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Hardware, software, network effects – what is the price we pay for using a computer?

Abstract

The paper provides two alternative views of the problem of measuring the price development for IT goods:

First, desktop or notebook computers are products, which are only useful when they are combined with an operating system and a set of software applications. Thus, the interaction between Hardware and Software is relevant for pricing computers. New software releases often include new functionalities, which may be important improvements for the user of the software. But on the other hand, the new software releases do in many cases also make higher demands on the hardware or the operating system. Higher hardware or operating system requirements do mean higher costs for the consumer. In order to account for the interaction between hardware and software, both product types should be taken together and priced in combination. This concerns not only the operating system of a computer (e.g. Windows XP) but is also true for the final user software (such as Word, Excel or a computer game).

Second, computers are so called network goods. The consumer behaviour of other users is important for the utility of any particular user. The term "network good" derives from economics of information. A network can for example consist of all consumers using the same technology. The relationship between the users is in this case not physical, but abstract. All consumers using the same technology constitute a "virtual network". The users of a certain software or hardware are tied together by the fact that they jointly determine the potential demand for products which are system-compatible with the respective technology. For example, the users of the operating system Windows XP jointly determine the potential demand for software applications which are compatible with Windows XP. In turn, the range of XP-compatible products offered on the market will depend on the number of users applying this operating system. In order to measure user costs for computer, it is important to account for network effects. Take for example a user who invests in an obsolescent technology, as the operating system "Windows 95" has been in the end of the nineties. The utility derived from the computer system may than decline quite fast, because the range of software applications available for this system is shrinking.

In the paper, the implications of these views are discussed and compared with the current practice employed in Germany for the measurement of computer price developments.

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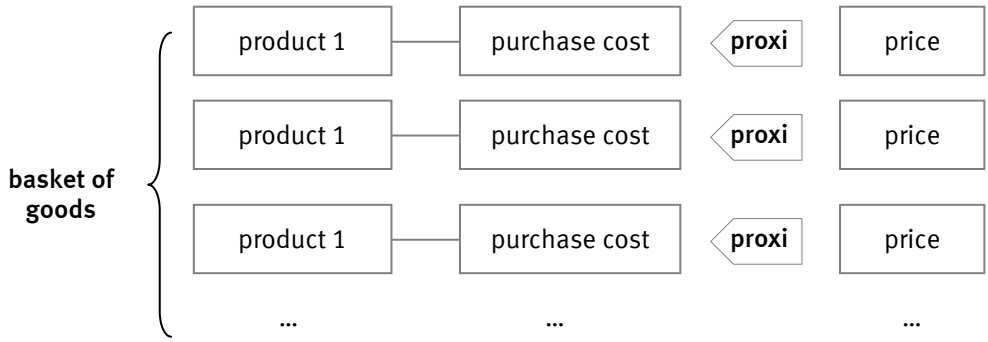
A. Cost of goods index for computers – current practice

In terms of its concept, the German consumer price index, like the Harmonised Index of Consumer Prices (HICP) at the European level, is what is called a cost of goods index. The trend of the index is measured on the basis of price changes which reflect, by approximation, the development of costs that are incurred when buying the products of a defined basket of goods. As a matter of fact, the parameter to be measured is the development of the total costs incurred when buying the products of a basket of goods that remains unchanged over a specified index period. An illustration of this principle is given in the below chart.

Chart 1: The concept of the cost of goods index

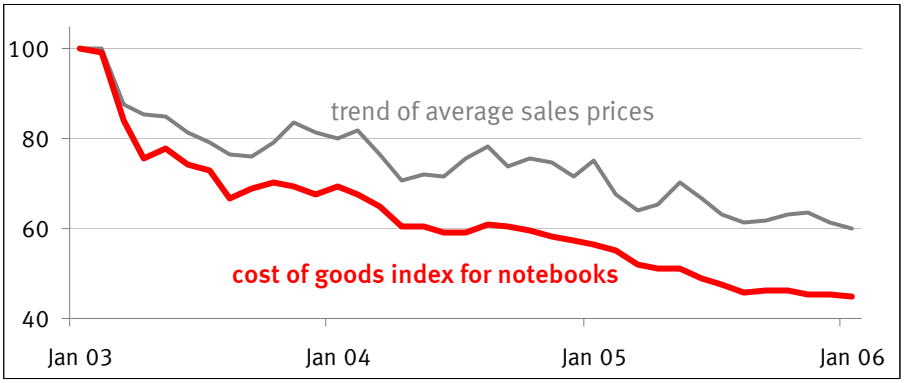


As to the measurement of the prices of *consumer durables*, the purchase costs in the cost of goods index are usually approximated by *adjusted purchase prices* which consumers pay for buying the relevant products. The adjustment is required as such products are often subject to change due to technological progress. As soon as changes occur in the quality of a product, its current purchase price can no longer be used directly for measuring the index development. The product which the purchase price refers to is no longer comparable to the product of the base period. This problem arising with technical products can be solved by taking instead of the actual price an artificial purchase price which would have to be paid for a quality unit of the product concerned. In many cases, product quality can be measured by the consumers' readiness to pay for certain qualitative properties.

As regards for instance the 'notebook computer', the consumers' readiness to pay for certain qualities is in Germany estimated by means of the so-called hedonic method. Based on a regression analysis, the average amount of money is determined which consumers would be willing to pay for definite qualitative properties of the product. The average amounts consumers would be willing to pay for such improved qualitative properties are then deducted as monetary values of quality changes from the directly observed price of a given product which has been newly included in price observation.

The below chart shows the effects of quality adjustment, taking notebooks as an example. The grey curve depicts the trend of the directly observed average sales prices which consumers paid for the notebooks. The red curve in turn shows the development of the price index where quality changes were taken into account. Obviously, the price index declines even more considerably compared to the average sales prices as qualitative developments were taken into consideration in compiling that index.

Chart 2: Cost of goods index for notebooks



The acceleration of the price declines is the typical effect of including quality changes into the price measurement and is due to the quality raising result of the technical progress. The average selling price for notebooks, which are directly observed, have for example fallen from round about 1500 € in 2003 to about 1150 € in 2005. Our estimation for the value of the quality improvements which occurred within this period is 400 €, so that the quality adjusted price has fallen from 1500 € to 750 €. As to product quality, the multimedia functions of the notebooks are becoming more and more important. The consumer are increasingly using their computers as "multimedia entertainment centres" and the products are cumulative providing new possibilities such as TV cards, DVD writer, wireless internet connections together with the requested computing speed and memory capacities with at the same time decreasing selling prices.

B. Interaction between hardware and software

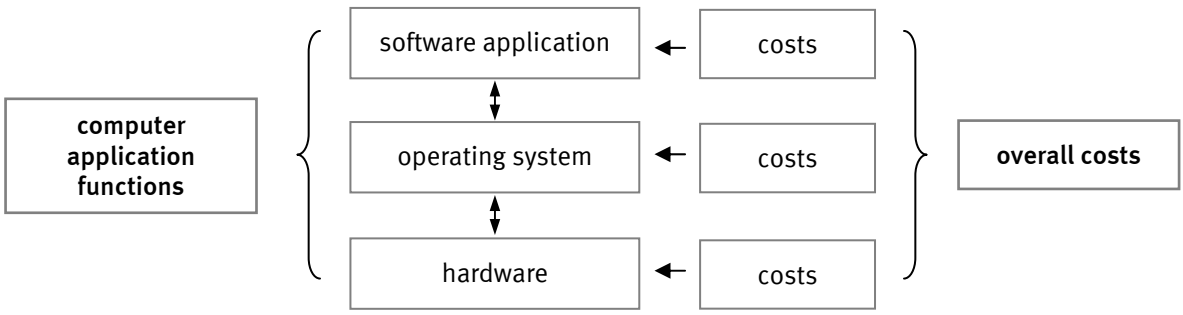
B.1 The problem

Some aspects which play an important role in the IT area are however not considered in determining the computer price development in the above manner. They include the interaction between Hardware and Software in the process of using computers and the life cycles of individual product generations. In this section, the interaction between Hardware and Software is considered in detail. Some pieces of the life cycles problem are discussed below in section C.

Prerequisites for using desktop or notebook computers are the availability of an operating system and application software. For this reason, hardware and software should be considered together and the price development be observed for the whole bundle of goods. In this context, software does not only include the operating system, but also and above all the application software which will be used (e.g. programs such as Word, Excel or a computer game). Though new software versions frequently encompass functionalities that deliver additional benefits to users, they at the same time often impose higher requirements on the hardware equipment or the operating system, which will eventually lead to an increased price of the total hardware and software bundle. Those effects must be taken into account in price measurements as, eventually, only the bundle as a whole will be of use to a user.

In order to account for the hardware-software interaction, the goal must be to calculate an index which indicates the price development for an overall system. The proposal of this paper is that the "basket of goods" of such an index should consist of so-called **"computer application functions"**, that is functions which the user wishes to perform on the computer system.

Chart 3: Cost index for complete computer systems



An important feature of such an index would be that hardware, operating system and software application are *not* unconnected elements of a certain "basket of goods", but rather "input factors" which must *fit together* in order to run the computer application functions. The overall price development for applying computer functions can thus not be calculated as a weighted average

of the price development of the single hardware and software components. The index does rather track the overall costs that are incurred when buying a complete computer system with all components needed to run a defined computer application function.

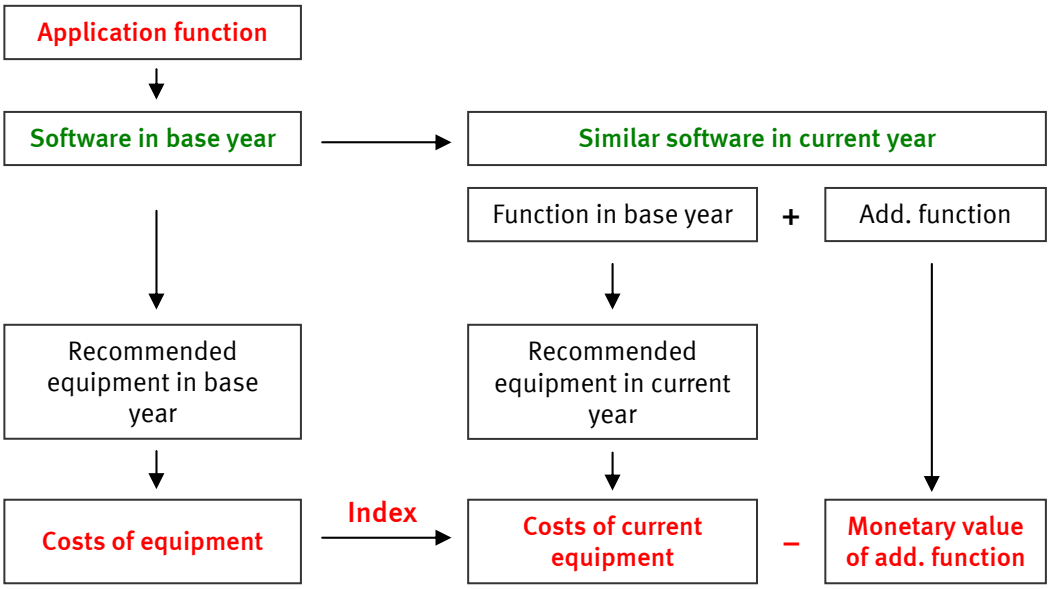
This implies that all important components have to be included into the index calculation – even if the price for one single component is zero. Software applications are for example sometimes available free of charge. They are nevertheless important for this type of index.

B.2 Attempting quantification

It is attempted in this paragraph to quantify, at least approximately, the effects of interaction between hardware and software. As more accurate figures are not available, very rough expert assessments are used, which cannot be considered more than an idea of what the actual quantitative development is like. The purpose of the following rough calculation is to get an idea of the importance of interdependencies between hardware and software in price measurement.

Application functions are, for example, text editing, photo editing and computer games. For the application functions examined, a frequently purchased software program that is able to perform the function is selected in the base period. For that program, the recommended operating system and the recommended minimum hardware equipment are noted. Then the costs of the entire system (software program, operating system, and hardware equipment) are calculated (see chart 4).

Chart 4: Quantification of the interaction effects between hardware and software



In the current period, the procedure is repeated. To take account of the market development, the software examined in the current period is not the same as in the base period; it is rather a soft-

ware program purchased frequently in the current period. Nevertheless, the new software should be quite similar to that of the base period (for example, a new version of the software originally selected) and should have the same functionality as that of the base period. For the new software, too, the recommended operating system and the minimum hardware equipment are ascertained in order to calculate the total costs of the new overall system.

For the new software, two changes generally occur compared with the base period: First, the new software versions frequently contain additional functions that were not contained in the original version. If those are useful additional functions, from the user's point of view, this involves an additional benefit for the consumer, which must be taken into account. Second, the new versions often set higher requirements to be met by the operating system or the hardware, which may lead to higher overall costs of the new system. This is especially relevant for the long term development.

The starting point of our calculation are the so called computer application functions. The following four application functions have been included:

(1) Text editing weight: 42%
(2) Spreadsheet weight: 21%
(3) Photo and video editing weight: 9%
(4) Computer games weight: 27%

For each of those functions, a separate sub index was created. The overall index was calculated as a weighted average of the sub indices, using the weights indicated on the right side. The weighting information was obtained from a study of the Allensbach Research Institute on computer use and refers to the frequency with which the various functions are performed on average by households.

The next step was to select the relevant software programs which are frequently bought to perform those functions. The selection is shown in table 1.

Table 1: Selection of the current software programs

year	text editing	spreadsheet	photo & video editing	PC game
1996	word 7.0	Excel 7.0	Corel Draw 6.0	MS Flug 5.1
1999	word 97	Excel 97	Corel Draw 8.0	MS Flug 98
2001	word 2001	Excel 2001	Corel Draw 10	Fly 2K
2004	word 2003	Excel 2003	Corel Draw 12	Fly Sim 2004

For those software programs, the minimum requirements to be met by the operating system and the hardware, as indicated by the producers, were collected. For the calculation of the costs of the overall system, three user types were defined:

(1) Small user
(2) Normal user
(3) Large user

Different equipment qualities are attributed to the user types. It was assumed, for example, that a computer system corresponding to the minimum requirements of the software program will be sufficient for a "small user". For a "large user", however, a particularly high-quality and high-performance hardware equipment was chosen. The overall costs for application software, operating system and hardware are displayed in table 2 for the example of photo and video editing. The costs for hardware and operating systems are not displayed separated, as in Germany, the price for the hardware does normally include the operating system.

Table 2: Equipment costs for photo and video editing

	Small User		Medium User		Large User	
1996	Corel Draw 6.0	377 €	Corel Draw 6.0	377 €	Corel Draw 6.0	377 €
	Celeron 166Mhz 16 MB RAM 2 GB HDD WIN 95	903 €	Pentium 233 MHz 32 MB RAM 2 GB HDD WIN 95	1 336 €	Pentium II 266 MHz 32 MB RAM 4 GB HDD WIN 95	1850 €
	total costs	**1 280 €**	**total costs**	**1 713 €**	**total costs**	**2 227 €**
1999	Corel Draw 8.0	383 €	Corel Draw 8.0	383 €	Corel Draw 8.0	383 €
	Celeron, 400 MHz 32 MB RAM 4,3 GB HDD WIN 98	530 €	Pentium III 433 MHz 64 MB RAM, 6,4 GB HDD WIN 98	1 021 €	Pentium III 450 MHz 64 MB RAM 6,4 GB HDD WIN 98	1 712 €
	total costs	**913 €**	**total costs**	**1 403 €**	**total costs**	**2 095 €**
2001	Corel Draw 10	314 €	Corel Draw 10	314 €	Corel Draw 10	314 €
	Duron 800 MHZ 128 MB RAM 20 GB HDD WIN XP	446 €	Athlon 1.2-1.4 GHz 256 MB RAM 40 GB HDD WIN XP	754 €	Pentium 4 1.6-1.8 GHz 256 MB RAM 60 GB HDD WIN XP	1 083 €
	total costs	**760 €**	**total costs**	**1 068 €**	**total costs**	**1 398 €**
2004	Corel Draw 12	534 €	Corel Draw 12	534 €	Corel Draw 12	534 €
	Celeron 1.2-1.8 GHz 256 MB RAM 40 GB HDD WIN XP	367 €	Pentium 4 2.0-2.6 GHz 512 MB RAM 60 GB HDD WIN XP	621 €	Pentium 4 2.8-3.8 GHz 1024 MB RAM 120 GB HDD WIN XP	1 021 €
	total costs	**901 €**	**total costs**	**1 154 €**	**total costs**	**1 555 €**

To calculate the cost index of purchasing a complete computer system, the costs of the equipment in the base period are compared with the costs of the current equipment in the present period. Frequently, however, the current equipment contains additional functions which were not

offered yet in the base period. To take this into account, the monetary value of the additional functions is assessed and is deducted from the costs of the current equipment.

The following calculations had to be based on rough expert estimates as there are no figures available on the monetary value of additional software functions. The question to be answered was: "What would the consumer in average be ready to pay for the additional functions available with a new software version?" The estimations have been carried out with the help of a computer expert of the German Computermuseum in Paderborn[1]. Table 3 shows the results of the rough estimations.

Table 3: Rough estimates of the monetary value of additional software functions / photo and video editing

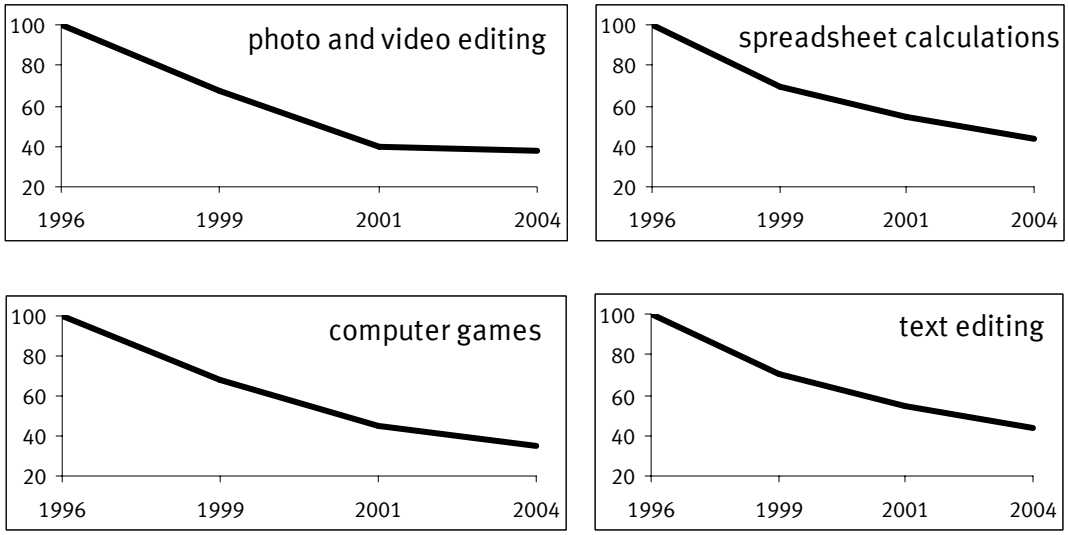
period	software version	additional functions	rough estimation: consumer valuation of the additional functions		
1996	Corel Draw 6.0	(base year version)	small user	normal user	large user
1999	Corel Draw 8.0	Web compatibility, improved colour- and 3D-effekts, flash-animations and video editing, extended print functions, simplified menus and dialog fields	**~ 90 €**	**~ 220 €**	**~ 380 €**
2001	Corel Draw 10	professional photo editing, professional photo effects (red eyes remove), new optimised user interface, many new features as to photo and video editing	**~ 90 €**	**~ 190 €**	**~ 310 €**
2004	Corel Draw 12	export in MS Office applications, optimisation for Windows XP, optimisation of the Performance	**~ 50 €**	**~ 100 €**	**~ 190 €**

The estimated monetary values of the additional software functions have been subtracted from the current prices of the complete computer systems. The index is then calculated by tracking the in this way adjusted costs that are incurred when buying the complete computer systems. The index thus indicates the "quality-adjusted" development of the overall costs of a current com-

[1] see www.hnf.de/index_en.html

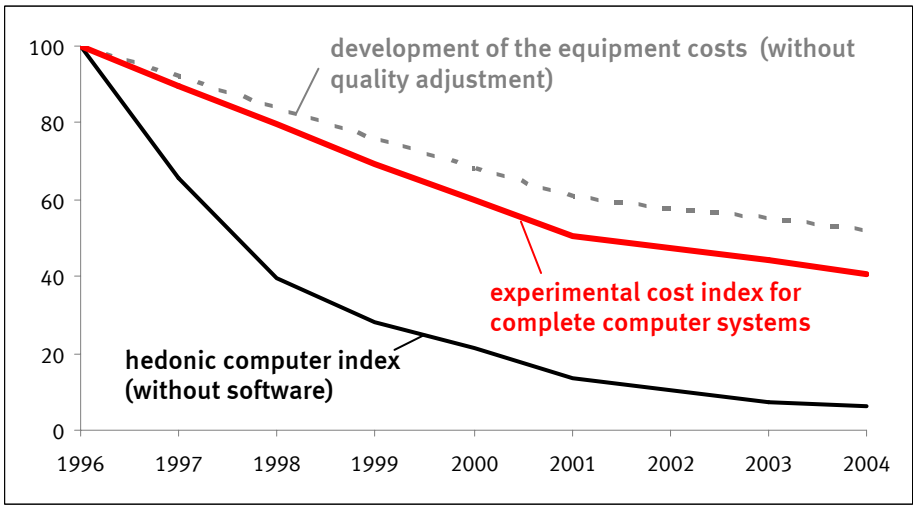
puter system that may be used to perform the respective functions. The following chart display the development of the adjusted costs for the four single computer application functions:

Chart 5: cost indexes for running certain computer application functions



By weighting these four indexes, an overall cost index for complete computer systems is calculated. It is shown in chart 6.

Chart 6: experimental cost index for computer systems including hardware and software



The results suggest that a cost index for complete computer systems would probably show less price declines than the hedonic index for desktop computers. This is due to the fact this calculation is preliminary based on the technical progress attached to the software rather than to the hardware. The hardware is in this consideration only an input factor which is needed to run the application software. Hardware improvements do in this calculation not in every case lead to a higher benefit for the consumer.

But the experimental cost index does show faster price declines than the decrease of the average costs for the equipment (including hardware and software). The grey line indicates the development of the equipment costs without quality adjustment. The faster price decline of the experimental index is due to the fact that recent equipments provide improved computer functions, which cause additional benefit to the user.

C. Network effects

The aim of calculating the experimental cost index for computer systems was to account for the effects of interaction between hardware and software. As mentioned above, there are further particularities of the IT sector, which should be considered when measuring the prices for using a computer. In this section, the implication of so called network effects will be considered very briefly.

Computers systems are in some respects what are called "network goods", which means that the purchasing patterns of several consumers play a role. In the context of information economics, the term network stands for a group of consumers using a given product or technology[2]. The relationship between the individual users is not necessarily of a physical nature, but may exist in abstract terms only. Such an abstract relationship, i.e. a 'virtual network', exists for instance between all users of a specific computer system, even though there may be no other relations between them. For example, the fact of how many application programs and peripheral devices are available for the relevant system in the market plays an important role to all of them. In turn, the range of application programs and peripheral devices offered depends on the number of users applying the given operating system.

As regards the measurement of price trends, it is important to know how the number of users develops over time. If a user bought a technology which would be phased out soon, as it was the case with the Windows 95 operating system at the end of the 1990s, he should take into account that the use of the whole bundle of goods (computer, operating system and application software) might decline relatively soon. In the aforementioned example the number of available software applications for Windows 95 has declined since the changeover to Windows XP.

The presence of network effects leads to the fact that a computer system do have a limited useful life. For itself, a complete computer system may be working for very long time without much wearing out. An old ATARI computer system bought in 1988 may still work today and run the old software applications of the time. But the old system from 1988 will not fit with the recent software or peripheral devices. Thus there is a "virtual" depreciation rate, which forces the user of a com-

[2] See Katz, Michael; Shapiro, Carl: Network Externalities, Competition and Compatibility. In: The American economic review, 75 NO. 3 (1985): S. 424-440.

puter to replace it after a certain time span – at least when he wants to connect his machine to current devices or run recent software applications. The useful life of a computer may be quite long, but the time spans are nevertheless very relevant for the measurement of the development of computer prices. This is especially true for changes in the life spans of computer systems. A shorter durability would lead to higher hardware expenses and thus the costs of using a computer would increase.

The so called user cost formula can be applied to describe the phenomena. The user cost approach has often been applied for modelling the price development of owner-occupied dwellings. The costs of purchasing a consumer durable are with this approach distributed over the entire period of using the good. The user costs are thus allocated to the periods in which the good is actually used. The user costs can be shown for a period of use as the difference between the purchase price (with accruing interest added) and the residual value of the product:

(1) $u = (1+r)P^0 - P^1s$

u ... user cost of the period
r ... interest rate
P^0 ... purchase price of the respective product in the beginning of the period
P^1s ... resale price in the end of the period

The product's residual value corresponds to a resale price, whose development depends on two factors: The product-specific price trend and the decrease in value caused by wear and tear. The development of a computer value differs considerably from the development of the value of other consumer durables, such as real estate. For real estate, the decrease in value occurs mainly through physical wear and tear and the product-specific price trend is rather positive, whereas the situation for computers is the opposite. In many cases, the price of a computer has strongly decreased already after a few months and a second-hand product can be resold at a very low price, if it can be resold at all. This is mainly due to the product specific price decrease and not only to wear and tear.

The product-specific price trend is referred to as $(1-i) = (P^1/P^0)$, where the letter (i) indicates the rate of price *declines* measured for computers. The abrasion rate can be written as $(1-d) = (P^1s/P^1)$. The user cost formula would with that be written as:

(2) $u = (1+r)\cdot P^0 - (1-d)\cdot(1-i)\cdot P^0$

Neglecting the small term (i·d), the formula can be written as:

(3) $u = (r+i+d) \cdot P^0$

u … user cost of the period
r … interest rate
P^0 … purchase price in the beginning of the period
d … physical abrasion rate
i … product specific rate of price decline

The product specific price development could for example be measured by the hedonic method, as it was shown in the first section of this paper. A rate of 20% would for example mean that the quality adjusted prices for notebook computers, observed for the German market, would have fallen by one fifth in the respective period.

It shows up that the rate of price declines for computers is positively correlated with the costs of using the computer: Higher price declines lead to faster product obsolescence and with that to a shorter life span of the product. Shorter life spans do in turn mean higher costs for the user. The user cost formula shows that the cost of using computer systems do thus not only depend on the purchase price P^0 but also on the development of the prices after purchase.

A rapid price decline after purchase may not affect the monetary situation of the consumer, because he will normally not attempt to resell his computer. But as we have seen in section A, the quality adjusted price can be interpreted as a consumer valuation of the respective product. A decreasing consumer valuation may be due to the fact that the usefulness of the product has declined, what in turn can be the result of network effects. To maintain the initial level of utility, the concerned consumer would have to upgrade his computer or he would have to buy a new model. Either would increase the costs of using a computer. Thus in the presence of network effects, decreasing purchase prices can lead to higher user costs for the consumer.

D. Conclusion

The hedonic approach is very useful for the measurement of a quality adjusted price development of hardware components. The approach aims at explaining current purchase prices of individual products by its physical features. However with this approach, some aspects which are important from the point of view of the consumers cannot be captured. Two aspects – the hardware-software interaction and network effects – have been highlighted in this paper.