was technologically impossible to produce in previous periods. A similar problem is posed by the disappearance of old products insofar as the new products replacing them are not superior across all the characteristics [see Nordhaus (1998)].

Foreseeably, there will be a much broader debate in the future on the advantages, drawbacks, and uses of these methods. Attention at present is focused mainly on the impact that the use of these techniques has on economic growth and productivity figures, at both the sectoral and aggregate levels. Such attention is justified. At the sectoral level we have seen how the use of a common deflator for the computers and office machinery sector for various countries reduces but by no means eliminates the sector's productivity differentials, especially if the changes in the quality of the inputs used by the sector are taken into account. Note, however, that the adjustments to price series will affect investment and capital series, and by extension, the interpretation, too, of economic growth. This is because they alter the distribution between total growth accounted for by the growth of inputs and total factor productivity growth.

On studying the aggregate impact, the upward correction that occurs in real sectoral output figures will pass through all the more to the aggregate growth figures the greater the relative weight of the sector in final demand and the greater the sector's national output (as opposed to imports). It should also be borne in mind that the use of hedonic indices makes it more necessary than in the case of traditional price indices to employ indices allowing for the substitutions that arise as a result of changes in the relative prices of goods. The use of these indices will offset, in part, the upward estimation of aggregate growth figures. This is the outcome of several studies that have calculated the effect of quality adjustments to the prices of various sectors affected by changes in quality (computers, semi-conductors, scientific instruments, radios, and TVs, principally) on the aggregate GDP of several countries. These adjustments assume that the difference between a price index calculated using traditional methods and an index using hedonic regressions is the same for the set of countries analysed. The conclusion is that significant effects on investment or exports are obtained, but not on GDP, the estimated growth rate of which for several countries does not increase by more than two-tenths of a point.

The magnitude of the adjustments applied (for example, –10% in the computer sector) is not controversial on average in the light of the empirical evidence available (see section II). However, a factor to be taken into account in cross-country comparisons is that the traditional methods used by different statistics offices are not the same and may capture the changes in product quality to very different degrees. Therefore, applying a country-common difference between the traditional method and the hedonic method, as the studies cited in the survey do, may be a significant source of error in the comparisons.

APPENDIX

TABLE A.1

QUALITY ADJUSTMENT OF MEASURES OF FINAL EXPENDITURE: SIMULATED RESULTS (a)
Growth volume, annual average growth rates

	Private Con - sumption	*Gvt. Con - sumption*	*Invest - ment*	*Exports*	*Imports*	*Total Final Expendi - ture*
CANADA, 1986-92 - BASED ON:						
Fixed weights (Laspeyres), volume index, not adjusted for quality (b) .	2.12	2.74	2.64	4.94	5.30	2.18
Fixed weights (Laspeyres), volume index, quality-adjusted	2.21	2.85	3.49	5.66	6.57	2.21
Superlative index (Fisher), quality-adjusted	2.13	2.73	3.05	5.22	5.95	2.15
Effect due to quality adjustment, with fixed weights	0.09	0.10	0.85	0.73	1.28	0.03
Effect due to the index	–0.08	–0.12	–0.44	–0.45	–0.62	–0.06
Total effect	**0.02**	**–0.01**	**0.41**	**0.28**	**0.66**	**–0.03**
FRANCE, 1985-96 - BASED ON:						
Fixed weights (Laspeyres), volume index, not adjusted for quality	2.14	2.04	1.53	4.28	4.28	2.01
Fixed weights (Laspeyres), volume index, quality-adjusted	2.25	2.04	2.44	4.86	4.95	2.22
Superlative index (Fisher), quality-adjusted	2.18	2.03	2.21	4.71	4.99	2.13
Effect due to quality adjustment, with fixed weights	0.11	0.00	0.91	0.58	0.67	0.21
Effect due to the index	–0.07	–0.01	–0.23	–0.15	0.03	–0.08
Total effect	**0.04**	**–0.01**	**0.68**	**0.43**	**0.71**	**0.13**
JAPAN, 1985-94 - BASED ON:						
Fixed weights (Laspeyres), volume index, not adjusted for quality	3.26	2.46	4.73	1.82	6.78	2.94
Fixed weights (Laspeyres), volume index, quality-adjusted	3.40	2.46	6.05	4.43	7.66	3.67
Superlative index (Fisher), quality-adjusted	3.27	3.59	5.16	2.84	7.25	3.41
Effect due to quality adjustment, with fixed weights	0.13	0.00	1.32	2.61	0.88	0.73
Effect due to the index	–0.13	1.13	–0.88	–1.60	–0.41	–0.26
Total effect	**0.01**	**1.13**	**0.44**	**1.01**	**0.47**	**0.47**

QUALITY ADJUSTMENT OF MEASURES OF FINAL EXPENDITURE: SIMULATED RESULTS (a)
Growth volume, annual average growth rates (cont.)

	Private Con - sumption	*Gvt. Con - sumption*	*Invest - ment*	*Exports*	*Imports*	*Total Final Expendi - ture*
NETHERLANDS, 1986-93 - BASED ON:						
Fixed weights (Laspeyres), volume index, not adjusted for quality	3.06	1.98	1.57	4.91	4.17	3.16
Fixed weights (Laspeyres), volume index, quality-adjusted	3.18	1.98	2.93	5.87	5.49	3.42
Superlative index (Fisher), quality-adjusted	2.88	1.97	2.28	5.46	4.84	3.11
Effect due to quality adjustment, with fixed weights	0.12	0.00	1.36	0.96	1.31	0.27
Effect due to the index	–0.31	–0.01	–0.65	–0.41	–0.65	–0.31
Total effect	**–0.18**	**–0.01**	**0.71**	**0.56**	**0.67**	**–0.05**
UNITED STATES, 1987-93 - BASED ON:						
Fixed weights (Laspeyres), volume index, not adjusted for quality	2.05	0.85	0.82	7.49	3.26	1.99
Fixed weights (Laspeyres), volume index, quality-adjusted	2.15	1.03	2.38	8.46	4.55	2.28
Superlative index (Fisher), quality-adjusted	2.08	0.99	1.73	8.01	3.99	2.13
Effect due to quality adjustment, with fixed weights	0.10	0.19	1.56	0.97	1.29	0.29
Effect due to the index	–0.08	–0.04	–0.65	–0.45	–0.56	–0.15
Total effect	**0.03**	**0.15**	**0.91**	**0.53**	**0.73**	**0.14**

Source: Schreyer (1998).

(a) Assumptions used on the difference in the changes in price indices due to quality adjustments:
Computers –10 %.
Radios, TVs, etc. –2 %.
Scientific instruments –2 %.
Semi-conductors –10 %.
These differences are assumed to be the same for all the countries.
(b) In this table quality adjustment means hedonic quality adjustment.

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