EXPERIENCES WITH APPLYING HEDONIC METHODS IN THE GERMAN PRICE STATISTIC

Stefan Linz

Summary

Hedonic methods have come to play a growing role in measuring price trends and economic growth in recent years. Germany's Federal Statistical Office has formulated a step-by-step plan for the implementation and a detailed examination of the effects and practicability of applying hedonic methods.

The objective of official price statistics is to measure what we call "pure" price changes, purged of the adulterating influence of changes in consumption patterns, types of goods and quality features (Laspeyres Principle). The price of an item at two separate times can only be usefully compared if the quality of the item remains constant. If this is not the case – for instance due to technological progress – quality adjustment is undertaken in order to introduce the monetary value of an item's quality change into price observation.

Hedonic methods constitute a specific quality adjustment technique. The hedonic method uses regression analysis to measure the influence of product features on the sale price. Thus price changes due to qualitative improvements in certain features can be distinguished mathematically and purged from the pure price change which the price index is actually called upon to measure.

In June 2002, the German Federal Statistical Office introduced the hedonic method to the regular monitoring of prices for home computers as a first step. The second step was to evaluate the quality adjustment procedure hitherto applied to the consumer price index for motor vehicles. The third step was to design a hedonic price index for used cars. In May 2003 a used car price index based on the hedonic approach was included in the consumer price index. Hedonic price indexes for the categories "electrical home appliances" and "consumer electronics" will be implemented by January 2005.

The most recent step was the implementation of hedonic producer, import and export price indexes for selected data processing equipment in June 2004. In this paper, the method of calculating these indexes is described in detail.

1. HEDONIC PRICE MEASUREMENT AT THE GERMAN STATISTICS AGENCY

The purpose of official price statistics is to measure what are known as "pure" price movements, i.e. without accounting for changes in consumer patterns, product categories or the quality of those products. This reflects the underlying philosophy of the Laspeyres Principle: a shopping basket is defined as containing certain goods, and those contents are kept as constant as possible over a determined period of time.[i]

One essential feature of this principle is that the prices of an item in two different periods can only be meaningfully compared if the quality of the item remains constant. If that is not the case – for example, due to technological progress – an adjustment normally has to be performed to compensate for the change in quality. The aim is to factor the monetary value of the improved quality out of the price comparison.[ii]

A hedonic quality adjustment draws on regression analysis to establish a mathematical link between the quality of the item and price at which it is sold. This makes it possible to assess the monetary value of shifts in quality and to take this into consideration when measuring prices.[iii]

Prior to this, hedonic quality adjustment had only been applied by the German statistics agency to subsets of the consumer price index. Since June 2002 this has included a sub-index for personal computers[iv] and since May 2003 a sub-index for used cars[v] based on hedonic methods. In early 2003 an evaluation of the subset "new cars" in the consumer price index was concluded in which the existing index was tested against hedonic techniques. As no systematic deviations came to light between the results obtained by the quality adjustment technique applied hitherto and the hedonic method, the existing technique was retained for new cars[vi]. In early 2004 hedonic price measurements were also used to calculate a house price index as part of a European pilot study[vii]. Work is currently in progress on hedonic consumer price indexes for the subsets "electrical household appliances" and "consumer electronics". The intention is to implement these in our regular reporting by January 2005.

Now that hedonic methods are being applied to producer, import, export and wholesale price indexes for IT products, the technique has entered the domain of price measurements in upstream phases of the economic chain.

The index of producer prices for industrial products measures price movements for products made and sold within Germany by the manufacturing industry, energy and water utilities and mining sector. For the total index the reference variable is the sum of all industrial sales revenues in the base year, which at present is 2000. It includes both sales of industrial goods to domestic purchasers further down the economic chain and sales between industrial companies. The total index is calculated as the weighted average of price movements measured for a representative selection of industrial products. The weightings are derived from the percentage of overall sales accounted for by the selected products in the base year.

The foreign trade price indexes (import and export prices) measure price movements for goods traded between Germany and abroad. The reference variable for the total index is the total value of imports and exports in base year 2000. Public duties (customs tariffs, the agricultural levy, monetary compensatory amounts, turnover tax on imports and exports, consumption taxes and export aid) are not included in the prices. Only prices in euros are entered in index calculations.

The wholesale selling price index measures movements in prices for goods sold in Germany by wholesalers, as long as these sales reflect the inherent functions of the wholesale trade (e.g. resale contracts, contracts with processors or other wholesalers). The goods themselves may have been produced domestically or imported. The reference variable for the total index is the sum of all sales revenues generated in the wholesale sector in base year 2000, minus any retail

sales and other vending activities not attributed to the wholesale function, and the value of exports. Business between wholesalers is included.

2. DATA SOURCES

2.1 The approximation principle

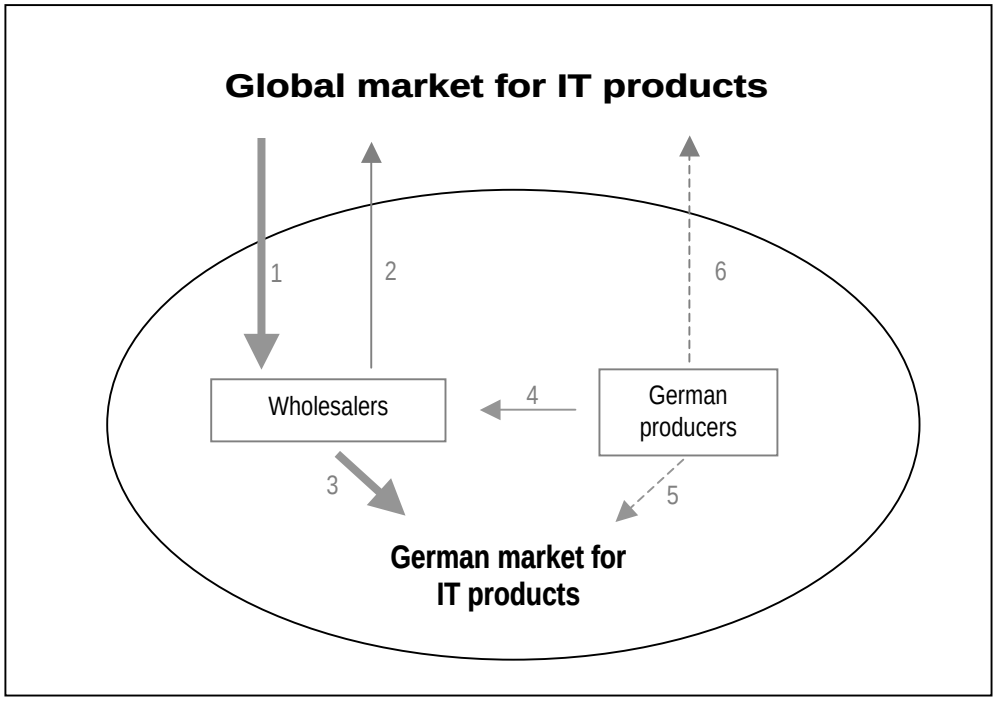
In a hedonic quality adjustment, observed product prices and features are fed into a regression function. This means that the method is only feasible if the quality of the product concerned can be described by a manageable number of features. In other words, the products must be standardised to a broad degree. Moreover, the technique can only be applied if a relatively large number of price observations are available each month, reflecting different variations of the same type of product.

If producer or export price indexes for IT products are to be obtained for Germany, the first problem is that very few manufacturers in this sector are based in the country. A large proportion of the IT goods sold in Germany are imports. The data for German companies who manufacture standardised IT products falls a long way short of what we require to calculate hedonic indexes.

The problem is resolved – following a common international practice in statistics – by adopting an **approximation** of producer prices. The European market for standardised IT products is a global market with very homogenous prices. In the IT sector, pricing mechanisms only function fully in the major producing countries, notably the United States, Japan and Taiwan. Germany's handful of manufacturers are obliged to adapt their prices for standardised products to prices in the global market if they wish to sell their wares. It is reasonable to assume, therefore, that the prices for IT products manufactured in Germany will move in parallel to the wholesale prices observed in Germany for the same category. Wholesale prices track price movements for products traded within the country at the wholesale stage, even though the goods themselves may have been manufactured abroad.

Figure 1 provides a simple outline of commodity flows. Standardised IT products (servers, desktop computers, notebooks, printers, processors, etc.) are usually imported by wholesalers and then sold on to German companies (businesses, intermediates, retailers). Wholesale buying prices, therefore, constitute a guide value from which German manufacturers must take their lead. The sales prices charged by German manufacturers (Arrow 4) can be approximated to the wholesale buying prices (Arrow 1) for these products.

Figure 1: Outline of commodity flows



There is also direct marketing by German manufacturers to businesses, intermediates and retailers in Germany (Arrow 5). The prices of goods sold in this manner can be surveyed by studying the Internet, as there are only a few products that need to be included to complete the picture. No approximation is required in this case.

Essentially export price statistics confront the same problem as producer prices and here again export prices can be substituted by wholesale prices. The data has shown that, when German manufacturers sell their goods abroad, 80% (in terms of sales revenue) is earned indirectly through wholesalers and 20% from marketing directly to customers abroad. The wholesaler selling price approximates to the prices for products from German IT manufacturers sold abroad via the wholesale trade. The wholesaler buying price approximates to the prices of products sold directly to clients abroad by German manufacturers. This is because German manufacturers sell their wares abroad in the same market where German wholesalers procure their wares.

2.2 Price statistics with hedonic indexes for IT products

The last section showed that hedonic wholesale price indexes for IT products can be used representatively for various indexes reflecting upstream phases in the economic chain. Table 1 lists the statistics which implement the hedonic indexes for IT products.

As described above, wholesale buying prices for IT products provide an approximation for manufacturers' prices, and this data is complemented by the manufacturers' actual prices where goods are marketed directly. When it comes to export prices for IT products, the approximation is based not only on wholesale buying prices, but also on wholesale selling prices and selling prices from direct marketing by manufacturers. As most imports in this capital goods segment are handled by merchant wholesalers, movements in prices for imports

can be measured directly through wholesale buying prices. In statistics on wholesale selling prices, wholesale prices are combined with direct marketing prices.

Table 1: Price statistics with integrated hedonic indexes for IT products

Statistics	Approximation:
Producer price statistics	Wholesale buying price + Direct marketing prices
Export price statistics	Wholesale buying price + Wholesale selling price + Direct marketing prices
Import price statistics	Wholesale buying price
Wholesale price statistics	Wholesale selling price + Direct marketing prices

2.3 Available data

The next step is to acquire wholesaling data on the requisite prices and quality features for these IT products. The wholesale sector includes, on the one hand, big players active throughout Europe who buy substantial volumes directly from the global market and sell to German intermediates and businesses. Among these merchants, buying prices shadow production closely and therefore lend themselves as an approximation to producer prices. Most of these merchants do not have their headquarters in Germany. There are, on the other hand, smaller German-based wholesalers (intermediates) who purchase their products from the big merchants. Their buying prices are not as suitable as an approximation for producer prices, as the trade operating margin is greater in this case.

When applying the approximation technique, therefore, the aim should be to include the major European wholesalers. However, if we wish to survey our own data by asking merchants to disclose information under our domestic rules, we can only approach the smaller merchants based in Germany. For European wholesaling we have to draw on data from market research. The market research companies compile their data directly from the merchandise information systems operated by the wholesalers they survey, and they are charged for it. They are therefore better placed than official statistics agencies to obtain the data required. We complement this data by conducting our own direct marketing surveys.

In the final analysis, the products we selected were influenced by the data which market research institutes would be able to acquire from wholesalers whose pricing shadows the point of production closely. The prices and features we monitor are those of the following nine products:

Table 2: Products measured for the hedonic IT sub-index

(1) Desktop computers	(6) Multi-purpose printers
(2) Notebooks	(7) Processors
(3) Servers	(8) Memory chips
(4) Laser printers	(9) Hard disks
(5) Inkjet printers	

2.4 Representative prices for product categories

The goods included in producer, import, export and wholesale selling statistics are classified in accordance with our Index of Goods for Production Statistics, the Güterverzeichnis für Produktionsstatistiken, in its 2002 edition (GP 2002). The IT segment in this Index is essentially composed of sub-category 30 (Office equipment, data processing devices and facilities) and sub-category 32 (Communications equipment, radios and televisions, electronic components). The IT product classes listed by the Index are "collective items" and as such they can be very mixed bags. Under "data processing devices", for example, we find Index No. 3002 12 000, which is defined as follows:

> "Portable digital automatic data processing equipment weighing 10 kg or less consisting of at least a central processing unit, a keyboard and a screen."

This includes what are now known as notebooks, but there is also a whole range of other products which meet this description (e.g. palm-held computers or specialised measuring devices). The products in Table 2 therefore function as representatives for the various classes of product in the basket.

Where these representatives are available, they fully replace our previous price notifications. One result of using representatives is that we have a narrower spectrum of variation for each product class, but we obtain greater product depth in our statistics. If, for example, we take "Desktop computers" as a class, we have hitherto monitored just nine products, not only desktops in the general sense but also some highly specialised devices such as patient monitors. After conversion to hedonic price measurement, only desktop computers in the purest sense will be included, but we will cover about 130 different products.

2.5 Weighting the baskets

IT products are a major factor, especially in import statistics. The basket for the German import price index attributes them an overall weighting of 8.8%. They also constitute around 5% of the basket for export and wholesale prices. The producer price index embraces a very broad spectrum of goods of all kinds, and IT products only account for 1.3% here. Those product categories in the statistics for producer, import, export and wholesale selling prices that are now represented by hedonic indexes are listed in Table 3 along with their share of the basket.

Table 3: Hedonic price indexes and their weightings for IT products

		Share of basket (%)			
GP[viii] or WZ[ix] no.	**Name of hedonic price index**	**Producer prices**	**Import prices**	**Export prices**	**Wholesale prices**
30 02 12	Portable digital automatic data processing equipment	0.305	0.522	0.354	
30 02 13	Stationary digital automatic data processing equipment	0.048	0.181	0.044	
30 02 14	Digital data processing equipment in the form of systems	0.463	0.286	0.093	
30 02 15	Digital data processing equipment in the form of systems, other		0.572	0.454	
30 02 16	Data input or output devices, including those incorporating memory units in shared casing	0.033	1.206	0.471	
30 02 17	Memory units		1.024	0.426	
30 02 18	Other data processing devices		0.271	0.090	
30 02 19	Parts and accessories for automatic data processing equipment and component units	0.234	2.114	1.146	
32 10 6	Integrated electronic circuit boards and assembled electronic microcircuits (microcomponents)	0.223	2.653	1.964	
WZ 51.64	Wholesale trade with data processing equipment, peripherals and software				4.948
Totals for IT products		**1.306**	**8.829**	**5.042**	**4.948**

3. THE HEDONIC METHOD

3.1 Imputation

Before calculating the hedonic price index, the monthly data on the prices and features of the chosen products is divided into three sample subsets A, B and C:

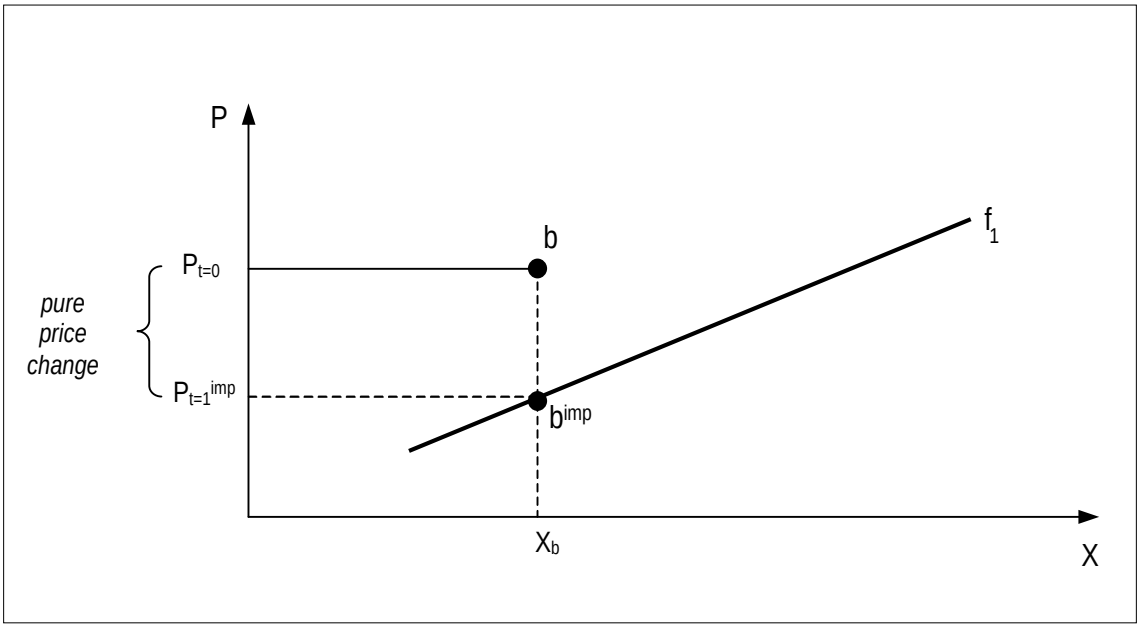
Table 4 : Sample subsets

Sample subset	Base month	…	Current month
A: Unchanged products	Product exists	…	Product exists
B: Old products	Product exists	…	-/-
C: New products	-/-	…	New product

The "unchanged" products were available in the market both in the base month (t=0) and in the current month (t=1) with the same features. No quality adjustment is required for these products because pure price movement can be observed directly. The "old" products were included in the sample in the base month, but they can no longer be observed in the current month. A price is imputed to these products for the current month: this is the average that would have to be paid for a product of the old quality under current market conditions. The "new" products were not yet available in the market during the base month, but have begun to be observed in the current month. A base price is imputed to these new products: this is the price that would have been paid for a product of the current quality under the market conditions prevailing in the base period. The entire index series for the product type concerned is then calculated as the average price movement for unchanged, old and new products together.

Regression analysis is used to impute current prices for old products and base prices for new products. Figure 2 illustrates how this principle would apply to an "old" product in subset B. Regression function f_1 is calculated exclusively from data drawn from the current month. It indicates the quality-related price that purchasers are prepared to pay on average during the current period for a choice of quality profiles X. Product b was included in the sample during the base period, but in the current period it is no longer on the market. A product price is therefore estimated and imputed for the current month. The difference between the imputed current price P_1^{imp} and the true base price $P_{t=0}$ for Product b reflects the pure price change for this sample product for the current month over the base month.

Figure 2: Imputation of a current price for an "old" product



The same technique is used to estimate the base price for a "new" product, except that in this instance the regression function is calculated exclusively from data obtained from the base period.

3.2 Index calculation

The index for a class of product is the geometric mean calculated from the price series for the sample subsets A, B and C. Table 5 shows this in summary form.

Table 5: Index calculation

Product	Sample subset	Prices		Unit price change
		Base period	Current period	
1	A	$P_{t=0}$	$P_{t=1}$	$\hat{P}_1 = P_{t=1} / P_{t=0}$
2		$P_{t=0}$	$P_{t=1}$	$\hat{P}_2 = P_{t=1} / P_{t=0}$
3	B	$P_{t=0}$	$P_{t=1}^{imp}$	$\hat{P}_3 = P_{t=1}^{imp} / P_{t=0}$
4		$P_{t=0}$	$P_{t=1}^{imp}$	$\hat{P}_4 = P_{t=1}^{imp} / P_{t=0}$
5	C	$P_{t=0}^{imp}$	$P_{t=1}$	$\hat{P}_5 = P_{t=1} / P_{t=0}^{imp}$
6		$P_{t=0}^{imp}$	$P_{t=1}$	$\hat{P}_6 = P_{t=1} / P_{t=0}^{imp}$

The two products in sample subset A are on the market in both periods and their quality does not change, so the price movements in this sample subset can be measured directly. The

products in sample subset B are no longer available in the current period, and so a current price needs to be imputed. For sample subset C the missing base prices are imputed and the current prices are replaced by estimates. Imputation permits the formation of consistent price series for sample subsets B and C founded on constant product quality. The required price index is the average obtained from all unit price changes in sample subsets A, B and C:

$$(1) \qquad \text{Price index for a produce class} = \prod_{i=1}^{n} \hat{P}_i^{w_i}$$

w_i … Weighting factor for product i $(\Sigma_i w_i = 1)$

$\hat{P}_i$ … Price change over base period for product i

Individual price series are weighted to reflect the market share (as a proportion of sales revenue) of the manufacturers. If more than one product in the sample is from the same manufacturer, this market share is divided equally between the products concerned. It would be better to weight these different products accurately based on their own market share, but this information is not available.

3.3 Regression analysis

A log-log function is used to calculate the equation of regression. This is a more appropriate form than the linear or the simple log function, partly because non-linear links and links between specific features can be mapped more easily. For desktop computers, for example, the following regression is used:

$$(1) \qquad \ln(P) = \beta_0 + \beta_1 \cdot \ln(\text{Power}) + \beta_2 \cdot D_1\text{RAM} + \ldots + \beta_4 \cdot D\ \text{Graphics} + \beta_5 \cdot D_1\text{Brand} + \ldots + \beta_9 \cdot D_1\text{Processor} + \ldots + \beta_{11} \cdot D\ \text{Software} + \varepsilon$$

Power	=	processor speed in MHz
D_iRAM	=	dummy variables for different sizes of working memory (i=1,2)
D Graphics	=	dummy variable for the graphics card
D_jBrand	=	dummy variables for different manufacturer brands (j=1,…,4)
D_kProcessor	=	dummy variables for different types of processor (k=1,2)
D Software	=	dummy variable for type of operating system
ε	=	stochastic variable

The price of a desktop computer is explained with the aid of the following features: processor speed and type, size of working memory, graphics card, brand and operating system. Size of memory is not expressed as a metric but as a dummy variable, as there are not many options available for memory size. The size of the hard disk is not included as it correlates closely with working memory. Besides, the size of the hard disk is a dwindling factor in purchasing decisions. The dummy variable D Graphics expresses whether the PC has a graphics card or whether graphics are managed by a microprocessor on the mother board.

The features package is adjusted month by month. By way of an example, Table 6 shows the results of regression analysis for desktop computers in February 2004. The reference model, for which all dummy variables are given a value of zero, has an Intel Pentium 4 processor and a working memory of 512 MB, was made by FSC and operates on Windows 2000. The power coefficient can be interpreted in the log-log model as elasticity: for each 1% increase in speed, purchasers will usually pay roughly an extra 1.6%.

Table 6: Regression analysis for desktop computers in the import price index for February 2004

Variable	Parameter estimator	Standard error	t-value	Variance inflation factor
Constant term	-5.667	2.82	-2.01	0
ln(Power)	1.567	0.35	4.42	1.87
D_1RAM (128 MB)	-0.512	0.16	-3.14	1.88
D_2RAM (256 MB)	-0.089	0.05	-1.65	2.13
D Graphics	-0.183	0.07	-2.75	2.18
D_1Brand (Acer)	-0.196	0.05	-3.68	1.46
D_2Brand (HP)	0.162	0.05	3.27	1.55
D_3Brand (IBM)	0.215	0.07	3.06	1.71
D_4Brand (Sony)	0.296	0.11	2.74	1.61
D_1Processor (Celeron)	-0.271	0.06	-4.74	1.47
D_2Processor (Athlon)	-0.153	0.09	-1.79	1.69
D Software (XP)	0.110	0.05	2.18	1.67
Number of observations = 87 Coefficient of determination R^2 = 81%				

With the coefficient of determination at 81%, the explanatory power of this model for desktop computers is very high. The coefficients are similarly high for the other products (notebooks 70%, servers 88%, laser printers 93%, inkjet printers 65%, multi-purpose printers 73%, RAM 80%, hard disks 95%, processors 86%). The variance inflation factor is a measure for collinearity. As in all the other regression models, it usually lies below two, or at most slightly over.

4. TRADITIONAL QUALITY ADJUSTMENT TECHNIQUES

Hedonic indexes differ from matched model indexes insofar as hedonic price measurements adjust for changes in quality. Apart from the hedonic technique for quality adjustment, there are other, older methods which under certain circumstances can lead to very similar results. Earlier analyses in conjunction with the consumer price index displayed only slight differences between hedonic and traditional quality adjustment techniques for the product groups Computers and New cars. This is why introducing hedonic methods exerted a much smaller impact on the price changes expressed in the consumer price index than we are now witnessing for producer, import, export and wholesale prices, where the matched model index was applied and thus no comprehensive quality adjustment has been implemented before.

[i] *Cf. also* Kunz, D.: *"Ausgewählte methodische und praktische Probleme des zeitlichen Preisvergleichs" in Allgemeines Statistisches Archiv, vol. 55, no. 1/1971, pp. 23 ff.*

[ii] *On quality adjustment techniques see* Szenzenstein, J.: *„Preisindizes für industrielle Güter in der amtlichen Statistik" in Harhoff,* D./Müller, M. (eds.)*: "Preismessung und technischer Fortschritt", ZEW-Wirtschaftsanalysen, Baden-Baden, 1995.*

[iii] *On hedonic price measurement see e.g.:* Griliches, Z.: *"Introduction: Hedonic Price Indexes Revisited" in* Griliches, Z. (ed.): *"Price Indexes and Quality Change, Studies in New Methods of Measurement", Harvard University Press, Cambridge, Massachusetts, 1971 and* Harhoff, D.: *"Methodik und Einsatz hedonischer Preisindizes - Ein Überblick" in Harhoff,* D./Müller, M. (eds.): *"Preismessung und technischer Fortschritt", ZEW-Wirtschaftsanalysen, Baden-Baden, 1995; also* Brachinger, H.: *"Statistical Theory of Hedonic Price Indices" Working Paper, posted in the Internet at http://www.unifr.ch/stat/en-home.php.*

[iv] *Cf.* Linz, S./Eckert, G.: *"Zur Einführung hedonischer Methoden in die Preisstatistik" in WiSta 10/2002, pp. 857 ff.*

[v] *Cf.* Linz, S./Dexheimer, V./Kathe, A.: *"Hedonische Preismessung bei Gebrauchtwagen" in WiSta 6/2003, pp. 538 ff. An updated version of this article has been posted in the Internet at http://www.destatis.de/themen/d/thm_preise.htm.*

[vi] *See the press release from the Statistisches Bundesamt dated 17 February 2003 (http://www.destatis.de/presse/deutsch/pm2003/p0580051.htm).*

[vii] *Cf.* Behrmann, T./Kathe, A.: *"Zur Anwendung hedonischer Methoden beim Häuserpreisindex" in WiSta 5/2004, pp.525ff.*

[viii] *Güterverzeichnis für Produktionsstatistiken (GP 2002)*

[ix] *Klassifikation für Wirtschaftszweige, 1993 edition*