Measurement Errors in the Japanese Consumer Price Index

Shigenori Shiratsuka

In Japan, the consumer price index (CPI) is widely used as a measure of inflation or the cost of living. The CPI is constructed by using a fixed-weight Laspeyres formula. This formula is used mainly because of its ease of calculation and comprehension, thus limiting the total cost of constructing the statistics. However, such simplicity makes it difficult for the CPI to reflect dynamic changes in economic activity such as changes in consumers' behavior between goods in response to relative price fluctuation, the introduction of new goods, and the disappearance of old goods. As a result, measurement errors are introduced into the CPI. In this paper, I summarize the problems pertaining to measurement errors inherent in the Japanese CPI, and provide some quantitative assessment. Based on currently available information, I place the point estimate for overall bias in the CPI at about 0.90 percentage point per year. Although this is the best estimate taking into account all information currently available, it is true that the estimate was based on various, rather bold assumptions. In addition, it should be noted that accuracy of the estimate is not necessarily high due to the lack of existing studies in this field in Japan.

Key words: Consumer price index; Measurement errors; Cost of living index; Quality changes; Boskin Report

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I. Introduction

In this paper, I review issues pertaining to measurement errors inherent in the Japanese consumer price index (hereafter CPI), and quantitatively evaluate the magnitude of its upward bias.

The CPI, which is widely used as a measure of inflation or the cost of living in Japan, is constructed by using a fixed-weight Laspeyres formula. This formula has been used mainly because of the simplicity of its concept, which aggregates individual price quotations using weights fixed at the base period, thus limiting the total cost of constructing the statistics.

At the same time, however, such simplicity makes it difficult for the CPI to reflect the dynamic nature of economic activity such as changes in consumers' behavior between goods in response to relative price fluctuation, the introduction of new goods, and the disappearance of old goods. As a result, measurement errors are introduced into the CPI. In particular, quality changes brought in by technological innovation are a major cause of measurement errors, and the magnitude of such biases is crucial under the current trend of rapid technological innovation.

Moreover, accuracy of inflation measures becomes a more important problem when considering whether to go further down from an already low inflation rate.[1] In the 1970s, it was perfectly apparent whether it was desirable to cut the inflation rate because inflation was high and prices were rising in any inflation measures. However, with recent low and stable inflation rates in major countries, the issue of measurement problems in price statistics becomes much more important for monetary policy makers. Measurement errors in price indices are an especially important issue in a country like Japan, where there is controversy as to whether the country is on the verge of deflation.

This paper is constructed as follows. In Chapter II, I examine the sources of measurement errors in the CPI, from the practical viewpoint of statistics compilation. In Chapter III, I make a quantitative evaluation of measurement errors in the CPI. In these two sections, I specify four major causes of the upward bias in the CPI: (1) problems in the index formula; (2) problems in aggregating individual prices into item levels; (3) inappropriateness of the quality adjustment method; and (4) effects of structural changes in retail markets. Then, each cause is quantitatively assessed and aggregated to get the point estimate of the magnitude of bias. In Chapter IV, I compare my estimate of the Japanese CPI with that in the United States by the Boskin Report (Advisory Commission to Study the Consumer Price Index [1996]).[2] In Chapter V, I discuss some policy implications of measurement errors in the CPI. In Chapter VI, I conclude the paper by proposing some possible measures to improve the accuracy of the CPI.

1. Such concern was explicitly pointed out in the speech of Federal Reserve Board Chairman Greenspan (1996) at the conference held by the Federal Reserve Bank of Kansas City in August 1996.
2. For the discussion in the United States, see also Gordon (1990), Wynne and Sigalla (1994, 1996), Fixler (1993), and Shapiro and Wilcox (1996). Moulton (1996) summarized various estimates of the magnitude of upward bias in the U.S. CPI in tabular form. Discussion on this issue between academia and Bureau of Labor Statistics (BLS) economists continues, and the 1998 winter issue of the *Journal of Economic Perspectives*, a special issue on the measurement errors in the U.S. CPI, covers various contributions from members of the Boskin Report, BLS economists, and academia (Boskin *et al*. [1998], Abraham *et al*. [1998], Deaton [1998], Diewert [1998], Nordhaus [1998], and Pollak [1998]).

II. Sources of Measurement Errors

In this chapter, I first show the limitation of the fixed-weight Laspeyres index formula used in constructing the CPI, and then examine various causes of measurement errors from the practical viewpoint of constructing the CPI statistics.

A. Limitation of the Fixed-Weight Laspeyres Index Formula

The CPI is constructed by using a fixed-weight Laspeyres formula. This formula has been adopted because (1) it is a simple formula that calculates the weighted average of sample prices using weights fixed at those of the base period; and (2) it is only necessary to survey the prices of the reference period in order to calculate the price index, thus making it possible to limit the total cost of constructing the statistics.

At the same time, however, the adoption of the fixed-weight Laspeyres formula to compile the CPI is also a main cause of measurement error. Within the framework of the Laspeyres formula, it is difficult to cope with dynamic changes in economic activity such as changes in consumers' choices in response to relative price changes, the introduction of new goods, and the disappearance of old goods.

These problems result in the introduction of measurement errors in the CPI through its three components: (1) accuracy of sample prices; (2) accuracy of the weights; and (3) appropriateness of the index formula. Specific problems that affect these components are, as examined below: (1) substitution effects induced by relative price changes; (2) effects of quality changes; (3) effects of the introduction of new products; and (4) technical problems in constructing the statistics.

When measurement errors in the CPI are discussed, the CPI is compared to the cost of living index, which represents the changes of total expenditure while holding the households' utility level constant.[3] In other words, measurement errors in the CPI can generally be expressed as:

(changes in the CPI) =
(changes in the cost of living index) + (measurement error).

In this case, the problem of measurement error can be analyzed from the viewpoint of its size and variability. In the following, I focus on the size of the bias in the CPI, while also referring to its variability by discussing its upper and lower bounds.

B. Substitution Effects

Since the CPI is constructed by surveying prices of specific goods and services at specific outlets for a fixed consumption basket at a specified base period, it does not thoroughly reflect changes in households' purchase behavior in response to relative price changes (substitution effects).

More specifically, substitution effects might be easier to understand when they are divided into (1) substitution among item levels; (2) substitution in aggregating

3. The Laspeyres index indicates the upper bound of the cost of living index for the utility level at the base period. For the details on this discussion, see, for example, Deaton and Muellbauer (1980).

individual prices surveyed into item levels; (3) substitution among brands within the same category; (4) substitution among outlets; and (5) substitution induced by the emergence of new discount outlets (outlet substitution effects).

(1) Substitution among item levels: This bias is induced by the fact that the weight used to calculate the weighted average of prices is fixed at that of the base period. For example, fish and meat are generally thought to be substitutes, thus there will be a shift in household expenditure from meat to fish when the price of meat increases. Since the weights applied to meat and fish in the CPI are those of the base period, an upward bias is introduced by the overvaluation of the price increase of meat.

(2) Substitution in aggregating individual prices surveyed into item levels: This bias is introduced at the stage of aggregating individual prices, which are at a lower level than the publicized items, into the item levels.

(3) Substitution among brands within the same category: This bias is induced by the fact that there exist many goods other than those surveyed that are close substitutes. For example, the current CPI adopts a color television set of 21-inch multiplex-voice type with brand specified as the survey sample. However, electronics chain stores and supermarkets carry various television sets, ranging from large color television sets with satellite tuners to compact low-price television sets. Although the CPI price surveys are conducted while considering a product's representativeness in the market, most of the items surveyed are specified as one brand or specification, making it difficult in many cases to gauge the price changes in the product categories as a whole.

(4) Substitution among outlets: This bias is induced by the inability to thoroughly grasp consumers' price search activities. For example, many consumers are believed to shop around neighboring outlets such as supermarkets, department stores, and brand shops in order to purchase the cheapest product at the time of shopping. Since the CPI surveys the selling price on a specific date and at a specified shop, it fails to thoroughly reflect such activities.

(5) Outlet substitution effects: This bias is induced by the structural change in retail stores that have been the focus of recent attention in relation to the "price busting" phenomenon. The CPI price survey fails to cover most of the discount stores, thus insufficiently reflecting the consumers' shift from retail shops and department stores to discount stores.[4]

These substitution effects are classified into the problem of index formulation ([1]), the problem of aggregating sampled prices into an item level ([2]), and the problem of survey prices ([3]–[5]).[5]

4. In order to incorporate the effects of advance in discount outlets into the CPI, it is necessary to examine whether price differences between existing outlets and discount outlets correspond to quality difference between them. One criterion is to observe changes in consumers' behavior: if consumers are shifting from existing to new discount outlets, it can be assumed that the number of consumers who felt the products in discount outlets to be less expensive after taking account of quality differences is increasing. It should be noted that what are referred to here as quality differences are not only the differences in the "product itself," but also the difference in "retail services" such as how easy it is to shop and how crowded the parking lot is.

5. The Boskin Report, introduced in Chapter IV of this paper, calls (1) "upper level substitution," (2) "lower level substitution," and (5) "new outlet substitution."

In addition, as years pass after the base period revision, the levels of the price index for various items differ substantially. Such differences will lead to an overvaluation of the items whose price has increased in the case of an arithmetic average index such as the Laspeyres.[6]

C. Effects of Quality Change

The CPI surveys specific items continuously, which becomes difficult in many cases where the products surveyed have disappeared from the market or have lost representativeness as a result of structural changes in the economy or the development of technological innovations. Therefore, it becomes necessary to substitute survey samples (specifications) in line with the transition of product cycles in the market. In such cases, quality differences between new and old specifications are adjusted so that pure price changes are reflected in the price index: these adjustments are called specification changes.

The current Japanese CPI mainly adopts the following three methods of specification changes. First, when the change does not involve any difference either in quantity or in quality, the price of the new specification is directly linked to that of the old one (direct comparison method). Second, when there is an apparent qualitative improvement as well as a price increase, the price index is automatically linked by assuming that the price index of both specifications is constant (price link method). Third, when there is no qualitative change and the difference between the new and the old specifications is attributable to the difference in quantity, the prices are linked after adjusting the ratio of the new and old quantities.[7,8]

As a price index is supposed to represent a price change of a product while keeping its quality constant, its rate of change should be equal to the rate of change in product price minus the rate of a quality change: that is,

$$\Delta(\text{price index}) = \Delta(\text{product price}) - \Delta(\text{quality}),$$

where $\Delta(\bullet)$ represents the rate of change of the variable in parentheses. This relationship is useful for explaining the above three methods for quality adjustment in the Japanese CPI.

The direct comparison method assumes a "quality improvement rate equal to zero," making the price index increase rate equal to the nominal price increase rate. The price link method, on the other hand, assumes a "nominal price increase rate equal to the quality improvement rate," thus making the price index increase rate

6. See Shiratsuka (1995a) for details.
7. In the case of the Japanese Wholesale Price Index (WPI), besides the widely used "cost comparison method," which is adjusted for quality changes based on the difference in production cost, the "hedonic approach" has also been used for some of the items. The hedonic approach is the methodology that analyzes the price-quality relationship by regressing prices on numerous characteristics of a product. See Berndt (1991), Ohta (1980), and Shiratsuka (1995b) for the details of this approach.
8. In the United States, the Bureau of Labor Statistics (BLS), which compiles the U.S. CPI, adopts similar methods for quality adjustment. However, it also employs commodity analysts to examine how to handle the quality difference in substituting items surveyed in detail. The U.S. procedure seems more rigorous in dealing with quality changes, compared with the *ad hoc* methodology applied in the Japanese CPI. For the details on the U.S. procedure, see, for example, Armknecht, Lane, and Stewart (1997).

zero. However, both methods are not that realistic: in the real world, there might be quality changes, and such changes might not be equivalent to price changes. Thus, quality differences are appropriately adjusted only when the third method can be applied, that is, when quantity has changed without any qualitative changes.

As a result, it is apparent that the CPI does not fully account for actual quality changes. Therefore, the quality adjustment methods in specification changes are a most likely source of measurement errors in the official CPI, especially in products subject to rapid technological innovation, such as electronic products.

Shiratsuka (1995c) checks the accuracy of the quality adjustment method in the CPI through a simulation of specification changes for automobiles, and suggests that quality changes are likely to have caused an upward bias in the CPI.

Some 13 Toyota and Nissan models were selected as simulation samples, and their quality changes from the models in the previous year are evaluated by the pre-estimated hedonic functions.[9] Table 1 presents the rate of changes in product price, quality, and quality-adjusted price indices. Toyota Corolla models, for example, changed in 1990–91 and product prices rose 20.5 percent. However, as the quality change computed by the hedonic function increased 17.3 percent, it follows that the quality-adjusted price index rose only 3.2 percent (20.5 percent minus 17.3 percent).

In the 52 simulation samples (13 automobiles times four years), 28 cases are deemed to have some quality changes. Among these 28 cases, it is only with respect to the 1994 Toyota Camry that the rate of change in the quality-adjusted price index is less than two times the standard errors in the bottom row in the table. Therefore, the other 27 cases have experienced a statistically significant change in the quality-adjusted price index. An increase in the quality-adjusted price index is found in 11 cases and a decrease in 16 cases.

The above simulation used relatively continuous models to ensure consistency in terms of size and styling of the simulation samples. In practice, however, the construction of a price index is faced with product diversification in terms of sizes and styling such as an increase in the number of standard cars and recreational vehicles in the market. In such cases, the present construction methodology of the CPI is less than appropriate and a bias is likely to exist. Moreover, because quality changes are not properly taken into account, there is a high possibility that a specification change in the sample structure may miss the best timing.

9. See Appendix 2 for the details of the evaluation method for quality difference used in the simulation.

Table 1 Simulation for Specification Changes

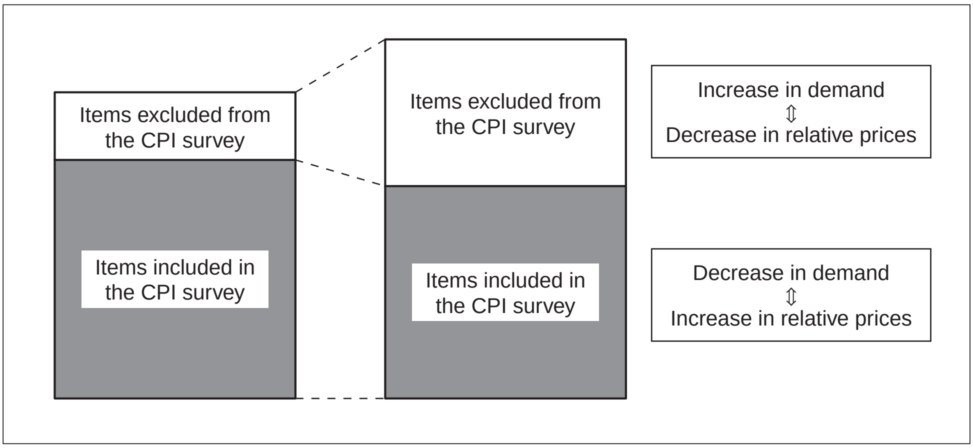
		1991	92	93	94
Toyota					
Corolla	Product price	20.5	0.0	1.4	0.7
	Quality	17.3	0.0	0.0	0.0
	Quality-adjusted price	3.2	0.0	1.4	0.7
Carina	Product price	0.0	–9.5	0.0	9.1
	Quality	0.0	–15.6	0.0	14.3
	Quality-adjusted price	0.0	6.1	0.0	–5.2
Corona	Product price	0.0	8.6	0.0	0.9
	Quality	0.0	18.0	0.0	0.0
	Quality-adjusted price	0.0	–9.5	0.0	0.9
Camry	Product price	0.0	11.9	0.0	–4.0
	Quality	0.0	9.7	0.0	–4.3
	Quality-adjusted price	0.0	2.2	0.0	0.3
Mark II	Product price	0.0	0.0	10.4	2.6
	Quality	0.0	0.0	50.9	–6.2
	Quality-adjusted price	0.0	0.0	–40.5	8.8
Crown	Product price	7.8	0.0	1.8	0.0
	Quality	14.1	0.0	–1.0	0.0
	Quality-adjusted price	–6.3	0.0	2.8	0.0
Celsior	Product price	0.0	5.3	0.2	0.7
	Quality	0.0	0.0	0.0	2.5
	Quality-adjusted price	0.0	5.3	0.2	–1.8
Nissan					
Sunny	Product price	3.0	2.9	5.9	–4.4
	Quality	0.0	0.0	21.8	–16.5
	Quality-adjusted price	3.0	2.9	–15.9	12.1
Primera	Product price	3.0	4.7	0.8	1.7
	Quality	9.8	9.7	0.0	5.0
	Quality-adjusted price	–6.8	–5.0	0.8	–3.3
Bluebird	Product price	1.3	0.8	1.8	4.1
	Quality	9.2	–8.9	0.0	11.3
	Quality-adjusted price	–7.9	9.7	1.8	–7.1
Skyline	Product price	11.6	0.0	–1.9	14.0
	Quality	9.7	0.0	15.1	23.0
	Quality-adjusted price	1.9	0.0	–17.0	–9.0
Cedric	Product price	13.8	0.0	5.8	0.0
	Quality	27.1	–11.0	12.1	0.0
	Quality-adjusted price	–13.3	11.0	–6.3	0.0
Cima	Product price	0.0	–0.7	9.5	0.0
	Quality	–7.0	–8.7	24.2	0.0
	Quality-adjusted price	7.0	7.9	–14.6	0.0
Inadequate quality adjustment case		7	7	6	7
Increase in quality-adjusted price (shaded)		3	5	1	2
Decrease in quality-adjusted price (squared)		4	2	5	5
Standard errors for hedonic price index		0.7	0.7	0.7	0.7

Note: Squared areas, and squared and shaded areas are cases of increase and decrease in quality-adjusted prices, respectively. The crossed-out area indicates that the quality difference is insignificant.
Source: Shiratsuka (1995c).

D. The New Goods Effect

Since new goods and services are not brought into the CPI basket immediately, but only after a time lag after their introduction in the markets, the impacts of the appearance of new goods and services on the CPI are not thoroughly reflected. When new products are introduced and come into wide use among households, they will create new demand as well as replace old products. This phenomenon suggests that households regard new products as relatively less expensive than old products on a quality-adjusted basis. In other words, unless the new products are included in the survey sample, the price of items included in the survey will become relatively more expensive than those excluded from the survey, thus resulting in an upward bias in the CPI. Figure 1 illustrates this point.

Figure 1 Impact of the Appearance of New Goods and Services



As shown in Table 2, which lists the products newly adopted at the time of base year revision, new products are not introduced at the appropriate time. In fact, new products included in the CPI basket after a certain time lag from the time they came into widespread use in each household are compact cars (under 2,000 cc engine displacement) and pianos (1970); fully automatic washing machines, stereos, and tape recorders (1975); microwave ovens, and portable calculators (1980); room air-conditioners (1985); word processors, and camcorders (1990); medium-sized cars (over 2,000 cc engine displacement), and telephones (1995). In addition, personal computers, facsimile machines, and cellular phones are yet to be included in the survey range.[10]

Lags in introduction are also observed in the case of some services. For example, garage rental charges and amusement park fees are included from the 1985 base, and prices for fast food such as hamburgers and rental fees for videotapes are included

10. The Statistics Bureau of the Management and Coordination Agency, which compiles the CPI in Japan, plans to incorporate personal computers and cellular phones from the 2000 base CPI, according to the information on their web site (http://www.stat.go.jp). Unfortunately, only Japanese-language information is readily available at the moment.

Table 2 Items Newly Introduced in the Base-Year Revision

Base year	Durable goods	Services
1970	Automobiles (661 cc to 2,000 cc engine displacement), pianos, room air-conditioners, color TV sets	Lesson fees (driving school), fire insurance premiums
1975	Washing machines (fully automatic type), stereo phonograph sets, tape recorders, gas water heaters	School lunches, expressway tolls
1980	Microwave ovens, portable electronic calculators	Lunch plate for children, women's hairdressing charges
1985	Room air-conditioners, video tape recorders	Garage rental charges, amusement park fees, automotive insurance premiums (optional), sewerage charges
1990	Word processors, camcorders	Hamburgers, video rental fees
1995	Automobiles (over 2,000 cc in engine displacement), telephones	Pizzas, karaoke fees
Excluded items	Personal computers and peripherals (e.g., printers), faxes, cellular phones	Telephone bills of new telecommunications companies, rent-a-car fees, financial services, Internet

from the 1990 base. Telephone bills of the new telecommunications companies and rent-a-car fees are still not included, and various financial services such as credit card fees and account transfer fees are excluded from the survey range.[11]

Such lags are especially large in the case of products subject to rapid technological innovation and short product cycles. For such products it is difficult to measure quality changes, and this makes it very hard to construct and update quality-adjusted price indices using conventional methods. As a result, it has been decided to postpone introduction of these items into CPI basket until some time in the future.

In addition, it has been pointed out that, since items are subdivided into lower disaggregation levels, newly adopted commodities are not always compared with existing ones with similar functions in the CPI basket. For example, when personal computers are included in the future, effects that stem from their substitution for word processors will not be taken into account.[12] This implies that the appearance of new goods affects the accuracy of the CPI through not only the improvement in quality but also the increase in the range of goods and services.

E. Technical Problems in Constructing the CPI Statistics

In addition to the aforementioned substitution bias, quality change bias, and new product bias, there are unique technical problems pertaining to the compilation methodology of the Japanese CPI. Such technical problems can be divided into the problems of price survey and those of weighting methods.

11. The Corporate Service Price Index (CSPI) already includes various financial service fees such as those of bank account transfers.
12. Of course, since many of the new products provide new functions that are not available in the old products, there exists a limit for exact comparison. Correspondence by electronic mail on the Internet and usage of cellular phones are regarded as substitutes for communication based on existing telephones, facsimiles, and postal services, which also have strong features as new ways of communication. See Nordhaus (1997) for the detailed discussion on this point.

There are two major problems in price survey. First, since price quotations are collected on a specific date, irregular factors such as bargain sales and seasonal prices are easily introduced. The CPI survey is, in principle, conducted every month on Wednesday, Thursday, or Friday in the week that includes the 12th day of the month, thus the actual survey date will vary by a maximum of eight days (see Figure 2).[13] As a result, the price quotation of some items can differ substantially depending on whether the survey date coincides with a special event such as a bargain sale.[14] Second, monthly changes in private rents tend to differ substantially, since their price quotations have been collected only once every three months and the number of samples is limited.

Figure 2 Date of Price Survey

Earliest case

Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31		

Latest case

Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

Note: Price quotations are collected during the shaded dates.

With regard to the weights, a major source of the problem lies in the Family Income and Expenditure Survey (hereafter FIES), compiled by the Management and Coordination Agency, from which the CPI weights are calculated. Mizoguchi (1992) reviewed the past discussion of this issue and highlighted the following two points. First, there is a bias in the process of selecting the household samples. Second, the survey is insufficient to gauge the total expenditure of the household, since it excludes households with one person and collects information mainly through housewives who might not be fully aware of other family members' expenditures.[15] In addition, problems pertaining to the calculation of the weight of imputed rent have been pointed out.[16]

13. As an exception to the principle, hotel charges are collected every month on the weekend (Friday and Saturday) in the week that includes the fifth day of the month. In addition, price quotations of fresh foods, which often show large changes due to factors such as bad weather, are collected three times a month.
14. The CPI excludes, in principle, items sold at specially reduced prices from the viewpoint of collecting price samples of goods and services regularly sold; although the survey includes items sold at such special prices for more than seven days at the time of the survey. As such, since the survey date is subject to differ by eight days at the most, items sold at special prices will be sometimes included and sometimes excluded.
15. On September 8, 1996, the evening edition of the *Nihon Keizai Shimbun* newspaper carried an article "Four Problems of the Household Expenditure Survey," which highlighted the following problems: (1) the survey requires a great deal of time to fill out, with small reward, and is prone to omission; (2) it excludes households with only one person; (3) the sample number is small; and (4) uncertain expenditures such as pocket money and social expenses are increasing.
16. See Shiratsuka (1995a) for details.

III. Magnitude of the Measurement Error: A Quantitative Evaluation

In this chapter, I will present a quantitative evaluation of the upward bias in the CPI. I will first specify, among the causes of the measurement errors we have discussed so far, which ones are suitable for quantitative evaluation at this stage. Then, I will calculate the point estimates for each of the individual causes specified, and estimate the overall bias by summing them up.

A. The Range of Quantitative Evaluation

As a starting point, I will rearrange the four causes of measurement errors—substitution effect, quality change, introduction of new products, and technical problems pertaining to the construction of the statistics—from the viewpoint of the three components of the CPI—index formula, accuracy of prices surveyed, and accuracy of the weights—and specify the range for quantitative evaluation at this stage.

First, as previously mentioned, there are four problems with the substitution effects: (1) the index formula for aggregating the upper level items; (2) the substitution in aggregating prices surveyed into item levels; (3) the substitution among brands within the same category; and (4) the substitution among existing outlets, and substitution due to the appearance of new outlets. Among these, the first two problems, i.e., the problems in index formula for aggregating the upper level items, and the substitution in aggregating prices surveyed into item levels, can be evaluated as problems in the index formula. The last problem of substitution due to the introduction of new discount outlets is relevant to the accuracy of price information. However, the other problem magnifies monthly variability, but does not have a significant impact on the direction of measurement bias.

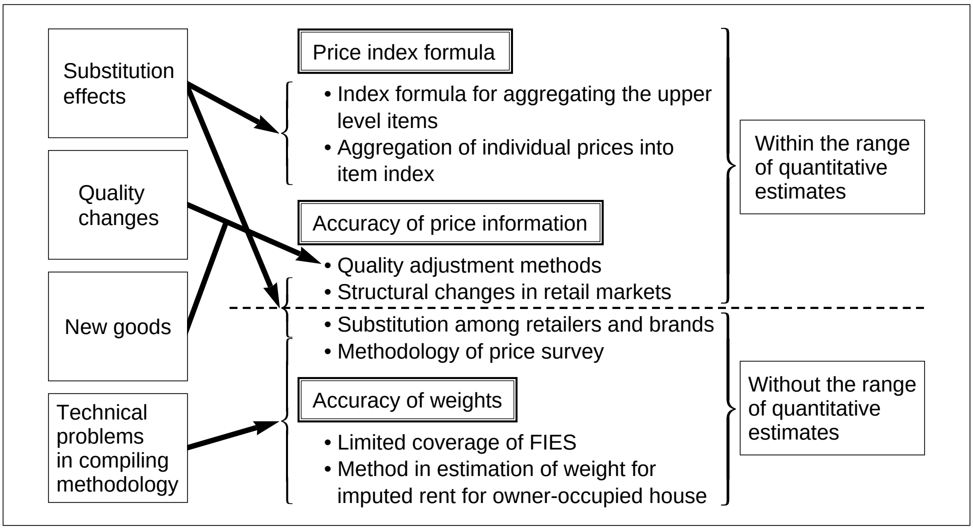
Second, I will quantify the impact of quality change and the introduction of new goods and services together as problems in quality adjustment methods that substantially affect the accuracy of prices surveyed. Since quite limited quality adjustment methods have been adopted in Japan, the problem of quality adjustment is deemed to be significant.

In the previous chapter, I discussed quality changes and the introduction of new products separately: the former as the improvement of the quality of goods and services in the survey, and the latter as the introduction of new goods and services into the price survey. However, the difference between quality change and the introduction of new products depends heavily on how finely disaggregation levels of commodity classifications are subdivided. Thus, from the practical viewpoint of constructing statistics, it is quite difficult to separate them in an explicit way. In addition, the official CPI does not cover all products, because quality changes in some products are difficult to measure using the conventional methods.

Finally, technical problems in constructing the statistics are excluded from the range of quantitative evaluation in this paper. This is because it is assumed that they may not have a substantial impact on the accuracy of the index when we consider a longer term such as a yearly average.[17] Although these problems can be major causes of measurement error, many of the technical problems are factors that lead to a magnification of the monthly variability of the price index.

In summary, what I can quantitatively estimate at this stage are the effects of index formula for aggregating the upper-level items; aggregation of individual prices into the item level; quality adjustment methods; and structural changes in retail markets. Figure 3 illustrates the relationship between causes of measurement error and quantitative evaluations to be shown in this paper.

Figure 3 Range of Quantitative Evaluation



B. Problems of Index Formulas

As in previous studies, I will evaluate the problem of index formula by comparing fixed-weight Laspeyres index to the superlative indices such as the Törnqvist and Fisher indices (see Appendix 1 for the details on the index formula).[18] To this end, I picked up, from the CPI data series, the lowest classification (88 commodities) available continuously from 1970 up to now; estimated the corresponding weights

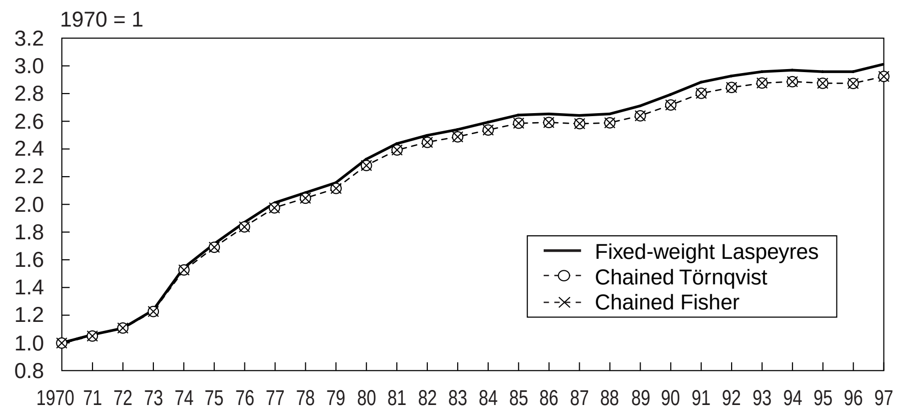
17. With regard to the accuracy of the weights, it is true that the possibility of remaining bias even on a yearly average basis cannot be denied. For example, if there is an item that shows a smaller increase than that of the total index and the weight of such an item is undervalued, then the total index incorporates an upward bias. In the Japanese CPI, weights of durable goods, which decline more sharply than the overall index, are deemed to be undervalued because of the low coverage of the expenditure pattern of family members other than the housewife. As such, it can also be considered from the viewpoint of the accuracy of weights that the Japanese CPI possibly inherits an upward bias.
18. The Törnqvist and Fisher indices are defined as a superlative index in Diewert (1976, 1978). From the viewpoint of index number theory, they have a desirable characteristic of being consistent with a flexible aggregation function. Thus, they are assumed to be good proxies for the cost-of-living index.

annually by using the FIES[19] and composed the fixed-weight Laspeyres price index (corresponding to the CPI), as well as the chained Törnqvist and Fisher price indices.

Figure 4 reports the estimation result: the fixed-weight Laspeyres index, the chained Törnqvist index, and the chained Fisher index (1970 = 1) are 3.011, 2.923, and 2.923, respectively. When converted into annual change rates, each index level corresponds to the annual inflation rate of 4.167, 4.053, and 4.053. Therefore, the fixed-weight Laspeyres index has upward biases over both the Törnqvist and Fisher indices at the rate of 0.114 percentage point from 1970 to 1997. These figures are somewhat smaller than the U.S. estimate of 0.2 percentage point, although bias can be expected to become larger once specifications are further divided into more detailed items.[20]

In Table 3, I further divide the series into time periods of five years and compare the divergence of the chained Törnqvist and Fisher price indices from the fixed-weight

Figure 4 Comparison of Various Price Index Formulae



Source: Author's calculation from FIES and CPI statistics.

Table 3 Comparison of Laspeyres, Törnqvist, and Fisher Price Indices

		1970–75	75–80	80–85	85–90	90–95	95–97	70–97	90–97
Annual changes									
Fixed-weight Laspeyres	(a)	11.379	6.297	2.604	1.095	1.155	0.892	4.167	1.079
Chained Törnqvist	(b)	11.052	6.194	2.534	0.994	1.137	0.849	4.053	1.055
Chained Fisher	(c)	11.052	6.194	2.534	1.001	1.137	0.831	4.053	1.049
Deviations									
Chained Törnqvist	(a) – (b)	0.327	0.103	0.070	0.101	0.017	0.043	0.114	0.025
Chained Fisher	(a) – (c)	0.327	0.103	0.070	0.094	0.018	0.061	0.114	0.030
Relative price changes		3.207	1.191	0.745	1.114	0.953	1.346	1.442	1.065

19. Each index formula is composed by using the smallest 88 specifications for which a continuous series is available since 1970 in the CPI data, and by estimating the CPI weight from the FIES. It should be noted that imputed rents are excluded due to the difficulty of calculating the weight of each year. For the fixed base series, weights are modified every five years taking into account that the base year is revised every five years.

20. This point is suggested in Aizcorbe and Jackman (1993), employing the smallest-specification CPI data in the United States (44 regions and 207 item strata).

Laspeyres price index. It shows that the variability of biases varies according to periods and index formula. However, the divergence of the chained Törnqvist and Fisher price indices are 0.025 and 0.030 percentage points per year, respectively, in the 1990s, which illustrates that substitution effects are almost negligible at the moment.

One possible explanation for the recent decline in the impact of substitution effects is that the variability of relative prices was reduced under the low inflation rates, and, as a result, consumers might have had less scope for substitution recently. To test this hypothesis, following Shapiro and Wilcox (1997), I calculated an index of the cumulative change in relative prices, J_t, defined as follows:

$$J_t = \sum_i w_{i0} \left| \ln\left(\frac{p_{it}}{p_{i0}}\right) - \ln P^G_{0t} \right|, \tag{1}$$

where w_{i0} is the expenditure share in the base period, p_{it} is the price of item i at time t, and P^G_{0t} is the fixed-weight geometric mean index that is defined in Appendix 1. The bottom row in Table 3, previously mentioned, shows changes in the index J from the previous year. Except for the period from 1970 to 1975, when the first oil crises occurred, both the magnitude of substitution effects and the pace of relative price drift are mild.

Taking into account the results, the size of upward bias caused by the index formula is in the range of 0.00–0.25 percent, although it differs according to the period analyzed and the index formula adopted. In addition, such bias is deemed to be negligible for the latest period.

C. Problems in Aggregating Individual Sample Prices into Item Level

Since the Management and Coordination Agency does not release the price index of those lower than the item level, problems in aggregating individual sample prices into item levels have not been estimated.[21] However, taking into account the fact that (1) the increase in the Japanese CPI is now at a low rate, thus biases caused by the index formula are deemed to be almost negligible; and (2) the classification of Japanese CPI items is more detailed than the item strata used in the United States, it can be safely assumed that biases caused in the process of aggregation of individual prices into item level are considerably smaller than the U.S. estimate of 0.25 percent.[22]

In this paper, I will assume the bias stemming from the process of aggregating individual prices to item level to be 0.10 percent, a figure derived as the difference between upper level substitution and lower level substitution, which were both estimated in the Boskin Report.

21. With respect to the WPI, the Bank of Japan began to compile and release a reference index using a geometric mean formula in June 1998. In the reference index, geometric mean is partly used in the lower level of the aggregation, from "sample price" to "commodity class," and the Laspeyres formula is used in the upper level of the aggregation, from "commodity class" to "all commodities." The Bank of Japan (1998) shows that the Laspeyres index has an upward bias over the geometric mean index at the rate of 0.3 percent annually from 1995 to 1998.

22. See Advisory Commission to Study Consumer Price Index (1996) and Bureau of Labor Statistics (1977) for the details of the estimation.

D. Problems in Quality Adjustment Method

My previous research (Shiratsuka [1995b, c], Shiratsuka and Kuroda [1995]) estimates hedonic functions for the quality-adjusted prices for durable goods such as personal computers, automobiles, and camcorders, and shows that their quality-adjusted prices indicate declining trends. In the official CPI, however, such quality adjustment is not sufficiently implemented, and thus appears to introduce an upward bias.

1. Upward bias in durable goods

Shiratsuka (1995b, c) and Shiratsuka and Kuroda (1995) have estimated hedonic price indices for certain durable goods and calculated the upward bias by replacing the CPI item indices with their estimated indices. The results are summarized in Table 4.

Table 4 Upward Bias in Durable Goods

	Weight (percent)	Annual change (percent)			Contribution (percent)	
		CPI	Hedonic index	Difference	To durables	To overall
Automobiles	1.8	0.1	–0.4	–0.5	–0.16	–0.01
Camcorders	0.1	–4.0	–9.6	–5.6	–0.09	–0.01
Personal computers	0.1	n.a.	–24.4	n.a.	–0.36	–0.02

Notes: 1. The estimates of upward bias are the average from 1991 to 1994.
2. The weights are on the basis of 1990.
3. Estimated on the assumption that half of the weight for word processors in CPI is replaced by personal computers.
4. "n.a." indicates not applicable.

Sources: Author's calculation is based on Shiratsuka (1995b, c) and Shiratsuka and Kuroda (1995).

When hedonic price indices for automobiles, camcorders, and personal computers are included, the level of the overall CPI is lowered by 0.01, 0.01, and 0.02 percentage points, respectively; and that of CPI durables is lowered by 0.16, 0.09, and 0.36 percentage points. By just adding up these figures, the upward bias reaches 0.04 percentage points for the overall index and 0.6 percentage points for the durable goods index. Considering the fact that the relative importance in the CPI basket of these three goods totals just 2 percent, contribution of durable goods as a whole to the overall bias can well reach a substantial amount when such hedonic estimates are obtained for various other microelectronic products.

It should also be noted that the magnitude of quality change bias also changes over time. For example, in the case of automobiles, the upward bias for the total CPI increased from 0.01 to 0.02 percent during 1993 and 1994.

In addition, among durable goods, microelectronic products such as personal computers are subject to rapid technological innovation and have short product cycles. This suggests that such products are subject to the problem of quality adjustment at the time of specification change. The prices of these products are difficult to track on a continual basis, and normally accompany lags in their inclusion in the CPI basket. In fact, personal computers are yet to be included in the CPI, and word processors are included only from the 1990 base CPI.

2. Quality adjustment for services in the CPI

With respect to services in the CPI, there have been many unresolved problems such as the difficulty in specifying "one unit for standard service," and it is thought to be an area where price accuracy can be greatly improved.[23] In Japan, however, existing studies in this area are limited.[24] In the following, taking rent, the cost of privately owned houses, and medical care as examples, I will point out the problems inherent in quality adjustment in the CPI services.

In the case of the CPI rent, the current compilation method is likely to introduce an upward bias because it fails to take account of the recent improvement in the structure and convenience of houses. The CPI surveys average rent per residential area on three classifications of houses: (1) small wooden houses (residence area less than 30 square meters); (2) medium-sized wooden houses (residence area over 30 square meters); and (3) non-wooden houses. Table 5 illustrates how the structure and facilities of houses have developed over time. It shows that the structure of the houses has undergone a major shift from wooden to non-wooden, with an increasing share of reinforced-concrete and steel frame construction. In the wooden house category, that of fireproof houses has substantially increased. In addition, the state of facilities seems to have improved as the ratios of those houses with flush toilets in bathrooms increase year after year.

Table 5 Construction Structure and the State of Facilities

Percent

	1973	78	83	88	93
Ratio of wooden houses	86.2	81.7	77.4	73.0	68.1
(Ratio of wooden and fire-proof houses)	19.7	25.4	31.3	31.7	34.0
Ratio of non-wooden houses	13.8	18.3	22.6	27.0	31.9
(Ratio of ferroconcrete houses)	10.5	15.2	20.0	24.5	29.0
Ratio of houses with flush toilets	31.4	45.9	58.2	66.4	75.6
Ratio of houses with bathrooms	73.3	82.8	88.3	91.2	93.5

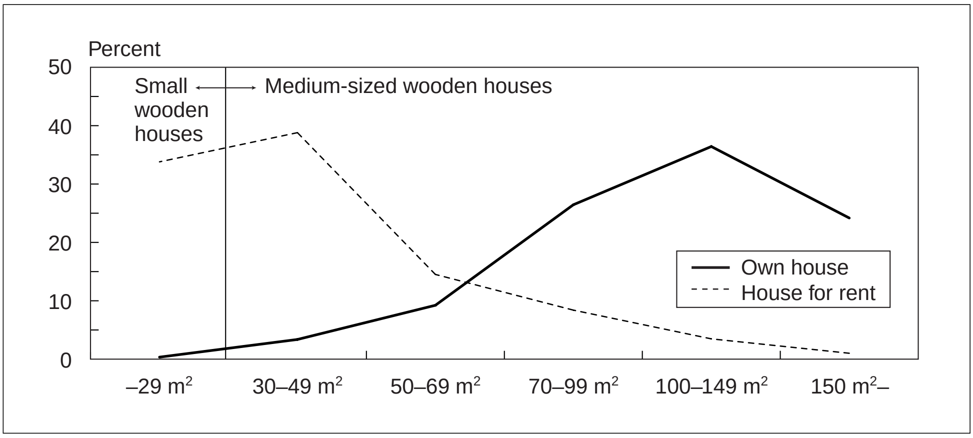
Source: Management and Coordination Agency, *The Housing Survey of Japan.*

23. For example, see Griliches (1992) and Kroch (1991).
24. With respect to the relation between changes in service price and changes in quality, there are estimates such as Ito and Hirono (1993), Kasuga (1996) for house rent, and Nanbu *et al*. (1994) for medical expenses, although all of these studies are deemed problematic for use in examining the impacts on the measurement errors in the CPI. Ito and Hirono (1993) derived price and specification data from the new contract rent carried in housing magazines, and those data are deemed to overestimate the average rent which should be gauged in the CPI. Nanbu *et al*. (1994) stated that explanation variables in the hedonic function were not sufficient to adjust for quality changes brought by technological innovation, and a substantial effect of quality changes was mingled in the estimate parameter of the annual dummy variable.

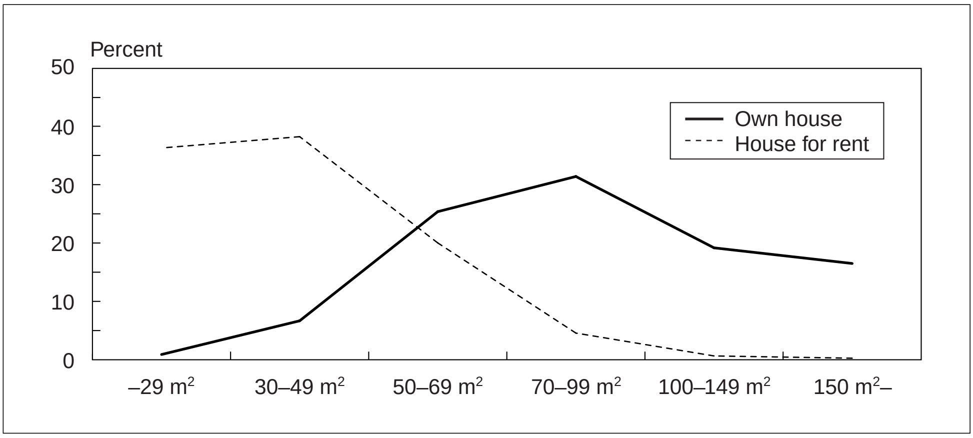
With respect to the cost of privately owned houses, the Japanese CPI covers it as an imputed rent. However, since there is a large difference in facilities and comfort between privately owned houses for rent and owner-occupied houses, the quality adjustment of the surveyed price becomes important. As shown in Figure 5, distribution of the amount of floor space, which can be deemed as a proxy for comfort of the house, differs substantially between privately owned houses for rent and owner-occupied houses regardless of construction materials (wooden or non-wooden). Therefore, it has been questioned whether the current CPI appropriately gauges the actual owner's equivalent rent, which are houses with large residential space.

Figure 5 Distribution of the Amount of Floor Space

[1] Wooden Houses



[2] Non-Wooden Houses



Source: Management and Coordination Agency, *The Housing Survey of Japan.*

With regard to medical care in the CPI, gauging advances in medical technology has been a big problem.[25] In Japan, however, the survey items are quite limited, and there has been great doubt whether the survey reflects overall medical expenditure appropriately (see Table 6). For example, only standard medicines sold over the counter in a drugstore are included, while medicines on prescriptions provided in hospitals are not. In regard to hospitalization expenses, the survey includes that for childbirth but not for others such as general medical treatment or operations.

Table 6 List of CPI Items: Medical Care

Item	Weight	Specification
Medicines		
Medicines for colds (multipurpose)	0.0011	"Shin Lulu A"
Medicines for colds (antipyretic and analgesic)	0.0005	"Bufferin A"
Gastroenteric medicines (digestive)	0.0002	"Ohta's Isan"
Gastroenteric medicines (combined)	0.0005	"New Pan Siron"
Vitamin preparations, multivitamins	0.0012	"Panvitan Hi"
Vitamin preparations, vitamin compounds	0.0012	"ALINAMIN A"
Health drinks	0.0012	"Ripobitan D"
Dermal medicines	0.0005	"MENTHOLATUM"
Plasters	0.0004	"TOKUHON A" or "SALONPAS A"
Breath fresheners	0.0007	"Jintan SILVER PILLS"
Chinese medicines	0.0029	For women, decoction, "Chujoto"
Medical services		
Medical treatment	0.0128	Rate of charges shared by the insured
Hospital charges	0.0032	Charges for ordinary delivery, eight days' hospital treatment
Massage fees	0.0004	Except in the application of insurance, massage from head to foot, about one hour

Source: Management and Coordination Agency, *Annual Report on the Consumer Price Index.*

It should also be noted that the weight for medical expenses is underestimated, and the quality adjustment in this area can result in a large impact on the overall bias. The weight used in the CPI is calculated based on the FIES, which surveys medical expenses directly paid by the households. Considering the fact that most of such expenses are paid indirectly, through health insurance, the weight calculated only on the basis of direct payment would probably result in an underestimate of actual medical expenses.

3. Quality change bias in the total

Table 7 shows the items that are thought to be difficult to adjust for quality changes, and their weights add up to about 30 percent of the overall CPI.

In order to estimate the average upward bias for these items, I take an annual average of 1.0 to 1.5 percent for total durable goods (estimate in Gordon [1990]) as a starting point.[26] Then, I assume the upper limit of the bias to be approximately

25. Shapiro and Wilcox (1996) examine the measurement issues in the medical service in detail.
26. The declining pace of the price of durable goods is not very different between the United States and Japan. According to the estimate of Shiratsuka (1995b), the hedonic price index for personal computers has been

Table 7 Weight Affected by Quality Adjustment Problem

	Weight	Weight affected by quality adjustment problem	Note
Commodities	0.51589	0.09530	
Agricultural and aquatic products	0.08663	0.00000	
Food products	0.13494	0.00000	
Textiles	0.06544	0.04592	
Clothing	0.02727	0.02727	
Shirts and sweaters	0.01864	0.01864	
Others	0.01952	0.00000	
Durable goods	0.05462	0.03911	
Domestic durables	0.00601	0.00601	Microwave ovens, refrigerators, etc.
Heating and cooling appliances	0.00446	0.00446	Room air-conditioners, etc.
Automobiles	0.01818	0.01818	
Recreational durables	0.00972	0.00883	TV sets, camcorders, etc.
Toys	0.00311	0.00087	Household video game machines
Others	0.01315	0.00076	Telephones
Other industrial products	0.11315	0.01027	
Medicines	0.01043	0.01043	
Others	0.10272	0.00000	
Electricity, gas, and water charges	0.04377	0.00000	
Publications	0.01734	0.00000	
Services	0.48411	0.21568	
Private house rent	0.03161	0.03161	
Imputed rent	0.13401	0.13401	
Public and personal services	0.25077	0.05007	
Medical charges	0.01579	0.01541	Excluding massage fees
Airplane fares	0.00381	0.00381	
Telephone charges	0.01745	0.01745	
Hotel charges	0.01340	0.01340	
Others	0.20031	0.00000	
Eating-out	0.06773	0.00000	
General	1.00000	0.31099	

3 percent, taking into account the following three factors. First, the Japanese CPI does not employ the hedonic approach at all, and the quality adjustment methods for the current Japanese CPI do not account for the actual quality changes appropriately. Second, survey items of the Japanese CPI are fairly subdivided and their specifications are stipulated in detail, thus the introduction of formerly uncovered new products into the survey is limited at the time of the base-year revision. Third, there is a

declining annually at the rate of about 30 percent, and this is almost equivalent to that in the United States, estimated by Berndt and Griliches (1993). However, it should be noted that these estimates assume that the CPI for services inherits the same size of upward bias as that of durable goods. As mentioned, the CPI for services is deemed problematic from the viewpoint of price accuracy, although the size of such a problem has yet to be empirically examined.

time lag before the inclusion of products subject to rapid technological innovation in the survey sample. As a result, the impact of quality adjustment is estimated to be somewhere in the range of 0.30 to 0.90 percent. I assume the median to be about 0.70 percent, slightly higher than the mean value of the range.[27]

E. Effects of the Structural Change in the Retail Market

The effects of sampling are difficult to quantify because of the lack of appropriate statistical evidence. In the United States, Reinsdorf (1993) estimated the upward bias stemming from the advance in discount outlets for food and gas as 0.25–2.00 percentage points. However, admitting its extreme nature, I have made an examination of the case of the Great Southern Hyogo Earthquake that took place in January 1995.[28] The CPI showed a very peculiar movement before and after the earthquake, which could be used to obtain a hint of the magnitude of the effects of the prevalence of discount stores on the CPI.

In February 1995, the CPI of Hyogo Prefecture, where Kobe city is situated, decreased by 2.3 percent from the previous month, falling substantially lower than the CPI decrease of 0.4 percent in the Tokyo metropolitan area. Since the Great Southern Hyogo Earthquake broke out between the dates of CPI price survey in January and February, such irregular changes in prices may suggest some connection with the earthquake. In practice, it is reported that reasons behind this phenomenon were (1) the price of fresh foods which needed fire to cook decreased; (2) damaged shops made a discount sale of their stocks or reduced the price of their products; and (3) supermarkets which carried rather cheaper products were substituted for department stores and shops which were shut down.[29]

Table 8 compares the price movements of commodity groups between Hyogo Prefecture and the Tokyo metropolitan area for the period before and after the earthquake. The table lists 19 commodity groups in which the Hyogo CPI declined two percentage points more than the Tokyo CPI in February 1995, placing them in reverse order. Items normally believed to be discounted more deeply in the discount stores such as alcoholic beverages (beer, whiskey, etc.), recreational goods (toys, sporting goods, etc.), and other clothing (ties, belts, etc.), rather than fresh foods, ranked in the top class. The size of the decline compared with the previous month was far larger than the average change of the previous three years. Furthermore, if three categories—fish and shellfish, meat, and dairy products and eggs, which are regarded as fresh foods—are excluded from the above 19 commodity groups and the weighted average of the difference in the monthly change rate between the two areas is calculated using the Tokyo metropolitan area weights, it is estimated that the overall index was lowered by about 1.7 percentage points.

27. The estimate here specifies the range affected by quality changes, and assumes an average upward bias within the range, and no bias without the range. This is an unavoidable treatment due to the lack of existing studies in judging to what extent individual goods and services contain an upward bias. However, it is also reasonable to think that the size of upward bias differs for goods and services. This question awaits future study.

28. The Great Southern Hyogo Earthquake was the worst natural disaster in Japan in 70 years. More than 5,000 people died, and about two million people, including foreign residents in Japan, suffered from the disaster.

29. For example, see evening edition of the *Nihon Keizai Shimbun* newspaper on March 3, 1995.

Table 8 Comparison of CPI Movements in Hyogo Prefecture and Tokyo in February

Percent

	1992–94 (a)	1995 (b)	Difference (b) – (a)	Notes
Alcoholic beverages	0.0	15.1 (–0.2)	–15.1 (–0.2)	Beer, wine
Underwear	0.8	–14.0 (–0.1)	–14.8 (–0.1)	
Japanese clothing	–0.4	–11.4 (–0.1)	–11.0 (0.0)	Toys and sporting goods
Recreational goods	2.8	–10.8 (–0.3)	–13.6 (–0.3)	
Tutorial fees	0.0	–7.9 (–0.1)	–7.9 (–0.1)	
Eating-out	–0.1	–6.2 (–0.5)	–6.1 (–0.5)	
Other clothing	–0.7	–5.8 (0.0)	–5.1 (0.0)	Neckties, belts
Books and others	–3.0	–5.5 (–0.1)	–2.5 (0.0)	Newspapers, magazines
Cakes and candies	–0.2	–4.8 (–0.1)	–4.6 (–0.1)	
Domestic utensils	0.0	–4.6 (0.0)	–4.6 (0.0)	Tableware, kitchen utensils
Fish and shellfish	–0.1	–3.8 (–0.1)	–3.7 (–0.1)	
Personal effects	0.5	–3.4 (0.0)	–3.9 (–0.1)	Bags, watches
Medical supplies	–0.2	–3.3 (0.0)	–3.1 (0.0)	Disposable diapers
Personal care services	–0.2	–3.3 (0.0)	–3.1 (0.0)	Men's haircut charges
Medicines	–0.2	–2.9 (0.0)	–2.7 (0.0)	
Communication	0.0	–2.7 (–0.1)	–2.7 (–0.1)	Postage, telephone charges
Meat	–0.7	–2.6 (–0.1)	–1.9 (0.0)	
Dairy products and eggs	0.6	–2.5 (0.0)	–3.1 (0.0)	
Repairs and maintenance	–0.2	–2.3 (0.0)	–2.1 (0.0)	
Total		(–1.9)	(–1.9)	
Excluding fresh food		(–1.7)	(–1.7)	

Notes: 1. The above figures are the difference between the rates of change from the previous year of CPI of Hyogo Prefecture and the Tokyo metropolitan area.
2. Figures in parentheses are the contribution to the percent change of the overall CPI the weights of the Tokyo metropolitan area.
3. The items for which figures exceed 2 percent in 1995 are listed in the above table.
4. Fresh food consists of fish and shellfish, meat, dairy products and eggs.

Sources: Management and Coordination Agency, *Consumer Price Index*, Hyogo Prefectural Government, *Hyogo-ken no Shouhisha Bukkashisuu Sokuhou*.

Based on the above result, the downward bias caused by the substitution of the outlets surveyed is deemed significant, taking into account the finding that commodity groups with large divergence were thought to be greatly affected by adding discount outlets to the survey.[30] Of course, it is true that this result should be interpreted carefully, since the divergence of the two areas is due partly to Hyogo Prefecture's unique factors such as stock clearance sales by shops which had suffered damage during the earthquake (for example, Japanese clothing).

It should be noted that the expansion of new and low-priced outlets such as discounters and roadside shops, sometimes represented by the development expressed as "price busting," does not progress at a constant pace. In particular, recent price developments and consumer behavior suggest that the shift from department stores and specialty shops to discount outlets has largely subsided, and price differences

30. Of course, price differences between existing retail outlets and discount stores partly reflect the difference in the retail services provided, which also needs to be adjusted in the CPI.

between these outlets has settled down to a level consistent with the difference in retail service quality provided by them. This phenomenon implies that measurement errors induced by structural changes in the retail market have been diminishing in recent years.

Bearing these points in mind, I will assume the upward bias of the CPI to be 0.10 percentage point for the median, 0.05 percentage point for the lower limit, and 0.60 percentage point for the upper limit, which corresponds to one-third of the above estimation result.

F. The Magnitude of Measurement Errors

1. Evaluation of upward bias in total

As discussed above, the measurement biases are introduced by way of index formula, aggregation of individual prices into item index, quality adjustment method, and price survey sampling. If I sum my point estimates measurement biases in those four sources, the total bias is, at this moment, judged to be some 0.90 percentage point, as shown in Table 9.[31] However, it should be noted that a possible range of estimates will be as wide as from 0.35 to 2.00 percentage points, according to various conditions.[32]

Table 9 Magnitude of Measurement Errors in the CPI

Source of bias	Lower-bound	Mid-point	Upper-bound
Price index formula	0.00	0.00	0.25
Aggregation to item levels	0.00	0.10	0.25
Quality adjustment	0.30	0.70	0.90
Price sampling	0.05	0.10	0.60
Total	0.35	0.90	2.00

2. Reservations for the results of the estimates

It should be noted that the method adopted in this paper, that is, the individual examination of the problems inherent in the Japanese CPI and the simple adding of the results, has the following limitations:

(1) At present, available research results are quite limited in Japan. With respect to the effects of quality adjustment, for example, it has been proven that there is an upward bias for certain durable goods, especially for microelectronic products which are subject to rapid technological innovation. However, for nondurable goods and services, there is no accumulation of studies in Japan, which leads to an indecisive conclusion with respect to the impacts of quality adjustment on the price index.

31. The size of measurement error is, as described later, less than 1 percent on an annual basis, although it is quite important to adjust appropriately for such errors taking into account the cumulative effect on assessing the general price level and productivity.

32. In this paper, I update the estimation results of the upward bias in the Japanese CPI shown in Shiratsuka (1998). The point estimate remains unchanged, while the upper limit was lowered from 2.35 to 2.00 percentage points per year, based on the revised estimation results on the upper substitution bias.

(2) The question has been noted as to whether effects of the problems inherent in the CPI with regard to its accuracy can be correctly estimated by this simple adding. As already shown, sources of measurement errors in the CPI and the sources that introduce such error are mutually correlated and quite complicated. Adding them without any adjustment means that I assume no correlation among sources.[33]

(3) I have shown that the point estimate of the upward bias in the Japanese CPI is judged to be 0.90 percentage point on an annual basis with a possible range of 0.35–2.00 percentage points. However, this range does not refer to a statistical confidence interval. The point estimate itself is the most reliable "best shot" based on all the available information to date, although it is true that the calculation is also based on many assumptions. Therefore, it should be noted that the estimates shown in this paper are not necessarily ones with a high accuracy.

IV. Comparison with the Boskin Report

In the United States, the Senate Finance Committee's Advisory Commission for studying the CPI presented a report "Toward a More Accurate Measure of the Cost of Living" (the Boskin Report) in December 1996.[34] The report specified four sources of measurement error: (1) upper level substitution; (2) lower level substitution; (3) new products/quality change; and (4) new outlets. The report examined past studies in detail for the above four sources, and presented its best estimate of the size of the upward bias as 1.10 percentage points per year (see Table 10 for details).

Table 10 Comparison with the Estimate in the Boskin Report

Source of measurement error	United States (Boskin Report)	Japan (author's estimates)
Upper level substitution	0.15	0.00
Lower level substitution	0.25	0.10
New products/quality change	0.60	0.70
New outlets	0.10	0.10
Total	1.10 (0.80–1.60)	0.90 (0.35–2.00)

Source: Advisory Commission to Study the Consumer Price Index (1996).

33. In order to solve the problem of mutual dependence of sources of measurement errors, and that of estimates of measurement errors and credibility range, Shapiro and Wilcox (1996) specified the (subjective) probability distribution of biases for each source, and calculated the probability distribution of overall measurement errors taking into account such mutual relationships.

34. Since the publication of the Boskin Report, there has been a lot of discussion on support for, and criticism of, their estimation results. However, Boskin *et al*. (1998) take the position that there is no reason to change the original estimate of a 1.1 percentage point per annum upward bias in the U.S. CPI. See also Gordon (1999) for a more recent discussion on this issue in the United States.

If I roughly compare the four sources pointed out in this report with those of our study, they will correspond to (1) the index formula problem; (2) the problem of aggregation of individual prices; (3) the quality adjustment methods problem; and (4) the survey sample problem. Among these sources, lower level substitution has not been studied in Japan due to data availability, thus the estimate for this cause should be regarded as preliminary.[35]

V. Economic Policy Implications

In this chapter, I will discuss the policy implications of measurement errors in the CPI.

1. Measurement of price stability

As the measured inflation rate approaches zero, it is generally believed that measurement error portion increases within the observed inflation rate. Therefore, although the accuracy of the price index will not be that problematic in the process of lowering the inflation rate from, say, 10 percent to 3 percent, it will become crucial in considering bringing down the rate from 3 percent to zero.

In this sense, mismeasurement in the CPI matters a lot for the conduct of monetary policy. The existence of upward bias in the CPI means that pursuing a zero inflation rate is to conduct a deflationary policy, thus possibly resulting in a loss of economic welfare. This suggests that true price stability will not necessarily correspond to zero measured inflation.

In addition, the time-varying nature of this problem in the short-run suggests that it is difficult to interpret movements in the measured inflation rate. In other words, to accept a certain inflation rate as an upward bias may also lead to the loss of economic welfare, since the magnitude of measurement error is deemed to change according to economic conditions. Bearing this point in mind, one sees that how measurement errors in the price index change over time in relation to the business cycle is an important issue awaiting solution.

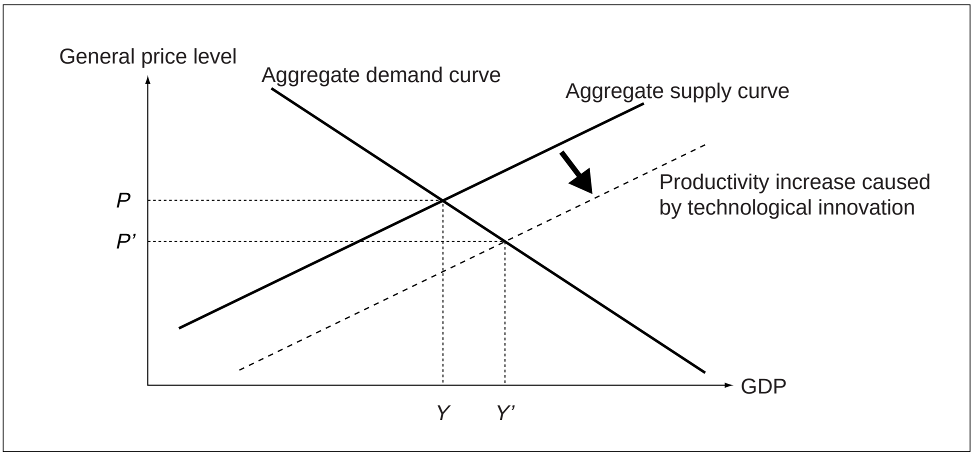
Furthermore, an overestimation of inflation is, to put it differently, an underestimation of productivity growth or economic growth. For example, if a price decline is brought about by a downward shift of the aggregate supply curve as a result of an increase in productivity, it is possible to argue that such downward pressure on the general price level is acceptable (Figure 6). Even if the price index incorporates an upward bias of the same magnitude, the implication for monetary policy will differ according to the source of such bias.

2. Treatment of asset prices

As far as monetary policy tries to achieve the medium- to long-run sustainable price stability, it is not sufficient to monitor only the fluctuation of current price indices. Therefore, it is important for policy judgment to take into account the asset prices that implicitly reflect the future development of goods and service prices as well as current price indices. From the viewpoint of considering the dynamic nature of

35. As the range of plausible values of the upward bias in the Japan CPI, I have set 0.35 to 2.00 percentage points (0.8 to 1.6 in the case of the Boskin Report) around the point estimate of 0.90 percentage point. Due to the lack of similar studies in Japan, the estimate is bound to be quite preliminary, thus taking quite a wide range.

Figure 6 Impact of Productivity Increase Caused by Technological Innovation



consumer behavior, it is important to extend the current price index concept in order to trace intertemporal changes in the cost of living, depending on the future path of consumption.

However, asset price information can only be used as a supplementary measure to price indices in making policy judgments on price developments because of the following two reasons. First, current asset prices are affected by various factors other than price expectations for future goods and services, thus current changes in asset prices do not necessarily indicate future changes in prices of goods and services. Second, the accuracy of such asset prices is quite low compared with those of existing price indices. Therefore, it is deemed difficult to attach a central role to price indices, including asset prices, in the judgment of monetary policy.[36]

3. The need for exploring additional methods to gauge the underlying trend of inflation

In order to conduct a preemptive monetary policy, it becomes necessary to gauge appropriately the changes in underlying inflation trends. To make use of the asset prices mentioned above is one way, and to reexamine information contained in relative price changes across the various goods and services is another.

What makes it difficult to trace the underlying inflation trends are not only the size and variability of biases in price indices, which both stem from measurement errors, but also the adjustment method pertaining to transitory or temporary fluctuations in the prices of individual items. In order to cope with the latter issue and to supplement the judgment of underlying inflation trends, central banks employ various devices. For example, Japan uses the CPI series that excludes fresh-food items; New Zealand and the United Kingdom sometimes employ a limited influence estimator, an index that excludes items located on both tails of the cross-sectional distribution of inflation.

The limited influence estimator provides important information concerning changes in underlying inflation trends, and could well be a quite useful and powerful

36. Treatment of asset prices in price indices is discussed in detail in Shiratsuka (1999).

indicator for policy judgment. Shiratsuka (1997) shows that such an indicator is applicable to the Japanese economy, and points out that the indicator helps to (1) reveal the underlying trend in price changes by adjusting for temporary disturbances such as rapid yen appreciation and sudden rises in oil prices; and (2) clarify the magnitude of upward pressure on prices by making use of monthly and yearly changes in the index.

4. Fiscal balance and implication on fiscal policy

The major incentive for compiling the Boskin Report was that upward bias in the CPI had a great impact on the fiscal budget. In the United States, upward bias in the CPI has been a major source of the increase in the federal budget, since about 30 percent of fiscal expenditure (such as Social Security and pension payments) and 45 percent of fiscal revenue (income tax) are tied to the CPI. According to the Boskin Report, the Congressional Budget Office (CBO) has estimated that if the change in the CPI were reduced by an average of 1.1 percentage points for the next decade, it would slash as much as US$148 billion from projected federal deficits by the year 2006 (see Advisory Commission to Study Consumer Price Index [1996]).[37]

When the fiscal system and inflation indexation are discussed, however, examination of the validity of the price basket is also important. In the case of pensions, it could well be the case that the average consumption basket of all households and that of pension recipients are quite different.

VI. Conclusion

In this paper, I have summarized the problems pertaining to measurement errors inherent in the Japanese CPI, and have provided some quantitative evaluations. Based on currently available information, I presented the point estimate of about 0.90 percentage point as the size of measurement error. Although this is the best estimate taking into account all information currently available, it is true that the estimate was based on various, rather bold assumptions. In addition, it should be noted that the accuracy of the estimate is not necessarily high due to the lack of existing studies in this field in Japan.

Despite the efforts of many statistical institutions in constructing accurate statistics, measurement errors are unavoidable to some extent. Thus, the most important point is to ascertain whether they are small enough to be safely ignored in practice or serious enough to mislead users. The debate about the accuracy of CPI should therefore be aimed at investigating the sources of measurement errors and the extent to which they affect accuracy. Unfortunately, research on price index measurement errors has been limited in Japan, and further research in the area is necessary.

Treatment of the three problems quantitatively estimated in this paper—the index formula problem, the effects of quality changes, and the effects of structural change in retail markets—can be somewhat clarified by adopting the following methods.

37. Pension payments constitute the only item in Japan's fiscal budget that is tied to the CPI, and its weight was, in fiscal 1994, about 13 percent of the total expenditure of the general government (current expenditure + total capital formation + acquisitions less disposal of land) in the System of National Accounts.

1. Introduction of chained CES index formula

The superlative indices such as the chained Törnqvist and Fisher indices have more desirable features than the fixed-weight Laspeyres index formula currently used in the CPI as a measure of the cost of living. This is because the chained Törnqvist and Fisher indices reflect the substitution effect appropriately. However, such indices cannot be computed on as timely a basis as the current CPI due to the delays in the availability of the required expenditures data.

Therefore, it is important to produce an approximation of the chained Törnqvist and Fisher indices with data available to the statistical agency when they compile the CPI. One possible answer to this question is application of the CES index formula, proposed by Shapiro and Wilcox (1997). More specifically, I construct the version of the CES index that is defined as

$$P_t^{CES} = \left[\sum_i w_{it} \left(\frac{p_{it}}{p_{i0}} \right)^{1-\sigma} \right]^{1/(1-\sigma)}, \qquad (2)$$

where σ is the elasticity of substitution between items (assumed to be identical for all possible pairs of goods and services in the CPI).

Table 11 compares the annual rates of change in the cost of living indices, computed by the eight different index formulas. The first two rows use the Törnqvist and Fisher index formulas. The remaining rows apply equation (2) for six different assumptions about the elasticity of substitution, that is, σ = 0.3, 0.4, 0.5, 0.6, 0.7, and 1.0 (identical to the geometric mean formula with one-year lagged weight). This table shows that the elasticity of substitution, on average, lies between 0.4 and 0.5 from 1970 to 1997, and between 0.5 and 0.6 in the 1990s (the shaded area in the table). This estimate is a little lower than that in the United States of 0.7, reported in Shapiro and Wilcox (1997).

Table 11 Introduction of the CES Index

	1970–75	75–80	80–85	85–90	90–95	95–97	70–97	90–97
Superlative indices								
Chained Törnqvist	11.052	6.194	2.534	0.994	1.137	0.849	4.053	1.055
Chained Fisher	11.052	6.194	2.534	1.001	1.137	0.831	4.053	1.049
Chained CES indices								
σ = 0.3	11.104	6.218	2.541	1.005	1.139	0.879	4.072	1.065
σ = 0.4	11.078	6.197	2.539	1.000	1.135	0.865	4.060	1.058
σ = 0.5	11.052	6.175	2.536	0.987	1.139	0.850	4.049	1.056
σ = 0.6	11.026	6.154	2.533	0.982	1.127	0.852	4.037	1.049
σ = 0.7	10.999	6.132	2.531	0.976	1.123	0.855	4.026	1.046
σ = 1.0 (geometric mean)	10.827	6.127	2.582	1.004	1.120	0.858	4.010	1.045

2. Introduction of hedonic approach as quality adjustment method

Bias induced by quality changes can be made small enough by the introduction of the hedonic approach. I propose to adopt a framework of using a pre-estimated hedonic function in adjusting the quality difference between new and old products (for the details, see Appendix 2). This framework can avoid the cumbersome process of estimating the hedonic function every time the price index is constructed. In addition, this framework is deemed to be highly feasible since it is relatively compatible with the methodology of surveying specific prices every month. In fact, the Japanese WPI employs this framework for some computer items and has been constructing a price index on a monthly basis.

3. Review of survey outlets

Whether the development of "price busting" has been appropriately reflected in the CPI is still an open question. However, judging from the case study of the Great Southern Hyogo Earthquake, I believe that the effect of the expansion of discount outlets on price survey is substantial. Therefore, the review of survey outlets is worth considering in order to improve the accuracy of the CPI.

APPENDIX 1: INDEX FORMULAS

In Appendix 1, I practically summarize some basic price index formulas applied in the paper.

The basic components of a price index are the price of item i in time t, denoted p_{it}, and the quantity of this item purchased in time t, x_{it}. Then, the fixed-weight version of Laspeyres (P^L_{0t}), Paasche (P^P_{0t}), Fisher (P^F_{0t}), Törnqvist (P^T_{0t}), and geometric mean (P^G_{0t}) indices are defined as follows:

$$P^L_{0t} = \sum_{i=1}^{n} p_{it}\, x_{i0} \Big/ \sum_{i=1}^{n} p_{i0}\, x_{i0} = \sum_{i=1}^{n} w_{i0} \times \frac{p_{it}}{p_{i0}}, \tag{A.1}$$

$$P^P_{0t} = \sum_{i=1}^{n} p_{it}\, x_{it} \Big/ \sum_{i=1}^{n} p_{i0}\, x_{it} = \left(\sum_{i=1}^{n} w_{it} \times \frac{p_{it}}{p_{i0}} \right)^{-1}, \tag{A.2}$$

$$P^F_{0t} = \sqrt{P^L_{0t} \times P^P_{0t}}\,, \tag{A.3}$$

$$P^T_{0t} = \prod_{i=1}^{n} \left(\frac{p_{it}}{p_{i0}} \right)^{(w_{i0}+w_{it}/2)}, \tag{A.4}$$

$$P^G_{0t} = \prod_{i=1}^{n} \left(\frac{p_{it}}{p_{i0}} \right)^{w_{i0}}. \tag{A.5}$$

The chained index formula first aggregates individual prices in period-to-period basis to compute intermediate period indices, and then chains these intermediate period indices to obtain a long-term index. In general, chained price index (CP^k_{0t}) is defined as follows:

$$CP^k_{0t} = P^k_{01} \times P^k_{12} \times \cdots \times P^k_{t-1,t} = \prod_{s=0}^{t-1} P^k_{s,s+1} \text{ (for } k = L, P, F, T, G\text{)}. \tag{A.6}$$

Therefore, chained Laspeyres (CP^L_{0t}), Paasche (CP^P_{0t}), Fisher (CP^F_{0t}), Törnqvist (CP^T_{0t}), and geometric mean (CP^G_{0t}) indices are written as

$$CP^L_{0t} = \prod_{s=0}^{t-1} P^L_{s,s+1} = \prod_{s=0}^{t-1} \sum_{i=1}^{n} w_{is} \times \frac{p_{i,s+1}}{p_{is}}, \tag{A.7}$$

$$CP^P_{0t} = \prod_{s=0}^{t-1} P^P_{s,s+1} = \prod_{s=0}^{t-1} \left(\sum_{i=1}^{n} w_{is} \times \frac{p_{i,s+1}}{p_{is}} \right)^{-1}, \tag{A.8}$$

$$CP^F_{0t} = \prod_{s=0}^{t-1} P^F_{s,s+1} = \prod_{s=0}^{t-1} \sqrt{P^L_{s,s+1} \times P^P_{s,s+1}} = \sqrt{CP^L_{0t} \times CP^P_{0t}}\,, \tag{A.9}$$

$$CP^T_{0t} = \prod_{s=0}^{t-1} P^T_{s,s+1} = \prod_{s=0}^{t-1}\prod_{i=1}^{n}\left(\frac{p_{i,s+1}}{p_{is}}\right)^{(w_{is}+w_{i,s+1}/2)}, \tag{A.10}$$

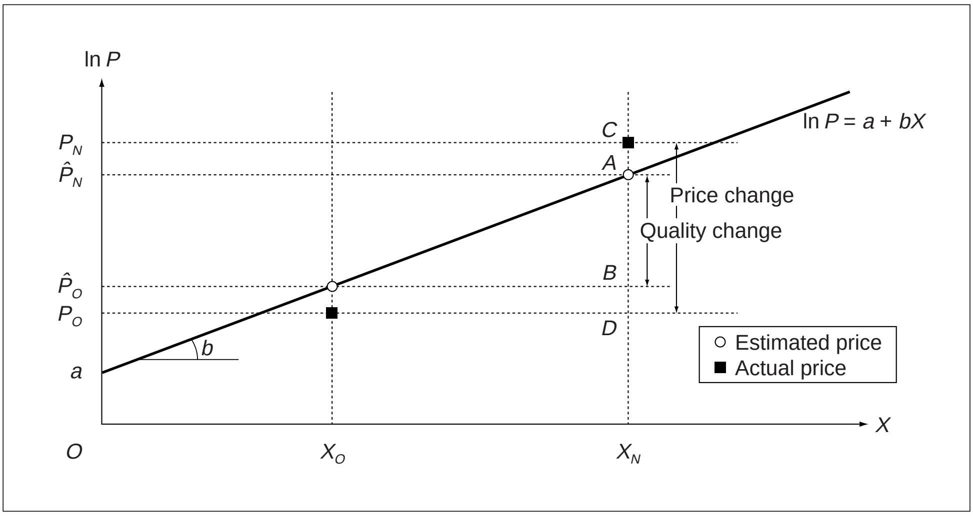
$$CP^G_{0t} = \prod_{s=0}^{t-1} P^G_{s,s+1} = \prod_{s=0}^{t-1}\prod_{i=1}^{n}\left(\frac{p_{it}}{p_{i0}}\right)^{w_{i0}}. \tag{A.11}$$

APPENDIX 2: APPLICATION OF THE HEDONIC APPROACH TO SPECIFICATION CHANGES

In Appendix 2, I present a practical method for constructing a reliable CPI by adjusting quality changes with the hedonic approach. This method is something of a compromise between the following two requirements. On the one hand, it is necessary to employ the hedonic approach to account for quality changes more adequately. On the other hand, it is also necessary to sustain the conventional methodology of surveying specific prices every month. Thus, it is not appropriate to use the anti-logarithm of the estimated parameter for the year dummy as a quality-adjusted price index.

Appendix Figure 1 describes the method for applying the hedonic approach to specification changes in the case of one performance characteristic (functional form for the hedonic function is assumed to be a semi-log linear). The x-axis measures the characteristic, and the y-axis measures the logarithm of the product price. A straight line with a constant (a) and a slope (b) represents the pre-estimated hedonic function.

Appendix Figure 1 Application of the Hedonic Approach to Specification Change



Let X_O and X_N represent the characteristic values of the existing and new products, respectively. Then the theoretical price (that is, the estimated price based on the hedonic function) is given by the anti-logarithm of ln $P = a + bX$, that is, $\hat{P}_O$ and $\hat{P}_N$ for the old and new products, respectively. The quality change between the existing product and the new product is measured by the difference in the theoretical prices between the existing product and the new product, which is depicted by AB in

Appendix Figure 1. Let ■ be the observed prices for old and new products P_O and P_N, respectively. Then, *CD* measures the change in the product price. Therefore, the difference between *CD* and *AB* corresponds to the change in the quality-adjusted price index. In this particular example, the quality-adjusted price index rises with an introduction of the new product because *CD* > *AB*.

With this methodology, the following relationships hold among rates of change in terms of product price, quality, and the quality-adjusted price index.

Δ(product price) > Δ(quality) ==> Δ(price index) > 0
Δ(product price) = Δ(quality) ==> Δ(price index) = 0
Δ(product price) < Δ(quality) ==> Δ(price index) < 0

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