The Treatment of Quality Changes in the German Consumer Price Index[*]

Johannes Hoffmann
Frankfurt am Main / Germany

Abstract: Today most experts agree that the treatment of quality changes poses the most important problem for price statistics. In Germany adjustments for quality changes are made chiefly by price collectors in the field. As a result, judgmental procedures have to be applied. Recently the German Federal Statistical Office has revised the guidelines for the treatment of quality changes as part of a general movement towards harmonising consumer price statistics in Europe. This reform will reduce the potential quality adjustment bias at "high" rates of inflation. However, some problems, which are relevant in a "low" inflation environment, will remain.

Keywords: consumer price index, quality adjustment

I. The problem of adjusting prices for quality changes

"One does not wish to speak of an increase in price if a good has simultaneously improved to the same extent ..." Horstmann (1963)

Comparing prices over time makes sense, strictly speaking, only for goods that do not change. However, this restriction cannot be maintained over a longer period, as the range of goods available is constantly changing. In the case of many manufactured products, for example, annual changes in models are the rule; in the case of clothing, fashion changes twice per year in line with the seasons. Moreover, in most cases a new model replaces an old model. Therefore price statisticians have no choice but continually to link the price series for old models and those for new ones. That being the case, price comparisons conducted over longer periods are meaningful only if the monetary value of the change in quality is subtracted from the difference in price between the new and the old variants. In other words, the price difference must be broken down into the true change in price and the (monetary) equivalent of the change in quality. Moreover, there is some evidence that retail outlets couple replacements of products with changes in prices. Thus, methods, which interpret the difference in price between the old and the new model as the monetary value of the quality change, run into trouble. The importance of this problem is highlighted by the fact that in US consumer price statistics the changeover to new product variants accounts for a considerable share of the aggregate US price increase.[1]

In a dynamic economy the quality of many products improves steadily. Thus a price index without any adjustments for quality changes will tend to overstate the "true" rate of inflation. However, contrary to a well-known prejudice, statistical agencies adjust prices for changes in quality, using a variety of methods. Thus the so-called

"quality-change bias" inherent in the recorded rate of inflation might be less than zero, equal to zero or above zero.

The paper is organised as follows: In section 2 certain aspects of the German Consumer Price Index which are relevant for the treatment of quality changes are described in some detail. Section 3 analyses the instructions for the German Consumer Price Index, which were in effect prior to and including the year 1996. Section 4 describes how the instructions were changed at the beginning of 1997. Section 5 examines the effect which changes in market segment ("trading up" or "trading down") have on the accuracy of price measurement. In section 6 the consequences of the methods employed are illustrated by using the example of washing machines. Section 7 ventures an assessment of the quality-adjustment procedures insofar as they contribute to the overall accuracy of inflation measurement in Germany.

II. The German Consumer Price Index

In Germany the Consumer Price Index (CPI) is based on the principle of measuring pure price change.[2] It is calculated as a Laspeyres index with a weighting pattern that does not change over several years. Although the index is rebased every five years as a rule, the weights are about two years old when a new index is introduced. Hence, the age of a basket of goods is seven years when switching to a new base year takes place.

The sampling of products for which prices are to be collected is carried out in two stages. The first stage, the broad specification of products, is undertaken by the Federal Statistical Office; price collectors in the field conduct the second stage, the sampling of specific product variants, for most products. In the first stage the Federal Statistical Office broadly specifies a limited number of goods. These so called "representative products and services" form the basket of goods (since 1991 approximately 750 products and services). Total expenditure by consumers is then allocated to these goods in accordance with the Classification of Individual Consumption by Purpose (COICOP). Thus, German price statisticians follow the principle of representative weighting, which means that the total amount spent on a certain purpose of use is assigned to a limited number of goods and services. This is a useful method for reducing the input required for collecting the data when the prices of a product included in the basket of goods and of the other products thus represented move more or less in line.

The representative products and services are selected by the procedure of "typical cases" (purposive selection). This selection is updated every five years. The specifications of the representative products and services in the basket of goods are deliberately worded in broad terms in order to allow price collectors to be flexible in sampling the concrete product variants whose prices are to be collected.

Since difficult assessment problems arise when models are replaced, the Federal Statistical Office requires that a sampled good, once selected, should be retained as

long as possible.[3] Price statisticians are therefore instructed to select goods for price monitoring that are as widely traded as possible and that can be expected to remain on the market for a long time without undergoing any alterations. In general, the price statisticians should opt for the model with the highest turnover rather than, say, a slow-seller. A good with a major importance for turnover is generally likely to be sold for a longer period. In case of doubt, a good of medium quality should be selected. If it is not possible to find a model corresponding to the official specification, a good that is as similar as possible and that has a major importance for turnover may be selected. The relevant factor in the sampling procedure is the product variant's importance for turnover in the reporting unit (rather than in Germany as a whole). Thus, goods belonging to different market segments are selected for price observation.

The statistical offices of the local authorities, and, in exceptional cases, the statistical offices of the Länder, undertake the collection of prices for about 650 out of the 750 or so representative products and services. The prices of nation-wide suppliers - such as insurance companies, the health sector, the postal and telecommunications sectors and mail-order houses - as well as list prices of car manufacturers and car importers are collected directly by the Federal Statistical Office. The number of individual prices per item varies depending on the extent to which the respective goods and services are disseminated over the reporting municipalities, and on the number of inhabitants in each of the latter. A total of approximately 250,000 price series has most recently been maintained for the CPI in Western Germany.

The statistical offices have two tasks to perform in connection with changes in product specifications: to identify quality changes and to assess the monetary value of quality changes. In Germany, price collectors working for the statistical offices of the Länder and the municipalities usually do this. Only the prices that are collected centrally by the Federal Statistical Office are adjusted accordingly for changes in quality. The treatment of quality changes is co-ordinated by guidelines issued by the Federal Statistical Office.

The Länder report the unadjusted average prices and the quality-adjusted index figures to the Federal Statistical Office, plus - since 1997 - information on replacements and the kind of quality adjustment performed. However, no detailed description of the sampled products and services is conveyed to the Federal Statistical Office. The Federal Statistical Office is therefore unable to make a detailed check of the adjustments that have been made. Only a broad plausibility check of the short-term changes in the Länder index figures and a count of replacements and methods applied is carried out centrally. The assessment of the quality changes can therefore vary considerably among price collectors. This has, perhaps, the advantage of ensuring that the overall result constitutes a "democratic" assessment of quality changes; on the other hand, the average of many assessments that are more or less accurate is not necessarily a reliable estimate of pure price change.
Since in Germany price collectors in the field make adjustments for quality changes for most goods, judgmental procedures have to be applied. The Federal Statistical Office has recently modified the corresponding instructions for price collectors. Thus the next chapter analyses the instructions that were in effect prior to and including

the year 1996; the subsequent chapter examines the modifications, which became effective in January 1997.

III. The instructions for quality adjustments effective prior to and including the year 1996

Box 1 presents a summary of the instructions, which were given to price collectors by the Federal Statistical Office prior to and including the year 1996.[4] The major methods applied were linking in overlapping periods, direct comparison, and linking with a fixed adjustment factor of 50 % or 100 % of the difference in price.

Box 1: Instructions for quality adjustment prior to and including the year 1996

1. If, in an overlap period, prices for both the old and the new model are available, then adjust the base price (the preceding month's price) by the price ratio between the new and the old model in the overlapping period (**linking in overlapping periods**).
Or:
2. Break down the change in the market price Δp into the "true" change in price, Δp_r, and the monetary value, Δp_q, of the change in quality: $\Delta p = \Delta p_r + \Delta p_q$. Then compare these two variables with one another:

Case a): The true increase (or decrease) in price included in the price difference is greater than the improvement (or deterioration) in quality. In this case, the price change should be calculated on the basis of the price of the new model and the base price (**direct comparison**).

Case b): The true increase (or decrease) in price included in the price difference is roughly equal to the improvement (or deterioration) in quality. In this case, the base price has to be increased (decreased) by half the difference in price (**linking with an adjustment factor of 50 %**).

Case c): The true increase (or decrease) in price included in the price difference is less than the improvement (or deterioration) in quality. In this case, the base price is adjusted by the full difference in price (**linking with an adjustment factor of 100 %**).

Case d): Quality change without any change in price. In this case, the price change should be calculated on the basis of the price of the new model and the old base price (**direct comparison**).

Case e): Improvement in quality coinciding with a decrease in price. In this case, the price change should be calculated on the basis of the price of the new model and the old base price (**direct comparison**).

Case f): Deterioration in quality coinciding with an increase in price. In this case, the price change should be calculated on the basis of the price of the new model and the old base price (**direct comparison**).

The main problem affecting all the methods is that the quality adjustments depend on a difference in the price alone.[5] Thus, if there is no difference in price between the old and the new model, no adjustment is made for differences in quality. If there is an improvement in quality and a decline in price, once again no adjustment is under-taken. And even if there is an increase in price and an advance in quality, an adjust-ment will be made only to the extent of the difference in price between the new and the old model. Thus, the methods employed by the Federal Statistical Office prior to 1997 worked quite well, provided that:
- an increase in quality was accompanied by an increase in price, or
- a decrease in quality was accompanied by a reduction of price, and

that the change in price was equal to or larger than the monetary value of the change in quality. If these conditions were not fulfilled, the methods applied resulted in a distorted estimate of pure price change.

It is, however, questionable whether these conditions are fulfilled in practice. It is true that economists expect price differences to reflect differences in quality in a long-run market equilibrium under the condition of perfect competition; thus, by and large, the methods employed by the Federal Statistical Office yield an undistorted estimate of pure price change, assuming a long-run market equilibrium. In that case, however, product replacements are not necessary, and the problem of forced replacements does not occur, either. But barring a long-run market equilibrium neither economic theory nor empirical evidence is inconsistent with the idea of new goods being simultaneously less expensive and of higher quality.

The same is true in the case of discontinuous price recording, the use of which is inevitable in price statistics. List prices or prices given in mail order catalogues, which remain constant for a longer period, offer rather extreme examples. Since price collectors cannot haggle over prices without loosing their credibility, they have to rely on such list prices. Under these circumstances, nothing prevents a new car, for example, from being less expensive than and superior in quality to an old car, supposing the list price has remained constant for a year or more.

In the light of the foregoing analysis, it seems appropriate to distinguish among the following cases:
- There is an advance in quality and the price of the newly sampled good is the same or lower than that of the model replaced: In such cases, the base price (the preceding month's price) is not adjusted for the change in quality (case d, case e). Thus the quality-change bias will be large and positive.
- The price difference between the new and the old model is positive and there is an advance in quality. In this case, the Federal Statistical Office's instructions call for an additional distinction:
- The true increase in price is greater than the improvement in quality. Then no adjustment is made to the base price (case a). A positive bias arises.
- The true price increase is roughly equivalent to the improvement in quality. Then the base price is adjusted by 50 % of the raw difference in price (case b). On average the bias will be small and indeterminate in sign.
- The true price increase is less than the improvement in quality, but positive. Then the base price is adjusted by the full difference in price (case c). This procedure results in a negative bias.
- The true price change is zero. Then the base price is adjusted by the full difference in price (case c). There will be no bias.
- The true price change is negative. Then the base price is adjusted by the full difference in price (case c). This procedure results in a positive bias.

IV. Recent changes in the instructions for quality adjustment

The Federal Statistical Office's instructions concerning the treatment of quality changes have recently been revised as part of the general effort to harmonise consumer price statistics in Europe. The instructions have, in general, been simplified and improved in several respects.[6] For example, the conditions under which the method of linking in overlapping periods may be applied have been specified in greater detail, with the result that this method, which typically results in distorted estimates of pure price change, is now almost never employed. The conditions under which the method of direct comparison may be utilised have been specified in greater detail as well.[7] A flexible adjustment factor was introduced for the method of linking, which allows the base price to be adjusted exactly by that part of the price difference attributable to the change in quality. This new technique supplements the procedures of linking with a fixed adjustment of 50 % or 100 % and of direct comparison. As a result, the difference in price may be adjusted for an advance in quality, even if the monetary value of the quality change is small compared with the true change in price. Thus the potential for bias is reduced for replacements which are more expensive than the older models.

Box 2: Instructions for quality adjustment since 1997

1. If, in an overlap period, prices for both the old and the new model are available and the market is more or less in equilibrium, then adjust the base price (the preceding month's price) by the price ratio between the old and the new model in the overlapping period (**linking in overlapping periods**).
Or:
2. If the range of goods in an outlet is changed, collect the price difference between the old and the new model in another outlet. Then adjust the base price by the price ratio between the old and the new model found in the other outlet (**linking in overlapping periods**).
Or:
3. If the new volume seller is highly similar to the old model, then the price change is to be calculated on the basis of the price of the new model and the old base price (**direct comparison**).
Or:
4. If the new volume seller is dissimilar to the old model in several aspects, then the base price is to be adjusted by the full difference in price (**linking with an adjustment factor of 100 %**).
Or:
5. Given information indicating that the price difference between the old and the new model includes a true change in price, the base price is to be adjusted by the part of the price difference attributable to the difference in quality (**linking with a flexible adjustment factor**). Where no exact information is available, it is permissible to adjust the base price by half the difference in price (**linking with an adjustment factor of 50 %**).

Despite all these improvements, the adjustment for differences in quality still depends on a difference in price between the new model and the replacement. If the newly sampled product is less expensive than the old model or if the price quote remains unchanged, still no adjustment for an advance in quality is made. The same applies to deterioration in quality associated with price increases.

V. Changes in market segments and the accuracy of price measurement

These preliminary findings give rise to the question of whether it is possible to derive more general results. In my earlier study on this subject[8] I immediately proceeded to venture an assessment of the accuracy of the methods applied, making this depend on the specific rate of price change for a product and, subsequently, on the overall rate of inflation. Unfortunately, this analysis itself might have been biased in favour of a large quality adjustment bias. My earlier analysis rested on four central assumptions:

• Model changes occur once a year. This seems to be true for many products and services.

• Prices are typically adjusted when models change - because of menu costs - and remain constant until the next change of model.

• No change in market segments takes place.

• Price statisticians correctly identify the quality change and follow the instructions of the Federal Statistical Office.

The third assumption is frequently violated in practice. If price collectors are forced to replace sampled products and services, they have to choose a new product variant.[9] The Federal Statistical Office's instructions stipulate that they have to select the model with the highest turnover. The newly sampled model, however, might belong to a different market segment from that of the model being replaced, depending on whether customers in this specific outlet now prefer less expensive and less comfortable products or more expensive and more luxurious products. The first kind of change in market segment might be described as "trading down", the second as "trading up". In that case, however, the underlying trend in quality could be concealed by the difference in quality between the old and the new market segment (Figure 1). A typical value for the trend rate of quality growth might be 1 % or 2 % p.a.; the price and quality difference between market segments typically amounts to more than 10 %.

Figure 1: Advance in quality and change in market segment

Quality

Product range

"trading up"

"no change"

"trading down"

t₁   t₂   Period
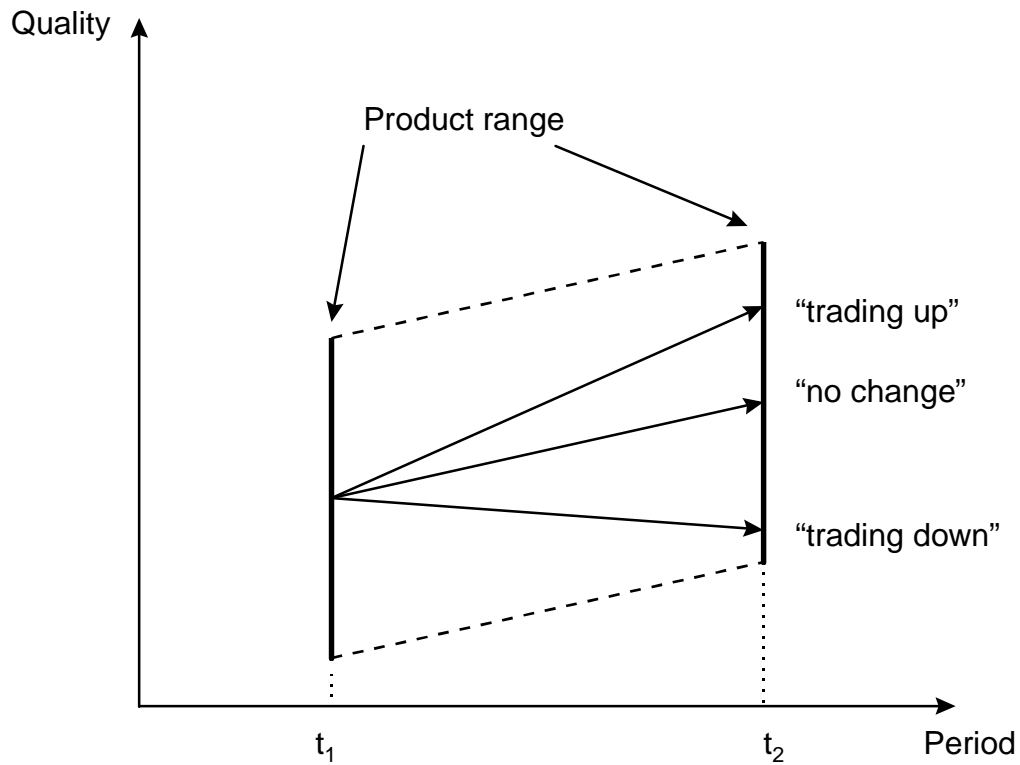
In the examples shown in *Box 3* the difference in quality between the new and the old product variant is broken down into effects attributable to an overall advance in quality in the market concerned and effects attributable to a change in the market segment. In these examples a market with an overall improvement in quality of DM (or 💰) 2 is analysed (column 3); conversely, the results apply to products and services showing an overall decline in quality. Case 1 describes a market with an overall reduction in price (DM - 4; column 6). In detail, the following pattern emerges:

Box 3: Price change, change in market segment and quality adjustment										
(1) Change in market segment	(2) Intersectoral difference in quality	(3) Intertemporal difference in quality	(4) Total difference in quality (2) + (3)	(5) Intersectoral difference in price	(6) Intertemporal difference in price	(7) Total difference in price (5) + (6)	(8) Quality adjustment of base price	(9) Difference in price after quality adjustment (7) - (8)	(10) True difference in price - (3) + (6)	(11) Bias (9) - (10)
Case 1: Price reduction										
"no change"	0	+ 2	+ 2	0	- 4	- 4	0	- 4	- 6	+ 2
"trading down"	- 10	+ 2	- 8	- 10	- 4	- 14	- 8	- 6	- 6	0
"trading up"	+ 10	+ 2	+ 12	+ 10	- 4	+ 6	+ 6	0	- 6	+ 6
Case 2: No change in market prices										
"no change"	0	+ 2	+ 2	0	0	0	0	0	- 2	+ 2
"trading down"	- 10	+ 2	- 8	- 10	0	- 10	- 8	- 2	- 2	0
"trading up"	+ 10	+ 2	+ 12	+ 10	0	+ 10	+ 10	0	- 2	+ 2
Case 3: No change in quality adjusted prices										
"no change"	0	+ 2	+ 2	0	+ 2	+ 2	+ 2	0	0	0
"trading down"	- 10	+ 2	- 8	- 10	+ 2	- 8	- 8	0	0	0
"trading up"	+ 10	+ 2	+ 12	+ 10	+ 2	+ 12	+ 12	0	0	0
Case 4: Moderate price increase										
"no change"	0	+ 2	+ 2	0	+ 4	+ 4	+ 2	+ 2	+ 2	0
"trading down"	- 10	+ 2	- 8	- 10	+ 4	- 6	- 6	0	+ 2	- 2
"trading up"	+ 10	+ 2	+ 12	+ 10	+ 4	+ 14	+ 12	+ 2	+ 2	0

- If there is no change in market segment, the already well-known result applies and the instructions of the Federal Statistical Office yield a positive bias.
- If "trading down" occurs, the newly sampled models will be both less expensive and of lesser quality than the models being replaced. The instructions issued by the Federal Statistical Office demand that the base price is adjusted by the part of the price difference attributable to the difference in quality (Box 2, instruction no. 5). The overall difference in price amounts to DM - 14 (column 7 in Box 3), the overall difference in quality to DM - 8 (column 4). Accordingly the base price is adjusted by DM - 8 (column 8). The change in price after quality adjustment adds up to DM - 6 (column 9), which is the same as the "true" difference in price (column 10). Thus, for products, whose quality is improving overall and whose prices are declining, the switching to lower market segments potentially offsets inadequacies in the instructions concerning quality adjustments. The implicit change in quality within the price statistics will then be negative, even if there is an overall advance in quality in the market.
- If "trading up" occurs, the prices and quality of products increase simultaneously. The increase in price (DM + 6; column 7), however, is much smaller than the monetary value of the advance in quality (DM + 12; column 4). The instructions issued by the Federal Statistical Office demand that the base price is adjusted by the part of the price difference attributable to the difference in quality (Box 2, instruction no. 5). Accordingly the base price is adjusted by DM + 6 (column 8). The change in price after quality adjustment totals DM 0 (column 9), which is more than the "true" difference in price (DM - 6; column 10). Thus, even if the raw difference in price is completely disregarded for inflation measurement, a positive bias ensues which is larger than that which would have occurred if there had been no "trading up".

If there is no overall price increase in the market (Case 2), similar results are obtained as in the case of declining prices: Assuming "trading down" to occur, the bias vanishes. If there is a (moderate) price increase overall (Case 4), a potential for a negative bias emerges: Assuming that buyers choose less expensive products ("trading down"), the difference in price between the new model and the model being replaced will be negative. The same is true for the monetary value of the difference in quality. However, since there is an overall price increase, the difference in price will be smaller in absolute value than the difference in quality. The difference in price is deleted for the measurement of price change, and a negative bias appears.

Thus, instead of the relatively simple relationship between the rate of price change and the measurement bias found in my earlier study, a more complex pattern emerges:

Table 1: Change in market segment and the accuracy of inflation measurement
(overall advance in quality)

Bias	Price reduction	No price change	Price increase
"trading down"	= 0	= 0	< 0
"no change"	> 0	= 0 / > 0	= 0
"trading up"	>> 0	= 0 / > 0	= 0

VI. A case study: washing machines

As with the majority of other goods, the specification of washing machines in the German Consumer Price Index is broadly defined (see Table 2). Since 1980, the product specification has been altered only once, marginally (in 1992) and, if anything, its scope was broadened. The specification includes top-loaders, in addition to normal front-loaders. The consumer price statistics indicate that prices of washing machines have risen by a total of about 25 %, or by an average of 1.2 % p.a., between 1980 and 1998 (see Chart 1). According to the Federal Statistical Office improvements in quality contribute about one-third to these price increases. Thus the quality-adjusted index figure rose by 17 %, or 0.8 % per annum. The implicit adjustment for quality of 7.2 % corresponds to a rate of quality advance of 0.4 % p.a. on average.

Table 2: Washing machines in the West German Consumer Price Index

Basket of goods	Specification	Relative importance	Average price at the beginning	Average price at the end
1980	Fully automatic washing machine, programmable, cylinder system, for 4-5 kg dry laundry	0.245 %	DM 901.77 (01/1980)	DM 1,002.44 (09/1989)
1985	Fully automatic washing machine, programmable, cylinder system, for 4-5 kg dry laundry (until 12/1992)	0.167 %	DM 1,010.73 (01/1985)	DM 1,079.91 (12/1991)
	Fully automatic washing machine for 4-5 kg dry laundry (from 01/1992)		DM 1,120.10 (02/1992)	DM 1,166.44 (12/1992)
1991	Fully automatic washing machine for 4-5 kg dry laundry	0.216 %	DM 1,043.72 (01/1991)	DM 1,146.32 (12/1998)

Source: Federal Statistical Office, own calculations.
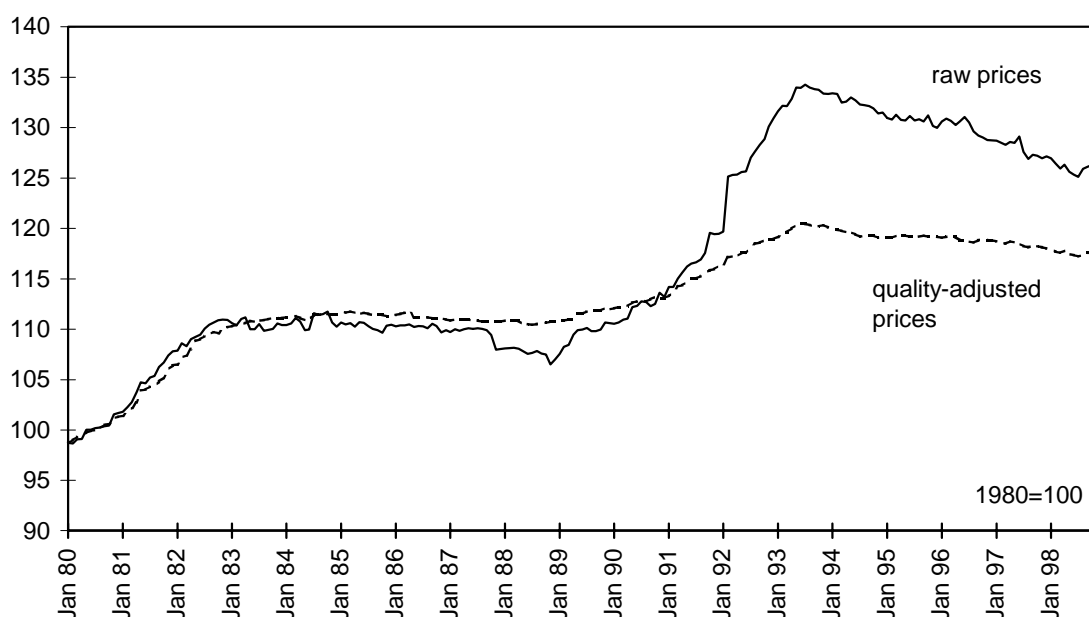
Chart 1: Price trends for washing machines

Table 3: Price and quality changes in the price index for washing machines
(in % per annum)

Period	Raw prices	Quality-adjusted prices	Quality adjustment
01/1980 –10/1982	+ 4.3	+ 3.9	+ 0.4
10/1982 –11/1988	- 0.7	+ 0.2	- 0.8
11/1988 –07/1993, of which			
11/1988 - 01/1992	+ 3.8	+ 1.6	+ 2.1
02/1992 - 07/1993	+ 5.1	+ 2.0	+ 3.0
07/1993 -12/1998, of which	- 1.2	- 0.5	- 0.7
12/1997-12/1998	- 1.3	- 0.8	- 0.5
01/1980 -12/1998	+ 1.2	+ 0.8	+ 0.4

Source: Federal Statistical Office, own calculations.

The analysis of the instructions for the quality-adjustment of prices suggests that, on average, fewer adjustments are undertaken in times of relative price stability than in times of moderate price increases. Accordingly, the entire period was split into four subintervals with varying rates of price change (Table 3). When the data are examined in detail, the following picture emerges:

• Until the autumn of 1982, prices for washing machines rose sharply. The quality-adjusted change in the index figure hardly differs from the change in average prices. On average, prices were adjusted for changes in quality. The analysis of the instructions for the quality adjustment of price changes suggests that larger adjustments might actually have been expected during that period.

• A period of broadly stable prices ensued, beginning in the autumn of 1982 and continuing up to the end of 1988. Average prices even declined slightly from the mid-eighties on; the quality-adjusted index-figure more or less remained unaltered, however, so that, on average, the quality adjustment was, in fact, negative!

- The period from November 1988 up to and including 1993 shows sharp increases in prices. However, the picture is distorted insofar as at least some price collectors took advantage of a modification in the specification at the beginning of 1992 to switch to models of a higher price segment. These changes took place during 1992, principally in February. Between January and February 1992 the average price rose by 4.5 %, with the index figure rising by as much as 0.6 %. In the period between February 1992 and July 1993, the change in average prices amounted to + 5.1 % p.a., the change in the index figure being only + 2.0 % p.a. Hence, during this period of sharp price increases, more than one-half of the rise in prices was discounted as representing an advance in quality.
- From mid-1993 on, the prices of washing machines fell. The price index also showed a decline in line with this. The decline in average prices, totalling - 6.5 % up to the end of 1998, was more marked than the decline in the index figure (- 2.7 %). During that period, the implicit quality index figure again registered a decline of - 3.9 %, or - 0.7 % per annum.

Assuming that the advance in washing machine quality is not correlated with the true rate of price increase, this pattern seems to support the thesis that changes in quality may be adequately accounted for when prices are rising moderately, but that the generalising procedure of the Federal Statistical Office results in the true rate of price increase being overstated when prices are stagnating or even declining. However, it cannot generally be ruled out that enterprises forgo improvements in quality during periods of price stability, since price adjustments could be particularly expensive during such periods. On the other hand, improvements in the quality of products can be especially effective in prompting sales if prices are stable. At all events, the data from the product tests which will be analysed in detail later do not offer any indication that the advance in quality was subject to standstills during the mid-eighties or in the mid-nineties (see Table 5).

Thus some changes in market segments must have caused the decline in quality during the second and the fourth periods. A replacement of price representatives would be appropriate if stagnating incomes and increased employment risks were to cause households to switch to models which are not of the highest quality but are less expensive. In that case, average prices would fall, but the accompanying decline in quality should be deleted from the price index (see section 5). The result would be a decline in the implicit quality index, even if there were an ongoing improvement in quality in the market.

Table 4: Replacement of washing machines in the West German CPI (1998)

Number of monthly collected prices	169
of which	
• replacements (per year)	48
of which	
• optional replacements	0
• forced replacements	48
Percentage of price difference deleted	
• 0 %	19
• 1 - 49 %	2
• 50 %	7
• 51 - 99 %	6
• 100 %	14

Source: Federal Statistical Office.

Recently, replacement rates and counts of the methods applied for quality adjustments have become available in Germany (see Table 4). The specific replacement rate for washing machines in 1998 was just 28 %, which is extremely low compared with that of other countries.[10] In France, for example, average replacement rates of more than 100 % can be found in such categories like consumer durables.[11] These figures are much more in keeping with the common experience that electrical appliances are generally replaced once a year.

In the absence of more detailed information it is difficult to know why replacement rates are so low in Germany. This might be explained, in part, by the way price collectors choose the products for price collection and by the fact that volume sellers stay in the market for a longer period than do less successful models. It is, however, extremely unlikely that products like washing machines remain on the market unchanged for an average of approximately 4 years, as the replacements rates in Germany would seem to imply. It is much more likely that many price collectors indicate "no replacement" if there is a change in the sampled product, but no price adjustment is actually called for by the Federal Statistical Office's instructions. This happens either (see section 4):
- when there is no change in quality,
- when the new model is highly similar to the one being replaced,
- when there is no difference in price, or
- when there is an advance in quality but a reduction in price and vice versa.

All replacements for washing machines in 1998 have been forced replacements, i.e. the price collectors had to sample a new model because the old model had disappeared from the reporting outlet. Thus, the method of linking in overlapping periods was not applied to washing machines in 1998. In 40 % of all replacements, the prices of new and old product variants were directly compared; in 30 % of the cases the entire difference in price was deleted for inflation measurement. For 30 % of all replacements the method of linking with a flexible adjustment factor was used; in about 50 % these cases, the escape clause was invoked of adjusting for half of the difference in price. This suggests that price collectors find it difficult to estimate the monetary value of the price difference precisely.

Since replacement rates for electrical appliances approach 100 % in other countries and since it is common knowledge that models typically are replaced once a year in such markets, it seems sensible to suppose that the true replacement rate was approximately 100 % in Germany, as well. On this assumption adjustments were made for differences in quality for only 17 % of all washing machine replacements in 1998; in 83 % of these cases the method used was that of direct comparison. These results are consistent with the hypothesis that in periods of stagnating or even declining prices no adjustments for the advance in quality are undertaken. Conversely, the implicit quality index also declined in 1998 (see Table 3). Thus, the few adjustments that were made for quality change, must have been done predominantly for changes in market segments ("trading down"), and not for the ongoing advance in quality.

Detailed data on prices and product characteristics accumulated over a long period are needed to test the overall accuracy with which pure price change is measured. Since such data are not available in the consumer price statistics in Germany, the following analysis has had to rely on other data sources. The monthly magazine "Test", published by "Stiftung Warentest"[12], regularly reports on the prices and quality characteristics of electrical appliances. A market research institute usually collects the prices in a representative sample of outlets. The median price is quoted for models that are traded on a decentralised basis; in exceptional cases, the mean price or the price stated by the manufacturer is listed instead. The catalogue price is quoted for mail-order appliances. Product tests also involve quite detailed descriptions of their technical attributes, some of which are examined in the tests. Data on the market shares of individual models are not published; however, information provided by "Stiftung Warentest" indicates that the products' market importance is taken into account when selecting models for the tests. Normally, products belonging to a specific market segment (e.g. medium price range or luxury models) are combined in one test so that different segments of the market are scrutinised alternately. The present study uses issues of the magazine "Test" dating from early 1980 to the spring of 1999.

Table 5: Tests of washing machines carried out by Stiftung Warentest

Test no.	Publication 'Test'	Prices	Market segment	Number of models	Average price (DM)	Average load (kg)	Average maximum spinning speed (rpm)	Average con-sumption of water (litres per kg laundry)	Average consump-tion of electricity (kwh per kg laundry)
1	Vol. 4/80	11/79	middle price range	13	1,102	4.5	791	33	0.77
2	Vol. 2/81	(10/80)	lower price range	24	689	4.6	492	27	0.59
3	Update of 4/80	10-11/80	middle price range	9	1,146	4.6	819	33	0.75
4	Update of 2/81	8-9/81	lower price range	13	911	4.6	621	31	0.59
5	Vol. 3/82, 1/83	11/81	luxury class	15	1,935	4.7	1,028	27	0.36
6	Vol. 1/83	8-9/82	upper price range	14	1,215	4.6	813	28	0.36
7	Vol. 1/83	(10/82)	luxury class	12	2,028	4.7	1,025	28	0.37
8	Update of 1/83	9-10/83	upper price range	10	1,234	4.7	816	28	0.36
9	Vol. 8/84	2-4/84	space-saving models	15	950	4.4	471	27	0.39
10	Vol. 5/85	9-11/84	upper price range	18	1,190	4.6	836	25	0.36
11	Vol. 5/86	9-10/85	lower price range	30	784	4.5	461	26	0.37
12	Vol. 11/86	6/86	upper price range	16	1,380	4.7	1,004	22	0.31
13	Vol. 4/87	9-10/86	space-saving models	16	1,264	4.5	834	25	0.37

Test no.	Publication 'Test'	Prices	Market segment	Number of models	Average price (DM)	Average load (kg)	Average maximum spinning speed (rpm)	Average con-sumption of water (litres per kg laundry)	Average consump-tion of electricity (kwh per kg laundry)
14	Vol. 5/88	6-9/87	middle price range	22	1,219	4.7	848	23	0.28
15	Vol. 4/89	9/88	middle price range	15	1,378	4.8	975	19	0.27
16	Update of 5/88	11-12/88	middle price range	20	1,360	4.7	855	23	0.28
17	Vol. 4/90	9-12/89	upper price range	14	1,591	4.9	1,127	17	0.25
18	Vol. 10/91	6/91	space-saving models	26	1,544	4.5	998	21	0.31
19	Vol. 1/93	9/92	luxury class	15	2,002	4.9	1,341	15	0.23
20	Vol. 10/93	2-5/93	middle price range	12	1,232	4.6	862	19	0.25
20	Vol. 10/93	2-5/93	space-saving models	8	1,427	4.5	860	18	0.24
21	Vol. 10/94	6/94	middle price range	16	1,409	4.8	1,000	14	0.21
22	Vol. 10/95	6/95	upper price range	14	1,589	4.9	1,200	12	0.21
23	Vol. 10/96	6/96	space-saving models	16	1,371	4.3	984	15	0.22
24	Vol. 3/97	11/96	space-saving models	7	1,135	3.7	970	15	0.24
25	Vol. 1/98	10/97	space-saving models	11	1,515	4.5	1,073	13	0.22
26	Vol. 3/99	12/98	luxury class	11	2,046	5.0	1,518	10	0.19

Since 1980, Stiftung Warentest has presented 26 tests (including 4 updates) for washing machines, comprising between 7 and 30 models (Table 5). In total, the prices and product qualities of 412 models were collected. Some of these models were subjected to multiple tests, and some of the models within individual tests were identical in construction. The tests refer to front-loaders and top-loaders and cover various market segments ("luxury models", "upper price bracket", etc.). Accordingly, the price range extends from under DM 500 to DM 2,500 (Chart 2).

Chart 2: Prices of washing machines in product tests (DM)
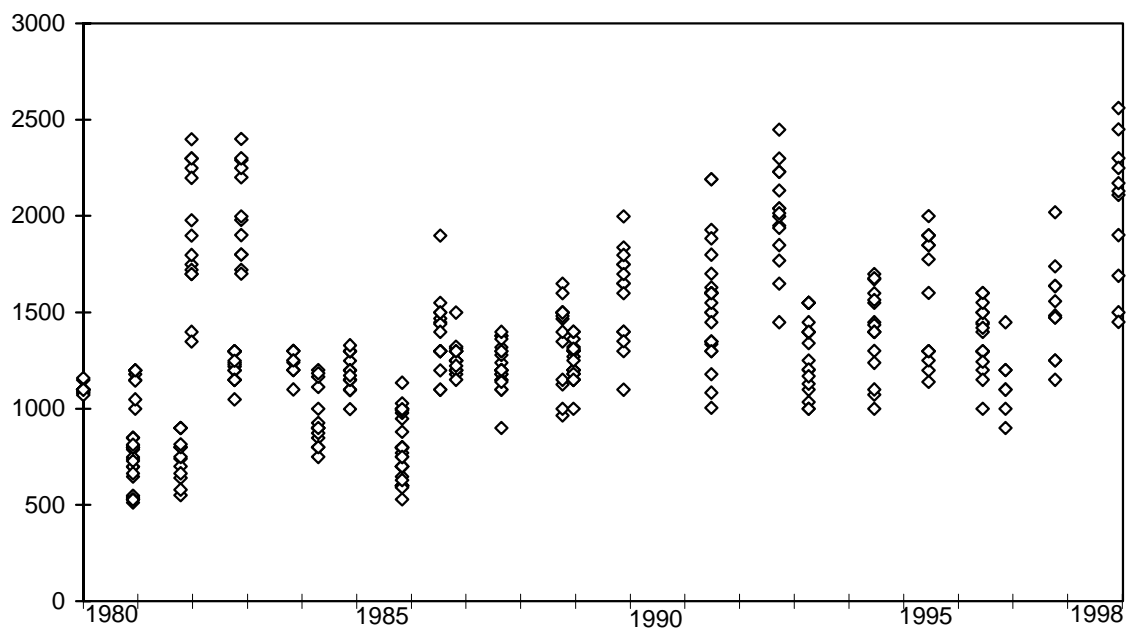
The prices in the product tests are significantly higher than the average prices in the consumer price statistics (Table 2). This seems to suggest that the models included in the price statistics were for the most part less sophisticated. Nevertheless, the prices in the product tests also exhibit a rising overall trend. This applies particularly to models of the middle and upper price brackets. By contrast, luxury models (tests 5, 7, 19, and 26) have become only marginally more expensive.

Even at first glance, what is striking about the data on product characteristics is that modern washing machines consume much less electricity and water per washing cycle than their predecessor models of the early eighties. Since then, water consumption has been cut by two-thirds, and the consumption of electricity has declined to one-quarter. The consumption of washing powder is likely to have declined in the same way.[13] In all market segments, the maximum spinning speed was raised significantly. In the first half of the eighties, a maximum spinning speed of 800 rpm was typical for models belonging to the middle range; in the mid-nineties, it was 1,000 rpm. Models of the central market segment achieved a level of performance in this respect that was typical for luxury models in the early eighties. At the same time, the middle range models also consumed far fewer resources in the mid-nineties than the older models of the upper range. Such luxury models achieved a price of about DM 2,000 in the early eighties (test no. 5), and corresponding middle range models (tests nos. 21 and 22) fetched about

DM 1,500 in the mid-nineties. This price difference by minus one-fourth within 12 years, or by approximately - 2 ¼ % p.a., can therefore be considered an initial approximation to the "true" quality-adjusted price change.

The following hedonic price estimates refer to the sample as a whole. On account of the small number of observations and the heterogeneity of the subsamples, neither the method of estimating separate hedonic equations for each sample nor the traditional time dummy method worked well. Thus all observations were dated and pooled into one comprehensive sample. The time variable - the dating of a product - is listed as an additional product characteristic that might potentially be price determining. This specification rests on a set of rather restrictive assumptions - constant relative prices of product characteristics, constant rate of quality-adjusted price change - which doubtless did not actually hold in the period under review. The purpose of the estimates, however, was simply to provide a broad assessment of the average rate of pure price change. Linear[14], semi-log[15] and log-linear[16] models were employed to estimate the hedonic relationship.[17] Table 8 shows the hedonic estimates for the quality-adjusted rate of price change for washing machines. The last two lines of the table contain the quality-adjusted price change, which was calculated from the coefficient of the time variable (TIME), and the average "bias"; this resulted from the difference between the rate of change in the (quality-adjusted) price index (Table 6) and the quality-adjusted price change according to the hedonic estimate.

Table 6: Price trends for washing machines

(01/1980-12/1998)	Raw prices	Quality-adjusted prices	Product tests (n=412)
C	6.8	4.7	6.9
t-statistic	1243.6	1628.7	217.3
TIME	0.001183	0.000653	0.002291
t-statistic	28.24	30.0	9.8
R^2	0.78	0.80	0.20
Change in prices (in % p.a.)	+ 1.4	+ 0.8	+ 2.8

Table 7: Price-determining characteristics of washing machines

Variable	
TOP	Dummy=1 for top-loaders.
LOAD	Maximum load in kg dry laundry.
RPM	Maximum spinning speed in revolutions per minute. The measured spinning speed was used, insofar as this could be ascertained.
ELEC	Consumption of electricity in kwh per machine load (up to and including test no. 4 for the 90°C programme; then up to test no. 18 for the energy-saving programme at 60°C; finally, from 1993 on, for the coloureds programme at 60°C).
WATER	Consumption of water for one machine load (up to and including test no. 4 for the 90°C programme; then up to test no. 18 for the 60°C energy-saving programme; finally, from 1993 on, for the 60°C coloureds programme).

Table 8: Quality-adjusted price changes for washing machines

(11/1979-12/1998) Number of brand dummies	linear	semi-log	log-linear	linear	semi-log	log-linear
	-	-	-	11	11	11
C	7.0	6.1	1.2	105.0	6.2	2.1
t-statistic	0.1	47.1	3.7	0.7	46.0	6.6
TOP	136.7	0.13	0.11	119.6	0.12	0.10
t-statistic	6.4	7.5	5.7	6.3	7.4	5.8
LOAD	67.4	0.049	0.35	54.0	0.03	0.27
t-statistic	2.2	1.7	3.0	1.7	1.2	2.4
RPM	1.4	0.001	0.86	1.17	0.001	0.74
t-statistic	21.1	27.0	26.8	17.6	22.9	22.8
ELEC	-79.8	-0.12	-0.16	-57.61	-0.09	-0.11
t-statistic	-4.7	-6.3	-3.8	-3.6	-5.2	-2.8
WATER	-0.10	0.001	-0.03	-0.16	0.001	-0.06
t-statistic	-0.2	1.6	-0.5	-0.3	1.1	-1.3
TIME	-0.001034	-0.001594	-0.001447	-0.000732	-0.001256	-0.001137
t-statistic	-4.5	-5.0	-4.1	-3.3	-4.3	-3.6
n	412	412	412	412	412	412
adj. R^2	0.79	0.79	0.78	0.82	0.84	0.82
SE	0.15	0.15	0.16	0.14	0.14	0.14
Quality-adjusted price change (in % p.a.)	- 1.2	- 1.9	- 1.7	- 0.9	- 1.5	- 1.4
Bias (in percentage point p.a.)	+ 2.0	+ 2.7	+ 2.5	+ 1.7	+ 2.3	+ 2.2

The t-values are heteroscedasticity consistent.

In interpreting the results, it must be borne in mind that each of the various sub-samples covers a different market segment and that their composition does not necessarily correspond to the appliances for which prices are surveyed as part of the official statistics. Differences between the price trends at the reporting units sampled by the statistical offices and those at the outlets at which Stiftung Warentest surveys prices may affect the result. Thus, a possible outlet substitution bias would be included here, too.[18] The most important results of the hedonic estimates may be summarised as follows:

• In general, the explanatory variables have the expected signs and are by and large plausible in terms of their order of magnitude. Top-loaders fetch a premium; similarly, higher prices are paid for a larger capacity and a higher spinning speed. Of the two variables for the consumption of resources, the coefficient of electricity consumption is statistically significant, having the anticipated sign. Brand dummies improve the adjustment of the hedonic equations to the data. The semi-logarithmic model has minor advantages; otherwise, the various specifications scarcely differ from one another in terms of explanatory value.

• The time variable has a negative sign throughout. It is statistically significant at a 95 % level lying below zero for all variants. Brand dummies increase the quality-adjusted rate of price change. The quality-adjusted price change is smaller in the non-linear approaches than in the linear models.

• According to these estimates, the quality-adjusted price change would have been between - 0.9 % and - 1.9 % p.a. on average during the period under review, rather than just + 0.8 % p.a., as recorded in the price statistics. The average "bias" would be in an interval between + 1.7 and + 2.7 percentage points per annum.

• The implied rate of quality change falls in an interval between + 3.7 % and + 4.7 % p.a. This is much higher than the implied rate of quality change in the consumer price statistics (+ 0.6 %). Both figures, however, may be distorted by changes in markets segments.

Although some caution must be exercised in interpreting the results of the hedonic estimates, they nevertheless imply beyond any reasonable doubt that the official price statistics in Germany do not always take the advance in quality adequately into account. In the period under review, the bias for washing machines amounts to an average of + 1.7 to + 2.7 percentage point per year. The counts of the methods employed by the price collectors indicate that few adjustments were made for advances in quality in 1998, when prices declined. It might be inferred from this that the bias lay above the average in periods with declining prices. However, since "trading down" plays some role, the increase of the bias at rates of price change near and below zero is less than assessed in my earlier study.

VII. Assessment of the overall quality change bias

For a central bank economist interested in the "true" rate of inflation, the question of generalising the various partial results naturally poses itself. Boskin and his colleagues on the Advisory Commission to Study the Consumer Price Index (1996) collected the results of a large number of studies on the subindices of the CPI and estimated the quality-change bias in a very detailed manner, using back-of-the-envelope calculations. It was not possible to do so in the present study, since hardly any up-to-date case studies exist for Germany. [19]

For that reason, in my previous study on the "Problems of Inflation Measurement in Germany", I had to rely on a simulation experiment, adopting an extremely simplified multi-sector model to generate prices; these prices were, in turn, adjusted for quality changes in accordance with the instructions that had been employed up to 1997.[20] These model calculations rested on four central assumptions:
- The overall rate of productivity growth is 2 % and the overall rate of advance in quality 1 % per annum.
- Model changes occur once a year and price adjustments are undertaken at the same time.
- No change in market segments takes place.
- Price statisticians correctly identify the change in quality and proceed in accordance with the Federal Statistical Office's instructions.

The following conclusion was reached on the basis of these assumptions: If inflation is moderate or if price-level stability has been nearly achieved, the bias caused by the generalising rules for quality adjustment will be just under ½ percentage point per annum. Below this level the quality change bias increases. At most it could be in the region of one percentage point per annum. At "high" rates of inflation there was also a potential for an overstatement of the "true" price increase.

Given the new rules and the new evidence concerning product replacements in the German consumer price statistics, this "guesstimate" has to be revised:
- Firstly, the introduction of the method of linking with a flexible adjustment factor reduces the bias for moderate and for "high" rates of inflation;
- secondly, the evidence on replacement rates may indicate that the calibration of the model itself may have been biased; and,

- finally, comparisons of raw price series and quality adjusted price series suggest that consumers change market segments.

There is some evidence that in periods of declining prices some reporting units switch to less expensive market segments. This might be explained by the fact that price increases typically are low in periods of slow growth and high or even rising unemployment. At such times people tend to buy less expensive products. Since price collectors are encouraged to collect prices for volume sellers, some replacements will take the form of a change in market segment. In this case, however, the Federal Statistical Office's methods for quality adjustment work quite well, since prices and quality decline simultaneously. This effect tends to reduce the extent of the bias' increase at declining rates of price change, if the latter is accompanied by rising unemployment and declining real income.

The following new "guesstimate" of the quality-adjustment bias in Germany, based on earlier model calculations and on these new findings, thus emerges:
- If inflation is moderate or if price level stability has been nearly achieved and the new rules of the Federal Statistical Office are correctly applied, then the bias caused by the generalising rules for quality adjustment might amount to about ¼ percentage point per annum. Improvements in the quality of many manufactured products are often likely to be linked to price decreases or to stable prices. In such cases, the prices of new models are frequently not adjusted for improvements in quality.
- Below this level the bias increases. Improvements in the quality of manufactured products and of processed food are typically linked to price decreases or to stable prices. In such cases, the prices of new models are typically not adjusted for improvements in quality. On the whole, the true rate of inflation is likely to be significantly overstated, assuming very low rates of price change. "Trading down", however, reduces the measurement bias if very low rates of price change go hand in hand with rising unemployment and declining real incomes. In that case the quality-adjustment bias could be in the region of ½ percentage point per annum. This estimate is based on the assumption that some "trading down" take place; otherwise the quality adjustment bias might be even higher (if no changes in market segments occur) or much lower (if a lot of reporting outlets switch to less expensive product variants).
- High rates of inflation: In the vast majority of cases, advances in quality occur only in combination with major price increases. Improvements in quality will often be small compared with the differences in price. According to the old rules of the Federal Statistical Office, no quality adjustment had to be made in most of these cases. If price statisticians adhered to these rules, the true rate of price increases was overstated. The new instructions for quality adjustment call for adjustments to be made in such cases; if this is done correctly, no bias will appear.

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*   This is an abridged, revised and updated version of chapters 2 and 4 of the discussion paper 1/98 "Problems of inflation measurement in Germany" of the Economic Research Group of the Deutsche Bundesbank. Without the generous support received from the experts at the Federal Statistical Office a critical review of the quality adjustment procedures in the German Consumer Price Index would have been doomed to failure from the outset. This paper also benefited greatly from discussions that took place in workshops (and among colleagues) at the Deutsche Bundesbank, at the ZEW, at the De Nederlandsche Bank, at the Austrian Central Statistical Office, at the Universities of Frankfurt and Rostock, and at the meeting of the Ottawa Group in Reykjavik. Ludwig von Auer (University Magdeburg) provided heldpful comments on an earlier version of this paper. It goes without saying that the opinions expressed in this paper are those of the author and do not necessarily reflect the views of the Deutsche Bundesbank and that any remaining errors (and incorrect assessments) are my own.

1   Armknecht showed this as early as 1984. See Moulton/Moses (1997) for a recent exposition.

2   For the German Consumer Price Index, see the current reports in the periodical "Wirtschaft und Statistik" published by the Federal Statistical Office or Hoffmann (1998) and Hoffmann (1999).

3   Thus, in the overwhelming majority of cases, the replacement of products in German consumer price statistics involves forced rather than optional replacements. Price collectors, however, are permitted to change the object of price observation if the old model is rapidly declining in market significance, as measured in terms of sales.

4   For details see Statistisches Bundesamt (1990).

5   For a detailed analysis of the methods applied see Hoffmann (1998).

6   For detailed exposition and a critical assessment of the new instructions see Szenzenstein (1999).

7   The price of a new model and the price of the product being replaced may be compared directly if the new model is highly similar to the old model. Given an (small) ongoing advance of quality in the market concerned, however, each replacement carries a potential for a (small) bias, which, taken together, might add up to a large bias over time.

8   Hoffmann (1998).

9   Similar problems occur if outlets have to be replaced.

10   The overall replacement rate is very low, too. See Szenzenstein (1999) for a discussion of the evidence.

11   See Bascher/Lacroix (1999).

12   Stiftung Warentest is a non-profit organisation, which was founded in 1964 by the Federal Government. Its most important task is to conduct tests of products and services.

13   However, in interpreting the consumption data, it must be borne in mind that these data refer to different washing programmes. Up to and including test no. 4, the data referred to the 90°C programme; from test no. 5 to test no. 18, to the 60°C energy-saving programme; and from test no. 19 on, to the 60°C coloureds programme. This failure to discriminate among programmes might present trends in the consumption of resources in a too favourable light. The above-mentioned 60 C washing programmes had not previously been available or their performance had not been satisfactory. Since the early eighties, however, the 60°C washing programmes have become so efficient - not least due to progress in washing agent technology - that the 90°C programme, which is wasteful in terms of consumption of resources, can be disregarded in almost all cases.

14   The linear model has been estimated with non-linear least squares. The prices are a linear combination of the characteristics:

$$p = \sum_i c_i x_i$$

If, however, several samples are combined and unchanged relative prices are assumed, a non-linear relationship holds between logarithmic prices and the product characteristics:

$$p = e^{c_t t} \sum_i c_i x_i$$

or

$$ln(\ p\ ) = c_t t + ln \sum_i c_i x_i \cdot$$

[15]
$$ln(\ p\ ) = c_t t + \sum_i c_i x_i \cdot$$

[16]
$$ln(p) = c_t t + \sum_i c_i\, ln(x_i) \cdot$$

[17] For further details, see my earlier study Hoffmann (1998).

[18] See, in particular, Triplett/McDonald (1977) on the problems which arise when the results of price statistics are compared with those of hedonic estimates, based on different data records.

[19] Exceptions are the studies in Hoffmann (1998) on washing machines, refrigerators and freezers and the study on automobiles by Harhoff (1999). These studies indicate that the quality-adjustment bias has on average been positive for these products in the period under review.

[20] For details see Hoffmann (1999).